Lecture Notes in Networks and Systems 911

Michael E. Auer
Uriel R. Cukierman
Eduardo Vendrell Vidal
Edmundo Tovar Caro *Editors*

# Towards a Hybrid, Flexible and Socially Engaged Higher Education

## Proceedings of the 26th International Conference on Interactive Collaborative Learning (ICL2023), Volume 4

Springer

# Lecture Notes in Networks and Systems 911


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Michael E. Auer · Uriel R. Cukierman ·
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Editors

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# Preface

ICL2023 was the 26th edition of the International Conference on Interactive Collaborative Learning and the 52nd edition of the IGIP International Conference on Engineering Pedagogy.

This interdisciplinary conference aims to focus on the exchange of relevant trends and research results as well as the presentation of practical experiences in Interactive Collaborative Learning and Engineering Pedagogy.

ICL2023 took place in Madrid, Spain, from 26 to 29 September 2023 and was supported by the Universidad Politécnica de Madrid, InnovaHiEd Academy, the Spanish Conference of Directors and Deans of Informatics Engineering and the Universidad Tecnológica Nacional from Argentina.

This year's theme of the conference was "Towards a Hybrid, Flexible and Socially Engaged Higher Education".

Again, outstanding scientists from around the world accepted the invitation:

Special Invited Guests

- **Jenna Carpenter,** President American Society of Engineering Education - ASEE
- **David Guralnick,** President International E-Learning Association - IELA

Keynotes

**Xavier Fouger**
Senior Director, Global Academia Programs, Dassault Systèmes
**Khairiyah Mohd-Yusof**
Full professor in the School of Engineering Education, Purdue University, USA
**Carlos Delgado Kloos**
Rector's Delegate on Digital Microcredentials, UC3M, Spain
**Antonio Recio Sanroman**
Head of Global Learning & Growth Partners, Siemens
**Miriam Reiner**
Director of the VR/AR and Neurocognition Lab at the Technion Institute, Israel

The following very interesting workshops have been held:

**Workshop/Roundtable on accreditation**
Chair: Eduardo Vendrell Vidal, Universitat Politècnica de València
**Increasing User Engagement in Software Applications for Commercial or Research Purposes.**
Mohammad Hajarian and Paloma Diaz, Universidad Carlos III de Madrid, Spain
**Supporting Open Educational Resources Creation, Personalization, Implementation, and Sharing through the Graasp.org Learning Experience Platform and its Associated Open Digital Library**
Denis Gillet, EPFL, Switzerland and Michele Notari, University of Teacher Education, Bern, Switzerland and University of Hong Kong

**Addressing the Engineering Skills Gap: How can industry and educators work together to integrate emerging technologies into student and professional education?**
Chair: Kirsten Williamson, Petrus
**How to Create Virtual Machine-Templates in a Public and in a Private Cloud Environment**
Michael Dietz, Technische Hochschule Nürnberg, Germany
**The Engineering Classroom: Promoting and Illustrating New Types of Learning and Effective Use of Practical, Evidence-Based Strategies to Support Student Motivation and Academic Success.**
Genny Villa, Université de Montréal, Canada and Natalia Rosa Rodriguez Carinthia University of Applied Sciences (Austria)
**Low-Cost/High-Impact: Success Skills Students Will Actually Use**
Peter J. Shull, Penn State University, United States of America
**From Teaching in the Industrial Age to Teaching in the Digital and AI Age**
Chairs: Carlos Delgado Kloos and Carlos Alario, Universidad Carlos III de Madrid
**Hands-on workshop on developing complex problem-solving skills using Problem-Based Learning**
Prof. Dr. Syed Ahmad Helmi Syed Hassan and Dr. Khairiyah Mohd Yusof
**Open Badges and Micro-credentials: Recognizing Learnings in More Flexible Ways.**
Uriel Ruben Cukierman and Juan Maria Palmieri, UTN, Argentine Republic and Eric Rousselle, Open Badge Factory, Finland
**BreakThrough Communication: Interactive Experiential Learning in a Hybrid World**
Susan R. Glaser and Peter A. Glaser, Glaser & Associates, United States of America
**Teach Quantum Computing!**
Chairs: Jose Christen and Maninder Kaur, QURECA

We would like to thank the organizers of the following Special Sessions:

- ***Entrepreneurship in Engineering Education 2023 (EiEE'23)***
  Chairs
  **Jürgen Jantschgi,** Higher College for Engineering Wolfsberg, Austria
- ***AI in learning – a double face Janus (AiL'23)***
  Chair
  **Elena Bendíková,** Faculty of Education CU, Ružomberok, Slovakia
- ***Digital Education Strategy and Engineering Pedagogy (DESEP)***
  Chair
  **Roman Hrmo,** DTI University

Since its beginning, this conference has been devoted to new approaches in learning with a focus to collaborative learning and engineering education. We are currently witnessing a significant transformation in the development of education. There are at least three essential and challenging elements of this transformation process that have to be tackled in education:

- the impact of globalization and digitalization on all areas of human life, and
- the exponential acceleration of the developments in technology as well as of the global markets and the necessity of flexibility and agility in education
- the new generation of students, who are always online and don't know to live without Internet
- the increasing interdependence between the different sectors of education (secondary and post-secondary education, vocational education)

Therefore, the following main themes have been discussed in detail:

- Collaborative Learning
- Mobility and Smart Cities
- New Learning Models and Applications
- Project-Based Learning
- Game-Based Education
- Educational Virtual Environments
- Computer-Aided Language Learning (CALL)
- Teaching Best Practices
- Engineering Pedagogy Education
- Public-Private Partnership and Entrepreneurship Education
- Research in Engineering Pedagogy
- Evaluation and Outcomes Assessment
- Internet of Things & Online Laboratories
- IT & Knowledge Management in Education
- Approaches of Online Teaching
- Virtual and Augmented Learning
- Mobile Learning Applications
- Connection between Universities and the Labour Market
- Further Education for Engineering Educators

As submission types have been accepted:

- Full Paper, Short Paper
- Work in Progress
- Special Sessions
- Workshops, Tutorials

All contributions were subject to a two-step double-blind review. The review process was very competitive. We had to review more than 500 submissions. A team of about 260 reviewers did this terrific job. Our special thanks goes to all of them.

Due to the time and conference schedule restrictions, we could finally accept only the best 219 submissions for presentation.

The conference had more than 279 registered participants from 55 countries.
We thank **Sebastian Schreiter** for the technical editing of this proceedings.
ICL2024 will be held in Tallinn, Estonia.

Michael E. Auer
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# Diversity in Engineering Education

# Innovative Learning Technologies in the Process of Training Specialists of Engineering Specialties in the Conditions of Digitalization of Higher Education

Kobylianskyi Oleksandr[1](✉), Stavnycha Natalia[1], Sofiia Dembitska[1], Kobylianska Iryna[1], and Miastkovska Maryna[2]

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**Abstract.** Modernization of education, including complex changes related to the prospects of Ukraine joining the EU, requires a reconsideration of education programs, comprehensive approach to the study of general education and special disciplines, the introduction of a competency-based approach to education, and the formation of practical skills in engineering students. Currently, the process of creating prerequisites for quality training of future specialists in institutions of higher technical education is gaining special relevance. The objective of the research is scientific substantiation and development of didactic principles for the introduction of innovative learning technologies in the process of training specialists in engineering specialties in the conditions of digitalization of higher education. The object of the study is the educational process in the institutions of higher education in the conditions of the digitization, the subject of the study is the theoretical and methodological justification of the feasibility of introducing innovative educational technologies in the educational process of the higher school in the conditions of digitalization of society. The following research methods were used: analysis of educational documentation (training, industrial practice), observation, surveys and interviews, testing, expert evaluation, self-evaluation. On the basis of the conducted scientific research, ways to improve the educational process by introducing innovative learning technologies in the process of training specialists in engineering specialties in the conditions of digitalization of higher education have been suggested. The proposed principles of creating a subject-oriented and educational-informational educational environment create opportunities for using innovative multimedia products. This area of educational activity should become the basis for the formation and development of the professional competence of specialists in engineering specialties in the conditions of distance learning, the development of creativity in the process of professional tasks solution and decision-making in the conditions of internal and external challenges for enterprises and organizations, improving the efficiency of memorization.

**Keywords:** digitization of higher education · case technologies · projective technologies

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# 1 Problem Statement

More than 20 years have passed since the Cabinet of Ministers of Ukraine approved the resolution "On the Concept of Adaptation of the Legislation of Ukraine to the Legislation of the European Union", where at the state level the aspirations and directions of reforming Ukraine with the aim of joining the European community were proclaimed. In this document, it was stated that the priority result of the reformation of the educational system of Ukraine must be free access of its residents to quality education. At present, main directions of reforming the national higher education system until 2032 are formulated, regarding the access to fair, high-quality and comprehensive education throughout life for everyone, to achieve the goals of sustainable development of Ukraine are formulated in the approved order of the CMU "Strategy for the Development of Higher Education in Ukraine for 2022–2032". Accordingly, changes in the attitude of the civil society, reformation of the system of education and science, as well as the course towards European integration, led to its fundamental changes.

The Strategy defines operational and strategic objectives and tasks for its implementation, achievements (implementation) can be monitored by the relevant indices (indicators). The strategy is based on and comprehensively coordinated with a number of legislative acts adopted recently, in particular the National Economic Strategy for the period until 2030; "Human Development Strategy"; tasks of digital transformation for the period until 2023, defined by the order "Some issues of digital transformation".

Therefore, the Strategy formulates main directions of reforming the education system in accordance with modern requirements concerning the European integration of Ukraine and the challenges of society in terms of increasing the competitiveness of the students, obtaining higher education in Ukraine.

The objective of the article is scientific substantiation and development of the didactic principles for the introduction of innovative learning technologies in the process of training specialists in engineering specialties in the conditions of digitalization of higher education.

# 2 Analysis of Recent Research and Publications

The search for effective ways of training future specialists is an urgent issue, this statement is confirmed by a number of publications in scientific editions. Features of the use of active learning methods applicatin are reflected in the papers [1, 2] and other publications. Scientists have substantiated the undeniable impact of this technology on the formation of critical thinking and creative work skills. These studies emphasize the priority impact of active learning methods on the formation of productive cognitive activity of students. Future specialists from listeners turn into active acquirers of knowledge and skills, which they apply, solving complex professional tasks. However, we agree with scientists that main condition is the improvement of the professional skills of teachers, in particular in the direction of the formation of knowledge, abilities and skills regarding the introduction of active learning methods into the educational process.

Problems in the field of digitization, in particular in higher education, became particularly acute at the beginning of the pandemic and were actively discussed in publications

[3, 4] and other papers. Scientists stated that digitization is a significant factor in the development of political, economic, social, and cultural relations in society. Education is a key factor in social development, and therefore, it should be changed according to general trends. With this in mind, in the publications of the last decade, scientists presented the results of their research regarding the global trends of digital transformation and their impact on the development of higher education; an attempt was also made to develop criteria for the readiness of higher education institutions for digital transformation, the concepts of a unified information space of the university were proposed, the search for innovative forms, methods of educational activity and approaches to the management of a higher education institution in the conditions of digitalization continued. Researchers suggested the forecast regarding changes in corporate culture and approaches to the solution of the the problems, connected with the optimization of educational process in the digital age and many other things.

The forced transition to distance and blended learning during the period of quarantine restrictions additionally proved the relevance of digitalization of higher education and made perform the transition of higher education to the digital format in a short period of time, as well as realize the need in its integration with innovative pedagogical technologies.

It is worth noting that digitalization of higher education is an extremely complex and ambiguous process. In addition to a number of obvious advantages, it has disadvantages that must be taken into account while planning digital transformation. In particular, among such disadvantagesc, scientists distinguish the real decline in the status of university diplomas in the conditions of open and online education, the significant increase of the teachers‘ load in the conditions of the digitalization of education, which is not taken into account in the system of labour organization and payment compensation. Besides, the function of student's socialization, who are completely individualized in the digital environment, is cancelled out. Opinions are expressed that there is a potential threat of destruction of the traditional model of education and devaluation of humanitarian knowledge.

The conditions and features of using innovative technologies are discussed in publications [5, 6]. In scientific and pedagogical sources, methodological and theoretical problems of innovative educational activity are correlated with the technology of advanced education in higher education, since it is here that graduates are trained to solve professional issues and unforeseen problems in future professional activities.

## 3 Theoretical Substantiation of Innovative Learning Technologies Selection in the Process of Professional Training

Currently, any innovative learning technologies that appear in the practice of a higher school should be combined with digital technologies, since higher education is developing in the direction of its digitalization. Updating of learning technologies should be carried out taking into account the requirements of stakeholders, i.e. ensuring the optimization of the educational process. Such an approach involves not only clarifying the goal of training specialists in technical specialties in the conditions of digitalization of higher education, but also a systematic analysis of the real educational process with the subsequent identification and elimination of problematic points. At the same time, the logical and correct application of digital technologies should be ensured in accordance with the specification of the educational goal. The need for digitization of higher education is undeniable, especially after a long quarantine period. However, nowadays there are no criteria that allow to determine the level of digital competence formation of students of higher education and teaching staff, this problem slows down the updating of teaching aids.

Summarizing the results of the conducted theoretical analysis on the features of the real educational process at Vinnytsia National Technical University (VNTU), the following innovative trends were highlighted in the process of training specialists in engineering specialties in the conditions of digitalization of higher education: mobile learning, microlearning, active learning technologies, heuristic education and innovative digital tools. They will be considered in details.

1) *mobile learning*, as a type of distance learning, carried out using a mobile device. To determine the need for the development of mobile learning, we conducted a survey of students at Vinnytsia National Technical University. 98% of respondents have technical facilities to use mobile learning, which makes it relevant (Fg. 1).

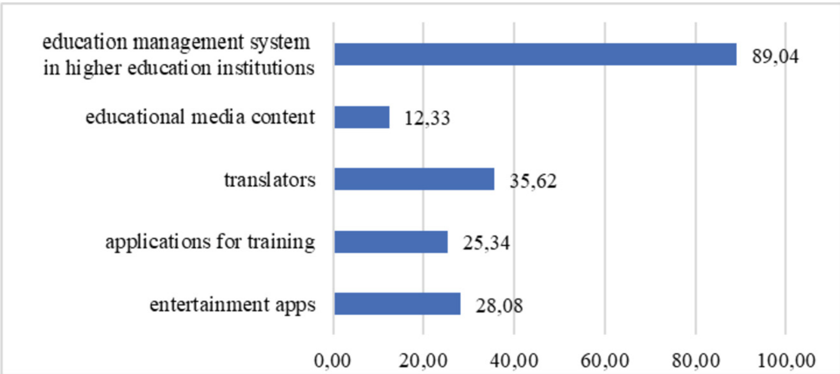


**Fig. 1.** Results of the survey of students regarding the use of mobile applications

As you can see, a third of the students now use a mobile phone as a learning tool. The institution's learning management system is installed in 89.04% of students, while 84% of respondents consider mobile learning to be promising.

The conducted survey of the teaching staff proved that mobile learning is not without reason starting to become a rating in the education system, because it meets all the requirements for learning: scientific character, objectiveness, connection between theory and practice, consistency and systematicity, accessibility, visibility, the activity of students and the strength of the aquired knowledge. 74% of respondents expressed a positive attitude towards the use of mobile learning, but 52% of them believe that such learning can become a powerful means of self-education and professional development, but it cannot fully replace classical education.

According to the results of the theoretical analysis and the conducted survey, the authors consider the advantages of mobile learning in higher education to be: equal access to education for all the participants in the educational process, regardless of their geographical location; possibility of continuous monitoring and operational assessment of the educational achievements of the students; ability to redistribute efficiently time to perform various types of work; ability to effectively organize individual and research work of students.

At the same time, mobile education has certain disadvantages that should be taken into consideration, in particular: the size of the screen of a mobile device requires a special selection of information that will be displayed; working with graphic editors is less convenient than on a regular PC; mobile devices become morally obsolete in a very short period of time; limited, as compared with a PC, the amount of memory and bandwidth of the device.

Taking into consideration the identified disadvantages and advantages, we believe that the use of mobile technologies in universities of a technical profile is the most appropriate for studying the disciplines of the humanitarian cycle, foreign language, etc. For studying the professional disciplines that require the use of powerful graphic editors or computer programs (in particular, in the training of professionals in the construction field), a mobile phone can only be used as the auxiliary tool.

2) micro-learning as one of the ways to implement distance learning. It is rather new trend in higher education, the content of which is to present information in small volumes. The results of the conducted research showed that the classic lecture, which was the main way of transmitting information from the teacher to the students at the university, continues to lose its relevance. One of the reasons is significant changes in the cognitive abilities of young people, in particular, a significant decrease in the duration of a person's attention span over the past 15 years from 12 to 8.25 s [7]. Now, micro-learning is gaining popularity in non-formal education and in the system of professional advanced studies.

Among the advantages of the proposed approach, the following are highlighted: focusing attention on the main idea of a separate information block, which makes it possible to better remember and analyze the presented information; a convenient learning format that does not require a lot of free time; the possibility of building a flexible educational program.

Among the main disadvantages the authors would like to underline the following: impossibility of studying complex topics with numerous stages and tasks.

Taking into account the fact that the idea of micro-learning consists in mastering the primary skills or competences of the basic level, in the process of training specialists in technical specialties, it is expedient to use micro-learning in the process of studying the disciplines of the natural cycle. In particular, at VNTU, a pedagogical experiment regarding the introduction of microlearning was conducted during 2020–2022 on the material of the higher mathematics course. 251 students took part in the experiment, among them: 119 students of the control group, 132 students of the experimental group. The control section of students' knowledge and skills at the beginning and after the end of the experiment is shown in Fig. 2.

As it is seen in Fig. 2, the structure of the control and experimental groups of students at the beginning and at the end of the experiment is different. The use of Pearson's statistical criterion confirmed the statistical significance of the obtained results and the efficiency of the proposed course construction methodology.

3) active learning technologies are implemented by building an individual educational trajectory, due to the use of digital tools. Nowadays, we have a number of developments that confirm the efficiency of this approach.

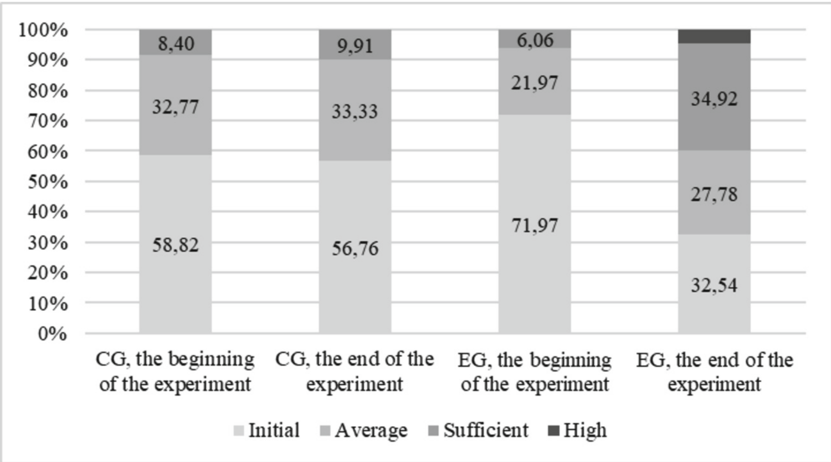


**Fig. 2.** Results of the pedagogical experiment concerning the implementation of micro-learning in the course of higher mathematics

The positive features of active learning technologies include: possibility of creating conditions for the development of critical, risk-oriented and creative thinking of future employees of technical specialties, since such an approach helps to change the role of a student from a listener to an active participant in the educational process; possibility of increasing motivation to acquire knowledge, skills and abilities, especially due to the active position of students; creating conditions for the formation of research skills of students.

Despite significant advantages, active learning technologies are not without a number of disadvantages. Taking into account the significant experience of introducing active learning methods into the educational process of VNTU, according to the results of the conducted survey of students and teachers, the following negative points were singled out: use of active learning methods involves the preparation of the teacher for such activities and the appropriate structuring of the educational material this requires additional time expenditures; in addition, modern development of education requires the inclusion of digital technologies in any teaching method, it imposes additional conditions on the pedagogical process; unwillingness of students to take responsibility for the results of their own educational activities, lack of creative skills, lack of desire to work in a team, etc.; difficulty of evaluating the results of students' work.

4) cooperative learning, as a method of joint activity of the student body, using digital technologies. In contrast to technologies aimed at individual or competitive efforts of students, technologies of cooperative learning involve cooperation in order to achieve a common goal. In the process of cooperative learning, students try to find a solution to the task by meeting not only individual educational needs, but also the needs of all team members. Co-operative learning opens opportunities for students to cooperate with their age mates, makes it possible to realize the natural desire of each person to communicate, contributes to the achievement of higher results in obtaining knowledge and the formation of skills. Such a model is easily and effectively combined with traditional forms and methods of education and can be applied at various stages of education, in particular, it was used in the process of studying the disciplines of the humanitarian cycle, philosophy, and political science. These disciplines differ in that they require from the participants of the educational process to develop communication and cooperation skills. It is expedient to use this type of activity during the organization of research and group work.
5) heuristic education, as one of the means of significant modernization of existing learning technologies (lectures, seminars, practical classes), interaction between teachers and students in distance and blended learning formats.

The advantages of heuristic training include: the ability to outline the objective of the discipline, ways to achieve it, and the final result at the beginning of the course; creation of additional incentives for students to prepare for classes more consciously; creation of conditions for the development of cognitive and search activity of all subjects of the educational process; extensive use of student-teacher, student-student dialogic interaction.

However, as in the case of active learning methods, such interaction requires from the teacher to spend additional time preparing for classes, structuring the educational material accordingly, identifying problematic issues and unresolved tasks, as well as the ability to manage the work of the student team and to direct them in the appropriate direction for scientific research.

6) *innovative digital tools*. In particular, technologies of augmented, blended and virtual reality, artificial intelligence, remote access technologies, etc., are among those that have been used in the educational process of higher education institutions. These tools are the integral component of modern higher education. However, now there is a problem of searching for methodical recommendations and pedagogical conditions for the effective inclusion of these tools in the educational process of a higher school. Some developments on this problem can be found in our publications [8, 9].

## 4 Conclusions

The results of the research are the following:

1) the process of searching and introducing innovative technologies into the practice of higher education is aimed at realizing the main tasks of higher education: meet the needs of the individual in intellectual, professional and cultural formation; development of science as a result of joint scientific research of students and teachers;

effective improvement of the qualifications of specialists; formation of the ability to work and self-development in the conditions of modern society, preservation and multiplication of its cultural and scientific values, etc.;

2) the theoretical analysis of scientific publications allows to state that the educational systems of all developed countries undergo rapid transformation within the framework of digitalization. This requires proper technical and informational support, in particular the development and implementation of a national IT strategy, providing equal access to digital educational resources, formation of digital competence among students and teaching staff, etc.;
3) the system-forming component of innovative processes in higher education is the competence approach, according to which, in the process of introducing innovations in the training of specialists in technical specialties, it is necessary to distinguish the content and methods of training, as well as the ways of implementing social partnership between all participants of the educational process. In each component of innovative activity, the teacher must embed innovative approaches (goals, content, development of abilities, methods);
4) based on the results of this pedagogical research, some innovative trends that had been successfully implemented in the process of digitalization of higher education (mobile learning, microlearning, technologies of active and cooperative learning, heuristic education) were identified, their advantages and disadvantages were determined, recommendations for their use in the educational process were formulated.

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# Conceptual Approach for Flexible and Hybrid Learning Strategies Using Cyber-Physical Systems

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**Abstract.** Engineering education faces complex constraints, not only future challenges, such as pandemic situations have to be taken into account, but also the heterogeneous pre-knowledge of students. Thus, the learning objectives should not only focus on complex knowledge or technical respectively problem-solving skills development but also on integrating sustainable aspects and resource efficiency. In context of individual needs of learners, it is also evident to consider gender and diversity aspects. Flexible and hybrid learning paths with hands-on experiences on cyber-physical systems may be appropriate to enable individual competence development. Thus, in this contribution the technical architecture and functional features of cyber-physical systems are analyzed to develop learning scenarios that meet the different requirements.

**Keywords:** Cyber-physical system · project-orientation · scenario-based learning

## 1 Introduction

In engineering education complex knowledge or technical respectively problem-solving skills development should be combined with creativity and sustainable aspects, such as resource efficiency to face future challenges. Thus, technical development and the correlating processes should not only focus on functionality and efficiency but also on environmental and social compatibility [1–3]. This multiperspective competence development depends on self-reflection, analytical and creative thinking, which poses high requirements on learning processes. Additionally, the heterogeneous pre-knowledge of students must be considered in evolving individual learning paths [4, 5].

Using cyber-physical systems as an interactive learning tool depicts a promising approach [6] being able to generate interactive and complex functions and being adapted to flexible and hybrid learning situations. The advantage of cyber-physical systems and their applications is the providing of a great variety of usage, e. g. in smart factories. The complexity requires fundamental technical knowledge that must be experienced through

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practical training. This learning context is challenged or even restricted by pandemic situations, which makes the integration of additional digital necessary [7]. So, in this contribution the basic technical architecture of cyber-physical systems is introduced, analysing the functional features of the used Festo CP Lab in context to the competence development and the possibilities of integrating digital tools for flexible and hybrid learning processes. Depending on the basic correlation two different learning scenarios are developed and tested, the impact and assessment, such as flexible applications and hybrid transfer, is discussed.

## 2 Basic Considerations and Technical Constraints

The architecture of cyber-physical systems and their flexible adaption to different applications are the basic elements of the development of learning situations. The usage of a special configuration of the Festo CP Lab enables reflective learning processes, the main components and features also may cause restriction due to the intended concept and technical constraints. This technical knowledge is introduced and discussed in context to learning processes and competence development.

### 2.1 Cyber-Physical System Architecture

Cyber-physical systems are the further development of mechatronic systems that consists of a basic mechanical or constructive system, combined with actuators and sensors for different applications, e.g. robots or automation production process systems [8]. In former developments of these technical systems the information processing enables more simple and repetitive tasks. With actual technology, especially complex software design, cyber-physical systems enable (partly) intelligent behavior, reacting to new impacts of environmental parameters. Innovative and complex design are used e. g. in smart factories, the basic architecture of intelligent cyber-physical systems shows Fig. 1 [9, 10].

A cyber-physical system consists of a basic a highly integrated mechanical system combined with complex actuator and sensor systems. Information, energy, and material are input flows are processed and changed to different information, energy and material output flows. Inside the system the information processes can be designed in a noncognitive (repetitive tasks), associative or cognitive manner, the latter enables an intelligent system control. Information processes are provided by embedded systems, connected to additional cyber-physical systems through different communication systems. The sensory system can process environmental impulses, also manual control is possible by a human-machine interface. Cyber-physical systems, especially interactive cyber-physical systems can be used in different contexts and depict a flexible production system with partly intelligent production control. In the following the Festo CP Lab as an industry 4.0 related cyber-physical production system is presented that can be used in a great variety of learning environments (Fig. 2).

The Festo CP Lab depicts an interactive learning system that consists of six application modules in order to produce a “prototype smartphone” in various configurations. Each application can provide one production step and the sequence can be determined

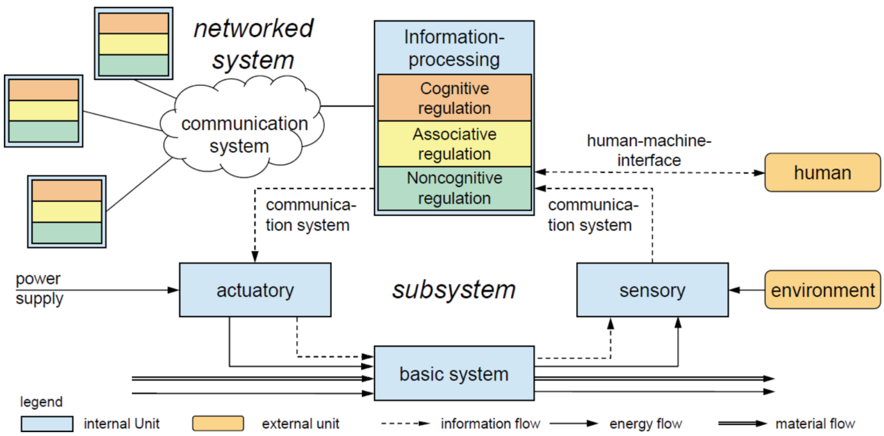


**Fig. 1.** Technological concept and architecture of intelligent cyber-physical systems [10].

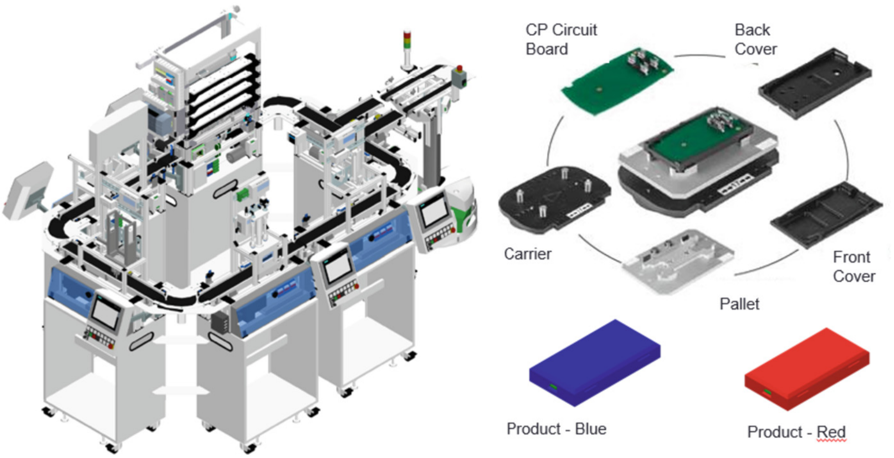


**Fig. 2.** The design of the Festo Cyber-Physical Lab for the production of different and customer specific "Smartphone" products [11, 12].

by a definite working plan appropriate to the customer specific requirements and the corresponding product features. As it can be seen in Fig. 2 the cyber-physical production system consists of six application modules, a storage, a drilling unit, a magazine, a pneumatic muscle, a turn-over unit and a bridge for the transportation robot Robotino. All application modules are connected to a transfer system moving the product parts with a carrier and pallet device, provided with an RFID chip where actual product and production data can be read and stored. The overall production control concept is realized with a manufacturing execution system (MES) that is able, in combination with the plc control, to start production orders in a self-organizational manner. Thus, the Festo

CP Lab covers complex smart factory topics and can be used as a basis for practical training in mechatronics, automation technology and smart factory technologies.

### 2.2 Learning Scenarios for Flexible and Hybrid Teaching and Learning

Interactive cyber-physical systems depict e. g. the basis for future production systems and are applicable to different project-oriented and scenario-based learning processes providing a flexible learning environment [13]. Learning scenarios can be used as an activating learning method to provide the self-reflection of the learners in the learning process [5]. In combination with digital tools, such as augmented reality or learning management tools including learning videos, individual support can be adapted to the various needs of the learning persons (Fig. 3).

In the following research question should analyzed and discussed for further development: How can competence development be supported by interactive cyber-physical systems for the development of innovative, creative technical problem-solving skills including gender, diversity, and sustainability aspects? Here special focus on the interdependency between learning objectives and the interactive cyber-physical system may provide complex learning processes. Thus, a future study course should enable students of different disciplines, such as industrial, mechanical, or electrical engineering, technical vocational didactics or computer sciences to gain complex knowledge in production systems and their future development in context of industry 4.0 [14]. It has also to be considered the heterogeneous pre-knowledge of the participants from different disciplines. The tasks that must be solved should be challenging, creative and innovative and may provide reflection and responsibility.

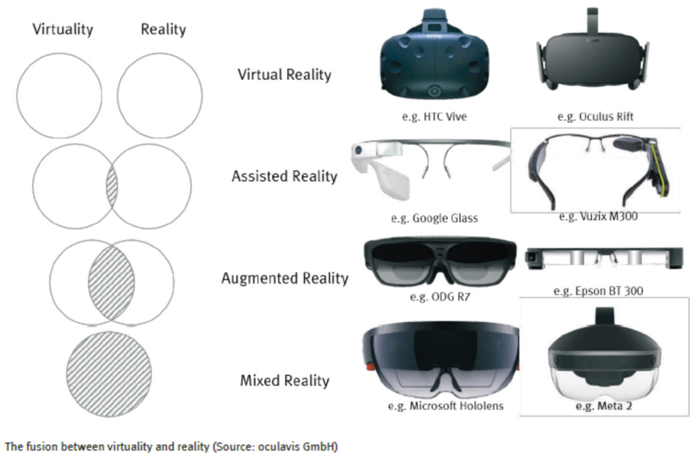


**Fig. 3.** Augmented and virtual reality devices for flexible and hybrid learning processes [15].

The learning strategy should be realized using project-oriented and scenario-based learning methods. As learning tool the Festo Cyber Physical Lab and a AR Glass of Realwear HMT-1 [16] is used, individual learning paths can be integrated into a learning management in future. Due to the advantages as outlined before, the benefits of the methods are inevitable but complex learning scenarios are complicated to assess [17, 18]. Here the combination with the holistic competence model may help to make the learning processes individual and flexible. In combination with the interactive cyber-physical system and additional tools it depicts an innovative way of gaining complex knowledge as intended in the educational setting.

### 2.3 Criteria for Competence Development

Due to the complex knowledge for understanding the applications and functions of cyber-physical systems and integrating sustainability in assessment the holistic approach of shaping competence depicts an appropriate approach for competence development [19, 20]. As a basis for competence assessment the holistic approach of shaping competence is used including the following criteria:

- clearness/presentation
- functionality
- use value orientation
- efficiency/effectiveness
- work and business process orientation
- social compatibility
- environmental compatibility
- creativity.

The criteria of clearness/presentation are correlating with the communication process in which way the developed solution is presented. The is most important aspect based for the best solution to the customer's need providing the core requirement that must be fulfilled in the task context is the criteria of functionality. Another important criterion is the use value orientation that proves how user-friendly the product solution is processed. The criterion of efficiency/effectiveness and the business process orientation are showing the economic value of the provided solution. In order to fit the future technological impacts, the criteria of social and environmental compatibility have to be assessed. Last but not the least criterion is the creativity of the learning situation that should lead to the best solution of the customer's requirements.

Each criterion is analysed by further questions that are helping to operationalize the competence assessment process. The knowledge for competence development can be differentiated into three levels of work process knowledge, the know-that, know-how and know-why, that is necessary to solve actual problems in real or simulated work situations [21]. With these criteria not only the static and actual competence of the learner can be assessed, also the competence model can be used to assess a competence development comparing the competence criteria at different assigned times. As a basis for competence assessment the holistic approach of shaping competence is used including the technical constraints and learning methods as outlined before.

## 3 Learning Processes and Experiences

In order to use the cyber-physical system for interactive learning two different scenarios are created that depicts the possibility to examine the topics in an experiential and reflective manner. The learning of complex knowledge about cyber-physical systems and its applications in smart factories must be experienced through hands-on and practical trainings and provides flexible learning processes. The learning scenarios are tested in different contexts to gain a great variety and understanding of the individual learners' needs. Additionally, tools and strategies for providing digital support are tested that should be integrated in a holistic study course concept.

### 3.1 Design of Learning Scenarios

The following two learning scenarios show the possible variety of using the different tools in correlation with the provided systems. In the first scenario the focus lies on product development and its impact on the production process planning, especially integrating sustainable aspects. The second scenario analyses the complex control system in form of the manufacturing execution system (MES) in correlation customer specific product requirements and with distance support through AR technology.

**Learning scenario "Product Design":** The main product is changed to get a more sustainable product, e. g. reducing the used material and the correlated energy consumption in the production process. Figure 4 shows the product feature study, analyzing the impact of material reduction. The stability of the product is verified by the finite element method (FEM), integrated in the Computer Aided Design (CAD) system.

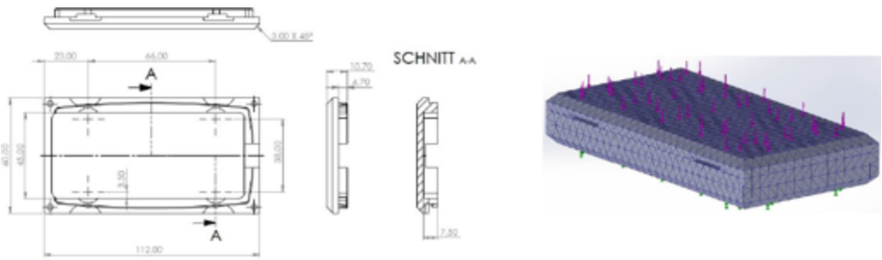


**Fig. 4.** A product development with integrated sustainability aspects [22].

**Learning Scenario "Optimization of Production Processes":** Customer specific products have to be integrated in the production processes therefore the MES system has to be adapted. This requires complex knowledge about the MES in combination with plc, that can be assisted by distance support, e. g. via an augmented reality glass. Additionally, learning videos can be easily made with the AR glass, also changes and variation of production processes or different solutions can be documented. Figure 5 shows the different applications of the Festo CP Lab and their combination in workplans as a basis for the manufacturing execution system (MES).

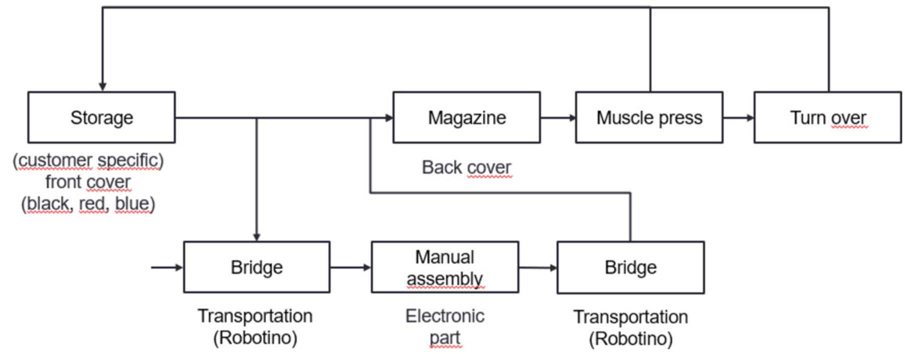


**Fig. 5.** Complex combination of the application (Festo CP Lab) realized in the manufacturing execution system (MES) [23, 24].

Obviously, the MES should be developed in a flexible manner, so that all production process configurations can be realized and supported. Both learning scenarios are tested and assessed by different groups using the criteria for the holistic shaping competence.

### 3.2 Impacts and Assessment

The two designed learning scenarios are evaluated by different groups using the eight criteria of shaping competence, the results are shown in Fig. 5 due to the three level of work process knowledge (1: know-that, 2: know-how and 3: know-why) (Fig. 6).


**Fig. 6.** Shaping competence development for the designed learning scenarios [22, 23].

In the assessment of the first scenario "Product Development" the design is evaluated by two independent rater. The assessment of the product design learning scenario provides similar values, the most important difference is the use value correlation, the work and business process correlation, the environmental compatibility, and the creativity. The clearness/presentation, functionality and efficiency show the same results, whereas the social compatibility is in between. The two criteria of clearness/presentation and functionality are reaching the deepest level of know-why, this is only for one rating the case for creativity or environmental compatibility. This shows that parts of the intended variation of the learning scenario may be fulfilled, whereas the integration of sustainable aspects may need some more modification.

The second scenario "Optimization of Production Processes" is assessed as practical training in two groups, each group consisting of two learning persons. The competence development is assessed by two rating persons. The results of this scenario are more difficult to understand, as they differ in more than one criterion. The clearness/presentation, functionality, use value orientation and creativity show almost the same value on the know-how level. The criteria of efficiency/effectiveness social and environmental compatibility are varying enormously. The criteria of work and business process orientation only differ slightly. All criteria only are reaching the know-how level. Here the scenario has to be tested by more groups in order to gain valid data, here the different solutions of the two groups may influence the assessment.

### 3.3 Flexible Application and Hybrid Transfer

The realized and tested learning scenarios, the various settings, several pre-studies and gained experiences [24] that have been made for the design of the introduced learning scenarios verify the intended approach and enable the development of a future study course. In this development individual learning paths to train technical skills and creativity must be integrated in a flexible and hybrid manner. These constraints require a holistic approach and the implementation of various learning tools. In the pre-study and restricted practical work in the cyber-physical system, previous knowledge and support are inevitable to make the practical work more efficient. This may influence the criteria of work and business process orientation and of course on the efficiency/effectiveness. Integrating distance learning as previous training may be a valuable component of a new study course.

In the design of a study course the heterogeneous pre-knowledge is considered aiming at different target groups, using the cyber-physical system and application scenario for student of industrial engineering (bachelor's and master's degree), technical computer science (bachelor's degree), and technical vocational didactics (master's degree). Especially students without technical knowledge of production systems and functionality of the different components of a cyber-physical system need more support from the learning environment, this can be provided through individual design of a learning management system. Here also learning videos depict a useful supplement of the development of the future study course.

## 4 Summary and Acknowledgements

The gained results are yet underdetermined, especially the integration of tools for distant learning must be integrated into the model for competence development, here further research work is evident. Also, the integration of the tools is an additional complex challenge to handle with in the design of the developed learning scenarios. The first scenario must be tested in practical training, the second needs more empirical data for valid discussion. In both learning scenario the constraints are more complex as it could be seen in research design. The effect is immanently in the interactive cyber-physical system, that shows especially the results of the second scenario.

Nevertheless, the recent pre-studies promise a successful approach to the research question of shaping competence development. Further work is required to improve the previous results, especially testing interdisciplinary group work and integrating real time learning settings. Also, the usability for disabled persons is not yet integrated, this may face new challenges and more profound and individual learning paths. The integration of additional learning tools may also be implemented in future work. The basic correlations were elaborated in the Master-Thesis of these highly motivated students: Alina Wurm, Robin Ohl, and Nicolas Sukup, thanks for the inspiring ideas and motivation on experimental work.

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# The Attitude of Engineering Students Towards Robotization

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**Abstract.** The investigation of the attitudes of members of society towards robotization has been the focus of research for years. The studies, in addition to being task and development oriented, also focus significantly on the social effects of robotization. Opinions about the human-likeness and communication abilities of robots are measured, as well as the emotional factors formed by joint tasks with robots.

This research was conducted among engineering students studying at the Budapest University of Technology and Economics (Hungary), in which 320 students participated. The main goal of the research is to map the attitude of university students towards robotization, as a result of which we want to formulate a proposal for the further development of the curricula.

In relation to robotics, artificial intelligence, cloud-based IT and Big Data education are considered the most important. As the studies progress, these areas of knowledge are considered more and more important, and this is especially the case for women and those participating in part-time training (that is, those with work experience). Those students who have already learned about robotics or who can be considered professionals (mechanical engineer, electrical engineer, IT engineer, mechatronic engineer) attach more importance to the education of these topics. The topics to be taught were combined into three factors: (1) robotics in production, (2) virtual robotics, (3) integrated network communication.

**Keywords:** Robotization Attitude · Engineering Students · Empirical Research

## 1 Problem Statement

The investigation of the attitudes of members of society towards robotization has been the focus of research for years [1]. The studies, in addition to being task and development oriented, also focus significantly on the social effects of robotization. Opinions about the human-likeness and communication abilities of robots are measured, as well as the emotional factors formed by joint tasks with robots [2–4].

Koverola, et al. [5] emphasizes the importance of understanding attitudes towards robots and robotization from the point of view of understanding social-cultural-economic changes. A novel, multidimensional scale is presented, which is suitable for the multi-faceted exploration of the relationship between man and technology. The scale examines attitudes towards robots in four dimensions: on a personal and social level, in terms

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of positive and negative attitudes. The novelty of the measuring instrument can best be grasped in its applicability to the assessment of broadly understood social effects. According to their view, fears and hopes are not bipolars of the same dimension, but rather form two separate constructs. It is possible for someone to have high hopes and fears about something at the same time.

The human factors of robotization were also captured by Wullenkord & Eyssel [6], who classify the appearance of robots in various areas of life as a problem of social diversity, and suggest that negative attitudes and stereotypes must also be combated in this regard. During the study, implicit and explicit attitudes were measured, which indicate different aspects of behaviour. The results showed that people do not like the “robot perspective”, they do not like to look at anything from a robot’s point of view. Obtaining information about robots, innovative technologies and preliminary ideas can be a more effective solution in developing a positive attitude.

## 2 Purpose, Questions and Method of Research

We conducted our research among engineering students studying at the Budapest University of Technology and Economics (Hungary), in which 320 students participated. The main goal of the research is to map the attitude of university students towards robotization, as a result of which we want to formulate a proposal for the further development of the curricula. With our research using a self-developed questionnaire, we sought answers to two questions regarding robotization: (1) What existing experiences do students in technical higher education have? (2) By teaching which technologies would they expand their knowledge, i.e. what competence demands do they express to the institution?

The students had to fill out the questionnaire online, not in person, without a time limit. The online framework was self-developed, which made it possible to measure the completion time: background questionnaire (M = 166 s; SD = 97.1 s); robotic attitude (M = 220.7 s; SD = 124.3 s). The results were obtained with the SPSS statistical program, applied analytics: descriptive statistics, Chi-square test, cross-tab analysis, factor and cluster analysis. We also checked the reliability of the questionnaire: Cronbach-alfa = 0.796.

Age distribution of the students: 75% younger than 25 years, 12.8% older than 27 years, and 12.2% are between 25 and 27 years old (M = 24.42 years; SD = 6.13 years). 67.2% (215 people) of the students are men and 32.8% (105 people) are women, 59.1% (189 people) are studying at a bachelor’s degree, 33.1% (106 people) at a master’s degree, while 7.8% (25 people) participate in doctoral training. A significant proportion of the students are IT engineers (23.8%), electrical engineers (13.23%), mechanical engineers (10.05%), chemical engineers and mechatronics engineers (9–9%), and 34.92% study at the university’s 10 other engineering courses. 90.6% of them study full-time, while 9.4% study by correspondence.

# 3 Results

## 3.1 Experiences Related to Robotization

Regarding the robotization experiences gained during their university education, 60.6% (194 people) of the students responded that they did not have such a course in their previous trainings, 27.5% (88 people) said that they had such a course and 11.9% (38 people) stated that they had several such courses. Regarding the students who stated that they had such a course (126 people), 74.60% (94 people) of them were men and 25.40% (32 people) were women. 43.72% of men and 30.47% of women had such a course.

76.9% (246 people) of the students did not learn about the social effects of robotization at the university, 20.3% (65 people) mentioned one course, and only 2.8% (9 people) said that they learned about it in several courses. Regarding the students who stated that they had acquired such knowledge (74 people), 55.41% (41 people) of them were men and 44.59% (33 people) were women. 19.07% of men and 31.43% of women had learned about the social effects of robotization.

In the survey, we also asked whether the students had already worked in a job where they were expected to have some knowledge about robotization. 83.8% (268 people) answered no, 11.6% (37 people) had moderate, 3.1% (10 people) had medium, 1.6% (5 people) had significant robotization work experience. Among the students who stated that they had some level of robotization experience (52 people), 80.77% (42 people) of them were men and 19.23% (10 people) were women. This is 19.53% of all male students and 40.00% of all female students. 64.6% of undergraduate students, 56.6% of graduate students and 48.0% of doctoral students did not have a robotization-related course.

As for the social effects of robotization, the situation is even worse. 82.0% of undergraduate students, 69.8% of graduate students and 68.0% of doctoral students did not study about it. Only 7.9% of undergraduate students, 28.9% of graduate students and 28.0% of doctoral students had worked in jobs where they would have been expected to have knowledge about robotization.

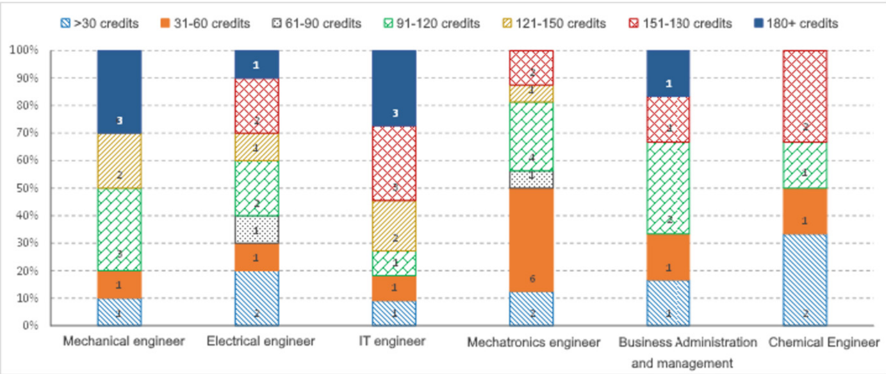


**Fig. 1.** Students having studied robotics by major.

Students having studied robotization were also examined by major. Among those in the undergraduate programme, 94.1% (16 students) of the 17 mechatronics engineers, 68.4% (13 students) of the 19 mechanical engineers, and 32.0% (8 students) of the 25 Electrical Engineers majors indicated that they studied robotization. Somewhat surprisingly, only 11 of the 45 IT Engineering students (24.4%) marked this option. On the other hand, 40.0% (6 people) of the 15 Business Administration and management major students and 35.3% (6 people) of the 17 Chemical Engineer major students stated that they had such a course. We also examined how many credits they have completed during their studies so far (Fig. 1).

## 3.2 Demand for Technology Education

In the course of the research, we also asked which technologies they would consider important in higher education. Students were asked to indicate their opinion on a six-point Likert scale (1: not important at all; …; 6: very important). This part of the background survey can be considered reliable since the Cronbach's alpha was 0.796. In the majority of the domains, it was below 10% who could not give an answer. Excluding them, the descriptive statistical indicators of each domain are given in Table 1 and Fig. 2. There were three topics that were considered especially important to teach about robotization: artificial intelligence, cloud computing and Big Data. The vast majority of students considered the university education of these topics to be very important. Among the less important topics they mentioned virtual reality and augmented reality.

The domains with the highest standard deviation were subjected to a more thorough analysis based on the background variables. In the analyses, we excluded in advance those students who could not judge the importance of the education of the given domain.

**Table 1.** Assessment of the importance of domains related to robotization.

| Domains | N | M | SD | Me | Mo |
|---|---|---|---|---|---|
| Machine-to-machine communication | 295 | 4.54 | 1.399 | 5 | 6 |
| Artificial intelligence | 310 | 4.97 | 1.168 | 5 | 6 |
| Robotics | 295 | 4.42 | 1.256 | 5 | 5 |
| Digital inventory and production planning | 294 | 4.14 | 1.489 | 4 | 6 |
| Automatically controlled production cell | 265 | 4.12 | 1.511 | 4 | 6 |
| Application integration | 271 | 4.38 | 1.271 | 5 | 5 |
| Virtual reality | 303 | 3.79 | 1.523 | 4 | 3 |
| Big Data | 274 | 4.74 | 1.261 | 5 | 6 |
| Cloud computing | 300 | 4.95 | 1.164 | 5 | 6 |
| Augmented reality | 290 | 3.88 | 1.516 | 4 | 4 |

Description of the variables (Tables 1, 2, 3, 4 and 5): N = Number of samples; M = Mean; SD = Standard Deviation; Me = Median; Mo = Modus; U = Mann–Whitney U test; p = calculated significance level

Considering the comparison by gender, it can be stated that women consider the education of most domains related to robotization to be significantly more important (Table 2).

We also examined the assessment of the various domains by level of training, but we found no significant difference in the averages. However, it can be said that with higher levels of training, the averages that are anyway high were even higher during the doctoral programme, and the ones that are low there were even lower. For example, the averages and standard deviations of the Big Data topic were as follows: Undergraduate ($N = 117$): $M = 4.62$; $SD = 1.305$; Graduate ($N = 74$): $M = 4.70$; $SD = 1.279$; Doctoral programme ($N = 14$): $M = 5.21$; $SD = 1.122$.

**Table 2.** Assessment of the importance of domains related to robotization by gender.

| Domains | Women | | | Men | | | U | p |
|---|---|---|---|---|---|---|---|---|
| | N | M | SD | N | M | SD | | |
| Artificial intelligence | 60 | 5.28 | 0.958 | 145 | 4.90 | 1.206 | 3583.5 | 0.035 |
| Digital inventory and production planning | 60 | 4.68 | 1.255 | 145 | 3.99 | 1.509 | 3215.0 | 0.003 |
| Virtual reality | 60 | 4.20 | 1.527 | 145 | 3.66 | 1.551 | 3497.0 | 0.025 |
| Big Data | 60 | 5.05 | 1.126 | 145 | 4.54 | 1.323 | 3367.0 | 0.008 |
| Cloud computing | 60 | 5.28 | 1.075 | 145 | 4.79 | 1.207 | 3242.5 | 0.002 |
| Augmented reality | 60 | 4.37 | 1.301 | 145 | 3.70 | 1.538 | 3269.5 | 0.004 |

Comparing the opinions of students in undergraduate and doctoral programmes, there is already a significant difference regarding teaching artificial intelligence ($\chi^2 =$ 1464,000; $p = 0.003$) and Big Data ($\chi^2 = 1403.000$; $p = 0.029$).

**Table 3.** The importance of robotics-related knowledge by training form.

| Domains | Full-time training | | | Part-time training | | | $\chi^2$ | p |
|---|---|---|---|---|---|---|---|---|
| | N | M | SD | N | M | SD | | |
| Artificial intelligence | 281 | 4.93 | 1.189 | 29 | 5.38 | 0.862 | 3.745 | 0.053 |
| Virtual reality | 274 | 3.73 | 1.538 | 29 | 4.31 | 1.285 | 3.770 | 0.052 |
| Cloud computing | 271 | 4.93 | 1.149 | 29 | 5.21 | 1.292 | 3.108 | 0.078 |
| Augmented reality | 262 | 3.81 | 1.523 | 28 | 4.61 | 1.257 | 7.046 | 0.008 |

As for permanent residence (not the residence in the dormitory), we found a significant difference ($\chi^2 = 9{,}200$; $p = 0.027$) regarding the assessment of Big Data:

- Capital (N = 163): M = 4.93; SD = 1.171
- Big city (over 50,000 residents) (N = 30): M = 4.43; SD = 1.501
- Small town (N = 51): M = 4.57; SD = 1.285
- Municipality, village (N = 30): M = 4.33; SD = 1.295

According to the form of training, we found significant or near significant differences in several domains (Table 3). It can be clearly seen that the students participating in part-time training, who also have work experience, considered the education of these domains to be more important.

Depending on whether they have learned something about robotics, we also found significant or near significant differences in some domains (Table 4). It can be stated that the acquisition of domain knowledge has a positive effect on the importance of teaching the specific course. This is especially true for three topics.

**Table 4.** The importance of robotics-related knowledge according to robotics-related studies.

| Domains | No such course | | | One such course | | | Several such courses | | | $\chi^2$ | p |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | M | SD | N | M | SD | N | M | SD | | |
| Machine-to-machine communication | 172 | 4.43 | 1.419 | 86 | 4.59 | 1.419 | 37 | 4.92 | 1.441 | 5.089 | 0.079 |
| Robotics | 174 | 4.22 | 1.276 | 84 | 4.64 | 1.126 | 37 | 4.89 | 1.265 | 12.618 | 0.002 |
| Automatically controlled production cell | 155 | 3.93 | 1.517 | 76 | 4.34 | 1.457 | 34 | 4.53 | 1.502 | 6.653 | 0.036 |

Based on the majors studied by the students, we formed two groups: professionals and non-professionals. The former included students who study mechanical engineering, electrical engineering, IT engineering, mechatronics engineering, that is, in a major where the domains related to robotics are more relevant.

We found three domains among undergraduate and two among graduate students, where there is a significant or near significant difference between the opinions of professionals and non-professionals (Table 5). Digital inventory and production planning was reported by the undergraduate students, while augmented reality was identified by graduate students in the relevant specialty as less needed during their studies, and they considered the other two specialties and another significantly more important than their non-professional counterparts.

**Table 5.** The importance of robotics-related knowledge by training form.

| Domains | Professional | | | Non-professional | | | $\chi^2$ | p |
|---|---|---|---|---|---|---|---|---|
| | N | M | SD | N | M | SD | | |
| *Undergraduate* | | | | | | | | |
| Machine-to-machine communication | 65 | 4.88 | 1.242 | 52 | 4.30 | 1.320 | 6.818 | 0.009 |
| Robotics | 65 | 4.51 | 1.173 | 52 | 4.16 | 1.250 | 3.272 | 0.070 |
| Digital inventory and production planning | 65 | 3.66 | 1.468 | 52 | 4.52 | 1.422 | 11.545 | 0.001 |
| *Graduate* | | | | | | | | |
| Automatically controlled production cell | 31 | 4.39 | 1.706 | 42 | 3.86 | 1.424 | 2.764 | 0.096 |
| Augmented reality | 31 | 3.48 | 1.480 | 42 | 4.36 | 1.394 | 6.516 | 0.011 |

The relationship between the ten domains was established using Spearman's correlation analysis. Table 6 shows the results of men and women. Cells with a grey background indicate domain links which both genders judged equally, and relationships with bold italics differ significantly between men and women. There were two domain links (machine-to-machine communication – robotics, application integration – cloud computing), which women judged more of the same way.

Under the main diagonal, the relationship between the domains was given, and the correlation factors that showed a strong relationship were indicated in italics. The automatically controlled production cell was judged in a similar way to robotics, as well as digital inventory and production planning, augmented reality, virtual reality, and Big Data.

We compared the relationship systems between the opinions of undergraduate and graduate students regarding the education of the given domains. As seen in Table 7, the opinions of graduate students are more coherent than those of their undergraduate counterparts, as the importance of domains was assessed by more people the same way.

In the background survey, we also asked about the students' previous studies on robotics (robotization course, course showing the social effects of robotization) and their work experience. We examined how these affected the assessment of the importance of the above domains by cross-tabular analysis. We found few significant correlations.

Male students considered teaching robotics markedly more important and very important ($\chi^2$ = 21.740; p = 0.016, $\Phi$ = 0.327) if they already had such a course than those who did not (Fig. 2). The strength of the relationship is considered medium.

**Table 6.** Relationship system of domains related to robotization and its relationship by gender.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.00 | .11<br>.21* | .55**<br>.26 | .19<br>.30 | .31*<br>.35** | .19<br>.41** | .08<br>.18* | .15<br>.22** | .23<br>.42** | .07<br>.14 |
| 2 | .18* | 1.00 | .27*<br>.26** | .01<br>.08 | .01<br>.06 | .10<br>.15 | .06<br>.31** | .08<br>.45** | .28*<br>.29** | .121<br>.40** |
| 3 | .34** | .26** | 1.00 | .40**<br>.43** | .51**<br>.42** | .06<br>.25** | .20<br>.30** | .22<br>.23** | .18<br>.19* | .33*<br>.31** |
| 4 | .26** | .08 | .41** | 1.00 | .64**<br>.73** | .22<br>.36** | .12<br>.14 | .28*<br>.10 | .25<br>.10 | .15<br>.22** |
| 5 | .34** | .04 | .44** | .69** | 1.00 | .37**<br>.54** | .06<br>.16 | .20<br>.18* | .12<br>.09 | .02<br>.13 |
| 6 | .34** | .15* | .20** | .33** | .49** | 1.00 | .28*<br>.19* | .20<br>.40** | .47**<br>.30** | .09<br>.16 |
| 7 | .15* | .26** | .27** | .17* | .14 | .21** | 1.00 | .31*<br>.43** | .25<br>.24** | .61**<br>.77** |
| 8 | .19** | .37** | .22** | .17* | .19** | .35** | .40** | 1.00 | .30*<br>.50** | .44**<br>.41** |
| 9 | .35** | .31** | .17* | .17* | .09 | .35** | .26** | .45** | 1.00 | .20<br>.27** |
| 10 | .11 | .35** | .31** | .23** | .10 | .15* | .74** | .43** | .28** | 1.00 |

Note: Upper values were female (N=60) and lower values were male (N=145).
* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).
Domains (Table 6-7): 1 Machine-to-machine communication, 2 Artificial intelligence, 3 Robotics, 4. Digital inventory and production planning, 5 Automatically controlled production cell, 6 Application integration, 7 Virtual Reality, 8 Big Data, 9 Cloud computing, 10 Augmented reality.

Regarding male students, we also found a link between the domains on digital inventory and production planning ($\chi^2 = 20.328$; $p = 0.026$, $\Phi = 0.321$) and virtual reality ($\chi^2 = 18.203$; $p = 0.052$, $\Phi = 0.299$) and Big Data ($\chi^2 = 20.738$; $p = 0.023$, $\Phi = 0.330$) and what they learned about the social effects of robotization (Fig. 3). Those who previously had such courses considered the education of these domains more important than those who did not.

**Table 7.** Relationship system of domains related to robotization by level of training.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.00 | .12 | .33** | .26** | .30** | .23* | .00 | .03 | .29** | .07 |
| 2 | .28* | 1.00 | .27** | .11 | .08 | .16 | .28** | .34** | .30** | ***.41*** |
| 3 | ***.42*** | .21 | 1.00 | .34** | ***.43*** | .20* | .24** | .28** | .21** | .31** |
| 4 | .19 | .11 | ***.60*** | 1.00 | ***.71*** | .31** | .18 | .09 | .13 | .22* |
| 5 | .36** | -.01 | ***.60*** | ***.64*** | 1.00 | ***.54*** | .10 | .09 | .08 | .08 |
| 6 | ***.44*** | .17 | .23* | .32** | ***.43*** | 1.00 | .11 | .23* | .22* | .04 |
| 7 | .35** | .21 | .31** | .19 | .18 | .34** | 1.00 | .37** | .18 | ***.77*** |
| 8 | .40** | ***.45*** | .19 | .25* | .22 | ***.54*** | ***.42*** | 1.00 | ***.48*** | ***.44*** |
| 9 | .38** | .37** | .15 | .19 | .09 | ***.48*** | .36** | ***.45*** | 1.00 | .33** |
| 10 | .10 | .23* | .29* | .29* | .13 | .26* | ***.68*** | ***.42*** | .19 | 1.00 |

Note: Above the main diagonal are the undergraduates (N=117), below the graduate students (N=74).
* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

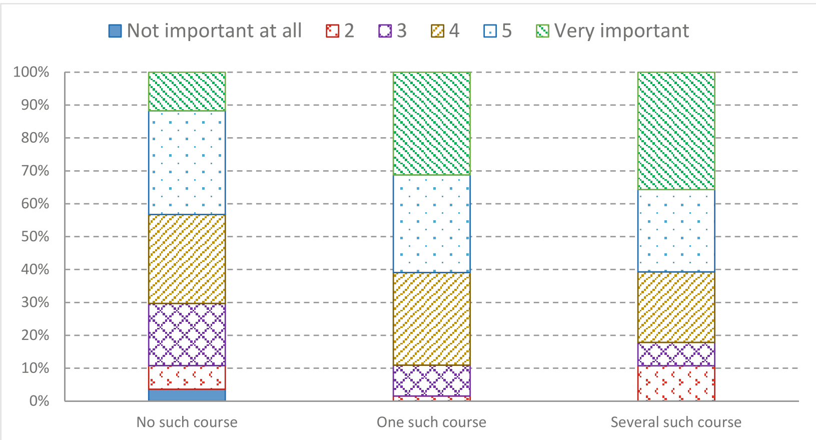


**Fig. 2.** Assessment of the importance of robotics by studies on robotization.

We also compared the assessment of the importance of the education of the individual domains according to the extent to which the learned profession is related to robotics (professional vs. non-professional). In this regard, we found a significant relationship between machine-to-machine communication ($\chi^2 = 13.906$; $p = 0.016$, $\Phi = 0.266$), digital inventory and production planning ($\chi^2 = 12.706$; $p = 0.026$, $\Phi = 0.255$), robotics ($\chi^2 = 10.535$; $p = 0.061$, $\Phi = 0.233$) and application integration ($\chi^2 = 10.829$; $p = 0.029$, $\Phi = 0.341$) among students (Fig. 4). Those who should be professionally more

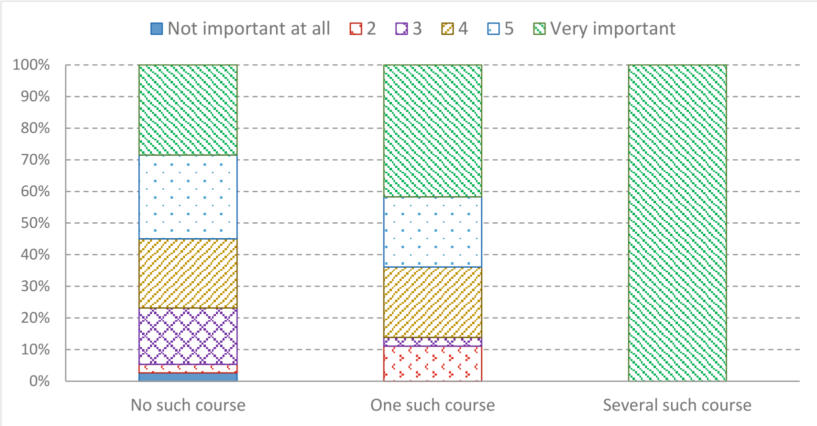


**Fig. 3.** The importance of Big Data by learning about the social effects of robotization.

competent considered the education of these domains more important than those who are less related to the field of robotics.

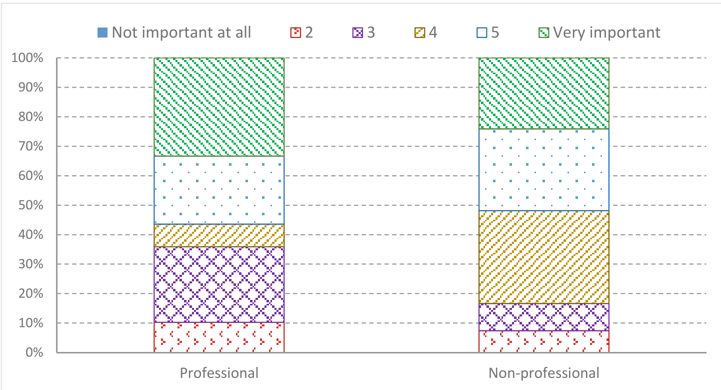


**Fig. 4.** The importance of application integration based on professional competence.

Using factor analysis and based on student opinions, we were able to combine each domain into three factors (Table 8) (KMO = 0.726; Bartlett test: $\chi^2 = 695.923$; $p = 0.000$).

The three factors are:

F1: Robotics in manufacturing;

F2: Virtual robotics (the standard deviation of the two related items is the biggest as we have seen before);

F3: Integrated network communication.

In other words, students of higher education consider these three topics the most important to learn about.

**Table 8.** Factor variables of domains related to robotization.

**Rotated Component Matrix**[a]

| | Component | | |
|---|---|---|---|
| | F1 | F2 | F3 |
| *Teaching technologies: Automatically controlled production cell* | *.905* | .009 | .067 |
| *Teaching technologies: Digital inventory and production planning* | *.833* | .185 | -.039 |
| *Teaching technologies: Robotics* | *.566* | .389 | .140 |
| **Teaching technologies: Augmented reality** | .115 | **.896** | .150 |
| **Teaching technologies: Virtual reality** | .120 | **.843** | .174 |
| *Teaching technologies: Cloud computing* | .020 | .148 | *.805* |
| *Teaching technologies: Big Data* | .072 | .423 | *.660* |
| *Teaching technologies: Machine-to-machine communication* | .466 | -.065 | *.538* |
| *Teaching technologies: Artificial intelligence* | -.032 | .378 | *.533* |
| *Teaching technologies: Application integration* | .526 | -.074 | *.530* |

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 7 iterations

Cluster analysis was also performed with the variables of domains indicating the highest and lowest standard deviations. Three sets of opinions can be distinguished from each other (Fig. 5):

C1: The group of respondents who believe the teaching of robotics to be less important ("the uninterested") – 50 people, 15.6%;

C2: The group of respondents who believe the teaching of certain topics to be important ("the picky") – 125 people, 39.1%;

C3: The group of respondents interested in all topics ("the omnivorous") – 127 people, 39.7%.

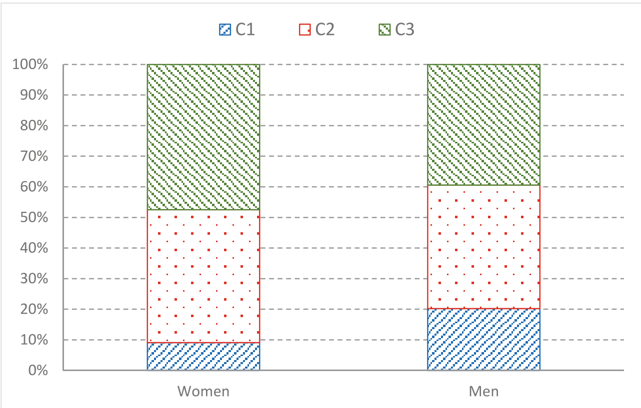


**Fig. 5.** Gender clusters related to the education of robotization domains.

The group of respondents who believe the teaching of robotics to be less important is relatively small, mostly characterized by the following: most of them are men (20.2% of men and 9.1% of women); big city (31.4%); undergraduate students (19.1%); studying full-time (17.2%); state scholarship holders (17.0%).

There is a significant difference between the three clusters by gender ($\chi^2 = 6.136$; $p = 0.047$). Women are more committed to robotization, while men are more cautious (Fig. 5).

## 4 Summary

With the participation of 320 students from the Budapest University of Technology and Economics, we conducted a non-representative online research (thus our findings apply only to the students participating in the research), in which we sought to answer the questions of what kind of experience the students of the technical university have about robotization, and the teaching of which technologies they would consider important in higher education. Based on the results of the research, we have come to the following conclusions.

About 40% of the students learned about robotization or robotics at the university, and about 20% of them about its social effects, while about 15% of students have practical work experience in this field. Nearly half of doctoral students, about 40% of graduate students and more than 30% of undergraduate students had such a course. Courses with the largest proportion of robotics students are represented in the following majors: mechatronics engineer, mechanical and electrical engineer, IT engineer.

Regarding robotics, respondents consider the teaching of artificial intelligence, cloud computing and Big Data to be the most important. As students progress in their studies, these domains are considered to be increasingly important, primarily by women and part-time students (i.e. those with work experience). Students who have already studied robotics or are considered professionals (mechanical engineer, electrical engineer, IT engineer, mechatronics engineer) attach greater importance to the education of these topics. The topics to be taught were combined into three factors: (1) robotics in manufacturing, (2) virtual robotics, (3) integrated network communication.

The main characteristics of the group of students who consider the teaching of robotics less important: male students from large cities participating in state-sponsored full-time undergraduate education, that is, the teaching of elective courses should be advertised among them.

Both international and domestic research findings and practical experience demonstrate the importance of digital transformation for companies in terms of market survival, development and growth. For this, it is essential to transform the way of thinking of chief executives and managers of companies. Based on the findings of our study, it is necessary to place more emphasis on increasing robotization knowledge and shaping the attitudes of future senior managers in university education.

Based on the research results, a subject showing the social and economic effects of robotization should be included in the curriculum of the university's engineering courses, with particular attention to artificial intelligence, employment, legal and ethical issues. In addition to these, the contents of certain technical subjects also need to be modernized.

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# Our University's Women Engineers in Harmony with the Past and the Present - A Presentation Paper from the Organizers of the ICL-IGIP 2025 Conference

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**Abstract.** We would like to give you some information about our university, the Budapest University of Technology and Economics, our Technical Pedagogical Department, our colleagues and the path that women in Hungary have taken towards higher education and engineering. Our history begins in the times of the Austro-Hungarian monarchy, spans two world wars, then touches the 55 years of our country's economic, military and political existence under the Soviet Union and ends in today's days. In a separate chapter and in more detail, we present our pride, Esther Pécsi, the first Hungarian female engineer, based on the documentation and research of our university. The position of women changed greatly after the Second World War, and during the period of the socialist state, in which women had to become equal to men in all areas, this became even more pronounced. We interview a female engineer who was involved in the planning of the first prefabricated housing estates (panel construction) about this period. Our work is a historical outline from many perspectives. It is a scientific collection of the Hungarian engineering education of women, presented from the perspective and focus of the Budapest University of Technology and Economics, with which we would like to bring you a little closer to our university and arouse your interest to visit us in 2025 in the sense of a common knowledge transfer.

**Keywords:** Women engineers · History · Hungary

## 1 Introduction

Our paper is a small study in which we would like to introduce ourselves as the hosts of the conference to be held in two years.

We would like to present our university, the Budapest University of Technology and Economics, our department, our faculty, and the road women in Hungary could take towards higher education and engineering sciences. Our story begins at the time of the Austro-Hungarian Monarchy, spans two world wars, and then touches upon the 55-year period of our country's history during which economically, militarily and politically it belonged to the sphere of influence of the Soviet Union, and ends with present.

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Our work is a historical summary of many aspects. It is a scientific material presented from the perspective of and with the focus on the Budapest University of Technology and Economics that collects information on Hungarian women's engineering training, and with which we would like to bring our university a little closer to you and generate interest to visit us in 2025 in the spirit of joint knowledge transfer.

### 1.1 The history of the Budapest University of Technology and Economics from 1782 to the present

1782 – The Institute Geometrico-Hydrotechnicum was the first institute of civil engineering in Europe, where technical sciences were taught in a university system. Surveying and water construction skills were taught within the framework of applied mathematics. This preceded the French École Polytechnique, which was elevated to the rank of college in 1794, by 12 years.

1846 – Under the influence of increased economic demands and government regulation, the College of Technology was established. Here training was separated into three disciplines: technical, commercial and economic. As early as the time of the 1848–1849 Revolution and War of Independence, the idea of transforming the school into a university was born.

1850 – The Habsburg government merged the Institutum Geometrico-Hydrotechnicum and the College of Technology. However, as a sanction of the war of independence that had been crushed the year before, the new institution, registered as Joseph Industrieschule, was not allowed to operate at higher education level. The language of teaching was German and only technical training was permitted.

1856 – Transformed again as the Royal Joseph Polytechnic, the school regained its status as a higher education institution and, in addition to technical training, economic training could be started again. This also coincided with the differentiation of higher education, where separate training programmes were organised for mechanical engineers, general engineers and chemical engineers.

1860 – Hungarian-language education was restored, and the name of the Royal Joseph University was used instead of the name polytechnic.

1871 – Emperor Franz Joseph Habsburg of the Austro-Hungarian Monarchy and King of Hungary approved the new organizational rules of the Royal Joseph University. It was the first technical higher education institution in the world to include the word university in its name. In 1901 it was granted the right to confer the doctoral degree. The 1909/1910 academic year began on the current campus area.

1934 – The Hungarian Royal Palatine Joseph University of Technology and Economics was formed from the merger of four major higher education institutions. With 98 departments, it was the largest higher education institution in Hungary.

1949 – A few years after the Second World War, the political power of the time reorganized the institution, and the Technical University of Budapest was established. During the period of the socialist state regime, the university could continuously develop, expand with new faculties, and kept up with the technological development of the world.

2000 – The development of half a century and the political reorganization of Hungary's economy brought about a change in the name of the institution, and from then on, the new name of our university became the Budapest University of Technology and Economics [1].

## 2 Female Students in Hungarian Higher Education

It was a long journey for Hungarian women to the university, as they were not even allowed to go to high school in the early 1800s. This was only possible from the 1840s as a result of the activities of Countess Blanka Teleki (1806–1862), the pioneer of Hungarian women's education, as well as Teréz Karacs and Pálné Veres, when the doors of secondary schools and vocational training institutions were opened up for women [2].

In the 19th century, two schools opposed women's participation in higher education: one was that women's intellectual abilities and weakness of will did not allow them to attain higher education. The other said with conviction that the presence of women would distract men from their studies, and their results will deteriorate, which will cause the deterioration of the quality of higher education and the economic decline of the country in the long term. This discourse continued throughout the century, as there were a number many scientific works advocating women's right to education.

### 2.1 From the Beginnings to the First Female Graduates

In 1835, Professor József Nyíri considered the cultivation of the body and soul as the natural right of women. In 1848, Blanka Teleki's students took further steps.

The fall of the 1848–1849 Revolution and War of Independence for the Kingdom of Hungary delayed women's rights movements, but after the Compromise of 1867, the summary name of the agreements that settled the political, legal and economic relations between the Austrian Empire and the Kingdom of Hungary, it was back again on the agenda.

By 1870 it was part of the everyday scientific discourse and was a regularly covered topic in the press. However, in 1891, the Minister of Culture of the time refused the admission of women to universities.

In 1895, the new Minister of Culture Gyula Wlassics petitioned to the monarch, and on 18 November 1895 Franz Joseph, Emperor of the Austro-Hungarian Monarchy and King of Hungary, finally allowed the admission of women to Hungarian universities offering training in humanities, medicine and pharmacy [3].

**Ministerial Decree No. 65.719:** "The issue of allowing women's access to scientific careers has long been a matter of debate in the educated society, scientific circles, and the governments of most educated states. […] The changing social and cultural conditions have forced women to seek new professions instead of the traditional once that provide a better livelihood and acquire the knowledge necessary for this purpose. As a result, in addition to the gradual increase in the general education and knowledge of women, professions that required a certain degree of scientific preparation and were formerly held to be the exclusive careers of men were gradually opened up to women. Before the eyes of this generation, the concept of women's professions was transformed, and society's view was also followed by the appreciation of the state, because even in its own institutes for jobs previously filled exclusively by men, women were employed in large numbers, and everyone knows: with complete success. With the measures that the state has already taken in expanding the profession of women, the older social concept, therefore, has given way to the new approach that a woman can fulfil more serious careers if they have the disposition, talent and profession to do so" [1681. p. 4].

"His Imperial and Apostolic Royal Majesty in Vienna, by the supreme decision of 18 November of this year, has most graciously approved this proposal that women, in order to enter the humanities, medicine and pharmacy careers, should be admitted to higher education institutions on a case-by-case basis, provided that they meet the proper conditions, on the basis of a hearing at the competent higher education institution, and that a certificate of qualification should be issued to them after they have successfully completed their studies, in accordance with the existing rules" [1684 p. 4].

**The First Female Graduates.** Countess Vilma Hugonnai obtained her medical degree in Zurich in 1879, but when she wanted to naturalize it in Hungary in 1881, she was first obliged to pass the secondary school graduation exam. The university would have agreed to naturalize her diploma after the successful passing of a "medical science" exam, but the ministry refused. It only happened in 1897, two years after the decree above was declared.

Vilma Glükclich was the first female student to obtain a degree in humanities at the University of Budapest, where she began her studies in physics and mathematics in February 1896. A medical degree in obstetrics and gynaecology was first conferred upon Sarolta Steinberger on 3 November 1900.

In the 1896–1897 academic year, there were only three female students at the University of Budapest, and then their number increased continuously. A total of 62 women were admitted to the Faculty of Humanities and 25 to the Faculty of Medicine in the 1900–1901 academic year. Shortly thereafter, in the 1908–1909 academic year, there were 168 humanities, 63 medical and 18 pharmacy female students enrolled. The number of women in the faculties open to them continued to increase. In the 1916–1917 academic year, the proportion of women in the Faculty of Humanities was close to 50% (526 students), in the medical faculty 28.1% (467 students), and in pharmaceutical training 51.7% (46 students) were female [2].

## 3 Female Engineer Training and the First Hungarian Female Engineer

The aforementioned Royal Decree did not open up legal and engineering studies to women. These were only temporarily made available to women after World War I, during the period of the bourgeois-democratic revolution of 1918–1919, the "Soviet Republic". Ministerial Decree No 206626/1918 of 7 December 1918 repealed the restrictive measures on the admission of women to universities, thereby allowing "women to enrol in the secular faculties of universities, the technical university and the law academies under the same conditions as men (…) and, having completed their studies in accordance with the rules in force and having passed the qualifying examinations, to have the qualification decree issued to them" [378. p. 5] This state of affairs existed only for a short time, as after the fall of the Soviet Republic, there were again restrictions and limitations imposed on the admission of women to universities. Those, however, who started their studies in 1918, could complete them and receive a diploma [2].

The first graduating female students at the Technical University of Budapest in 1920 were civil engineer Eszter Pécsi, architect Marianne Sternberg-Várnay, and mechanical engineer Vilma Máhrer. Historical events in Hungary had a negative impact on women's engineering training after 1920. In her essay, Éva Vámos refers to the fact that "even after 1919, a significant number of women could not study in universities, and even *numerus clausus* laws were introduced to limit the number of female and Jewish students" [17 p. 6] In 1927, a decree was issued that women could not study general engineering, mechanical engineering and chemical engineering at the Technical University of Budapest. Women could be admitted to the Faculty of Architecture up to 5%of the total number of students, provided there were not enough male applicants. It was not until September 1935, when Secretary of State Dr. Kálmán Szily, a professor at the university himself, authorised that up to 5% of the students' women could be admitted to the first year of the faculty of mechanical and chemical engineering [6].

### 3.1 Eszter Pécsi, the First Hungarian Female Engineer

Our chapter on the life and work of Eszter Pécsi (maiden name: Eszter Pollák) is published based on the description of the website of our university. Between 1915 and 1918 she was a student at the Technische Hochschule in Berlin-Charlottenburg, then returned home in February 1919 and continued her studies at the Technical University of Budapest. She received her general engineer diploma, which is civil engineering in today's terms, on 8 March 1920.

Her first job was at the Guth and Gergely architectural engineering office in Budapest, where she became a senior designer a few years later. In the meantime, she met modernist architect József Fischer, whom she married in 1922, and they had two sons, both of whom became architects. Her works at this time included the articulated reinforced concrete arches of the Alfréd Hajós Swimming Pool in Margitsziget. The building is still standing and operates as a sports swimming pool. It was the first indoor swimming pool in Hungary and the largest in Europe at the time, in which the pool was covered by five 31-m span reinforced concrete beams with an internal height of 14 m.

In 1930, she founded her own architectural firm, which she and her husband ran until 1948. She designed and engineered significant floating reinforced concrete slabs and tower foundations, as well as higher-than-usual steel frame structures, working as a structural engineer with many of the period's leading Hungarian architects. Her designs of original structural solutions included the Traumatology Institute at Fiumei út, the first high-rise building in Budapest, the hospital in Kútvölgyi út, and the structural plans of several modern houses. She also participated as a structural engineer in the Hungarian group of the CIAM (Congres Internationaux d'Architecture Moderne).

During World War II, she helped many people with her husband, who was also a social democratic politician. After the war, she supervised the reconstruction of the bomb-damaged buildings of the capital, as well as the reinforcing works of the crushed roof of the National Theatre. She was honoured in recognition of her work. From 1949 she was an employee of the Design Office of the Ministry of Metallurgy and Mechanical Engineering (KGMTI) and then chief structural engineer.

After the 1956 revolution was crushed, she fled to Austria. There she worked for the Krapfenbauer architectural firm and designed the structural plans for the city's first downtown multi-storey car park near the Vienna Opera House She moved to New York in 1958. Initially she was a static engineer in the engineering office of Farkas&Barron, then she worked with Marcell Breuer, the world-famous Hungarian architect-designer, the master of Bauhaus. Later, she worked for SOM (Skidmore, Owings and Merrill), one of the most prestigious American architectural firms, including the static design of the city's tallest reinforced concrete structure at the time, the Hotel Americana, and two high-rise buildings at Columbia University. In 1965, Pécsi was awarded the "Best Structural Engineer of the Year" award for the special foundations method she invented which allowed high-rise buildings to be built on the banks of the Hudson River.

She suffered a massive stroke in 1970. She died on 4 May 1975 in New York, her ashes were brought back to Hungary and laid to rest in the Farkasréti cemetery. A plaque was placed on her birthplace in Kecskemét in 2000 and on the wall of the couple's house in Szent István Park in Budapest in 2001. The Budapest University of Technology and Economics named a room after her on the 100th anniversary of the first female engineering degree [7].

## 4 The Female Engineer as an Icon in the Era of State Socialism, 1947–1956

Finally, the Act XXII of 1946 opened the doors of all secular higher education institutions in Hungary to women. "Women can be admitted to all faculties of universities and colleges without any restriction within the limits of the established number of students" [2]. In connection with this period, Ildikó Asztalos Morell's writing points out interesting and at the same time less well-known details in her study "The Female Engineer: A liberated woman or a party-rhetoric discipline tool in the era of the personal cult in Hungary" (original Hungarian title: "A mérnöknő: felszabadított nő vagy pártretorikai fegyelmezőeszköz a személyi kultusz Magyarországán"). State socialism developed its rhetoric in the Soviet style and introduced new models into the public consciousness. This also included image of women. The woman engineer became the new icon, the new female ideal, and her figure was used to demonstrate the total takeover of power as a means of new social teaching. The emancipated woman is an important figure, because as a symbol of liberation, she no longer lived in a dependent relationship in the confinement of her home but was now independent. She took part in the construction of socialism and had an independent income. She was portrayed as a sort of socialist superwoman [8].

This image was connected to the narrative by those in power that while many things had been closed to women, it was only the taking over of power by the working class that made the dreams of the future women engineers possible. All this was further combined with the theory that the engineer possesses a technical knowledge that is fundamental to the development of the ages, including the socialism that was being built. The female engineer emerged as a modern figure, a pioneer, who represented the party's ideological superiority and revolutionary spirit. Young women who earned their engineering degrees at that time had already become creatures of state socialism, as the opportunity to study had elevated them to a higher social class. Raising children became the task of the state, so ideological education could be realized smoothly while women – workers, engineers – worked and built the country. Their children were brought up from infancy in a newly established and perfectly coordinated institutional system, where they were provided with 8–10 h of day care, education and upbringing: day care nursery, kindergarten, eight-year primary school, and vocational training or secondary grammar school depending on their learning performance [8].

"The subordinate position of women in society is also socially given according to Marxism, and it is therefore possible to change it. Hence the legitimacy of state socialist emancipatory rhetoric. The female engineer as an icon belongs to this rhetoric of women's emancipation, which emphasized that women's emancipation represents an organic part in the construction of the state of the working class. The emancipatory rhetoric of the 1950s did not question the primacy of the male norm. In contrast, women had the opportunity to ascend to the male standard through the world of work, that is, women, in addition to the fact that they usually had to and could participate in wage-based work, had the opportunity to occupy traditionally male jobs, such as bricklayers or tractor drivers. The engineering profession was clearly the bastion of masculinity and the technological basis of male power monopoly. The rhetoric suggested breaking up this customary gender pattern. [...] The entry of women into men's fields of operation was supported by quotas and positive discrimination. At the same time, men were not expected to take over some of the child rearing and caring responsibilities of women. Instead, the state had to facilitate the employment of women in earning employment by establishing a system of state public care. Men were not expected to take up jobs in the labour market in women's occupations, either" [149 p. 8]. The involvement of women as labour force was a fundamental and indispensable consequence of the significant increase in labour demand in the economy. This was due to the fact that the expansion of the centrally planned economy was limited not by market demand, as in the time of capitalism, but by resources [8]. Under the dictatorship of the proletariat, the central power deliberately weakened the groups that were not dependent on the state for their subsistence by nationalizing private property. This reorganisation included the involvement of women in the world of work, which also meant that the family handed over the education of children to state institutions. Women who might have still considered their role in child-rearing important had to be emancipated and re-educated to the party ideology.

They removed the woman, who also represented family security, from behind the man. A woman could build her own career and be sure that her children, as she was, of course, still expected to have children, could be raised in the safety of the state institutional system with all its support. "The relationship of the female engineer to the party is twofold. Using religious parallels, on the one hand, she paly an apostolic and redemptive role. Just as the apostle can bring the words of God to the people, so can the woman engineer enlighten and convert workers in the spirit of the ideology represented by the party. On the other hand, she is a maternal "saint" who commands a kind of respect" [162–163. p. 8].

Morell Asztalos references Joana Goven's 2002 study published in Issue no. 9 of Social Politics by the Oxford Academic entitled "Gender and Modernism in a Stalinist

State": "The emancipatory policy of state socialism was a kind of balancing act between the deconstruction and reconstruction of the gender power order" [170 p. 8] The party state made women indebted, and thereby expropriated the women's question.

## 5 Women in the Engineering Field After 1956 – A Discussion with a Female Engineer About the Miracle of the Blocks of Flats

### 5.1 Professional and Historical Background

Our partner in the processing of this historical part is a female engineer who lived through the 1956 revolution as a high school student. – Respecting her request for anonymity, her name and personal details will not be mentioned. This is how she describes this time in her life:

"I graduated from the machine tool department of the machinery polytechnic in Székesfehérvár in 1957. This class was not accepted to universities immediately for political reasons, so I was able to find employment in Ajka as a machine operator of the local construction company. I had to operate an industrial concrete mixer. I was a skinny 18-year-old girl who barely weighed 40 kg. I was supervised by an older chief engineer who knew my father from somewhere and fortunately took me to work in the office for the winter. I checked plans, helped with accounting, took inventory. It wasn't exactly a dream job, but I quickly learned how to run a big socialist company, which I admit was new to me, since my father was a motorcycle racer and had a car and motorcycle mechanic workshop in Veszprém.

I wanted to go to university, but I had to move to my relatives in Budapest and continue to provide my own livelihood. I was admitted to the Faculty of Mechanical Engineering of the Technical University of Budapest for evening classes, where I graduated from the faculty of building engineering in 1965. In parallel with that, I joined the Electrical Building Engineer group of the Building Engineering Department of the Budapest City Construction Planning Office (Hungarian abbreviation: BUVÁTI). As a result, my professional work has shifted towards building electrical design. At first, I worked on the so-called office no. 7. I worked with only older engineers, who were all old-fashioned ladies and gentlemen, and our office manager was a woman too, who also graduated before the war. This was the "penal company" of BUVÁTI. Former university professors, engineering colleagues from the old nobility and intellectual families who had their own engineering offices before the party-state world. But the state needed their knowledge and their work. We mainly surveyed the buildings of downtown Budapest. Often ruins, or heavily demolished dwellings, of which there were still plenty throughout the city at that time. We tried to determine their restorability and the possibility of being able to build floors and roofs on them to create additional apartments.

Housing was an insoluble problem in Budapest in the early 1960s, but also in other Hungarian cities. People lived in so-called co-tenancies, which meant that the remaining and habitable or already restored apartments were shared by several families, typically 2–4 who were strangers to each other. They used the kitchen, the bathroom and the toilet together, and their living space was limited to a single room. As the socialist economy united and nationalized agriculture into cooperative farms, young people were no longer able to find jobs in the countryside. The party state goal to strengthening the working class was also achieved as the rural youth moved to the cities. But there were no apartments, there was simply no place to live. I don't think young people today can imagine that. Empty plots of land on the site of bombed-out houses, ruined, sealed buildings for which there was no money or manpower to renovate or demolish."

## 5.2 Prefabricated Houses, Blocks of Flats

"And then came the panel, the prefabricated block of flats. That was a miracle! Suddenly, the housing issue, the liquidation of co-tenancies and the goal to provide young people with housing seemed possible to solve. We believed in it, we were enthusiastic and designed it, we did it to the best of our ability. After surveying the crumbling old walls, we could finally design. I know that today's young people only see the monster in the prefabricated housing estates, but at that time this was the solution – and a solution was urgently needed.

In 1964, I was transferred to the design team where we started to design panel apartments, that is, prefabricated blocks of flats for the first time in Hungary. First, under a Danish licence, the Larsen-Nilsen type of prefabricated blocks of flats, and by the time the designs and the related systems were complete, all this was pushed into the background in favour of the Soviet model, the Soviet licence.

I was fortunate enough to see the original panel houses in Copenhagen at that time, and I liked them very much, I was incredibly enthusiastic. The four-storey houses with wide streets, parking lots and wooded parks were located at a comfortable distance from each other. This is also how we imagined they would be in Hungary. But even the blocks of the housing estate in Őrmező were already tall and densely built. One of the architects of that housing estate was my later husband, who told me that the site was officially expropriated, the district was literally demolished, the trees were cut down and the area had to be built on a completely flat, empty plot of land with the density determined by the party leadership. The Danish miracle remained a dream.

In a short time, the construction of the Larsen-Nilsen houses was discontinued in favour of the Soviet-type panels. In these, there were even fewer options, if at all, and they were far from being aesthetic [9]. But we also came to like them because they were new buildings, with own apartment, bathroom, kitchen, central heating for everyone. They colour-edited design drawing was beautiful on the tracking paper, where the designer used different ink lines and sent it to the photocopier. Yes. The engineer negotiated, performed technical management and handed out the work to the designer, then the drawer drew it on tracing paper.

There were many female engineers. We became more and more numerous as we needed more and more design offices. But the tricks of the trade could only be learned in practice. We didn't learn how to design a prefabricated house in college. The name panel is very telling as it was worked out in advance, but the mechanical engineers had a difficult job ahead of them. Spatial designs and unit connections were solved by the architect and the structural engineer, but we had to design water, sewage, heating and electricity. The phone lines were added to the drawings much later, as there was no phone. We had to fit the engineering technologies of the time into the given places, so we struggled a lot. But we also learned to design public education facilities, because in a prefabricated housing estate such the nursery, kindergarten and school, and even the medical office.

Although the trees have grown and the parks have become greener, the housing estates have not become nicer, but they are still indispensable. We designed them from the best available materials and to the best of our knowledge at the time. For example, the "MM wall", that is the glued electrical wire was also a novelty at that time.

It was a miracle that could have been so much better, but it was made a political issue and the most crucial decisions were not left to the experts."

## 6 International Outlook

In the last decades it has become clear that the representation of women in higher education is increasing. In 2015 the portion of bachelor's degrees awarded to women has exceeded the 50% in many countries, including Hungary. If we also consider the chosen fields, it is obvious that women tend to choose other fields than computing and engineering sciences [10].

International literature also addresses the situation and opportunities for women in engineering education. Mozahem et al. [10] examined the perspectives of female engineering students in Lebanon using semi-structured interviews and found that the most important obstacles are family environment, workplace, and work-life balance. According to Bandura's Social Cognitive Theory [11] and the Social Cognitive Career Theory based on it [12], career paths are determined by three factors: personal factors, behavioural patterns, and environmental events. Individuals are not fully autonomous in this system of relationships, nor are they solely controlled by external influences. The individual's perception of self-efficacy is a key concept in the selection of the study field. As computing and engineering are historically considered male-dominated professions, women perceive lower level of self-efficacy on these fields. [13].

If one would like to understand the possibilities of women on the STEM field, it is needed to consider wider social contexts. Our study aimed to give an insight to one segment of the problem, presenting the historical aspects of the situation of women in Hungarian engineering education.

## 7 Closing Remarks

Hungarian engineers were responsible, well-trained skilled workers in the party state era. Architects had little opportunity to showcase their artistic side. From 2000 onwards, another development started again, which now allows the realization and application of the wide range of opportunities of the engineering profession. The histories of women, female engineers and Hungary shows a nice parallel in the alternating periods of trials and recovery. Nowadays, more and more young women choose technical careers, more and more of them graduate as engineers and stay in their selected profession for hopefully many decades.

The commitment of the Technical University of Budapest to gender equality is indicated by the completion of the BME Gender Equality Plan 2022–2025 (BME GEP) in

2021, which was adopted by the Senate of the University in December 2021, after a period of long preparations [14].

The proportion of female students in all training areas is gradually growing, and the ratio of women among all the students studying at the Technical University of Budapest exceeded 34% by 2021. According to UNESCO data, 35% of women participate in technical training worldwide. According to the data provided by the Hungarian Central Statistical Office, the proportion of female students in the field of technical training in Hungarian higher education is 27%, but this number is even higher at our university at 30.2%. In recent years, the ratio of women has increased significantly in the Faculty of Architecture's undivided architectural training programme (62.7%) and in the university's doctoral courses (32.2%). Particularly there is a sharp increase in the proportion of girls in the Faculty of Electrical Engineering and Informatics from 4% in the early 2010s to 15% in 2021. [14].

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# "Little Professors'" Cognitive Transformation Through Activity Triangles on Mechanics

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**Abstract.** Teaching approaches that focus on the field of science, adopting the activity theory, combined with the use of new technologies, become particularly interesting when they start with the exploration of alternative ideas and are aimed at students falling on the spectrum of high-functioning autism. In this light, two different detection-teaching activity systems were designed and developed, using semi-structured frameworks of observation, reflection and experimental exploration in real and digital educational environments, adapted and personalized to the specificities of the disorder concerned. The aim was to stimulate learning curiosity and to develop appropriate conditions for teaching interventions, starting from the detection of students' alternative ideas. The research sample consisted of 10 primary school students of fifth and sixth grade. The results of the research revealed that the adaptability of the specific tools to the individual skills of students with ASD, worked as a supportive factor both in the process of detecting students' alternative conceptions and in the creation of learning motivation through targeted activities of creative curiosity and participatory interaction.

**Keywords:** High Functioning Autism · Physics · Alternative conceptions · Activity theory · Science teaching

## 1 Introduction

Autism Spectrum Disorder (ASD) is a complex and multidimensional disorder, the spectrum of which includes dysfunctions, whose nature and intensity varies from person to person, while its clinical symptoms can range from mild to more severe and complex forms. According to the DSM-V, individuals, falling within the broad spectrum of Autism, are characterized by dysfunctions in social interaction by repetitive stereotyped behaviors [1], and are divided into three levels according to the need for supportive intervention required. The present study focuses on the group of individuals with autism spectrum disorder level one, whose behavior is judged to be deficient mainly in communication and social interaction, while displaying mild stereotypic behaviors.

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For students with autism spectrum disorder level one (high-functioning ASD), science is a distinct subject, showing considerable interest in the areas of everyday experimental applications [2, 3], a fact that contributes to the title "little scientists" being given to them by their social environment. However, in the effort to acquire scientific knowledge, there is an inherent objective difficulty in the coexistence of many different and interdependent forms of knowledge that each student acquires in the course of his or her cognitive development. One of these is empirical-experiential knowledge, which in most cases is depicted as a latent perception in students' ideas (alternative ideas), greatly influencing the learning process. Alternative ideas, being personal perceptions of students in their attempt to interpret their natural world, become particularly important when they are used to determine and design appropriate constructive approaches, in areas of science [4]. Their detection and recording are the basis on which modern educational techniques are built and adapted, influencing the design of teaching interventions in an attempt to bridge the gap between empirical and scientific knowledge [5].

In the last decades, several studies have highlighted the educational value of the activity theory as a conceptual framework based on constructive communication through dynamic interaction activities [6, 7]. Activity theory, adopting the logic of triangular links among subject, object and activity tool, focuses on the one hand on the social action and interaction of subjects, which relates to the specific characteristics of the disorder concerned, and on the other hand on constructive teaching of summative design promoting the generalization of knowledge [8].

Modern activity tools are designed and developed to take advantage of the use of new technologies. Such tools include interactive videos, which are based on dynamic interactions of cognitive and sensory nature in order to stimulate learning curiosity and create learning motivation. Interactive videos are high on the preferences of people with ASD, as they provide them with a calm yet entertaining learning environment [9]. Their design focuses on different adaptive behavioral and intellectual functioning skills, taking into account the specific characteristics of the learners of the disorder concerned.

## 2 Rationale for the Present Study

The educational techniques of teaching science, in line with the peculiarities of the modern heterogeneous classrooms, should adopt an inclusive orientation, cultivating students' skills at multiple levels, in order to fulfil their educational goals [10]. At the starting point of the design of teaching approaches we find students' alternative ideas that form a coherent and strongly structured model of latent concepts in their minds, being an inhibiting factor in the construction of scientific knowledge [11]. The use of appropriate educational techniques and tools with individualized and goal-oriented precepts can lead to their detection on the one hand, and to the creation of appropriate educational conditions of teaching intervention on the other hand.

In this light, two different exploratory-teaching activity systems were designed and developed, using semi-structured frameworks of observation, reflection and experimental exploration in real and digital educational environments, adapted and personalized to the specificities of each student, through which the stimulation of curiosity and the development of learning motivation were sought, starting from the detection of students' alternative ideas.

# 3 The Research

## 3.1 The Purpose of the Research -Research Questions

In view of the intended cognitive transformation of students' alternative ideas to engineering concepts, the aim of this study is the development and creation of learning motivation by creating "shocks" of curiosity on the basis of the construction of their primary concepts.

Its purpose is, on the one hand, to detect alternative ideas by delineating their breadth and depth in students' perceptions, and on the other hand, to investigate the degree of effectiveness of specific teaching approaches in stimulating student curiosity, creating appropriate conditions for teaching interventions, in students with ASD level 1.

## 3.2 The Sample

The study was conducted within the period of February and March 2023. The sample of the study is presented in the Table 1.

**Table 1.** Sample of the research.

| Type of student | Gender | Class 5th | Class 6th |
|---|---|---|---|
| ASD level 1 | Male | 3 | 3 |
| | Female | 2 | 2 |

The sample consists of 10 (six boys, four girls) fifth and sixth grade elementary public-school students, with a certified high-functioning autism spectrum disorder.

## 3.3 Research Tools

For the purposes of this study and in order to discover possible answers to our research questions, two research tools were designed and developed.

The first tool, consisting of a framework of creative curiosity activities, was designed and developed based on the use of simple everyday materials. Through this tool, the students in the sample were involved in a hands-on exploratory sequence of micro-experiments and practical applications, flexible development with strong sensory stimuli. Adopting the theory of triangular interactions among object, tool and subject, the process was adapted each time to the particularities of each student in the sample, seeking to stimulate their curiosity but also to activate their involvement in exploratory processes through which their alternative ideas were elicited. The activities were aligned within the context of the science control modules (force-motion, friction, weight, mass, pressure), with a focus on the particular skills and deficit characteristics of the disorder concerned. The selection and use of familiar everyday materials, as a means of interaction within the activity context, was adopted by the research team in an attempt to explore the depth

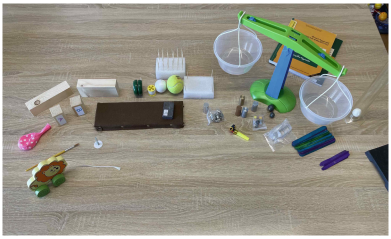

**Fig. 1.** Simple everyday materials to frame experimental activities

and breadth of alternative conceptions based on empirical treatment of concepts directly related to issues of everyday life (Fig. 1 below).

The students' interaction with this research tool was supervised by the research team that used interviews, adapted to semi-structured activities of observation, reflection and experimental exploration to record students' ideas, opinions and attitudes of the research process.

A digital interactive video application was used as a second research tool. The interactive videos were designed, developed and implemented by the research team, aiming on the one hand at learning the breadth and depth of ASD students' alternative perceptions and on the other hand at creating appropriate conditions for the teaching intervention. The topics of the videos focus, on the same science control topics (force-motion, friction, weight, mass, pressure) as those of the first tool. The protagonists of the interactive videos were children, of the same age as the research participant students. The design of this application was based on the one hand on its pleasant and entertaining characteristic and on the other hand on the meaningful process of interaction between the students and the protagonists of the videos. The interactive videos include dynamic activities of a two-way interaction of multiple stimuli, taking into account the specific behavioral characteristics of autism spectrum disorder, while also adopting techniques of active involvement in the exploratory process of students with kinesthetic peculiarities (low fine limb mobility). 'The protagonists of the videos involve their sample students in a pleasant and at the same time entertaining way, in a sequence of micro-experiments and applications they perform, raising concerns and questions. At the same time, through the answers students receive, the process evolves linearly, creating a dynamic interactive environment of creative interaction. The usage results- responses were recorded in a digital format so that the research team could easily access them.

Before they were administered, both tools were tested and evaluated for their pedagogical and technological features by respective evaluation groups of users, parents, experts and teachers.

### 3.4 Research Stages

Initially, the participant students were divided into two groups, equated in terms of their verbal intelligence, consisting of five people each.

The first group, consisting of three boys and two girls, was initially introduced to the first research tool and interacted with it individually, focusing on three engineering concepts "force, motion, friction". Each session was hourly, with a total duration of about three hours (approximately one for each concept), and were initially preceded by another session aiming to familiarize the student with the context and environment of the activities. Then, having completed the first phase, the same group of students interacted with the digital application of the interactive videos focusing on the remaining three engineering control concepts "weight, mass, pressure". At this stage, the individual interaction sessions with the interactive videos lasted a total of about two and a half hours for each student, and were also preceded by a one-hour session to familiarize and acquaint each student with the digital interface of the application.

The second group, consisting of three boys and two girls, were introduced to the research tools in the exact opposite way. First, each student interacted with the second research tool, the digital interactive video application, focusing on the first three engineering concepts "force, motion, friction" and then with the first research tool, the activity framework, using simple everyday materials, on the other three concepts "weight, mass, pressure". The procedure followed was similar to that of the first group. The sessions were individual, the duration of the interaction with each tool was similar to that of the students in the first group, and familiarization sessions with the research tools were implemented, just as in the first group of students in the sample.

## 4 Results

### 4.1 Method of Processing the Experimental Data

In order to collect research data on the use of the first exploratory tool, the research team used the free interview method with the research students. Specifically, during the participants' interaction with the first activity framework, the research team recorded their opinion and attitudes, using free-form questions, guided by the students' reflections, trying to identify the range of their alternative ideas. The exploration of the engineering concepts in simple applications, using everyday materials, allowed the formulation of students' views and the depth and strength of their alternative conceptions on the control concepts (Figs. 2 and 3).

The interview evolved freely, orienting the students' experimental interaction with the activity framework, within the thematic boundaries of the research. Throughout the intervention, the research process was assisted by a child psychologist specialised in the disorder concerned, who discreetly observed and recorded the attitudes and behaviors of the sample students.

As for the use of the digital application of the interactive videos, the activities focused on the same topics of mechanics (force-motion, friction, weight, mass, pressure), fully matching the objectives of the first exploratory research tool. The main characters of the videos posed concerns to the participants, who interacted with them by expressing their opinions, both through free-form responses (with the possibility of voice recording the response) and through closed-form responses (Fig. 3 below).

All data from the students' choices and responses were recorded in a computer system with the possibility of retrieving the data at any time by the research team.

**Fig. 2.** Student interaction with the experimental activities framework

**Fig. 3.** Student interaction with the application of interactive videos

### 4.2 Discussion of Results

The data obtained from the detection-research tools were analysed on a qualitative basis. Regarding the first tool, it is worth noting that, before the interaction, all participants felt excited and curious about the process. Their enthusiasm, as evidenced by their reactions, was due to the preference shown generally by students of the target disorder for educational activities of active participation [12]. Specifically, student SF1 reported "I can't wait to do the experiments, when will we start?", student SF2 reported "I'm very curious, what will we do with all these materials?", while student SM1 reported "I can't wait, I want to start", and the reactions of the other students also ranged at this level. As for the second tool, what aroused the students' interest, before they even started interacting with it, was the fact that they would be using a digital teaching tool. The idea of interacting with the protagonists of the videos evoked feelings of impatience and curiosity while wo cases of students, who were nervous at the idea of interactivity, were recorded. However, as soon as they came into contact with the friendly digital environment and the entertaining nature of the videos, they immediately relaxed and enjoyed interacting with them.

One particular characteristic, on which the research team focused its observation, was the level of the participants' concentration. The results revealed that, when students interacted with the interactive video application, their concentration levels were higher than when they interacted with the activity framework. Specifically, eight out of the ten research participant students remained focused, throughout the entire sessions of using the interactive videos, demonstrating high attention and engagement in their interaction with them, without being distracted by extraneous stimuli, (sounds, noises). This result concurs with what research findings support, based on which, several researchers have analysed the particular attachment of students with high-functioning autism spectrum disorder to digital software and applications of interest to the disorder [13, 14].

Regarding the preference shown by the students by gender, the majority of the boys, five out of six, seemed to prefer the activity framework, between the two didactic-detection tools, while the majority of the girls (three out of four) preferred the interactive videos. Student SM2 stated that he liked the process with the tangible experimental activities more, because he felt like a "scientist exploring physics secrets", while student SM4 stated that he preferred activities with materials that he could "touch" with his hands. Student SF3 seemed enthusiastic about the interactivity of the videos stating that "I really like helping the children in the videos to solve their questions", student SF4 stated that she prefers interactive videos because she feels that she is not good at activities involving experimental setups, while student SF2 stated that although she likes discovering new things, she gets nervous with experimental activities, even when they are very simple. Verifying past research findings, it can be seen that depending on their interests, students with the familiar disorder prefer teaching contexts that seem familiar to the skills they have cultivated, compared to others that are the cause of anxiety and insecurity [15].

At the level of alternative ideas, the results obtained from the use of the two probing-teaching tools verified past research results [16], recording a high degree of correlation between the engineering concepts tested. More specifically, students' interaction with the experimental activity framework of the first probe-research tool recorded high levels of student adherence to their initial conceptions, with the majority of students displaying strongly established alternative ideas of concepts and phenomena related to forces and motion, gravity and mass, and frictional force. These results were similarly verified by the second exploratory-research tool, the use of which recorded strongly crystallized views and perceptions of students on engineering concepts (force-motion, weight-mass, friction) as a result of personal experiences. However, of particular interest was the elicitation of students' alternative beliefs about the concept of pressure, with all participant students displaying latent ideas about the relationship between these two concepts, which was reflected in both probing tools. It is worth noting that no differences between the alternative ideas appeared between the two sheets, which verifies the international literature [17], however boys recorded higher levels of adherence to their initial conceptions.

The importance of the findings of the present study, apart from the emergence and recording of alternative ideas, lies in the particular disorder students' stimulation of curiosity and reflection concerned with physics concepts, in order to create the appropriate conditions for teaching intervention. Specifically, the use of the first activity framework recorded significant findings in the way in which the specific exploratory activities raised reflections on students' initial conceptions. A typical example of this is the students' reactions during the interaction with the specific probing-research tool, where student SM1 reported "and I was so sure about it, can we explain it?", while student SM3 reported "I didn't expect it, why is this happening?". At the same time, its experimental nature attracted the students' interest, with them becoming "little researchers" by exploring and experimenting on their own initial ideas. The ability to adapt the specific tool to the individual skills and specificities of each student of the disorder concerned, served to enhance both the process of detecting alternative perceptions and the creation of learning motivation. Upon the end of each session, all the research participant students asked for answers to questions related to the engineering concepts dealt with in the context of the activities, thus creating appropriate conditions for teaching intervention through the stimulation of student curiosity. The use of the second exploratory framework recorded significant results in the way of detecting alternative ideas of students with ASD, given the specificities of the disorder concerned. The students seemed to interact pleasantly with the interactive videos, and their relaxed and entertaining nature captured their interest [18, 19]. Given the deficient social behavioral skills, exhibited by individuals with autism spectrum disorder level 1, the results revealed that the majority of the girls participating in the research (three out of four) (SF1, SF2, SF4), expressed a particular willingness to cooperate with the protagonists of the videos, while SF3, although she preferred the use of this probing-teaching tool over the first one, simply expressed neutral feelings in terms of cooperation and interaction with the main characters of the videos. The boys as a whole had fun working with this application. It is noteworthy that although the majority of them (five out of six) stated that they preferred to use the first exploratory-teaching tool, after interacting with this particular application of interactive videos, four out of six asked the research team to also participate as protagonists in any future videos. The adaptability of the application, in addition to the cognitive and behavioral data of each student, led to the recording of better results of participatory interaction, as it activated the participation of the students of the relevant disorder with motor dysfunctions. Specifically, students SM6 and SF2, exhibited poor fine limb mobility resulting in difficulty in "hands on" activities. The use of this application activated their interest in experimental processes, stimulating their curiosity.

## 5 Discussions and Conclusions

In the present study, two exploratory teaching tools for students with ASD on the fifth and sixth grades were designed, developed and implemented, aiming on the one hand to detect their alternative ideas in engineering concepts and on the other hand to create appropriate conditions for teaching intervention by provoking their curiosity. The design of the tools was based on alternative interactive approaches, adopting the activity theory adapted to the specific characteristics of the disorder concerned.

Analyzing the results of the use of these exploratory-teaching tools, several conclusions emerged. Initially, before their administration to the participant students, feelings of excitement and impatience were recorded, while upon completion of the interaction, the students expressed feelings of joy and creative curiosity. Their concentration span ranged at higher levels when using the digital application of interactive videos, compared to that observed when using the activity framework. The majority of the boys, preferred the "hands on" activities of the first tool, while the majority of the girls preferred the interactive videos. In terms of detecting alternative ideas, these tools focused on testing the breadth and depth of ideas, while also detecting the degree of students' adherence to their latent initial conceptions. The results verified past research with boys demonstrating a higher degree of attachment to their alternative conceptions.

The importance of the findings, however, is summarised in the flexible nature of the two tools. The adaptability of the first tool, to the specificities of each student of the disorder concerned, on the one hand fulfils the objective of detecting alternative ideas and on the other hand creates conditions for creative reflection, preparing the ground for the forthcoming cognitive transformation. The design of the second tool focuses on both the cognitive and behavioral data of the students, emphasizing the deficit characteristics of the intimate disorder. The students' participatory interaction with the video characters enables the cultivation of their social and collaborative skills [20]. Furthermore, a particular feature of this application is the possibility of active participation offered to students with motor impairments who might be unable to participate in "hands on" activities.

The experimental process, based on the design and development of didactic exploration frameworks, highlights the didactic role of these tools in terms of cognitive reflection and the development of learning motivation, starting from the detection of alternative ideas of students with ASD. The use of new technologies through simple constructive exploratory processes of "dealing" with everyday physical issues in an entertaining way, taking into account the peculiarities of the disorder concerned, adopting inclusive pedagogical techniques, contributes substantially to the creation of appropriate conditions for teaching intervention [21], and to teachers' didactic work.

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# Programming Errors and Academic Performance in an Introductory Data Structures Course: A Per Gender Analysis

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**Abstract.** Computer Science studies is among the primary fields usually dominated by male audiences. But can the empirical data explain this preference or are other types of factors responsible for its perpetuation?

This study aims to contribute by examining the student performance in a per gender manner from an introductory Data Structures course taught in the second semester of a university's undergraduate program. The years whose data was used are 2021 and 2022.

Visualization and statistical analysis tests are applied on the programming errors and grades per student as an attempt to monitor said performance per gender throughout the semester and determine if any differences arise. Association rule mining is also used in order to uncover the role of the students' different attributes in shaping their course pass status. The findings suggest that the student's gender does not considerably affect their performance, while the two genders' results rarely were statistically different. Moreover, in all the cases where differences emerge, women are the gender with the higher academic performance.

**Keywords:** Gender Gap · Data Structures · Programming · Learning Analytics

## 1 Introduction

Significant progress has been made towards achieving true gender equality during the last century, but the goal has still not been definitively reached. The phenomenon where differences remain between the two genders favoring men, despite women being theoretically equal to them is referred to as "the gender gap" and it can be observed in various areas [1]. One domain characterized by it is scientific studies, like Information Technology (IT) and Computer Science (CS). Attempts to explain the gender gap in fields like programming support that women are more susceptible to facing anxiety, thus losing their motivation easier [2, 3]. But, are gender related reasons responsible for this phenomenon instead of other factors, probably of social nature?

Concerning Computer Science, its essence can be defined by the combination of Programming and Data Structures. Yet, as other studies have corroborated [6, 7, 9], these courses seem to cause particular difficulties for the students, something which can

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be observed by studying the advancement of their errors and academic performance alongside that of the instruction sessions. Utilization of machine learning techniques allows for the analysis of the corresponding student data and the better understanding of the situation from multiple angles. This could involve uncovering hidden useful patterns and relationships within the course's attributes affecting the students' learning process, making predictions or even revising aspects of the instruction procedure, if necessary.

Research on the topics of Computer Science and Gender concurrently has only recently started gathering more attention [2, 3]. Even among these more recent studies regarding the usage of machine learning techniques on data from programming courses, relatively few take into account the student's gender as a part of their examined factors [5] and even fewer elaborate on it as their core subject [3].

Therefore, the analysis of student results from an introductory course on Data Structures containing weekly programming assignments with an emphasis on per gender comparisons should be of major interest. Through methods like visualizations, statistical tests and association rule mining, it is possible to elaborate on the relationship between a student's gender and their programming course results, which can be considered as the combination of their tendency for making errors with their academic performance. Since the examination of this subject from the point of view of the comparison per gender is relatively new, supplementary empirical evidence could contribute towards its better comprehension. On that note though, for the purposes of this research, the genders are considered to be binary.

The rest of this paper is organized as follows. Section 2 shows some of the related work in the broader field. Afterwards, in Sect. 3, the research questions and context of the study are presented. Then, Sect. 4 contains results of applying learning analytics techniques on the data. A discussion on the findings and conclusions shape Sect. 5.

## 2 Related Work

While the relationship between a person's gender and its role in successfully completing an introductory programming course or a Data Structures course is usually not on its own the main subject of most published studies, the attempt to predict whether the student will pass one such course in addition to determining the factors that either aid them in passing it or prevent them from doing so have been important topics for decades [4]. From the available methods for conducting this analysis, the usage of machine learning algorithms for making predictions and the extraction of association rules are the most common.

Beginning with a case utilizing machine learning algorithms, in [5], the data from 1077 students with 47 attributes each from the distributed examination course Object Oriented Programming, during the years 2009–2017 was used for predicting whether the students would pass the course. Among the attributes there are a few describing the person rather than their academic performance like their gender or if they have membership to a study group. 12 attributes were formed from the preprocessing step and only 6 were chosen after feature selection, not including gender. Through various applied classifiers, accuracy of around 86% was achieved by week 8 out of 12.

In [6], the data from 85 students of the introductory programming course Introduction to Programming, from the first semester of the first year of the CS department of

Polytechnic of Guarda, was used in order to create student profiles useful for predicting course failure. The gathered information involved the students' assignment grades and some additional more abstract individual characteristics, like participation or perfectionism. A multiple back-propagation neural network was created and it achieved an accuracy level of over 94%.

Another interesting analysis is that of [7], which uses the students' coding characteristics like the time and attempts needed from 80 students in 78 short questions in a C++ introductory course from spring of 2017. With the gathered data, a struggle metric was proposed, and the activities that caused the most struggle as well as the most common compilation errors in them were determined.

Regarding association rules, their usage only for analyzing relationships found in introductory programming courses may be comparably less common. In [8], activity log file and grade data from a blended learning environment from 68 students of an "Introductory Programming" (IP) course and 55 students of an "Algorithm and Data Structures" (ADS) course from an informatics Bachelor program was used for association rule mining. The aim was to determine the characteristics of students' engagement with the course.

In [9] the association rules method in conjunction with markov chain analysis were used on the log data from 192 Java exercises by 569 students derived from 4 introductory programming courses during 2 years. The data consists of the program's output to the student's code, from which the compilation errors are extracted, as well as the person's email whose hash works for data aggregation. The aim is to find students' patterns of commonly repeated errors so as to provide suggestions for the adequate management of the situation by the instructors.

## 3 Methodology

The aim of this study is outlined by the following two Research Questions:

***RQ1****: Do students' errors and academic performance in programming differ based on gender?*

In order to answer the above question, the students' data will be used in two ways; for conducting statistical tests to determine if the two genders' population is homogeneous or not, something that would also indicate if statistically significant differences exist between them, as well as for the required visualizations.

***RQ2****: Can association rules help in better understanding the relationships formed among the course's attributes?*

Using the student-level data, association rules are mined in order to better comprehend the factors that aid a person in passing the course or prevent them from achieving this goal.

As an attempt to answer the proposed research questions, a study was conducted with data from the students of the undergraduate studies program of the Department of Applied Informatics of University of Macedonia in Thessaloniki, Greece spanning 2 academic years.

### 3.1 Course Outline

The course the data comes from is "Data Structures", which is taught in the second semester according to the undergraduate program's syllabus. Its topics are: 1) Sets, 2) Stacks, 3) Queues, 4) Lists – Dynamic Stacks & Queues, 5) Binary Search Trees and 6) Hashing. As homework, students are asked to solve weekly programming assignments, each consisting of two to three small to medium size programming exercises using the C programming language.

### 3.2 Participants

The participants in the study are students that attended the course in the years 2021 and 2022. In the first year, 34% of the attendants were of female gender and 46% of the total students had already been enrolled in it in a previous year, while in the second year, 31% of the students were women and 19% of the total attendants had been enrolled in it before. The total number of students in the course was 925 in 2021 and 694 in 2022, while the unique students from both years were 1323.

### 3.3 Data Analysis

The data used for the analysis performed in this study comes from two sources: the output files from the application of the automatic assessment tool on the students' exercise code, which are available for each assignment, alongside additional student data describing their status in the course and in the department, which is available for each year. Before gaining access to the files, they were anonymized to avoid storing students' personal data that is unnecessary for the study's purpose.

**Assignment Evaluation Files.** These files are created from the software of [10] and their data is at the level of each programming exercise of an assignment submitted by a student. In greater detail, for every such part, the information contained is:

- a comma separated triplet with the student's id, the grade they achieved in the current assignment and the name of the exercise being examined,
- the compilation field with the examined exercise code's compilation status and the errors that occurred alongside where they occurred, if there were any,
- one or more execution test fields showing the output of the exercise code being tested with input data chosen by the instructors and
- an execution result field with the result message of the exercise code's testing and the grade the student achieved in this exercise.

**Student Information Files.** These files contain supplementary information for each year's students enrolled in the course. From the available attributes, the used ones are: status, first enrollment, enrollment semester, overall grade and gender. The student id was also used but only for gathering each student's data, not as an element to be analyzed.

In order to begin the analysis procedure, the data from the assignment evaluation files is extracted through the usage of a custom parser. From the field of compilation problems, the errors, warnings and notes contained are parsed by the application of regular expression patterns. An error is considered to be made each time a pattern is activated, as many times as it happens in each exercise of a person's assignment code. The types of unique errors recognized are 46. In more detail, the extracted information concerns:

- the errors found and more specifically the categories they belong in, how many times they were made and by whom,
- the students' separate exercise grades as well as
- their assignment grades.

It should be noted that each student is identified by their student id and also that the amount of assignments in each year is not the same; there are 12 assignments in 2021 but 11 in 2022, and neither are the exercises they contain despite coming from the same assignment sheets. For a comparison to be possible between the results of the two years, it is considered that the completed assignments in each of them are just 10, something achieved by merging the contents of specific consecutive assignments that come from the same original assignment sheet. Moreover, before commencing with discussing the results, some details must be disclosed regarding the usage of statistical tests and association rules.

**Statistical Tests.** The tests are conducted for:

- the number of errors per student,
- the exercise grades of each person as well as
- their final grades.

The data used is at the level of:

- each of the years' assignments,
- the available data per year, for 2021 separately and for 2022 separately and
- all the available data, so the data of the two years together.

The examined confidence level is 95%. In all the examined cases, since none exist where the populations of both genders follow the normal distribution at the same time, the test chosen to determine the differences between genders is the Mann-Whitney population homogeneity test.

**Association Rules.** In order for the method to be applied, the data was transformed to a binary form where consecutive columns correspond to specific attributes. The columns for one attribute can either have one true value among them or multiple. The attributes used are the following:

- Male/Female: if the student is of male or female gender (one true value).
- Error_01,…, Error_46: if the student has done any of the examined compilation errors, notes or warnings in any of their submitted assignments (multiple).

- First_Enrollment/NOT_First_Enrollment: whether the student has not been enrolled in the course in a previous year, or differently if this is their first time participating in the course (one).
- Took_Course_in_its_Semester/NOT_Took_Course_in_its_Semester: whether the student is participating in the course during their second semester in the department, which is the semester the course is being taught according to the department's syllabus (one).
- Submitted_Assignment_01,…, Submitted_Assignment_10: if the student has submitted each of the assignments of their year, based on the consideration that these assignments are assumed to be 10 (multiple).
- Assignment_01_over_Base,…, Assignment_10_over_Base: with the same consideration, if the student managed a grade over base, meaning at least 5 out of 10 in each of the year's assignments (multiple).
- Passes_the_Course/NOT_Passes_the_Course: whether the student has managed to gain a final course grade over 5 out of 10 (one).

The algorithm chosen was Apriori with minimum thresholds 0.1 for support and 0.01 for confidence. The metrics used for the rules' evaluation are Support (Sup.), Confidence (Conf.), Cosine Similarity (Cos.) and Lift.

# 4 Results

In this section, we present the results of our empirical evaluation.

## 4.1 Errors Per Student

Figure 1 illustrates the errors per student by gender weighted by the amount of exercises submitted by the students of that gender for each year's ten assignments (a01,…, a10). The weighting of the errors per student from each gender's students was necessary in order to minimize the effect of the imbalanced nature of the two genders' classes, as women only constitute about a third of each year's total student population.

Comparing the differences per gender, it seems that female and male students are just as likely to make errors, though the females may tend to make slightly more. This is observed as in both years, more errors were found by women in 6 out of 10 assignments; from 2021, in the 1st, 2nd, 4th, 7th, 9th and 10th, while from 2022, in the 2nd, 3rd, 4th, 6th, 7th and 9th. Regarding the differences per gender, they tend to be lesser in 2021 than in 2022, with the largest seen in 2021 being around 40% in the year's 7th assignment, while in 2022, the 7th, 8th, 9th and 10th have a difference of at least 60% between genders. The dominance of relatively smaller differences in one year and of more extreme in the other indicates that 2021's students have closer error rates between genders than those of 2022.

## 4.2 Per Gender Average Assignment Grades

The next plot, Fig. 2, shows the per gender average assignment grades from each of the ten assignments of the two years.

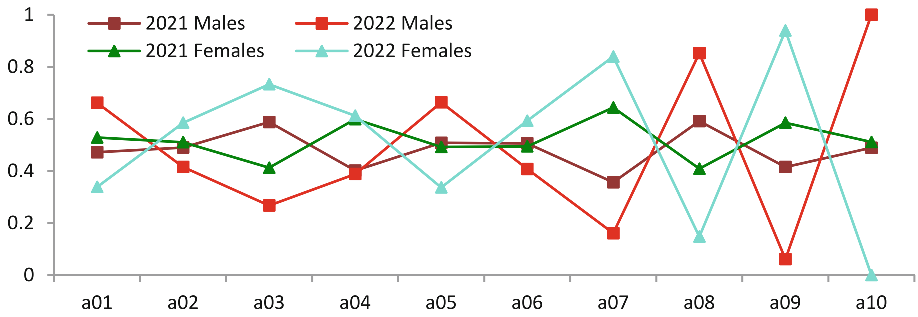


**Fig. 1.** Line plot of the number of errors by gender divided by the number of exercises contained in each assignment and submitted by students of a specific gender that have submitted each examined assignment.

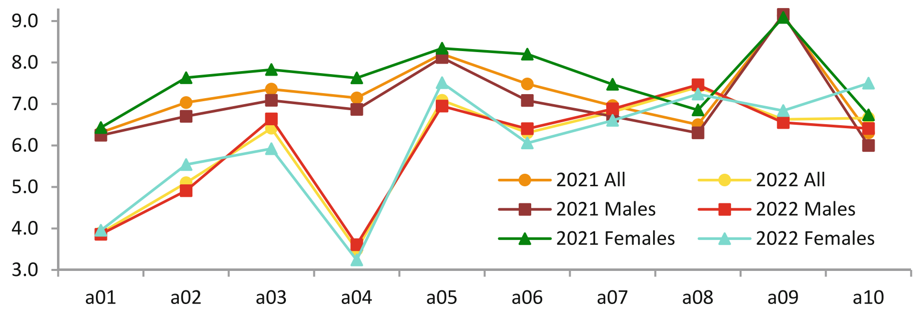


**Fig. 2.** Line plot of per gender average assignment grades the students achieved in each of the ten assignments.

Starting with the per gender comparison, it can be seen that in 2021, the averages of the female students surpass the male ones in all assignments but the 9th, while in 2022 the same observation is only made for half of them, for the 1st, 2nd, 5th, 9th and 10th. Since in both years the male candidates are significantly more numerous than the female ones, the averages from all the students are closer to the averages of the male students. The range of grades is smaller in 2021 than in 2022, as in the first case it is between around 6 and 9, making it 3 grades, while in the second case it is from somewhat over 3 up to around 7.5, making it greater than 4 grades. Interestingly, in all the assignments excluding the 7th, 8th and 10th, the lowest 2021 per gender average grade is visibly higher than the highest corresponding 2022 grade. The overall trend formed indicates that 2021's students tend to achieve higher performance than those of 2022, as well as that, women are higher achievers than men in 2021 even though the two genders' performance is much closer in 2022. So, although some indications exist pointing to that female students could possibly be somewhat more prone to making errors in comparison to their male colleagues, as observed by the corresponding plot, they may also possess an advantage in their achieved grades over them.

### 4.3 Per Gender Average Overall Grades

Figure 3 represents the average final course grades per gender as seen from the students of each gender that submitted each of the ten assignments of the two years.

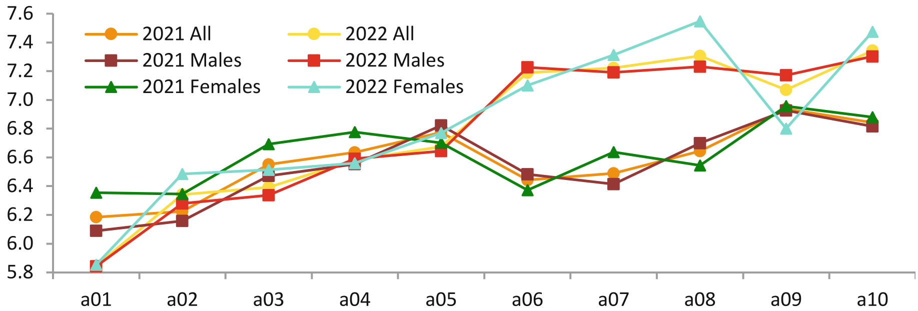


**Fig. 3.** Line plot of per gender average final course grades the students that submitted each of the ten assignments achieved.

Here, the average grades for the female students remain higher than their male counterparts' for seven assignments per year, with the exceptions being the 5th, 6th and 8th ones from 2021 and the 4th, 6th and 9th from 2022. Like in the previous plot, the averages of both genders are closer to the male ones, since they are the numerically larger population. The grades' range is again narrower in 2021 than in 2022, with it being from 6.1 to 7, less than 1 grade in the first case and from around 5.8 to 7.5, more than 1.5 grades in the second. Unlike the average assignment grades, though, here there is a clear difference in the grades per year only for half of the assignments, the 1st, 6th, 7th, 8th and 10th, from which solely in the 1st the grades are unequivocally better in 2021. Here, the highest averages were achieved by the 2022 students who submitted the assignments from the 6th and onwards, with the only exception to the rule being the women who submitted the 9th assignment of 2022. Regarding the performance per gender, women seem to retain an overall higher level of achievement in both years. Thus, by combining the information from all the three plots, it is possible that women may actually have an advantage over their male counterparts in terms of grades.

### 4.4 Statistical Test Results

The aim of this set of tests is to investigate if any statistically significant differences emerge between the two genders and if so in which cases these are found.

Regarding the errors made by each student, it turns out that, for the examined confidence level, the only case with a statistically significant difference between the two genders is the 11th assignment of 2022. In that though, the errors found were made exclusively by men, something that did not happen in any other assignment, so the result may not be particularly unexpected. This finding, when combined with the results of the corresponding plots, suggests that a student's gender does not play an important role regarding how susceptible they are to making errors.

Only one difference was also found in the case of the per gender examination of the assignment grades, in the examined confidence level, which came from the 7th assignment from 2021. In this case though, seeing that the female assignment average is around 8.2 and the male one is 7.1, it is more probable that women achieved a higher average grade compared to their male counterparts.

In the case of the students' final grades, no differences were found in any of the examined cases for the 95% confidence level.

The fact that only two differences per gender are found, one in the errors per individual and the other in each person's assignment grades, suggests that the student's gender does not seem to be a factor that heavily influences that person's academic performance. When studied along with the three plots above, it seems that the person being of female gender could be associated with a slightly higher level of academic performance.

### 4.5 Association Rule Mining

The mining of association rules aims at determining the factors that contribute to students' passing the course or if there are any preventing them from achieving this goal. The analysis of the following part concerns mainly whether the student has passed the course and the role attributes such as their gender have in this procedure.

In Table 1, some of the rules that have as consequence that the student passes the course, ordered by descending cosine similarity values, are shown.

It turns out most of the rules that have as consequent the student passing the course, have as antecedents the {submitted_assignment_XY}, {assignment_XY_over_base}, {submitted_assignment_XY, assignment_XY_over_base} or any combination of them, with XY being any number between 01 and 10. The assignment subjects whose knowledge seems the most valuable are the 2nd, 3rd, 4th, 1st and 5th, covering the first four topics mentioned in the course's outline. It also seems that if a student is attending the course for the first time or is participating in the semester the syllabus dictates, this person has a higher chance of passing the course.

Regarding the student gender's role in this situation, the results are generally less clear. By assessing the produced rules with the lift and cosine similarity metrics, as a means for determining their interestingness, a measure proposed by Merceron and Yacef in [11], some observations can be made. It seems that male students who belong in the categories mentioned above, the ones who complete these assignments and either participate in the course for the first time or are participating in the semester the course belongs in, are greatly associated with successfully passing the course. Their female counterparts have higher lift values but smaller cosine similarity values. It is interesting, though, that someone being of female gender is a factor positively associated with passing the course unlike for being male, as indicated by the corresponding lift metric values.

From all the rules produced, the only ones that result in the student not passing the course having a lift metric value over 1 are the seven shown in Table 2. From these, it can be observed that a student being of male gender is a noteworthy indication that they will not pass the course, although its importance is somewhat lower compared to that of the factors of someone either having enrolled in the course before or not attending it in the semester it is being instructed at. The combination of male gender with at least one of the two enrollment factors is arguably the strongest indicator that the examined

**Table 1.** A very small subset of potentially interesting association rules that show how the above factors contribute in someone's passing the course, ordered by descending cosine metric.

| Rule | Sup. | Conf. | Cos. | Lift. |
|---|---|---|---|---|
| {submitted_assignment_02}→{passes_the_course} | 0.35 | 0.93 | 0.78 | 1.70 |
| {assignment_02_over_base}→{passes_the_course} | 0.30 | 0.96 | 0.73 | 1.76 |
| {took_course_in_its_semester}→{passes_the_course} | 0.32 | 0.70 | 0.64 | 1.27 |
| {took_course_in_its_semester, first_enrollment}→{passes_the_course} | 0.32 | 0.70 | 0.64 | 1.27 |
| {first_enrollment}→{passes_the_course} | 0.33 | 0.69 | 0.64 | 1.26 |
| {male}→{passes_the_course} | 0.38 | 0.51 | 0.59 | 0.93 |
| {male, took_course_in_its_semester}→ →{passes_the_course} | 0.21 | 0.67 | 0.51 | 1.23 |
| {male, first_enrollment, took_course_in_its_semester}→{passes_the_course} | 0.21 | 0.67 | 0.51 | 1.23 |
| {male, first_enrollment}→{passes_the_course} | 0.21 | 0.66 | 0.51 | 1.21 |
| {female}→{passes_the_course} | 0.17 | 0.66 | 0.45 | 1.21 |
| {took_course_in_its_semester, female}→{passes_the_course} | 0.11 | 0.74 | 0.39 | 1.36 |
| {took_course_in_its_semester, first_enrollment, female}→{passes_the_course} | 0.11 | 0.74 | 0.39 | 1.36 |
| {first_enrollment, female}→{passes_the_course} | 0.11 | 0.74 | 0.39 | 1.35 |

**Table 2.** The rules with a lift value of at least 1 that result in a person not passing the course, ordered by descending cosine metric.

| Rule | Sup. | Conf. | Cos. | Lift |
|---|---|---|---|---|
| {NOT_took_course_in_its_semester}→ →{NOT_passes_the_course} | 0.31 | 0.58 | 0.63 | 1.28 |
| {male}→{NOT_passes_the_course} | 0.37 | 0.49 | 0.63 | 1.09 |
| {NOT_first_enrollment}→{NOT_passes_the_course} | 0.30 | 0.58 | 0.62 | 1.28 |
| {NOT_first_enrollment, NOT_took_course_in_its_semester}→ →{NOT_passes_the_course} | 0.30 | 0.58 | 0.62 | 1.28 |
| {male, NOT_took_course_in_its_semester}→ →{NOT_passes_the_course} | 0.26 | 0.61 | 0.60 | 1.36 |
| {male, NOT_first_enrollment}→{NOT_passes_the_course} | 0.26 | 0.61 | 0.59 | 1.35 |
| {male, NOT_took_course_in_its_semester, NOT_first_enrollment}→{NOT_passes_the_course} | 0.26 | 0.61 | 0.59 | 1.35 |

person will not pass the course. Something else that should be mentioned is that, in the entirety of the rules for not passing the course, including the ones with lift values less than 1, neither the female gender nor any errors are ever mentioned.

In the end, it turns out that female students are associated with passing the course and male students are not. This could be explained by the male students' result variance, which tends to be greater than that of women. In the data, there are possibly more male students that are considered excellent, while at the same time also more whose level of engagement with the course is unsatisfactory.

## 5 Conclusion

This study analyzed the data from weekly student programming assignments from an undergraduate course on Data Structures in a per gender manner. Its first aim is double; determining if any differences per gender exist in the students' errors per individual as well as in their academic performance. About their errors, it seems that women are slightly more prone to making errors than men. According to the statistical tests, though, the only case with a significant difference between genders favored women students. Then, about their performance, when examining either the students' assignment grades or their final course grades, women seem to have an advantage over men in many cases. Yet, it very rarely ended up being confirmed from the corresponding statistical tests. The study's second aim is gaining a better understanding of the course's attribute relationships, thus association rules are mined. Here, specific active male participants are generally highly associated with passing the course, possibly even a little more strongly than their similar female counterparts. But the factor of someone being male is on its own negatively associated with doing so, though less strongly than not enrolling in the course in a timely manner, whereas the opposite holds true for being female. In the end, it seems that, based on the course's data, the two genders' performance is broadly similar. Even though it is not possible to definitively accept or reject the notion of an actual performance advantage by any gender in this case, if it does exist, it would almost certainly belong to the female students.

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# Effect of Student Characteristics and Blended Learning Approach on Student Performance in Master's Level Chemical Engineering Courses

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**Abstract.** This study investigates the efficacy of the blended learning approach by examining the interplay between student characteristics, design learning features, and learning outcomes. Blended learning has become increasingly popular in modern-day higher education. However, research specifically focusing on the predictors of the efficacy of blended learning in Master's level courses in the UK is lacking. The study aimed to identify the predictors of learning outcomes and satisfaction by exploring the design learning elements and student characteristics that contribute to the efficacy of blended learning in advanced-level education. An evaluation research design was employed, and questionnaires were administered to students enrolled in various Master-level Chemical Engineering courses. The data were analysed using descriptive statistics, t-tests, and regression analysis. The findings indicate that student characteristics, e.g., their opinion of blended learning, learning management skills and design learning features, e.g., task-technology fit, synchronous features and support significantly influence their satisfaction, motivation, perceived learning, and performance. Moreover, the results suggest that students enrolled in Master-level courses exhibit a high tendency to actively participate in blended learning, especially concerning their proficiency in learning management and utilising synchronous features that enhance their overall learning performance.

**Keywords:** Blended learning · Student characteristics · University-level higher education

## 1 Introduction

Blended learning models capitalise on the advantages of offline and online learning environments, allowing students to access instructional content and resources remotely while engaging in interactive in-class activities facilitated by teachers. By leveraging technology, universities strive to optimise teaching and learning outcomes and create more dynamic and personalized educational experiences. However, it is important to recognise that student characteristics significantly impact the learning process. Individual differences, encompassing demographic factors and social aspects, can shape how students engage with blended learning and influence the outcomes they achieve. Blended

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learning has been extensively examined in prior studies, primarily focusing on metrics such as final performance, degree accomplishment, retention, and graduation statistics. However, there is a notable gap in research that specifically explores the efficacy of blended learning in relation to student characteristics, design learning features, and outcomes within the context of Master level courses in the UK. In general, Master's level students demonstrate greater academic maturity. However, the presence of a significant number of foreign students and efforts to diversify educational background in Master level courses have notable effects on student characteristics.

Master's level education differs from other educational settings in several ways [1]. Firstly, Master's level students generally possess higher academic maturity and have already acquired foundational knowledge in their respective fields. Additionally, efforts to diversify educational backgrounds among Master's students, such as accepting international applicants from various disciplines, further enhance the interdisciplinary nature of these programs. These factors contribute to a more diverse student body, fostering cultural exchange and the inclusion of various perspectives [2].

Given these unique characteristics of Master's level education, it is crucial to examine the efficacy of blended learning specifically within this context. Understanding how student characteristics, design learning features, and outcomes intersect in blended learning environments can inform instructional practices and enhance the educational experience for Master's level students. To date, no studies have investigated these aspects, highlighting the need for further exploration in this particular educational setting.

The present study aims to investigate the factors that contribute to the success of blended learning in Masters level Chemical Engineering courses in the UK, specifically focusing on the design elements and student characteristics that predict learning results and satisfaction. By examining the influence of these variables individually and collectively, we seek to shed light on the multifaceted nature of blended learning and its potential to enhance educational outcomes when technology is integrated into the learning process.

Heinich et al., [3] emphasised the importance of considering student characteristics when utilising instructional technology effectively. Their study revealed student characteristics have a strong influence to adopt and engage with technology. Previous research has shown that student characteristics contribute to student performance achievement, emotional and personality traits, and aptitude for excelling in online learning environments [4].

In a study conducted by Shraim et al., it was discovered that a significant proportion of students (75%) and teachers (72%) lacked the essential competence to proficiently utilise ICT-dependent learning tools [5]. This inadequacy stemmed from insufficient skills and comprehension of computer and internet-based programmes can outweigh the benefits of blended learning. Another work reported that students with good proficiency in computer usage and effective time management skills performed better in blended learning settings [6]. Research conducted by [7] suggested that within a blended learning environment, students can develop learning management and self-regulation skills and benefit from several feedback approaches e.g., instructor feedback, peer-to-peer and self-reflection feedback using a range of virtual tools and methods e.g., emails, discussion boards, live chat rooms, and online feedback tools. This proactive engagement aims to optimise the advantages derived from blended learning [7]. The same research also highlighted that factors such as familial obligations, demanding academic workloads, and limited time for task completion can prompt students to discontinue their participation in online settings [7]. The student's perception of online learning, their proficiency in ICT-learning tools and their engagement are among the important drivers of their perseverance in the online learning environment.

Perceived learning is another notable aspect of this research, closely intertwined with variables such as student satisfaction and motivation. Barbera et al., [8] revealed that the design of the course and the content of the learning material emerged as the most influential factors shaping student's satisfaction and perceived learning in online courses within the field of social sciences. According to Baber [9], factors such as, instructor expertise, design of learning content, student classroom engagement, and student motivation were identified as having a substantial and positive impact on student's perceived learning outcomes and satisfaction. Furthermore, Alqurashi [10] analysed that students engaged with learning material showed higher levels of satisfaction, while students with better IT competence showed higher perceived learning. Despite these factors, both teachers and students need time and support to improve their performance in online learning.

Exploring the identified characteristics in this study provides an additional perspective, specifically in relation to blended learning and its influence on the design of learning environments. This contributes to the continuous conversation surrounding technology-enhanced learning. By considering these characteristics, educators and researchers can gain valuable insights into how to effectively integrate technology in blended learning settings and optimize the learning experience for students.

In this work, we explored answers to the following three questions.

1. What are the student characteristics observed in Master level courses in a blended learning setting?
2. Which student characteristics factors and design learning features significantly impact learning outcomes in blended learning?
3. What are the significant predictors of the efficacy of blended learning in Master level courses?

Findings from this research can inform educational practitioners and policymakers in optimising the design and implementation of blended learning interventions, leading to improved educational experiences and outcomes for students in the digital age.

## 2 Method

### 2.1 Sample and Procedure

The study plan involves a blended approach of online pre-session teaching and learning, utilising a learning management system (Blackboard), followed by face-to-face problem sessions throughout the whole semester. This study measures student characteristics, design learning features, and their impact on learning efficacy in a blended learning environment. This study follows a evaluation research design based on the principles of 'Evaluating Professional Development' by Thomas Guskey [11], with the aim of informing the implementation of blended learning at Master-level courses.

This study employed a cross-sectional approach and utilised online questionnaires for data collection. The questionnaires, containing items related to student characteristics, design learning features, and learning outcomes, were administered to students enrolled in different Master-level courses in the field of Chemical Engineering. The sample size for this study consisted of 100 respondents. The study population comprised 70 male students, accounting for 70% of the participants, and 30 female students, representing 30% of the total sample size. The average age of the participants was 24.6 years. The variables examined in this study were derived from the blended learning effectiveness model [12], which encompassed twelve items as illustrated in Table 1.

**Table 1.** Research variables.

| Variables | Items |
|---|---|
| Student Characteristics | Learning management skills |
| | Opinion of blended learning |
| | Family support and social environment |
| | Information technology literacy |
| | Gender and age |
| Design Learning Features | Engagement with blended learning |
| | Actual usage of LMS and its tools |
| | Task-technology fit |
| | Synchronous features and support |
| Learning Outcomes | Motivation |
| | Satisfaction |
| | Perceived learning |

The questionnaires utilised in this study consisted of a Likert scale (1 to 5) and underwent validity and reliability testing based on Devillis's guidelines [13]. The results of these tests confirm that the questionnaires effectively measure the implementation efficacy of blended learning. Descriptive statistics, t-tests, and regression analysis are used to analyse the data and infer the significance of the different factors. To investigate performance disparities across various age groups, a one-way ANOVA was conducted. Moreover, a multiple regression analysis was executed to identify the significant predictors of blended learning efficacy. This analysis involved examining the associations between student characteristics, design learning features, and learning outcomes. Data analysis was performed using the widely used statistical software, SPSS.

## 3 Results and Discussion

In the context of research, reliability pertains to the degree to which research methods produce consistent and reliable outcomes. Cronbach alpha coefficient approaching one indicates a higher level of reliability, suggesting that the measure can be considered acceptable. On the other hand, if the Cronbach alpha coefficient falls below 0.70, it indicates that the questionnaire is inconsistent or unreliable. Table 2 presents the results of reliability test, showing that the obtained values surpass the threshold of 0.70. This indicates that the measures utilised in this study exhibit satisfactory reliability [14].

**Table 2.** Results of the reliability test.

| Item | Value |
|---|---|
| Number of entries | 27 |
| The number of entry variance | 7.036 |
| Total variance | 27.093 |
| Cronbach alpha coefficient | 0.767 |

The results pertaining to various aspects of student characteristics are presented by utilising the average percentages of the items. The student's IT literacy competence and usage were assessed revealing that they were proficient in general and possess advanced levels (above 80%) [15]. Learning management skills were found to be at good levels with a mean ranging between 3.5 to 4.2 for goal setting, organisation, task prioritization and time management, seeking assistance, and self-assessment. Overall, students exhibited positive opinion of blended learning, particularly in terms of student independence, educational resources, course organisation, online platform, and support. The mean and standard deviation range between 3.3 to 4 and 0.76 to 1 respectively.

Family and social support, encompassing a sense of connectedness and belonging, are regarded as vital components for students engaged in online collaboration [16, 17]. In this study, we examined the need for emotional, financial, and other forms of support for blended learning success. Family support was reported to be generally low, especially around financial, and technology-related issues with a mean ranging from 2.5 to 3.0. Students exhibited a lower level of peer support ($M = 3.1$, $SD = 1.0$), as perceived by them, within the community. Students who balanced work and learning had an enabling environment in a blended learning approach. The mean differences ranged from 3.7 to 4.1 ($SD = 1.05$ and 0.91) but the hours spent on non-study activities significantly affected their planning of study time ($M = 3.9$, $SD = 0.91$). International students were much more affected by this factor and had more issues managing their workload ($M = 4.1$, $SD = 0.83$).

The analysis of usability, accessing content, submitting work, group work features and perceived usefulness revealed that students generally found the tools and resources to be valuable and beneficial. The mean ranged from 3.5 to 4.3 ($SD = 1.5$ to 0.76), indicating a positive perception. However, there was a low mean of 2.8 regarding group work and online discussion. The use of Blackboard was also assessed, showing high utilisation for accessing content and average to low utilisation of certain features such as peer-to-peer discussion, group interaction and searching for material. When asked about their overall satisfaction with Blackboard as a platform to fulfil their learning requirements, the students provided a satisfactory rating (M = 3.2, SD = 0.95) but would prefer an alternative platform with better engagement student features.

Moving on to synchronous support, the students expressed satisfaction with the inclusion of face-to-face problem sessions in addition to the online content. With mean ranges between 4.1 and 4.3 (SD = 0.80 to 0.95), the students indicated their preference for continuing face-to-face problem sessions. They recognised the value of these sessions, emphasizing the importance of having synchronous tutorial sessions to practice concepts learned through a-synchronous material. Regarding the technology used in the intervention study, the students were generally dissatisfied with its availability, quality, and reliability (M = 2.8 to 3.3). Lastly, an analysis of interactions with instructors, between peer to peer and course material unveiled the presence of significant and meaningful engagements with mean ranges from 3.5 to 4.1 (SD = 0.95 to 1.0).

An independent t-test was conducted to examine the performance differences between male and female students in the blended learning environment. The purpose was to determine whether there were significant variations in performance based on gender. The results indicated that female students (M = 65.5, SD = 10.5) achieved slightly higher performance than male students (M = 61.1, SD = 11.2). This shows that female students tend to perform slightly better in a blended learning environment. To determine if there were performance differences among different age groups of students, a one-way ANOVA was conducted. The aim was to assess whether there were significant variations in grades between the two age groups i.e., young (20–25) and slightly older (25–30) in the blended learning context. The findings indicated that there were no noteworthy disparities in performance between the two age groups, as indicated by the non-significant F-value (F (2. 236) = 1.265, p = 0.0225). Thus, it can be concluded that different age groups have the potential to perform equally well in blended learning.

The students in the study reported high levels of motivation, indicating their strong interest and enjoyment in the tasks involved (80.2%). They also perceived themselves as competent in their learning (75.5%) and recognised the effort and importance required for successful blended learning (82%). However, a significant percentage of international students experienced pressure and tension, with feelings of nervousness (45.2%) and anxiety (53%), resulting in a pressure percentage of 55%. Despite this, the students expressed a high belief in the value and benefits of blended learning (87%), with most students acknowledging the advantages of combining online and in-person learning (92.5%) and demonstrating a willingness to engage in blended learning (90.5%). The students perceived blended learning as beneficial (91%) and an important approach to their studies (83.5%). Furthermore, student satisfaction was high, particularly in relation to instructors (87%) who encouraged student participation (89%), course content (79%) that aligned well with the course objectives (85%), technology (65%) with a sufficient online learning platform (72%), interactions (69%) including active participation in synchronous sessions (71%) that provided a comprehensive overview of the courses and their objectives (85%).

### Predictive Factors for Blended Learning Outcomes

A multiple linear regression analysis was conducted to explore the potential correlation between predictor variables, such as student characteristics and design learning features, and the criterion variables, which represent learning outcomes. The aim was to examine whether these predictor variables have a significant influence on the learning outcomes. Before conducting linear regression analysis, the data was assessed to ensure that it met the assumptions of the test.

Multicollinearity was studied and the tolerance values and variance inflation factor for student characteristics, design learning features, and learning outcomes were found to be close to 1, and the variance inflation factors are lower than 10. This indicates the absence of multicollinearity issues within our model.

The coefficient of determination, represented by the R-square ($R^2$) value, indicates the proportion of the dependent variable influenced by the independent variables. In this study, the coefficient of determination is 0.559, indicating that student characteristics, design learning features, and learning outcomes collectively contribute to 56% of the variance in student's overall satisfaction, motivation, and perceived learning. However, it is important to note that 44% of the efficacy is influenced by other factors beyond these variables.

**Table 3.** Significant predictive factors for blended learning efficacy.

| Factors | Satisfaction | | | Motivation | | | Perceived learning | | | Performance | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | β | t | p | β | t | p | β | t | p | β | t | p |
| Student Characteristics | | | | | | | | | | | | |
| Learning Management skills | 0.155 | 3.158 | 0.020 | 0.160 | 2.453 | 0.015 | 0.360 | 3.152 | 0.021 | 0.186 | 2.126 | 0.010 |
| Opinion of BL | 0.168 | 2.934 | 0.03 | 0.133 | 1.648 | 0.034 | 0.003 | 0.057 | 0.795 | −0.056 | −0.494 | 0.940 |
| IT literacy | −0.025 | −0.51 | 0.036 | 0.085 | 1.712 | 0.088 | 0.021 | 0.601 | 0.0867 | −0.032 | −1.24 | 0.528 |
| Design Learning Features | | | | | | | | | | | | |
| Task technology fit | 0.342 | 2.875 | 0.018 | 0.145 | 2.665 | 0.008 | 0.322 | 3.595 | 0.017 | 0.172 | 2.550 | 0.011 |
| Actual usage of LMS tools | 0.119 | 3.126 | 0.015 | 0.158 | 1.953 | 0.052 | 0.068 | 1.23 | 0.973 | 0.260 | 0.405 | 0.616 |
| Synchronous features | 0.542 | 2.317 | 0.015 | 0.245 | 3.545 | 0.018 | 0.421 | 2.954 | 0.022 | 0.186 | 2.954 | 0.051 |

* $p < 0.05$

Table 3 presents the regression results indicating the significant factors of student characteristics and design learning features and learning outcomes. The analysis revealed that certain student characteristics, such as learning management skills and opinions of blended learning influenced satisfaction while design learning features such as task-technology fit, and synchronous features and support were identified as predictors of student satisfaction. In terms of perceived learning, task-technology fit, and synchronous features and support were significant predictors among the design learning features. Additionally, learning management skills as a student characteristic predicted perceived learning and motivation, while task-technology fit, usage of online tools, synchronous features, and support were identified as significant predictors among the design learning features. Finally, learning management skills predict performance, while task-technology fit, synchronous features, and support are significant predictors among design learning features.

To understand the collective relationship between the variables of student characteristics, design learning features, learning outcomes, and the efficacy of implementing blended learning, a T-test and an F-test were conducted. The obtained p-values (less than 0.05) from the T-test and F-test indicate a statistically significant collective impact of student characteristics, design learning features, and learning outcomes on the successful implementation of blended learning. This is supported by the resulting regression model, as represented by the following equation:

$$Y = 0.176X_1 + 0.192X_2 + 0.185X_3 \quad (1)$$

The coefficients in Eq. (1) provide insights into the relative importance and contribution of each independent variable in explaining the variability in the dependent variable. The analysis indicates that the student characteristics, design learning features, and learning outcomes have positive coefficients of 0.176, 0.192, and 0.185, respectively. This suggests that improvements in these variables are associated with stronger efficacy in implementing blended learning.

## 4 Discussion

By analysing student characteristics, design learning features, and learning outcomes, this study makes a valuable contribution to the field of online and blended learning and the broader field of education. This work investigates the factors that influence student's experiences in implementing blended learning, specifically focusing on the perceptions of Master level students in Chemical Engineering in UK higher education. The findings indicate that student characteristics, including opinions of blended learning and learning management skills, play a crucial role in satisfaction, motivation, and perceived learning in blended learning.

Results on age differences were not found to impact learning performance in blended learning. Gender analysis showed that found that female students were more engaged in blended learning and achieved higher performance than their male peers. This is in alignment with the several literature findings [18–20] though different from the findings of Kintu et al., [12] which showed both genders performing same in an online environment.

It was found that students exhibited low levels of family and peer support. This could be due to the higher technicality of course content, technology and the short duration of the Master-level programmes compared to the Undergraduate-level where students have more opportunities to bond and develop study groups [21]. Working students, who can actively manage their workloads, demonstrate the feasibility of blended learning. While non-study activities significantly affected their study planning. In the case of international students, the influence of these non-study activities on their study planning tends to be more significant compared to domestic students. This could be due to the unique challenges faced by international students, including language barriers, cultural adjustments, and the need to adapt to a new educational system and environment [22].

Contrary to the findings of Shraim and Khlaif [5], our study suggests that low IT literacy is not a significant threat to blended learning. Our findings indicate that IT literacy did not emerge as a prominent factor influencing the efficacy of blended learning in our study. This suggests that the participants in our study, despite any potential initial lack of IT skills, were able to adapt and succeed in the blended learning environment. Student satisfaction with the online platform and its associated tools indicates promising prospects for the efficacy of blended learning. The findings highlight the importance of usability and perceived usefulness in blended learning. The challenges identified, such as group work and online discussion, can be addressed through improved design and facilitation strategies. Students expressed high levels of motivation and perceived themselves as competent (perceived learning) in their learning. International students experienced higher levels of pressure and anxiety but still recognised the value of blended learning. The study also emphasises the need for reliable and task-technology fit to support effective blended learning. Additionally, the performance and motivation differences observed among gender and international students suggest the importance of considering individual student characteristics and providing appropriate support.

As predictors of the efficacy of blended learning, the study found that certain design learning features and student characteristics predict student satisfaction, motivation, perceived learning, and performance in blended learning. Specifically, design learning features such as task-technology fit, and synchronous features and support were identified as predictors of student satisfaction. Student characteristics such as learning management skills and opinion of blended learning also influenced satisfaction. When it comes to perceived learning, task-technology fit, and synchronous features and support were significant predictors among design learning features. Learning management skills as a student characteristic was found to predict perceived learning and motivation, while task-technology fit, usage of online tools, synchronous features and support were identified as significant predictors among design learning features.

Previous research has consistently demonstrated the significant impact of student characteristics on their satisfaction in online learning [8, 23]. Kintu et al., [12] specifically found a positive relationship between student characteristics and their satisfaction. Building upon these findings, the present study emphasises that higher levels of student characteristics positively influence students' satisfaction with online learning technologies and their ability to successfully complete online learning assignments [24].

In technology-oriented studies, the concept of actual system usage by users is another crucial factor to consider. Previous research has established a robust positive association between user satisfaction and their actual usage of the system [25]. Increased time spent using technology is associated with higher levels of user satisfaction, as users are more likely to utilise the system when they are satisfied with its performance.

Learning management skills as a student characteristic was found to predict performance while task-technology fit, and synchronous features and support were identified as significant predictors among design learning features. Extensive research has examined the effect of task-technology fit and synchronous features on performance impact, demonstrating that both factors positively predict performance impact [26–28]. These results have not agreed with [12], who found that no independent variables as predictors of learning performance in blended learning but agree with Awad [28] and Butt et al., [29] who observed that task-technology fit enhances the efficiency and productivity of students while synchronous features (interactions, face-to-face problem sessions, instructor feedback) enhance critical thinking, thus leading to improvements in their overall performance.

The results of this study indicate that student characteristics, design learning features, and learning outcomes collectively exert a substantial influence on the efficacy of blended learning. These results diverge slightly from prior research conducted by Aditya et al., [30], which only found design learning features and learning outcomes to be the primary factors contributing to enhancing the efficacy of online learning environment. However, our findings align with research conducted by Harandi [31], which highlights the influence of student motivation and satisfaction on the efficacy of virtual learning environments. When students are motivated and satisfied with their learning experiences, they are more likely to actively engage in the learning process, leading to better learning outcomes and performance.

## 5 Conclusion

This study has provided valuable insights into the efficacy of blended learning by examining the interplay between student characteristics, design learning features, and learning outcomes for Master level educational settings. The results indicate that student characteristics, e.g., their opinion of blended learning, learning management skills and design learning features, e.g., task-technology fit, synchronous features and support significantly in-fluence their satisfaction, motivation, perceived learning, and performance. These findings emphasise the need to understand and cater to the diverse needs and backgrounds of students and well-designed technological tools with effective support in place in creating a positive learning environment for students. The results suggest that students enrolled in Master-level students demonstrate active participation in blended learning, particularly in managing their learning and utilizing synchronous features to enhance performance. This suggests that a well-designed blended learning environment can contribute to the development of analytical skills and the ability to critically evaluate information resources. Furthermore, the study suggests that students are receptive to technology, making blended learning design feasible. By recognising and harnessing the interplay between student characteristics, design learning features, and learning outcomes, universities can enhance the efficacy of blended learning and equip students with the skills and competencies needed for success in their future careers.

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# A Model of Two-Parameter Competitive Assessment of the Effectiveness of a Complex Sensorimotor Reaction of a Computer Operator

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**Abstract.** This article considers the program description, which is implemented through an operator's console or mobile phone to assess simultaneously the reaction of each participant in the experiment and the group as a whole to visual triggers that can vary in two ways: the digit value (from 0 to 9) – the digit color. Once the experiment is completed, individual and group performance scores of the complex sensorimotor reaction of the participants are displayed on the monitor screen, and the corresponding system database is generated for further processing and analysis of the results. Running the experiment with a program to test the sensorimotor reaction of a computer operator ensured high reliability in selecting computer operators and increased the technological capacity of the assessment by determining the efficiency of the complex sensorimotor reaction of a human operator rather than the time. This article provides the results of assessing the effectiveness of the complex sensorimotor reaction of a computer operator under group and individual conditions and presents their comparative values.

**Keywords:** Man-machine system · Sensorimotor Reaction of a Computer Operator

## 1 Problem Statement

As technology evolves and becomes more complex in the age of Industry 4.0, the human factor in production is gaining more significance. The need to study this factor and consider it when designing new equipment and technological processes, arranging production, and operating equipment is a must for the effective development of production. The functioning of technical devices and human activities involving these devices should be considered in close association. This approach resulted in the concept of a man-machine system, a system that includes a human operator (group of operators) and the machines that are employed to perform labor activities. The man-machine system is a particular

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subset of controlled systems where machine operation and human activity are linked by a single control loop. When arranging man-machine interaction, the key role rests with the psychological properties of a person: perception, memory, thinking, attention, etc. The need to study these human properties in the man-machine system led to the emergence and development of engineering psychology.

Currently, operator activity has significantly transformed human labor, and the workload has increased because the operator is faced with the task of managing an increasing number of objects and parameters. A person no longer deals with direct observation, but with an information display. The requirements for the accuracy, speed, and reliability of human actions, as well as the pace of psychological processes, are becoming more demanding. Working activity is associated with significant losses of nervous, emotional, and mental energy. Therefore, we must keep up with the constant changes in the world around us and create new systems for assessing the human operator's performance. This article aims at verifying the sensorimotor reaction of a computer operator with a developed program.

## 2 Analysis of Recent Research and Publications

The complexity of technology in the 20th century experienced significant advancements and witnessed the birth of numerous transformative innovations. Over the course of the century, technology progressed at an unprecedented rate, shaping various aspects of human life. The fourth industrial revolution or Industry 4.0 refers to the transformation of industrial sectors through the integration of digital technologies [1–3]. The basis for this change is the number of advancements made during the industrial revolutions, including mechanization, mass production, and automation, and takes them to a new level by using technologies such as the Internet of Things (IoT), artificial intelligence (AI), big data analytics and robotics. Industry 4.0 is creating new factories that are more interconnected, efficient, and capable of autonomous decision-making, with more flexibility, product quality, and customization, but these innovations oblige to workers upskilling and rethink the connection with machines [4, 5]. Authors [5] analyze this revolution characterized by smart systems and internet-based solutions, highlighting the interconnected assets aiming at higher productivity, and flexibility.

Ortiz [6] argues that this revolution is a symbol of social, economic and technological changes that happened all developed countries, bringing a collaborative environment, adding cyber physical systems with information as a key factor, namely because we are increasingly dealing with massive data, different information sources and a high-speed production-controlled system. The Internet of Things is now connected with cyber-physical systems, and the future is to have independent systems, able to decide and apply machine learning. Moreover, we also have Big Data, data analytics, augmented reality, artificial intelligence collaborative manufacturing, cloud computing, and 5G networks, and all this makes change unstoppable in economic, financial, social, cultural and environmental models, which affects human lives, of course, and the working places.

Carvalho and Cazarini [7] chose a definition that characterizes Industry 4.0 as advanced manufacturing model, incorporating different virtual and digital technologies, that bring disruptive matters regarding environmental performance and the work performed by human beings, reducing efforts and gaining efficiency. The authors define the most relevant visions for disruptive industry 4.0 change, according to authors [8] and summarize them as follows: "New level of socio-technical interaction: Autonomous and self-organized production resources carry out planning processes in value chains between organizations; Smart products: The products and the tolerable operating parameter of a certain production process are mutually known. These products can be grouped to optimize production; Individualized production: Flexible reconfiguration enables industries to consider the specific characteristics of customer demand and product during design, planning, production, and recycling phase; Autonomous control: Employees control and configure intelligent production resources based on targets sensitive to the present context; Product design controls product-related data: Product-related data becomes a central feature in managing its product life cycle" [7, p. 6–7].

This fourth revolution is also mainly associated with the man-machine system [9], a combination of humans and technological devices that work together, integrating human capabilities like decision-making with machine capabilities such as accuracy and data processing. This collaboration between humans and machines aims to achieve the same goal with enhanced system performance and efficiency and establishes new horizons for our partnership with machines [10, 11].

Pizon and Gola [12] define the fourth industrial revolution by emphasizing that intelligent machines are collaborating with humans in the same space, with a common goal: achieve a task using synchronized actions, as such authors [13] wrote. Furthermore, Pizon and Gola separate the human-machine coexistence (men and machines are using the same space, with this coexistence being monitored, as the robot controller is actively engaged), human-machine cooperation (agents collaborating with the possibility of conflict between goals or each agent works to facilitate the achievement of a common task.

Kaasinen et al. [14] analyzing the consequences of Industry 4.0 argue that the concept "Operator 4.0" is one of the major impacts. This operator is characterized by a symbiosis between humans and automation or cyber-physical systems, aiming at assisting humans in being more efficient having different possibilities like a smarter operator with an intelligent personal assistant or a collaborative operator with a robot.

Gerber et al. [15] refer to the ways humans perceive human-machine systems. Because to have full potential, simple acceptance from humans is not enough, it is required to have a partner vision regarding machines, and this is the key factor to creating a relationship, a symbiosis based on "human friendliness" requiring transparency and openness.

Geng, B., & Varshney, P. K. [16] go deeper into the human contribution to the system and refer to the roles that can be assumed like decision-makers, using machine measurements to create judgments and like "sensors" when acting to collect intelligence, making decisions that are later sent to a decision-maker. If the system is to have better functioning, then one must understand that machine outputs affect actions and decisions made by humans but on the other hand, humans also affect the deployments and algorithms of machines. These issues have been analyzed from a psychological point of view both in individual and group models, related to engineering, and this led us to the concept of engineering psychology.

One of the most important themes regarding human-machine interaction and engineering psychology is communication. For authors [17] efficient communication means that processes must be bidirectional, giving the user the possibility to send commands to the system, but also to receive data from it, creating a strong control loop. In this connection, embodiment is vital and feedback is a key element of the human-machine system.

## 3 Statement of Basic Material and the Substantiation of the Obtained Results

The model for checking the sensorimotor reaction of a computer set operator belongs to differential psychophysiology, engineering psychology and occupational health and can be used to determine the effectiveness of a complex sensorimotor reaction of a human operator in group activities (groups of operators, groups of athletes, groups of professional selection, groups with special working conditions, etc.)

Known examples of the use of systems for assessing the effectiveness of a complex sensorimotor reaction within the framework of studying the psychophysiological state of a person (for example, a method for integral assessment of the psychophysiological state of a person and a method for determining the level of sensorimotor reactivity of a person) are designed to conduct an individual study of the complex sensorimotor reaction of a human operator.

A human operator, as a subject of industrial relations, should be considered not only by itself, but also taking into account the system of relations and information flows that connect it with other subjects, which often create a competitive environment of competitive activity. A competitive environment should lead to an increase in productivity and efficiency, but in practice, this problem re-quires an additional research within the framework of differential psychophysiology, engineering psychology, and occupational health. The model is aimed at solving the problem of expanding the functions of the method of assessing the complex sensorimotor response of a human operator by conducting an experiment simultaneously for a group of up to 10 participants (during one-time period) and setting up to five variable parameters of the experiment. The use of the model also increases the manufacturability of the assessment due to the efficiency of the experiment's organization, collection, accumulation and processing of the results.

The principle of implementing the method of two-parameter competitive evaluation of the effectiveness of a complex sensorimotor response of a human operator is that in response to visual stimuli, variables in two parameters (digit value - digit color) appearing on the monitor screen in random order at fixed intervals, the participants of the experiment press the corresponding buttons on the operator consoles. A special software program monitors button presses on the operators' consoles and counts successful attempts. The effectiveness of a human operator's complex sensorimotor reaction is calculated as the number of successfully worked out visual stimuli to the total number of stimuli presented. The evaluation is performed simultaneously for each operator and for the group (Fig. 1).

According to this scheme, to implement the method of two-parameter competitive evaluation of the effectiveness of a complex sensorimotor reaction of a human operator,

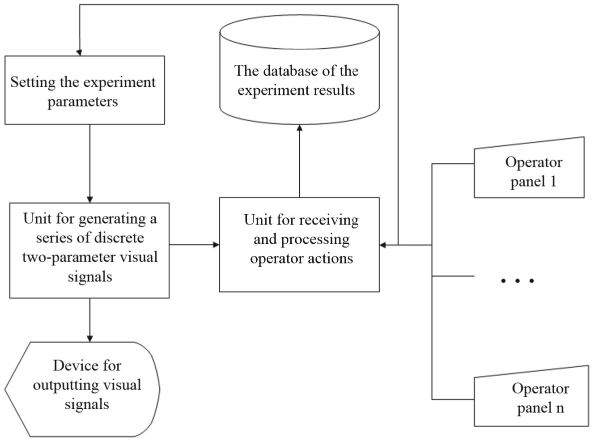


**Fig. 1.** Scheme of the model of two-parameter competitive evaluation of the effectiveness of a human operator's complex sensorimotor reaction.

the following components are necessary operator consoles (from 2 to 10 consoles); a unit for setting the parameters of the experiment according to six indicators; a unit for generating a series of discrete two-parameter visual stimuli at specified intervals and with a specified acceleration/deceleration of stimuli presentation; a unit for receiving and processing button presses on operator consoles; a database of experiment results.

The proposed model is used as follows: the participants of the experiment sit in front of the monitor screen, a remote control is placed in front of each participant, each participant is registered in the system by the remote-control number, and then the variable parameters of the experiment are set:

- number of participants in the experiment (from 2 to 10);
- the number of visual stimuli presented to each participant during the experiment;
- a set of visual stimuli (a sample from the numerical series from 0 to 9: either a single set of ten digits or an arbitrary sample from this set);
- color of visual stimuli (a separate color is set for each operator);
- time of presentation of one visual stimuli;
- acceleration/deceleration of the time of presentation of one visual stimuli.

In response to the visual stimuli appearing on the monitor screen at fixed intervals, the participants pressed the corresponding buttons on the operators' consoles. The visual stimuli presented to the participants differ in two ways: the type of stimuli (a single-digit decimal digit from 0 to 9) and the color of the stimuli, which is selected at the beginning of the experiment for each participant separately. When a digit of a certain color appears on the monitor screen, the participant presses the corresponding button on the operator's console. During the experiment, the screen of the software and hardware complex displays real-time data on the current efficiency of the complex sensorimotor response of the participants in the experiment. Each of the operators can track their results of working out visual stimuli on the screen and simultaneously compare them with the results of other participants in the experiment. At the end of the experiment, individual and group assessments of the effectiveness of the complex sensorimotor response of the participants are displayed on the monitor screen. The model, due to the simultaneous conduct of the experiment for a group of up to ten participants, can be used to conduct studies of large groups of the population, with using mobile versions.

The software of the sensorimotor reaction of a computer operator is a Windows application developed in the Studio C# environment. The Module of forming a form for entering personal data is presented on Fig. 2 and Database module is on Fig. 3.

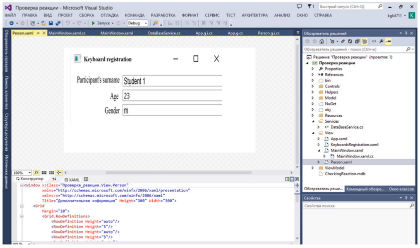


**Fig. 2.** The Module of forming a form for entering personal data

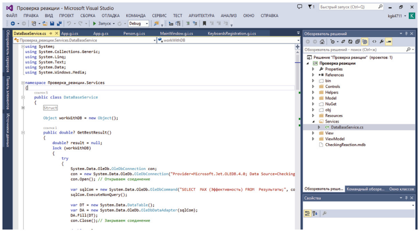

**Fig. 3.** Database module

When the software component of the system is launched to test the reaction, the main window of the program opens (Fig. 4) providing access to all general elements of the program, where the reaction is tested, statistics are displayed and settings are placed.

On Fig. 5 we can see experimental results, where student work in competitive conditions. The same tools, the same options, but there are neighboring operators working close to the student, which distracts from the operator's work, which is very important and related to numbers.

The experiment was conducted among 2–3-year students (25 girls and 34 boys) of engineering and pedagogical specialties: Energy, Computer Technology, Mechanical Engineering, Economics. During the experiment of the effectiveness of the human operator's complex sensorimotor reaction in group and individual activities the following results were obtained. The assessment was carried out on a scale from 0 to 1, where 0 is the lowest score, 1 is the highest score (Fig. 6).

The results of the experiment showed that students who was testing in collective conditions were less effective than in individual conditions. For example, student Shatsko received a score of 0.58 in individual conditions and 0.47 in collective conditions. This

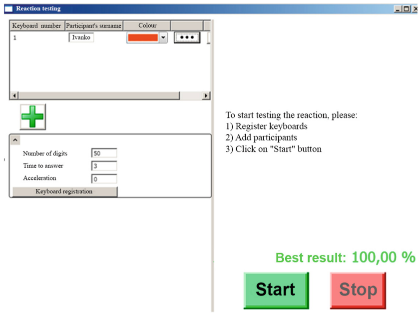


**Fig. 4.** The main window of the program

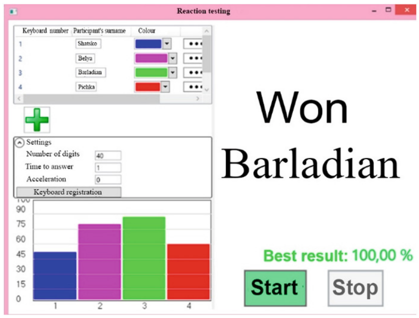


**Fig. 5.** Experimental results (competitive conditions)

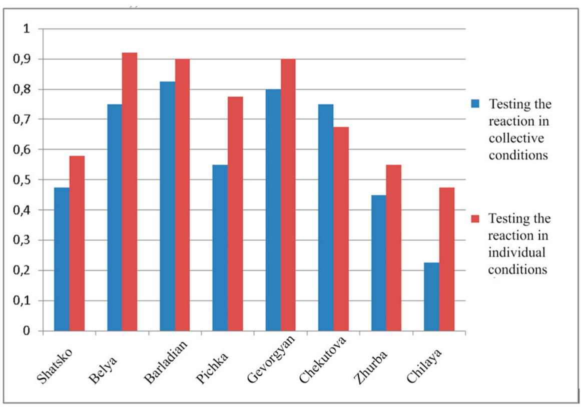


**Fig. 6.** Comparative results of the experiment

indicates that the performance of operator work in individual conditions is more effective and, accordingly, the complex sensorimotor reaction is higher than in collective conditions.

## 4 Conclusions

On the one hand, assessing the effectiveness of a complex sensorimotor reaction within a competitive environment promotes the participants' motivation to achieve the highest results, and, on the other hand, it makes it possible to determine the effectiveness of a complex sensorimotor reaction of a human operator in group activities. Moreover, this approach improves the overall capacity of assessing the effectiveness of a complex sensorimotor reaction by several times by obtaining simultaneous results of a group of operators, which yields significant advantages in mass examinations. The reliability of the results obtained is ensured by the positive out-comes of using this system under competitive conditions of human operator activity.

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# Entrepreneurship in Engineering Education

# Entrepreneurship Capacity Building for Higher Education

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**Abstract.** The technological power throughout Europe is declining as Research and Development (R&D) spending and entrepreneurial activities lag behind competitors like China and the US. With uneven R&D investment across EU countries, academia-industry connections and entrepreneurial skills require improvement. European entrepreneurs are more risk-averse, impacting access to capital and digital industry competitiveness. Pan-EU cooperation could address these challenges in higher education institutions (HEIs) aiming to boost entrepreneurship by unlocking deep tech talents skills. Projects focusing on capacity-building and entrepreneurial education HEIs seek to enhance employability and Europe's competitiveness. By providing resources, mentorship, and networking, Europe's entrepreneurial ecosystem can be strengthening, resulting in increased competitiveness in deep tech industries.

**Keywords:** Academic Startups · Entrepreneurial Mindset · Entrepreneurship Education · Capacity Building · Deep Tech Talents · Spin-offs

## 1 Introduction

Europe's technological power is declining, with R&D spending and entrepreneurship falling behind competing blocks and countries. In 2018 - China spent 2.14% of its GDP on R&D, the US 2.83% and the EU only 2.03% [1]. The European Commission Horizon 2020 2014–2020 budget of €80 billion was a huge boost towards this direction, in Europe, we still have very uneven fields. Particularly - Finland, Sweden and Austria have very high levels of R&D (Sweden 3.39%, Austria 3.2%, Finland 2.79%, while Portugal has only 1.4%, and Serbia 0.91%, in terms of R&D/GDP [1].

Although R&D spending has increased, there is still a need to enhance academia-industry connections and increase entrepreneurial skills. European entrepreneurs tend to be more risk-averse than their counterparts in the US. In the US, there is a strong cultural emphasis on individualism, entrepreneurship, and risk-taking [2].

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Additionally, risk attitudes are influenced by a wide range of factors, including education, personal values, and prior experiences. This can only be changed through a different form of entrepreneurial education. Access to capital is also a challenge for unproven businesses in the EU, and the region is losing competitiveness in disruptive digital industries (while US venture capital investment hit a record $130.9 billion (€116.6 billion) in 2018, Europe posted a comparatively meager €23 billion, for a bigger population.

Pan-EU cooperation could help overcome these challenges and strengthen the region's position for incoming talents and entrepreneurs. Our vision is to close the mentioned gaps in terms of entrepreneurial culture and access to finance, balancing two things - regional leadership in certain fields (e.g. health and manufacturing, that derive from our regional Smart Specialization Strategies) and pan-European links (between the whole continent - from Austria to Portugal and Serbia, thus connecting all Deep Tech and innovation ecosystems).

The HEICE[1] project, recently funded by the European Institute of Innovation and Technology (EIT), aims to contribute to Europe's technological innovation and entrepreneurship by unlocking the entrepreneurial potential of Deep Tech Talents in Austria, Portugal, and Serbia. Higher education institutions (HEIs) are seen as key drivers of this innovation, and the HEICE project aims to offer comprehensive entrepreneurial education for deep tech talents in the health and manufacturing fields, which fit the consortium's Smart Specialization Strategy (S3). The project also aims to capacity-build HEI teachers, academic staff, and non-academic staff to improve the internal processes of supporting student and academic entrepreneurship. By focusing on these three areas of capacity-building, the HEICE project aims to contribute to the employability of students and the competitiveness of participating partner regions and beyond.

The HEICE project aims to develop entrepreneurial skills and mindset, encourage interdisciplinary collaboration, and provide access to resources and networks. It will utilize entrepreneurship education, local clubs, workshops, incubators, accelerators, funding, mentorship programs, and networking events. The project will improve the entrepreneurial ecosystem in Austria, Portugal, and Serbia and increase the number of successful Deep Tech startups, bringing more business ideas to the market and strengthening Europe's competitiveness.

## 1.1 Objectives

HEIs aim to develop entrepreneurial skills, foster interdisciplinary collaboration, and provide resources and networks by utilizing entrepreneurship education, local clubs, workshops, incubators, accelerators, funding, mentorship programs, and networking events. The goal is to enhance entrepreneurial ecosystems, increasing successful deep tech startups and Europe's competitiveness. Key strategic objectives include expanding entrepreneurial education, positively impacting entrepreneurship propensity, mentoring interdisciplinary deep tech student teams, creating diverse mentor pools, establishing acceleration programs for deep tech talents, and funding of numerous academic startups and spin-offs. These objectives are achievable due to the collaboration of European partners in a HEI consortium, enabling more academic startup creation and funding to

[1] HEICE stands for High Tech Entrepreneurship and Innovation Competences.

foster a pan-European entrepreneurial ecosystem open to local stakeholders and future partners. The aim is to improve teaching formats for entrepreneurship education and create extracurricular opportunities, and to address the entrepreneur as a career option in external and internal communications. At the same time, HEIs are combating fragmentation by creating an ecosystem that allows deep tech students to both collaborate and compete within the consortium in accelerator programs.

The objectives of the HEICE project are manifold. Primarily, the project focuses on cultivating high-quality Deep Tech Talents with an entrepreneurial and innovative mindset, while supporting their entrepreneurial activities and the diffusion of innovation. Additionally, the project aspires to function as a knowledge and innovation hub for companies, especially SMEs, and to foster international collaborations through global networks. Thus, the HEICE project will strengthen knowledge exchange between academia, industry, and transfer by fostering the professional development of academic staff, learners, and professionals within the knowledge triangle.

Another goal of the project is to establish robust international networks, enhancing collaboration across borders. We also seek to enhance the knowledge exchange between academia and industry, enhancing the professional growth of academic staff, learners, and professionals within the knowledge triangle.

Recognizing the inherent value in diversity, we aim to facilitate an inclusive environment that provides significant benefits to the stakeholders of HEICE. The diverse backgrounds and experiences of our partners are poised to drive new business areas, research opportunities, and offerings for our target groups.

Further, we seek to leverage the unique composition of HEICE's project partners, including accelerators and HEIs representatives from Austria, Serbia, and Portugal. Their collective insights into Deep Tech and entrepreneurship ecosystems would foster a transdisciplinary approach to empower Deep Tech Talents for long-term employability in the middle of a shifting labor landscape. In the face of current business, education, and research challenges, HEICE aims to utilize interdisciplinary and solution-oriented approaches, streamlined communication channels, training activities, and acceleration opportunities.

One more purpose is to create or modify educational toolkits and mentoring programs that can be applied directly in training courses, fostering a more agile learning environment.

### 1.2 Approach

The methodology for European projects that aim to build entrepreneurship capacity often starts with a self-assessment of the respective HEI, focusing on entrepreneurial areas needing improvement. The HEInnovate self-assessment tool is a free, online diagnostic instrument designed to help HEIs assess their innovative and entrepreneurial potential. Developed by the European Commission and the OECD, this tool enables HEIs to evaluate their strengths and weaknesses in various dimensions related to innovation and entrepreneurship. To address the identified weaknesses, an Innovation Vision Action Plan (IVAP) needs to be created to improve both entrepreneurial learning and create a digital, measurable, and engaging entrepreneurship-learning journey.

The methodology for implementing educational measures to increase the entrepreneurship capacity building can be divided into two parts: 1) entrepreneurship learning journey and 2) acceleration journey. An entrepreneurial learning journey aims to develop entrepreneurial competences in students and staff using the EntreComp [3] framework and various tools, such as MOOCs, entrepreneurship weekends, and collaboration with the patent office. The acceleration journey consists of creating a diverse pool of mentors, and implementing a 4-week acceleration program for deep tech talents. The mentors come from various professional backgrounds, while the program focuses on idea validation, business development, solution improvement, and fundraising, as well as, pitching skills. This comprehensive and flexible program concludes with a final pitch in front of an experienced jury for valuable feedback.

## 2 Methodology

We developed our methodology on the basis of the self-assessment of the 3 HEIs to ensure the highest relevance and impact of the project activities. Figure 1 shows an illustrative representation of the eight categories delineated in the HEInnovate Self-Assessment Tool. From the results, we conclude that all HEIs have areas that need improvement.


**Fig. 1.** Methodology HEInnovate Self-Assessment Tool

TU Graz rated highly the dimensions of "knowledge exchange and collaboration," "internationalized institution," and "leadership and governance," while the dimensions of "entrepreneurial teaching and learning," "preparing and supporting entrepreneurs" and "digital transformation" were rated slightly above average. However, the dimension of "measuring impact" scored the lowest and needs improvement.

Registered group members of IPLeiria rated highly the dimensions of "knowledge exchange and collaboration" and "internationalized institution," while the dimensions of "preparing and supporting entrepreneurs" and "digital transformation" were below average. All other dimensions, including "leadership and governance," "organizational capacity: funding, people, and incentives," and "entrepreneurial teaching and learning," scored strongly below average and therefore, require significant improvement.

The main advantage of the ASSS is "organizational capacity: funding, people, and incentives". The dimensions of "preparing and supporting entrepreneurs" and "internationalized institution" are below average, and the lowest score is "measuring impact" that requires significant improvement simultaneously. All other dimensions, including "leadership and governance", "entrepreneurial teaching and learning", "preparing and supporting entrepreneurs", "digital transformation" and "knowledge exchange and collaboration" scored equal or slightly below average.

Distinct entrepreneurial thinking among students and staff is one of the guiding principles of all partner institutions of the consortium. Nevertheless, only a few ventures are founded in the form of startups or spin-offs and patents are rarely exploited, even though there is no shortage of ideas and science-related inventions in the deep-tech sector. In conclusion, we created an IVAP that aims to improve not only the number of students that have entrepreneurial learning but that also creates a digital, measurable and engaging online learning journey.

Students need skills and knowledge to identify and pursue opportunities in the ever-changing business and innovation world. Entrepreneurship education should be included in all curricula of a HEI because it not only helps students develop an entrepreneurial mindset but also teaches them how to identify and evaluate opportunities, develop and implement a business plan, and measure the impact of their efforts. Intrapreneurship education is also important, as it teaches students how to bring entrepreneurial thinking and action to an existing organization. Overall, a comprehensive entrepreneurship education at a HEI can benefit students by helping them succeed in their careers, regardless of the path they choose. Overall, the HEICE project aims to increase the number of successful deep-tech-oriented and knowledge-based startups by improving the entrepreneurial ecosystem in the three regions and promoting entrepreneurship among students and staff.

We will divide our methodology into 1) Learning Journey and 2) Acceleration Journey.

## 2.1 Learning Journey

The HEICE Learning Journey will develop entrepreneurship competences at different levels and depths. Already in the preparation phase of the planned activities, the EntreComp framework [3] is used for the formulation of learning outcomes. The respective competence levels will be deepened in the course of the Learning Journey, starting with the foundation up to the expert level. The entrepreneurship experts adapt the trainings and planned activities according to the level and competences of the target group. The toolkit template developed in work package 3 will contain a separate chapter on entrepreneurship competences analogous to the EntreComp framework in order to transparently present the competences to be acquired. Since we aim to train a considerable number of staff and students, and since we want to improve digital learning and measurement of entrepreneurial competences, we will use a Massive Open Online Course (MOOC).

As a part of the HEICE project, an already existing MOOC with the title *'Startup-Journey: Geschäftsmodell erstellen'* will be further developed to provide additional entrepreneurship relevant content to deep tech talents. This MOOC has been completed by participants over 900 times and offers them an overview of helpful methods for their startup projects. The aim of this MOOC is to enable students and staff to create business models for their own startup ideas. The MOOC entails 8 units of which 2 videos are offered weekly. Our intention is to i) expand the existing MOOC from a 1 ECTS to a 2 ECTS course by producing additional entrepreneurship units and ii) offer the entire MOOC in English (with Portuguese and Serbian subtitles) instead of German so that the content can be made available to students and staff all over Europe. The MOOC will be for free, so it is accessible to a wide range of learners regardless of their financial resources. The MOOC is available to anyone with an internet connection, so students can learn at their own pace in the location of their choice. The MOOC is asynchronous, so students and staff can work at their own pace and have the flexibility to fit learning into their lifestyle. The MOOC offers a variety of units from different content creators and disciplines, so learners have the opportunity to explore different topics and find the unit that best fits their interests. The MOOC provides a platform for students and staff to connect with peers, mentors, and industry professionals to share ideas, ask questions, and get feedback. The MOOC platform features interactive activities and discussions, which can help keep learners engaged and motivated. The MOOC is created and taught by experts in the entrepreneurship field, so learners can be assured of the quality of the course material.

Professors from the 3 institutions will be online tutors, guiding learners in the process.

In addition, the HEICE project provides comprehensive training and educational programs. These include workshops covering a wide range of topics, including market research, business development, fundraising, as well as techniques for effective pitching and storytelling. Deep tech talents will be able to network with each other, with founders, and other actors of the innovation ecosystem. The program will be mentored by experienced startup mentors who have worked in the startup scene. This program is aimed at motivating students and university staff to participate in our acceleration journey.

## 2.2 Acceleration Journey

We want to create a pool of mentors to tutor our acceleration teams. To that end, each institution will have to gather 10 mentors in the first phase and additional in the second. This will allow to have a mix of professional mentors, based quadruple helix concept (founders, academics, venture capitalists, and one government agencies), joining a Deep Tech ecosystem, and tackling the lack of knowledge of upcoming tech providing contact with founders, CTOs and VCs.

The program for deep tech talents focuses on helping them validate their ideas, start a business development plan, improve their solutions, and learn about fundraising and pitching. The program includes lectures and workshops led by experienced startup mentors and includes an introduction to the program, market research, design and prototyping workshops for health/med tech and manufacturing, a fundraising workshop, a business development workshop, and a pitch and storytelling workshop. The program concludes with a final pitch in front of an experienced jury, who will provide feedback on how to improve. The program is designed to be flexible and allows for remote participation to accommodate the busy schedules of researchers. The goal is to provide valuable lessons and tools for the deep tech talents to achieve success in their startups.

## 3 Development and Implementation of a 4-week Acceleration Program

The acceleration program for deep tech talents focuses on helping them validate their ideas, start a business development plan, improve their solutions, and learn about fundraising and pitching. The program includes lectures and workshops led by experienced startup mentors and includes an introduction to the program, market research, design and prototyping workshops for health/med tech and manufacturing, a fundraising workshop, a business development workshop, and a pitch and storytelling workshop. The program is designed to be flexible and allows for remote participation to accommodate the busy schedules of researchers. The goal is to provide valuable lessons and tools for the deep tech talents to achieve success in their startups. This program will be conducted in B-learning and a total of 16 teams will be accepted, since we want to mentor students from the learning journey and mix them in cross country teams.

One month before start - create a call for startups and teams, disseminated through all consortium partners. Objective is to have at least 20 applications and choose 16 (Table 1).

## 4 Actual or Anticipated Outcomes

An effective project implementation, that focus on building entrepreneurship capacity, enables consortium partners to exchange best practices through networking and mutual learning opportunities, including acceleration programs and entrepreneurial events. Providing hands-on training, support, and mentorship empowers deep tech entrepreneurs with the essential tools and knowledge for success. European projects focusing on building entrepreneurship capacity yield vital outcomes, such as interdisciplinary collaboration and transregional networking opportunities.

Cultivating multicultural teams and presenting ideas across different countries allows academic startups to tap into new markets and growth possibilities. The findings of these projects offer valuable insights for policymakers to inform future initiatives that support deep tech entrepreneurs. Ultimately, European projects striving to assist deep tech entrepreneurs through networking, mutual learning, and hands-on training opportunities contribute significantly to the development of skills and knowledge required for success in the rapidly evolving business landscape, by incorporating entrepreneurship education into curricula and fostering collaboration among students and staff.

## 5 Conclusions

Entrepreneurship education in HEIs is essential for fostering innovation and entrepreneurship in today's knowledge-based economy. HEIs are well positioned to unlock the entrepreneurial potential of deep tech students due to their proximity to factors

**Table 1.** Overview of the content of the 4-week acceleration program

| | |
|---|---|
| Week 1: Ideation and Validation | Introductions and program overview |
| | Idea generation and evaluation |
| | Value proposition development and customer validation |
| | Guest speaker sessions from successful deep tech entrepreneurs |
| | Understanding the deep tech ecosystem and identifying market opportunities |
| | Peer feedback and mentorship sessions |
| Week 2: Product Development and Testing | Refinement of value proposition and product concept |
| | Identifying key features and technical requirements |
| | Design thinking and prototyping |
| | Conducting customer testing and feedback |
| | Guest speaker sessions from experts in product development and testing |
| | Peer feedback and mentorship sessions |
| Week 3: Business Planning and Strategy | Understanding business models and pricing strategies in deep tech |
| | Financial modeling and forecasting |
| | Identifying key metrics and milestones |
| | Developing a go-to-market strategy |
| | Guest speaker sessions from successful deep tech investors |
| | Peer feedback and mentorship sessions |
| Week 4: Pitching and Investor Relations | Developing a compelling pitch deck and presenting to investors |
| | Preparing for investor meetings and due diligence |
| | Negotiating deal terms and understanding legal considerations |
| | Understanding the fundraising landscape and identifying potential funding sources |
| | Guest speaker sessions from investors and legal experts |
| | Investor pitch sessions and peer feedback |

of production such as knowledge and access to promising entrepreneurs. The authors conceptualize entrepreneurship as a life skill with broad applicability and present a unique, dual-faceted pedagogical approach that alternates between theoretical foundations and practical applications that is different from traditional management education. Deep tech talents who receive entrepreneurial education will acquire not only business knowledge, but also essential skills and attitudes like creativity, initiative, and resilience. European projects targeting deep tech students and staff strive to enhance their entrepreneurial mindset and capacity, ultimately bridging the gap between research and the market. These initiatives encourage participants to adopt innovative approaches and improve their market-readiness, fostering a stronger connection between academia and industry.

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# Digital Environments for Open-Access Entrepreneurship Education

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**Abstract.** This article describes the design and development of a digital system for the entrepreneurship education (EE) of engineering students or persons involved in lifelong learning. The positive evolution in understanding the importance of EE, together with our ever goal to better prepare our students for their future professional life, led us to create a digital ecosystem that could foster growth of their entrepreneurial knowledge and skills. The educational system was named BM-BINGS after our primary goals in its design: to facilitate students' acquisition of Business Modeling techniques (BM), familiarize them with Business Innovation (BI) models and professional networking (N), as well introduce them to Green and Sustainable (GS) business practices. Prior to design of the BM-BINGS digital ecosystem we conducted an investigation into the scientific literature on EE. The insights obtained from this research guided many of our design decisions and development strategies for the BM-BINGS system. The experience of our previous projects, which suggested the importance of transversal competences in entrepreneurial activities, led us to create a variety of interactive tools that would help students to acquire useful soft-skills, and to include these tools within the digital environments for EE. Of the three components of the digital ecosystem, the BM (Business Modeling) and BIN (Business Innovation) platforms are now operational in several European languages.

**Keywords:** entrepreneurship education · digital learning · open-access resources

## 1 Introduction

Entrepreneurship education (EE) aims to equip individuals with the knowledge, the skills, and the mindset necessary to start and run successful businesses, thereby contributing to socio-economic development. Moreover, EE is not only important for individuals who want to start their own businesses but also for those who are working in existing companies or institutions, or for those who want to enter the labor field.

Entrepreneurial activities have been recognized as a key driver of economic growth and job creation, and as a result, entrepreneurship education has gained significant attention in recent years [1, 2].

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This global evolution emphasizing importance of EE, together with our everlasting goal to better prepare our engineering students for their future professional life, led us to the idea of creating an educational system to support development of their entrepreneurial skills. The system was named BM-BINGS after the primary goals in its design and development: to facilitate students' acquisition of Business Modeling technique (BM), familiarize them with Business Innovation (BI) and professional networking (N), and introduce them to Green and Sustainable (GS) business practices.

Prior to design of the BM-BINGS digital ecosystem we investigated the scientific literature on EE study programs and their effectiveness.

Additionally, to the EE domain investigation, we inquired into users' perspectives, gathering input from students, educators, and employers on their preferences and opinions regarding the teaching and the learning methods in the EE field. The insights obtained from this research guided most of our design decisions and development strategies for the BM-BINGS project.

Over the past decade, we have been involved in many international projects which have included the creation of digital platforms offering educational materials across a range of subjects. Some of the results of this effort were published by the authors in [3–5] others are available on the projects' web pages [6–10].

Several of these international projects also aimed at studying the transversal skills importance for professional integration and fulfillment. In this respect, we noticed that many transversal skills (creative thinking, ability to synthesize ideas from content, capability to spot opportunities and make quick decisions, planning and risk management, etc.) which are insufficiently addressed in formal education, are also traits of successful entrepreneurs or of individuals able to better cope with challenges of life in modern society. This experience from our previous projects, led us to the outline of another important objective of the BM-BINGS project: include into the digital ecosystem for EE of various interactive IT tools that would help students to acquire useful soft-skills.

The next sections of this article will provide a description of the BM-BINGS initiative and project, which is currently in its final phase of development. The sections will cover the project research background, the design methodology employed, the components and features of the digital ecosystem, the outcomes from the completed testing pilot phases, the conclusions and the lessons learned from this unfolding initiative.

## 2 The Research Background for the Project

### 2.1 Literature Review

Considering the lasts decades' progression in teaching and learning entrepreneurship, before design and developing the key components of the BM-BINGS project, we undertook a literature review focusing on structure, content, expected outcomes, and real-life results of EE programs. Some of these findings are briefly presented below.

Comprehensive analyses [11–13] on the status of EE pointed out many positive aspects (and limitations) of teaching entrepreneurship in educational institutions globally.

Thus, we noticed that despite the obvious progress in EE field over the years, several negative factors often affected EE experiences and programs (see Table 1).

**Table 1.** Drawbacks identified by the research in creation of educational content, pedagogy or running of entrepreneurship courses.

| Category | Negative Aspects in Entrepreneurship Education (EE) |
|---|---|
| Content design | The EE content is crafted based on educational policies, often disregarding the expectations of students |
| Content design | The opinions and expectations of the students and of employers are overlooked |
| Pedagogy | There are certain limitations to the utilization of digital technology in EE |
| Pedagogy | Learning outcomes of the EE and the appropriate teaching methods for EE are still not clearly stated |
| Pedagogy | Specific tools for assessment of learning outcomes of the EE are lacking |
| Pedagogy | The motivation of students towards EE programs varies across countries due to cultural differences [14] |
| Course running | The inclusion of hands-on entrepreneurial experiences in the regular EE curriculum is often uncommon |
| Course running | EE programs in schools rarely engage employers and real-life entrepreneurs directly, typically only inviting them as occasional guest speakers |
| Course running | There is a lack of collaboration between universities and businesses when it comes to teaching and learning entrepreneurship |

Regarding the particular context of digital learning of entrepreneurship in engineering, the scientific production provided us with insights into the current state within the domain. A quick search in the Web of Science for articles published in the last years shows that from the total of 7000 articles containing "entrepreneurship education" in the topic, only 1200 (i.e., 17%) contain the keyword "engineering". Additional search filters connecting the topics of EE, engineering and e-learning in various formats reduces the number of hits to about 130.

### 2.2 Study of Users Opinions

Before outlining our project's main design approaches, and to prevent as many as possible of the above listed drawbacks when creating new EE digital platforms, we carried out a research study on users' preferences and opinions.

The primary objective of the study was to collect insights from both students and employers regarding: (a) the skills associated with entrepreneurship that they anticipate being fostered through EE, (b) the users' preferences on what concern the learning/teaching content and its delivery. In the first stages of the research, we conducted focus group discussions with 24 participants who represented small or medium-sized enterprises, including 8 entrepreneurs. Our objective was to investigate the essential attributes and competencies that are highly valued by employers when considering candidates for entry-level positions.

Our findings revealed that employers seeking to hire entry-level staff do not place significant emphasis on managerial competencies such as rapid decision-making or conflict resolution skills. Instead, they prioritize candidates who exhibit compliance with rules and the capability to work collaboratively within a team. However, employers are open to strengthening collaboration with universities by offering students practical experience through internships, workshops, mentoring and couching opportunities.

In second phase of our study, we surveyed a number of 86 students in computer science and engineering (63 males, 23 females), among which 37 undergraduates and 48 graduates, about various aspects of learning entrepreneurship.

Their responses to the research questions are briefly presented below.

In response to a question regarding the competencies they anticipate enhancing by participating in entrepreneurship courses, the students expressed their preference for practical experience as the most desirable learning outcome. They identified practical learning as the area that receives the least attention within EE courses they took.

Regarding the preferred approach of delivering the educational content for learning entrepreneurship, our students unequivocally express a preference for direct engagement with entrepreneurs through practical internships or long-term project collaborations with real entrepreneurs. On a broader scale, our engineering students exhibit a relatively low level of satisfaction with the quality and usefulness of their entrepreneurship courses. Once again, the primary reason for this dissatisfaction stems from the perceived lack of practical relevance within the courses. Furthermore, when asked about the challenges encountered in learning entrepreneurship, most students responded by highlighting the excessive theoretical and abstract nature of the educational content.

This finding aligns with the conclusion drawn in [15], suggesting that “it would be useful to give students more practical examples about the usefulness of self-analysis.”

From this perspective, an ideal EE course should integrate educational content aimed at developing a range of transversal skills and meta-cognitive competencies. This content should also be complemented by numerous practical opportunities such as internships, workshops, and real-life interactions with entrepreneurs.

As a result of this study and research, we have identified an additional significant objective for the BM-BINGS project. This objective entails developing a range of interactive tools that not only facilitate the teaching and learning of entrepreneurship-specific content, but also assist students in acquiring transversal competencies and practical skills. These tools will be seamlessly integrated as components within the digital ecosystem dedicated to EE. Another potential solution to address users’ feedback involves establishing a collaborative network that brings together educators, entrepreneurship teaching experts, real-life entrepreneurs, students, and learners. This network will serve as a platform for enhanced communication and collaboration among all stakeholders and will be supported by technology-enabled tools provided by e-learning platforms. This approach aims to create an engaging human-digital environment that fosters interactions and involvement among stakeholders, teachers, and learners, in order to better support an effective entrepreneurial education.

# 3 Digital Ecosystem's Structure and Features

## 3.1 The Ecosystem Components

The educational ecosystem BM-BINGS integrates three digital platforms meant to support entrepreneurial education and skill development for its users.

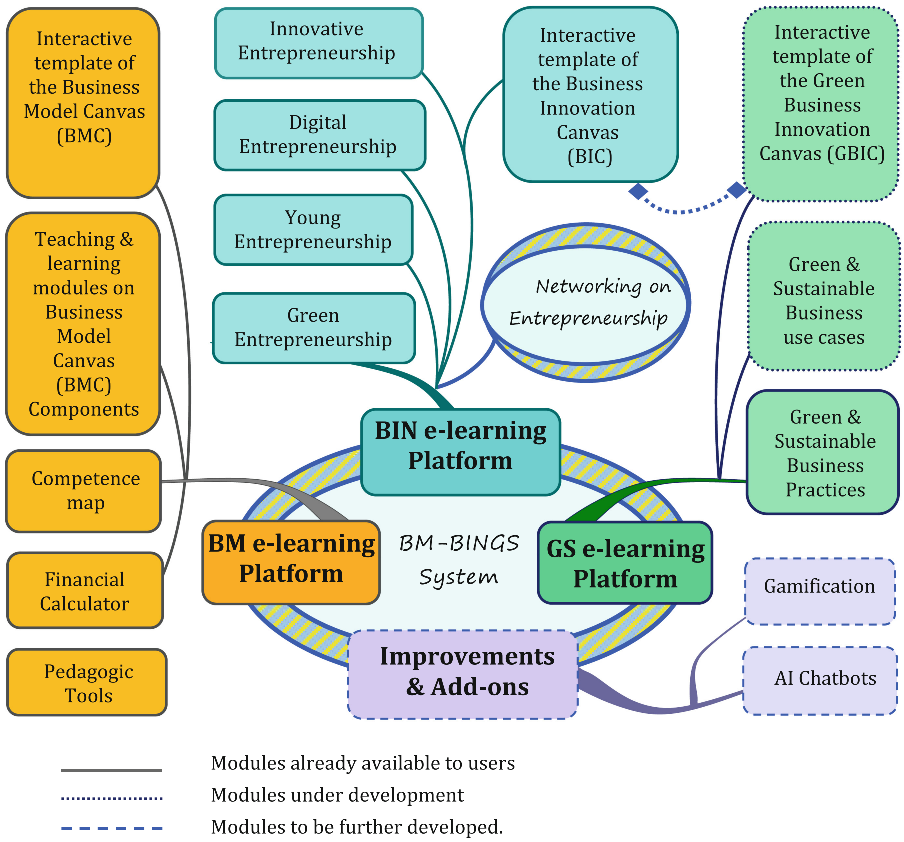


**Fig. 1.** A mind-map representing the BM-BING system's logical structure, showing its main components, their relationships and status of availability.

The first platform, BM, aims to assist learners in acquiring business modeling techniques. The second platform, BIN, is designed to familiarize users with various types of businesses (Digital, Young, Cooperative, or Green Businesses), and is providing insights into Business Innovation models and fostering creativity and innovation knowledge and skills. Moreover, BIN facilitates networking (N) for communication and collaboration among educators, entrepreneurship experts, real-life entrepreneurs, students, and learners. The third platform, GS, focuses on introducing learners to Green and Sustainable business practices (see Fig. 1).

## 3.2 The Design Model

The BM-BINGS system's conceptual model can be formulated by using a practical approach and employing the same entrepreneurial techniques that we aim to teach through it. Taking inspiration from the idea that project development is comparable to initiating a business, we utilized a well-known entrepreneurial modeling tool, the BMC (Business Model Canvas) [16] to conceptualize the design model of the digital system. The BMC is an abstract model presented in a template comprising nine logical blocks. This template enables users to describe and analyze their own business ideas, fostering critical thinking and exploration.

The BMC-supported modeling helped us to define the main components of our project concept, such as the "Key Activities", i.e., the main actions and undertakings in the project, the "Key Resources", which describe the resources necessary to carry out these activities, and the "Key Partners", which identify the work groups.

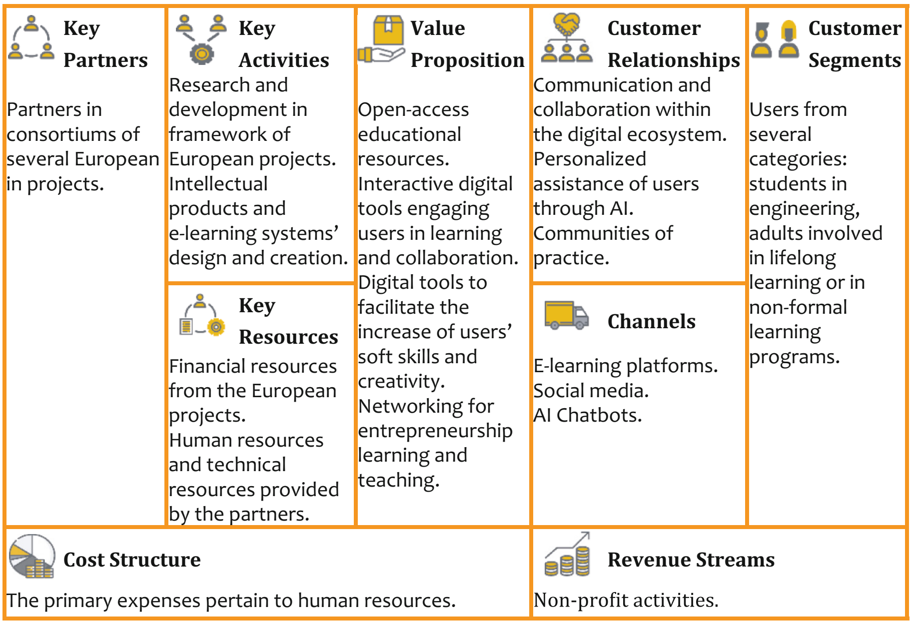


**Fig. 2.** The Business Model for development of educational systems in framework of European projects, regarded as an entrepreneurial endeavor to support digital learning.

The project added value ("Value proposition"), its target groups ("Customer Segment") and their interactions and experiences ("Customer Relationships") can also be conceptualized within the design model of the ecosystem. The methods of conveying services to users ("Channels"), which consist in our project of online open access to information, the project's "Costs Structure" and the returns from the project ("Revenue streams"), which in our case are the results obtained by users in acquiring entrepreneurship knowledge and skills, can be additionally considered as project's essential modeling components (see Fig. 2).

A crucial element of the BM-BINGS project is its "Value Proposition" or added-value, which consists in delivering quality, interactive content, and effective pedagogy to its users. A part of this value proposition is the offering of BIN platform, which proposes educational materials on (business) creativity and its teaching methodology. Additionally, the BIN platform serves as a technology-enhanced supporting system that could foster communication and collaboration among educators, learners, and entrepreneurs. What is more, the BM-BINGS digital system ensures unrestricted access to all educational content and learning tools, significantly enhancing the usability of the overall value proposition. Finally, the "Key Resources" required to implement the project consist of the financial support obtained from three European projects on entrepreneurship education (ProBM2, EntrNet, InnoGreen), along with the intellectual contributions of the project team members and the material resources provided by the partners' organizations.

### 3.3 Key Features of the System

The effectiveness and attractiveness of an e-learning system are notably influenced by both the educational content and the interaction with the users. The features of BM-BING system that enhance these attributes will be further presented in this section.

To enhance knowledge delivery and improve the user experience, the instructional content within the digital platforms of the BM-BINGS system has been carefully sequenced and restructured to facilitate digital micro-learning and mastery learning.

Digital micro-learning involves breaking down educational material into smaller, manageable units, while mastery learning incorporates brief assessment exercises conducted before and after each learning piece or lesson. These exercises are seamlessly integrated into the learning activities, allowing learners to track their progress. Adopting micro-learning and mastery learning approaches in training activities offers several benefits, such as saving time and reducing costs, as it focuses on addressing learners' specific educational needs and enables the achievement of specific goals through targeted learning units. Micro-learning gives learners greater control over the training process, allowing them to determine when and where they engage in learning activities [17–19].

In line with this vision, the e-learning content provided on the BM-BINGS platforms incorporates various elements to enhance user engagement and comprehension. These elements include user-friendly presentations, diverse types of quizzes presented in graphical formats, mini-labeling of graphic elements, embedded photos and infographics, mind maps and video-clip presentations, as well as self-reflection exercises and case studies. Furthermore, gamification was employed as a pedagogical method to engage users in practicing their skills through online interaction. Almost every lesson offers tests and interactive games to allow users to assess their understanding of specific business modeling concepts.

This approach fosters involvement in the learning process and facilitates better retention of key aspects. It enhances learners' intrinsic motivation, while extrinsic motivation is provided through scores and achievements within the interactive game-like exercises presented to users.

The collection of digital learning tools integrated into the system was augmented with the inclusion within the BM platform of an online interactive Business Model Canvas template and a free-access Financial Calculator.

The Financial Calculator allows users to manipulate numerical values associated with costs (fixed, variable, total), customer count, investments, income, and profit to observe fluctuations in NPV (Net Present Value), IRR (Internal Rate of Return), and Repayment Period. This tool facilitates the calculations required by entrepreneurs and startups to evaluate financial forecast data, including the break-even point and internal rate of return. The Financial Calculator provides economic estimation results that can be printed or downloaded as files for further discussions with tutors or colleagues.

To ensure a comprehensive understanding of the interrelationships between financial and economic parameters in a business, the Financial Calculator offers practical examples of financial calculations and explanations of business concepts.

The Financial Calculator, presented as a form of micro-learning, is closely linked to the efficiency of a business model. It assists users in creating and testing real-world scenarios, gaining insights into the various stakeholders involved in business model, and practicing financial aspects related to investments and profit.

## 4 Testing and Evaluation of the Digital System

Among the components of the digital ecosystem, the BM platform has already completed the pilot testing phase. The pilot test of the BM platform's usability and educational impact was performed with engineering students and adults enrolled in a continuing education program on computing. The survey was carried out through evaluation questionnaires. The main goal was to compare the users' perception and acceptance of the proposed digital system.

To assess users' opinions of the BM platform, two types of survey questionnaires were employed. The first questionnaire, Q1-SUS, utilized the System Usability Scale (SUS) [20, 21], a well-established tool for evaluating the usability of products and services. The second questionnaire, Q2-UX, focused on assessing the user experience specifically within the BM e-learning platform. Both questionnaires were quick to complete, previously validated, and yielded intuitive and consistent results [22].

Q1-SUS enabled users to provide their overall appraisal of the BM platform. By calculating a score for each participant, the questionnaire allowed for the determination of an average score derived from all respondents. Q2-UX, the user experience evaluation questionnaire, was adapted to consider six factors: Attractiveness, Perspicuity, Efficiency, Dependability, Stimulation, and Novelty [23].

These factors collectively provide a comprehensive impression of the user experience when engaging with a digital interactive service. Attractiveness captures the general impression of the website and whether users find it appealing. Perspicuity reflects the ease of learning to use the product, while Efficiency assesses the ease of accomplishing learning goals without unnecessary effort. Stimulation measures the level of motivation to use the platform, and Novelty indicates the degree of innovation and creative tools incorporated within the e-learning platform.

The pilot testing phase involved two distinct participant groups: the first group (G1) consisted of 59 individuals studying Computer Science and Engineering, while the second group (G2) comprised 44 adults enrolled in a continuing education program in the field of Information Technology. In the case of group G1, the BM platform served as a learning support tool within their Business Administration course, which is a part of their curriculum. Upon completion of the educational activities, the participants were asked to fill out both questionnaires.

Q1-SUS, focusing on the usability of the BM digital system, collected responses from 105 individuals. The resulting mean score was 77, surpassing the threshold of 68. This indicates that the overall satisfaction with the usability of the e-learning environment exceeds the average score typically associated with digital services.

Regarding the second questionnaire, Q2-UX, the responses were analyzed to interpret the average user experience for each factor. Individual factor values were plotted to identify any outliers during the evaluation process (see Fig. 3).

According to [24], values within the range of (−0.8 and 0.8) indicate a neutral evaluation of the corresponding factor. Values greater than 0.8 represent a positive evaluation, while values smaller than −0.8 indicate a negative evaluation. Although the scale ranges from −3 (extremely bad) to +3 (extremely good), the observed values in our experiment fall within a restricted positive range. This tendency can be attributed to the respondents' general inclination to avoid extreme responses.

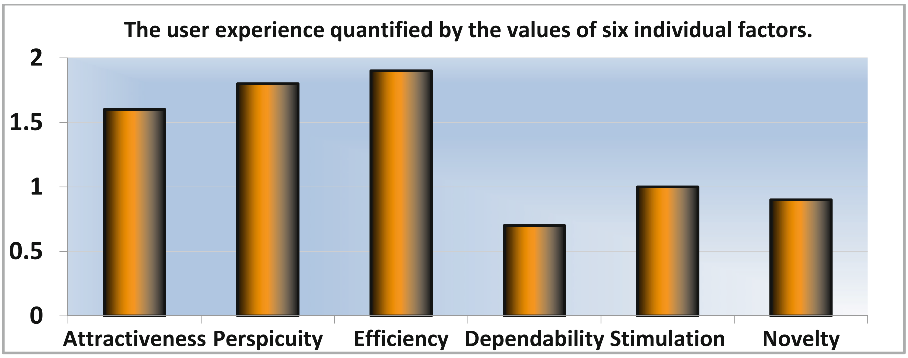


**Fig. 3.** Results of survey on user experience for the BM educational platform.

We compared the obtained results with the results of a benchmark offered by the authors of the Q2-UX user experience questionnaire. The benchmark provides a straightforward representation of the evaluated product's performance in comparison to the products within the benchmark dataset.

The measured means in our Q2-UX survey were compared with the benchmark data set, that contains data from 21175 persons from 468 studies concerning different products (business software, web pages, web shops, social networks).

The results of our survey fell within the specified benchmark, indicating a positive evaluation for the factors of Attractiveness, Stimulation, and Novelty, and a highly positive evaluation for Perspicuity, Dependability, and Efficiency. In our project context, the initial three factors pertain to the overall appearance of the platform, while the latter three factors relate to the user's interaction with the educational system.

By evaluating the factors and individual items, the Q2-UX questionnaires provided valuable insights for identifying areas of improvement. The distribution of answers for

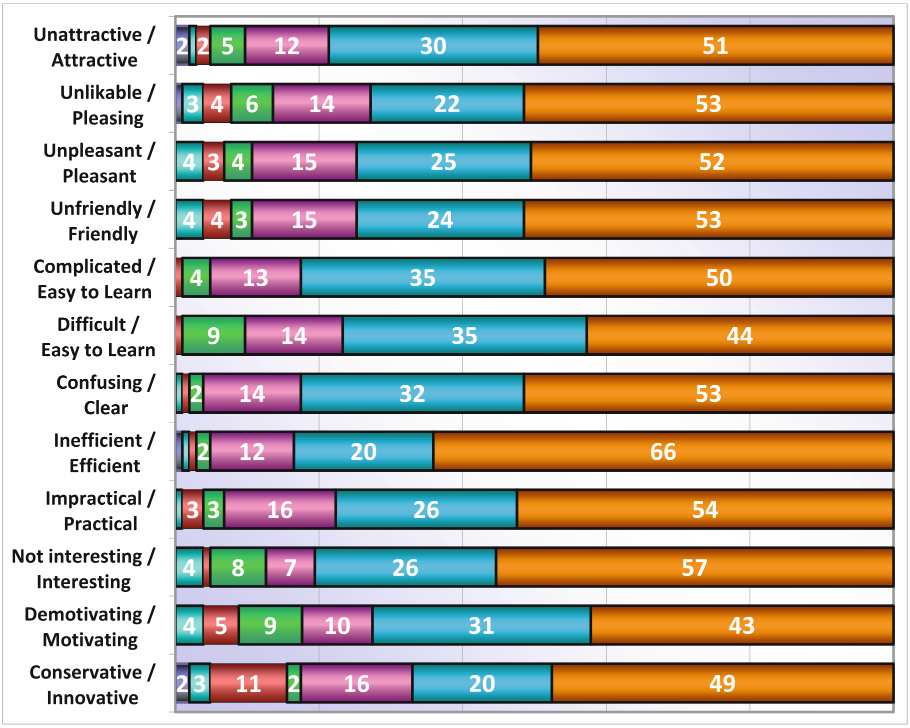


**Fig. 4.** Distribution of answers for each question in user experience questionnaire (Q2-UX)

each item, as observed in Fig. 4, highlighted certain aspects that could be enhanced. Despite the variations in the conditions under which the two groups utilized the BM digital platform, the evaluation of individual items indicated the potential for improvements in terms of innovative features (such as gamification and interactive tools), site appearance, and content.

## 5 Lessons Learned and Conclusions

Of the three components of the digital ecosystem, the BM and BIN platforms are now operational in several European languages. These platforms offer free access to a wide range of educational resources and can be utilized for teaching and learning entrepreneurship in technical fields or continuing education programs.

To assess the usability and learning impact of the BM platform, a pilot test was conducted with engineering students and a large group of adults enrolled in continuing education programs. The users' feedback, - rather encouraging, gave us the confidence to continue our project.

Moving forward, the next phase of the BM-BINGS initiative involves testing the BIN digital platform and developing the third environment, the GS (Green Sustainability) platform. The GS platform aims to provide users with a comprehensive set of digital tools to learn about the green aspects of businesses. Prior to designing this platform, an international study will be conducted to investigate the green practices, challenges, and solutions implemented by companies.

Throughout the development of our project, the lessons we have learned thus far will serve as a guide for improvement and extension. The educational ecosystem will be incorporated as a practical tool within the existing EE courses for our engineering students. Additionally, the overall digital system will undergo further evaluation, and the obtained results will inform further enhancements.

Finally, the BM-BINGS system will be equipped with an intelligent chatbot capable of answering user questions related to the educational content within it.

The robot will be developed based on yet available API provided by one chatbot platform, such as ChatGPT, Bard, Jasper, Bing, and will be trained to understand and "learn" the specific educational content incorporated in BM-BINGS. Then, through an on-site developed user interface, users will be able to submit their questions or other requests to the chatbot and to get the specific answer they needed.

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# Entrepreneurship in Engineering Curriculum

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**Abstract.** Entrepreneurship plays a very influential role in the economic growth of a country. Small and medium enterprises (SMEs) including microenterprises have contributed a significant role in fostering growth, creating wealth and create jobs. These have been integral to Malaysia's economic transformation process. The Malaysia government targets SMEs to contribute 50% to gross domestic product (GDP) by 2030 from current 37.4% (2021) and aspiration to become a high-income nation. Hence, more entrepreneurship policies, initiatives and drivers have been prepared to ensure the target is achieved, including cultivating more young entrepreneurs through higher learning institutions. The aim of this paper is to identify the entrepreneurship skills to enhance the entrepreneurship aspect of the engineering curriculum. The findings indicated that key skills such as critical thinking, innovative or creativity, financial knowledge, identifying opportunities, and new business start-up planning skills are the most relevant and shows that these are the skills most needed by the mechanical engineering graduates.

**Keywords:** Entrepreneurship Skills · Engineering Curriculum

## 1 Introduction

Malaysia's Ministry of Higher Education (MOHE) aspires to compete in the global economy by creating a higher education system that is ranked among world's leading education system. Major changes to the higher education ecosystem have been proposed in the Malaysia Education Blueprint 2015/2025 (Higher Education) [1]. Instilling entrepreneurial mindset throughout the higher education system is one of the main shifts in the MEB (HE), developing them to be a holistic, entrepreneurial and balanced graduates as well as moving them as job seekers to job creators [1].

Several studies have shown that entrepreneurship education can be taught and promote entrepreneurship in some way [2, 3]. One of the steps taken by MOHE is the introduction of entrepreneurship subjects related to entrepreneurship to primary and tertiary levels [4]. In addition, The Fourth Industrial Revolution, also referred to as the industry 4.0 or 4IR has given a new impetus to educational transformation. This was sparked by the steady development of the internet and leapfrogged further by cloud technology, which is connecting the world and driving a shared global economy. Hence, on top of mastering essential knowledge and skills in their chosen disciplines, graduates should be creative and critical thinkers that are able to evolve and fit to the needs and

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demands of industry needs and trends. This transformation is focused on the needs to produce graduates with strong entrepreneurial mind with matching skills in creativity, innovations, competitiveness and agility. Thus, it is with this realisation that in order to have such quality of graduates, updating and revamping the curriculum is of paramount importance to enable students to be equipped with the necessary knowledge and skills to negotiate and be successful in the dynamic environment of Industry 4.0.

Hence, this brings to the research question of identifying the gaps of entrepreneurial skills in mechanical engineering curriculum with the industry perspective.

## 2 Entrepreneurship Education in Engineering Curriculum

Introducing entrepreneurship education into engineering curriculum allows students to better understand of engineering enterprise (start-up of engineering business), namely developing concepts of leadership, innovation and creativity [5]. However, most of public universities are still facing difficulties in implementing entrepreneurship education effectively [6]. Major issues identified are the commitment towards entrepreneurship education by both educators and students, lacking of proper entrepreneurship training for educators as well as insufficient educators' qualification and curriculum exposures [6] particularly in producing professional practice workforce.

There was improvement on the aforementioned abilities of public universities graduates. However, more needs to be done to ensure the rate keep rising to enhance the entrepreneurship education [7]. Though there were improvements through the introduction entrepreneurship education courses, it was insufficient to aid students for future entrepreneurship development [8]. These perceived inadequacy is further added as the outcome of entrepreneurship education among engineering students as compared to business students have not been studied thoroughly enough [9]. Therefore, there is a need to identify, evaluate and suggest ways to enhance the entrepreneurship aspect of the engineering curriculum. The insufficiency of the entrepreneurship part of the engineering curriculum as suggested by Rasli et al. represent the gap that this research aims to undertake [8].

## 3 Methodology

This research includes sampling and data collection procedures for the survey. As per the analytical framework of the study, the data analysis comprises description, interpretation, and explanation of the variables of interest.

This research applies a quantitative approach by gathering all information at once in the respondent's life through a cross-sectional research design which encompasses the determination of relationship between variables. The target demographic of this research includes managers who have working experience in management or supervisory level in engineering related businesses for a minimum of five years in Malaysia. Identification and objectives definition are the initial steps to begin with since both are the essential key for the research.

Purposive sampling is selected by some random technique as it is known to be representative of the entire population and a good method in producing well-matched groupings. The objective is to select the sample based on criteria that are regarded significant for the specific study. This strategy is appropriate when the study places a high priority on the control of specific variables. It serves to provide; best available knowledge regarding the sample subjects, better control of significant variables, and matching sample group data.

An online survey was used to collect data. The addressees received an email with a link to a web-based questionnaire (hosted on an external server to ensure anonymity) and the author's contact details.

The one stage sampling technique was used in this research sample design. Those in managerial or supervisory positions are specifically targeted in this stage. This scope of experts will be from the senior management level and have over 5 years of industrial and engineering-related experiences. They are directly involved in hiring and managing graduate engineers.

The data sources of this research were from various background, among them are professional and experts from the mechanical-related engineering industry with a minimum of five years of engineering experiences and have held at senior management level in the organisation.

Research objective was administered to the respondents and all the questionnaires were successfully collected and utilised. According to the ethical consideration in research, the employers participated voluntarily and the procedure of data collection did not involve any risk, be it physical or psychological, on the part of the respondents.

The first part of the questionnaire was gathering the demographic of the respondents with the aims that the respondent data were relevant to the research question. The second part of the questionnaire purpose is to examine the gap in the current engineering curriculum for entrepreneurship education with respect to industrial practices. Lastly, the final part of the questionnaire resolves the entrepreneurship skills needed to close the gap.

## 4 Findings

This section explains the findings to identify the curriculum gaps between engineering industry perspective and mechanical engineering curriculum in relationship to entrepreneurial skills. Analysed data using SPSS which consists of independent sample t-test and one-way ANOVA that was used to compare the similarities in skills needed in both to become an entrepreneurship and employee in industries.

Descriptive analysis was conducted to understand the background of respondents who completed the survey questionnaires and explain the main features of data in the survey. Understanding their profile was important because it provides the background information about the types of respondents who were involved in this research. The profiles of the respondents were analysed based on gender, their job positions, nature of business, years of experience, employee's education background.

Descriptive statistics can form the basis of quantitative analysis. In most situations, it is needed to explain three major characteristics for each of the variables. The central tendency is an estimate for the central in the data and there are three types of estimates for central tendency that are mean, median and mode. The dispersion is the spread of the values around central tendency. There are two popular estimates for dispersion that are range and standard deviation.

This section describes the background of the respondents and their employees as illustrated in Table 1. The table consists of four background factors namely; gender, their positions, nature of business, years of experience, and employee's education background.

With regards to gender, among 45 of total respondents of, the descriptive analysis in Table 1 presented the gender distribution of male and female, in which males constitutes 24 (53.3%) and female were 21 (46.7%). This indicated that for engineering field there is almost male in the study area because of the nature of the working field, which does not comprise of both gender with almost even population distribution across the industries.

The working experience of respondents ranged from 0 to more than 10 years, in this regard, Table 1 showed that, there were no individuals with less than five years of experience, between 5 to 10 years of experience were 46.7% (21), and more than 10 years of experience were 53.3% (24). Considering the work of experience, mean score is 2.53 which more towards ten years and above of experience and standard deviation is 0.505. This indicated that managers in the working experience categories of 10 years and above were more than other experience levels.

In terms of the positions of the respondents, the descriptive analysis in Table 1 illustrates 21 (56.7%) respondents were a manager or supervisory level personnels. The purpose of this study was to get the feedback from entrepreneurs and other roles which are directly influenced in hiring new staffs. Individuals who were involved in the hiring process were the second most respondence with 16 (35.6%) respondence. 8 (17.8%) entrepreneurs answered the questionnaires. In whole, there were no academician which is the least category of roles.

As part of the data collection, the nature of the business was another point to consider. Based on Table 1, 64.4% of 29 companies were engineering related; on the hand, 35.6% or 16 companies' field of business were not related to engineering areas.

On the level of education, respondents having bachelor degree were 28 (62.2%), master degree with 11 (24.4%), and those who have PhD were 6 (13.3%).

Table 1 illustrates the distribution of number of engineering and non-engineering related fields among all the respondents. The analysis revealed that, the respondents who are working in engineering field were 24 (53.3%), and those who are working other than engineering field were 21 (46.7%). This finding showed that the questionnaires were distributed mainly in engineering related industries.

Lastly, education background of the employees under respondents was categorised into two sections; graduated from any Malaysian universities or graduated from outside of Malaysia.

### 4.1 Gaps Between Industries' Perspective and Mechanical Engineering Curriculum

Descriptive analysis was used to describe the skills considered as an essential gap between industries' perspective and mechanical engineering curriculum in relationship to entrepreneurial skills.

**Table 1.** Background of the respondents.

| | *f* | % | *Min* | *Max* | *Mean* | *SD* |
|---|---|---|---|---|---|---|
| **Gender** | | | | | | |
| Female | 21 | 46.7 | | | | |
| Male | 24 | 53.3 | | | | |
| **Work Experience** | | | 2 | 3 | 2.53 | 0.505 |
| Less than five years | 0 | 0 | | | | |
| between 5 to 10 years | 21 | 46.7 | | | | |
| more than 10 years | 24 | 53.3 | | | | |
| **Role** | | | 1 | 4 | 2.47 | 1.160 |
| Involve in the hiring process | 16 | 35.6 | | | | |
| An Academician | 0 | 0 | | | | |
| A Manager or Supervisory Level Personnel | 21 | 56.7 | | | | |
| An entrepreneur | 8 | 17.8 | | | | |
| **Nature of Business** | | | 1 | 2 | 1.64 | 0.484 |
| Non-Engineering related | 16 | 35.6 | | | | |
| Engineering related | 29 | 64.4 | | | | |
| **Level of Education** | | | 2 | 4 | 2.39 | 0.665 |
| Bachelor | 28 | 62.2 | | | | |
| Master | 11 | 24.4 | | | | |
| PhD | 6 | 13.4 | | | | |
| **Field of Education** | | | 1 | 2 | 2.51 | 0.505 |
| Non engineering | 24 | 53.3 | | | | |
| Engineering | 21 | 46.7 | | | | |
| **Employee's Education in field of Mechanical Engineering** | | | | | | |
| Yes | 45 | 100 | | | | |
| No | 0 | 0 | | | | |

Table 2 presents the frequency analysis of each skill which believes to be the gap based on the respondence. Out of 45 respondents, the skills such as finance, data analysis, agile, team player and sustainable mindset were found to be most essential skills.

For the second category, being able to solve problems, make business plan, generating new ideas, digital skills, leadership, and being adaptability were considered important.

Other skills such as negotiation, and risk management were considered somewhat important gaps. Lastly, accounting, communication and customer oriented were less important as compared to other skills in determining entrepreneurial or employability.

From the Table 2, have the highest mean score means engineering graduates are lacking and they are essential at the same time since majority of respondence focused on these skills.

**Table 2.** Frequency analysis (sorted in highest to lowest).

| Finance | 4.40 |
|---|---|
| Team player | 4.38 |
| Data analysis | 4.31 |
| Agile | 4.31 |
| Sustainable mindset | 4.29 |
| Problem solving | 4.13 |
| Business plan | 4.11 |
| Innovative & creativity | 4.11 |
| Adaptability | 4.11 |
| Digital skills | 4.07 |
| Leadership | 3.91 |
| Negotiation | 3.04 |
| Risk management | 2.64 |
| Customer oriented | 2.38 |
| Communication | 2.31 |
| Accounting | 1.76 |

To compare the difference in skills selection that might have affected by different genders among the respondents, independent samples t-test is used to compare the respondence (means) between two groups.

**Table 3.** Gender (t-Test).

| *Gender* | | *N* | *Mean* | *SD* | *Sig.* | *t* | *df* |
|---|---|---|---|---|---|---|---|
| Mean | Female | 21 | 3.6815 | 0.32889 | 0.181 | 0.589 | 43.0 |
| | Male | 24 | 3.6068 | 0.49298 | | 0.605 | 40.345 |

Based on the result in Table 3, the result of independent t-Test for equally of variances revealed that the variances between two groups were almost equal. The mean of skill selection between female respondents was 3.6815 and mean of male respondents was 3.6068. The result (Sig. 0.181, $p < 0.05$) does not supports the hypothesis that the means. Hence, there is not a significant difference between male and female respondence which means no effect was observed.

**Table 4.** Business nature of company and field of education (t-Test).

| *Business nature of company* | | *N* | *Mean* | *SD* | *Sig.* | *t* | *df* |
|---|---|---|---|---|---|---|---|
| Mean | Non-engineering | 16 | 3.5508 | 0.50323 | 0.238 | −1.076 | 43 |
| | Engineering | 29 | 3.6918 | 0.36897 | | −0.984 | 24.083 |
| *Education background* | | | | | | | |
| Mean | Non-engineering | 24 | 3.6536 | 0.48865 | 0.340 | 0.202 | 43 |
| | Engineering | 21 | 3.6280 | 0.34031 | | 0.206 | 41.057 |

Other factor that could be considered is nature of business of the company, whether the skills would change based on the engineering or non-engineering line of work. Based on the result in Table 4, the result of independent t-test shows no significant difference between engineering and non-engineering respondence. Similarly, the last independent t-test on the education background of the respondents indicates that not a significant difference between engineering and non-engineering respondence which means no effect was observed.

Besides gender, nature of business and education background, other question to indicate working experience, position or role of respondence and level of education were also part of the structured questionnaire. A five-point Likert scale was used for the questionnaire.

ANOVA test was conducted, a test of normality was done to check on whether to use a parametric or non-parametric measure to test hypothesis in the study. Prior to the ANOVA test, a normality test was performed to determine whether a parametric or non-parametric measure used for hypothesis testing in the study.

**Table 5.** Normality test.

| | N | Min | Max | Mean | SD | Skewness | | Kurtosis | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Statistic | Std. Error | Statistic | Std. Error |
| Mean | 45 | 2.19 | 4.44 | 3.6417 | 0.42146 | −0.886 | 0.354 | 1.950 | 0.695 |

The data shown in Table 5 is considered to be normal as the skewness value is between −2 and +2, and the same time the kurtosis value is between −7 and +7.

The first test was run for working experience and the obtained p-value of more than 0.05 in the one-way ANOVA analysis which provides strong evidence to not reject the null hypothesis as show in Table 6.

This result indicates that there are no statistically significant variations among the means of the compared groups. In other words, the observed data suggests that at none of the groups has a mean significantly different from the others. Observed data suggests that at none of the groups has a mean significantly different from the others.

**Table 6.** ANOVA analysis.

| ***Working experience*** | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 0.047 | 1 | 0.047 | 0.260 | 0.613 |
| Within Groups | 7.769 | 43 | 0.181 | | |
| Total | 7.816 | 44 | | | |
| ***Position/Role*** | | | | | |
| Between Groups | 0.118 | 2 | 0.059 | 0.321 | 0.727 |
| Within Groups | 7.698 | 42 | 0.183 | | |
| Total | 7.816 | 44 | | | |
| ***Level of education*** | | | | | |
| Between Groups | 0.480 | 2 | 0.240 | 1.373 | 0.264 |
| Within Groups | 7.336 | 42 | 0.175 | | |
| Total | 7.816 | 44 | | | |

In the context of the one-way ANOVA, position or role and level of education of the respondents were considered for the same test to gather evidence from the data to either support or reject the null hypothesis. Since the significant is more than 0.05, support the null hypothesis, The findings indicate a lack of significant effect, difference, or relationship, that being said, failing to provide sufficient evidence to support the alternative hypothesis.

This result can be explained by positive and strong gap between mechanical curriculum and entrepreneurship skills which has been identified by the individuals who are either entrepreneurs or hiring personnels where factors mentioned above does not affect on the selected skills. Having the mentioned skills above will have positive awareness of engineers about entrepreneurship opportunities to invent new business [10]. Graduates who have entrepreneurship skills are capable of seeing problems outside of engineering box therefore make proper adjustments by considering both engineering and business perspective in their line of work while facing various events and difficulties. These could help into overall economy of the country.

## 5 Conclusions

There are many research methodologies available and it is important to choose the right method for this research. As well-elaborated above, using questionnaire survey would yield much quantitative information and data required to carry out the next research objective. It will be a rewarding learning experience for the participants and the researcher.

Besides, selecting the right population sample size and a homogenous background are equally important to generate the right results. A great deal of planning and coordination are required for the data collection. This is to ensure minimal expenditure and unnecessary wastages during the session. As for the online survey, purposive sampling was the best method selection since the respondence had to meet educational and experience requirement which is appropriate when the study places a high priority on the control of specific variables.

The results indicated that key skills such as critical thinking, innovative or creativity, financial knowledge, identifying opportunities, and new business start-up planning skills are the most relevant. Hence, it can be concluded that these are the skills most needed by the students for them to improve as responded by the respondents. Although other skills such as negotiation, having sustainable mindset, and communication skills are also needed to be improved although they were not as crucial at the entry-level for the mechanical engineering graduates. Soft skills are equally important as technical skills as perceived by the industry and students, especially for the company that are involved in providing customer services [11].

The public universities need to help students to prepare them for the competitive world that we are living by either preparing them to become an entrepreneur or increase their employability after their graduations. The mentioned skills should be tailored to meet the needs of the future employee and industry. This could help to narrow down the gap between the future skills needed by the industries compare with what is being taught and developed in the institutions.

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# The Platform for Education on Digital Entrepreneurship

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**Abstract.** Digital innovation requires a major consolidation of existing systems and applications invoking retire/replace strategies and very demanding complex integration based on specific digital skills; acquiring the knowledge and experience needed here is the focus of our proposal and we will boost it through our regional business laboratory that will simulate and monitor the artificially created effect of digitally encouraged leadership and entrepreneurial characteristics of leadership. In this paper, we will describe how to include the Knowledge Triangle (interaction between business, education, and innovation, which are key drivers of a knowledge-based society) in an interdisciplinary approach (bringing together researchers and specialists from the software development, big data, business, entrepreneurial, mathematical, psychological, marketing, and financial domains) on designing the different educational programs for building innovations and entrepreneurial activities based on gamification, hands-on and learning-by-doing approaches for students currently enrolled on partnering HEI, but also, for Faculty and Staff, and others, like life-long learning students. We will also describe how these programs will be deployed on the specially developed digital platform that will enable online learning, blended learning, and offline learning.

**Keywords:** Digital Innovation · Platform Education · Digital Entrepreneurship

## 1 Introduction

### 1.1 Purpose

In today's rapidly changing technological landscape, leaders who are proficient in using digital tools and platforms are better equipped to stay ahead of the curve and adapt to new challenges [1], and with help from digital tools and platforms, they can predict more accurately project outcomes, communicate more effectively and efficiently with their teams, and produce market-ready solutions faster [2]. Our goal is to create an economic ecosystem that will develop a mindset, knowledge, and skills to implement sustainable manufacturing using digital technologies and to create solutions leaders. The students who will finish these educational programs will be able to use digital technologies to boost smart and sustainable business in a clean and green environment, adding value to the social and economic stakeholders [3]. By enabling digital platform literacy it will

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also be possible to overcome gender inequality [4]. Developing and deploying women who present one-half of the world's available talent has a huge bearing on the growth, competitiveness, and future readiness of economies and businesses in our region.

According to a report by the World Economic Forum [5], 54% of all employees will require significant re- and upskilling in digital entrepreneurship, and has the potential to create jobs and increase economic growth, particularly in low- and middle-income countries.

### 1.2 Digital Platforms

Digital platforms have significantly changed the face of education and IT services globally continue to grow. Predicted spending references in [6] show that in 2023 there will be more than 1,380 billion USD spent on IT services. This is true of all spheres: online learning, offline learning, and blended learning while increasing the number of workplace learning technologies and different e-learning objects referenced in [7]. Digital platforms have also accelerated the business development and success of SMEs, where they are now in the position to gain extra market, and customer relations channels and to build their different additional value proposition for the customers. However, a lot of business owners are still afraid of the possibilities and outcomes that digital platforms could generate because they are missing digital literacy about these platforms and the changes in their business models the platforms are generating [8]. Findings of the internal survey we conducted at our institute reveal that many students believe that digital platform literacy should become a priority in modern curricula. There is also a need in the context of the fact that the Worldwide e-commerce share of retail sales is constantly growing [9].

We plan to provide comprehensive education from all of the aspects of digital platform education – psychology aspect, managerial aspect, technical aspect, digital pedagogical aspect, and financial aspects. With this in mind, we will design some of the future jobs like Digital Product Managers and Internal Digital Trainers for SMEs to boost the competitiveness of digital products and SMEs where they are developed, but also to educate current business owners who would need help in adopting the digital concepts and adapting to business platforms.

## 2 Methods and Activities

Based on the aspects we mentioned in the introduction of this paper, we have focused on digital transformation, and development of digital readiness, and inclusion and diversity in all fields of education, based on our predicted activities:

*Interdisciplinary development of digital professional skills* is important because it enables individuals to approach problems and challenges from multiple perspectives, and to develop innovative solutions that draw on insights from different domains. Here we focused on the integration of computer science and design thinking. By combining these two disciplines, individuals can develop user-centered digital products and services that are both functional and aesthetically pleasing. Additional focus is on the integration of data analytics and business strategy, which enables individuals to make data-driven decisions that are aligned with the goals of their organization.

*The use of digital technologies for communication, collaboration, and professional development* is focusing on new possibilities for remote communication and collaboration, making it easier for people to connect and work together regardless of their physical location. Although in the IT world this activity is not part of any educational program and is considered a "must", we included this for entrepreneurs to realize possibilities of online development, social media platforms, and ways to communicate in online business environments.

*Accessibility and inclusion in digital platforms* are critical in ensuring that all individuals have equal access to information, communication, and opportunities online. To achieve digital accessibility, designers and developers must ensure that their digital platforms can be used by individuals with different abilities, including those who are visually impaired, hearing impaired, or have limited mobility, since our institute also has a long history of providing education for hearing impaired students.

*Digital communication and collaboration for SMEs* focuses on streamlining communication and collaboration processes to increase productivity, improve customer service, and reduce costs. In this aspect, we focus on online project management tools, online asset management, cloud services, and differences between DaaS (Desktop as a Service), SaaS (Software as a Service), PaaS (Platform as a Service), and IaaS (Infrastructure as a Service). This is important because each business with this knowledge could identify their needs and best business model.

*Digital problem-solving* refers to the process of using digital tools and technologies to identify, analyze, and solve problems. Here we focus on digital resources to gather data, analyze information, and develop solutions to complex problems. As a showcase, we represent here our work on blockchain and Internet Marketing Simulator, already presented in [10] and [11].

*Digital tools for improving the personal perception of business opportunities* help individuals improve their personal perception of business opportunities. We focus here on examples of Google Trends, LinkedIn Sales, Google Alerts, and similar because these digital tools are helpful for individuals looking to improve their personal perception of business opportunities.

*Best practices - mapping, analysis, and research of best practices* to develop digital skills in the future where we emphasize the importance of data sources and data analysis, together with data visualizations and using appropriate BI (Business Intelligence) tools like Tableau, Google Analytics, and language focused on data science like Python and R.

## 3 Impact

The generally expected impact is to strengthen the capacity of education and training institutions to provide high-quality and inclusive digital education that will contribute to the improvement and modernization of HEI (Higher Education Institutions) and programs on digital skills in several EU countries, and consequently in the rest of the EU. Enabling HEI Faculty members to use digital content in order to provide more efficient and inclusive education to future business owners by broadening the scope of the national limits and using online opportunities become more evident and visible during the current COVID-19 pandemic.

We address the main impact of this paper in digital education and training systems to face the challenges presented by the recent evident shift to online and distance learning as the opportunity to engage more HEI, students, and SMEs in the international collaboration that will additionally connect the labor market as well as upgrade the current teacher digital pedagogical competencies, student digital competencies and most importantly, to improve digital competencies of the entrepreneurs. The focus is on building the capacity of all participants to be able to implement online, blended, and distance teaching and learning, and to develop and use high-quality digital content such as innovative online resources and tools. In order to achieve the planned goal we started the creation of the Regional Center for Excellence in Digital Platform Education which will focus on the next generation of digital platforms that could have a profound impact on how students learn and teachers teach in the upcoming years, and also how business owners can benefit by proper usage of the platforms. Also, one of the main impacts is to reinforce the links between HEI and the labor market by providing an optimal workforce upon completion of studies. More specifically, the aim is to enhance the capacity of HEI providers to promote mobility activities aimed at improving the digital and entrepreneurship skills and competencies of HEI professors, students, and managers and the occupational prospects of young students.

As the teaching professions face rapidly changing demands, educators require an increasingly broad and more sophisticated set of competencies than before. In particular, the ubiquity of digital devices and the duty to help students become digitally competent requires educators to develop their own digital competence. The desired impact is to strengthen the capacity of education and training institutions to provide high-quality and inclusive digital education, education 3.0, and entrepreneurship 3.0 that integrates technology into learning and entails a confluence of neuroscience, cognitive psychology, and education technology, using web-based digital and mobile technology, including digital platforms consisted of different apps. The expected impact is to exchange the viewing of digital technology as a competitor to current teaching models and encourage HEI professionals to actively embrace new technologies to see how they can help students learn efficiently in order to move beyond mass education to mass-customized education through blended learning and using the flexibility of technology to help students of varying backgrounds and skills.

Finally, we want to promote Digital Entrepreneurship Education 3.0 which denotes a broadening of digital entrepreneurship education with the interdisciplinary appeal for non-business majors by elaborating on the usage of digital platforms to achieve that goal. It is important to mention that the essential desired impact is to use online tools and teaching environments to ensure the active participation of women in STEM professions with fewer opportunities by selecting certain individuals, groups, organizations, or HEI centers to work with.

## 4 Results

Since education is dominant to be carried out online, this enables us to use a myriad of different communication channels in order to reach a higher number of individuals. This way we will enable different target groups to upgrade the current level of digital skills extending the usage and its application to different fields. Additionally, the newly created job positions, like an internal digital trainer, will reinforce the impact of our endeavors extending it through the entire education institution system and SMEs.

In target groups for dissemination, we will include:

- University & High school professors
- University & High school students
- University & High school staff
- SME-s – business owners
- General public,

  with a general focus on:
- Research-to-Society (R-t-S) – by upgrading digital competencies through gamification for part-time students and working adults.
- Research-to-Media (R-t-M) – by providing information that can be turned into stories.
- Research-to-Research (R-t-R) – the project results that can contribute to the subsequent progress of knowledge, the formation of disciplines/curricula, training, and capacity building.
- Research-to-Policy (R-t-P) – establishing clearly defined impacts in order for the policymakers to understand how the triangle between digital competencies, science, innovation, and quality of life/well-being.

The following Table 1 gives a summary of the target audience that is considered for our Educational platform, the reasons why, and what are the predicted goals.

As a proof of concept, we implemented one course on Operations Management within the proposed framework and oriented on specific topics of Supply Change Management. Within the course, we implemented supply-chain simulation over the period of several weeks to leverage an interdisciplinary approach to foster digital professional skills. Students in their feedback emphasized the following results presented in Table 2:

**Table 1.** The target audience for the Education Platform.

| Target audience (s) at local/regional/national/EU level | The reason why | Goal |
|---|---|---|
| Local-level: university professors, secondary teachers | Lack of tools and teaching materials with the application of Classroom 3.0 and augmented reality in the regular teaching process on a regular basis | To bring curricula, students, and professors closer to the labor market needs and upgrade the current competencies |
| Local-level: SMEs and business owners | Using the European Digital Academy project (EDA), to make basic knowledge of emerging technologies available and accessible to citizens and SMEs | Increase the number of clients and the efficiency of the usage of the resources by training digital trainers for SME-s |

(*continued*)

**Table 1.** (*continued*)

| Target audience (s) at local/regional/national/EU level | The reason why | Goal |
|---|---|---|
| Regional level: university and high school professors | According to the OECD's TALIS survey [12], on average, just 10% of all upper-secondary teachers failed to participate in any CPD over the prior 12 months (15% for lower-secondary teachers) while average participation rates in in-service training, educational conferences and observation visits to other schools were 71%, 44%, and 19%, respectively, across participating OECD members24 | Competence is accumulated both in formal education and in informal contexts (experiential learning) it means flexibility, tolerating uncertainty, and a positive attitude to change |
| National level: Partnership with other organizations (other universities, schools, businesses, national agencies, and local authorities) | Working in partnership with other organizations (other universities, schools, businesses, national agencies, and local authorities), the universities and school ensures the provision of continuous professional development for its faculty and staff with a view to meeting the university and school's development needs, as well as the staff's individual development needs | Competence requires continuous assessment and development |
| EU level: All EU countries - benchmark analysis | Lack of teacher's capacities to use and apply digital tools during online teaching and technological solutions in closing the whole circle of the educational/learning process | Gaining new knowledge, practicing |

Overall, students were very satisfied (with an average of 90%, out of 117 students) with the best practices course emphasizing the importance of mapping, analyzing, and researching for developing future digital skills. Specifically, students mentioned the significance of data sources and data analysis, data visualizations, and the use of appropriate Business Intelligence (BI) tools such as Google Analytics or Tableau.

**Table 2.** The target audience for the Education Platform.

| Concept | Description |
|---|---|
| Integration of Digital Platforms and Design Thinking | This aspect of the course emphasizes user-centricity in the development of digital products and services. By combining digital platforms and design thinking, students can simulate a real business practice situation where the stakeholders have to make decisions. Using a digital platform, they can acquire knowledge and experience without "serious" consequences and in that way develop the needed skills |
| Data Analytics and Business Strategy Integration | The course allows students to make data-informed decisions that align with their organization's objectives. This segment aims to cultivate a strong understanding of the symbiotic relationship between data analytics and strategic business decision-making |
| Digital Technologies for Communication, Collaboration, and Professional Development | This segment centers around exploring new possibilities for remote communication and collaboration. It underscores the importance of online development, social media platforms, and communication in online business environments |
| Accessibility and Inclusion in Digital Platforms | The course underlines the importance of creating digital platforms that are inclusive and accessible. It emphasizes that digital platforms should cater to individuals with varied abilities, ensuring that all users have equal access to information, communication, and opportunities online |
| Digital Communication and Collaboration for SMEs | This part of the course focuses on streamlining communication and collaboration processes to boost productivity, improve customer service, and reduce costs. It covers online project management tools, cloud services, and the differences between DaaS, SaaS, PaaS, and IaaS |
| Digital Problem-Solving | This segment introduces students to the use of digital tools and technologies for problem-solving. The course provides insights into using digital resources for data collection, information analysis, and the development of solutions to complex problems |

(*continued*)

**Table 2.** (*continued*)

| Concept | Description |
|---|---|
| Digital Tools for Business Opportunities Perception | This section of the course aims to improve students' personal perception of business opportunities using digital tools such as Google Trends, LinkedIn Sales, and Google Alerts |

## 5 Conclusion and Future Work

In this paper, we described our platform which is designed to offer education and training activities in the field of digital skills. We focused our platform on business development, Entrepreneurial/Startup competence, spotting opportunity, creativity, vision, pedagogical use of digital technologies, and innovation management, marketing, and branding. We also presented the outcomes of one successfully implemented course on Supply Chain Management. By establishing a common basis that initiatives dealing with the promotion of entrepreneurship as a competence across levels of education, sectors, domains, and purposes of application can refer to, we will contribute to unleashing European citizens' potential to participate in all areas of society by transforming ideas into action. From the professor's perspective, the platform is useful because the professor gets a lot of information, both about the knowledge and skills of the students, as well as about the attractiveness of the course and the student's thoughts about it. The platform can be programmed in advance so that the comments, rubrics, and evaluations that the professor sends to the students are predefined, which greatly facilitates the work of the professor. The future development of the platform will be oriented toward implementing the complete set of courses and reaching all of the target groups to connect to our educational platform.

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# University Startup Clinics: A New Approach to Project-Oriented Education and Entrepreneurial Competences Development

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**Abstract.** Universities are an integral player of the entrepreneurial ecosystem. Today, almost all universities have startup centers, creative or innovation hubs, co-working spaces, etc. in their structure. A significant part of startups is born in universities and undergo their first testing there. Ukrainian universities train students in wide range of specialities and employ specialists from various fields, which allows to create university startup clinics, including Law Clinic, Business Model Innovation Clinic, Finance Clinic, HR & Culture Clinic, Sales & Marketing Clinic, as well as Soft Skills Clinic and Tech & Digitalization Clinic. The main tasks for each department are disclosed. For the launch of such clinics, a structured algorithm ("action protocol") is proposed in the paper. The goal is to test various projects in their early stages (stages of uncertainty). The lecturer-student-business interaction is outlined. In sum a favourable environment for the creation of innovative projects is generated. The launching of "multi specialised" startup clinics in Ukrainian universities is a vital step for reforming the education system and a practical step towards the introduction of practical-oriented training as well as raising the impact of Ukrainian entrepreneurial ecosystem locally and globally.

**Keywords:** University Startup Clinics · Project-Oriented Education · Early stage startups · Entrepreneurial Ecosystem

## 1 Introduction

The modern market dictates new requirements for mature specialists and graduates of educational institutions, who, in addition to professional knowledge and skills, must have a well-formed set of competencies, and above all, entrepreneurial ones. Thus, the European Commission's website emphasizes the need to develop people, teams and

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organizations with an entrepreneurial mindset at every stage of life as a challenge to the rapidly changing society in which we live. EntreComp: European Entrepreneurship Competence Framework was developed to group and systematize such competencies to develop the ability to generate ideas, act on opportunities, manage careers and shape the future. This framework provides a general idea of entrepreneurial thinking and combines 15 basic entrepreneurial competencies in three key areas [1].

In turn, the need to train specialists that meet the changing demands of society leads to the emergence of new methods and approaches to training, and the improvement of those that were used earlier. Project-Oriented Learning (also called Project-Based Learning) has been used as an educational technique for several centuries. L.M. Burlbaw, M. Ortwein, J.K. Williams (2013) provide a detailed historical review of the development of technology, starting from the 19th century, when the method was described in the works of F. W. Parker (1922) and J. Dewey (1934) [2]. The method has been actively used in the higher education system since the 1960s, when it was introduced at McMaster University in Canada. Project-oriented learning, which is "promoting twenty-first century learning", presupposes the involvement of students in various types of projects, the goal of which is to create a certain product. Most often, the main goal is the effect of learning, and not the product [3].

In Ukraine, project-oriented learning quite often corresponds to the VET education system [4]. Although such learning is also actively involved in higher education institutions. In [5] a practical case of using the project method to develop students' creative and social entrepreneurship skills is described. The cases of entrepreneurial skills development created during the implementation of various projects are outlined in [6].

Considering the advantages and prospects of using the method of project-oriented learning, there is a need to find institutionalized forms, which will in turn allow universities to be more actively integrated in the entrepreneurial ecosystem at the regional and international level.

This paper proposes the creation and integration of University Startup Clinics (USCs) as structural divisions of higher educational institutions (HEIs). The activities of which will contribute to the development of entrepreneurial competences of students and parties involved in the work of clinics by encouraging the development and support of startups that are in the early stages of development.

The purpose of the paper is to develop a generalized algorithm of actions for the full process of supporting and accompanying startups from the moment of their entry to the launch of a business within universities as integral actors of entrepreneurial ecosystem.

## 2 University Startup Clinics as an Integral Part of Entrepreneurial Ecosystem

### 2.1 Structure and Main Functions of University Startup Clinics

The development of the startup movement in Ukraine is very rapid. In 2022, Ukrainian startups received more than $6 billion in revenue, which is $542 million more than in 2021 [7]. The issue of strengthening the role of universities in the development of the startup movement has been raised many times, since universities today generate most startup projects, including those related to IT technologies, engineering, social, cultural and creative spheres. Thus, among the three main recommendations for the development of the startup movement in Ukraine in [8], two relate directly to universities. First, it is worth deepening the cooperation of universities and research institutions with accelerators and venture funds. Second, actors should establish connections between the elements of the Ukrainian startups ecosystem and the ecosystems of European countries at different levels: university-university, university-accelerator, accelerator-venture fund relationships.

Today, most universities already have startup centers, creative or innovation hubs, co-working spaces, etc. At the same time, the process of support, development, and most importantly testing and recovering startups in an early stage remains poorly structured. On the other hand, most of the leading universities of Ukraine cover a wide range of specialties in which students are trained. Universities can offer "first aid" for startups which are in the early stages. Promoters who have knowledge in various fields and require additional practical skills gain experience while supporting them.

Ukraine already has the first experience of launching law clinics at universities and business clinics as separate elements of the entrepreneurial ecosystem. Thus, M.T. Lodzhuk (2015) describes the prerequisites, peculiarities of formation, types of legal clinics in Ukraine, which are structural divisions of HEIs or independent consultation points [9]. As for business clinics, EU4Business opened seven COVID-19 Business Clinics in Ukraine to help Ukrainian small and medium-sized enterprises respond to the complex economic challenges that have become the consequences of the pandemic [10].

Summarizing the start-up movement development in Ukraine, it can be stated that Ukrainian universities have enough capacity to establish startup clinics involving only a small part of outsourcing services.

With the development of the start-up movement in Germany, the creation and launch of startup clinics were tested, which, in addition to the Law Clinic, also include the Business Model Innovation Clinic, Finance Clinic, HR & Culture Clinic, Sales & Marketing Clinic [11]. Taking into account modern realities, analysing the requirements for technological and creative startups, discussing with residents and owners of various incubation centers, hubs, creative spaces, etc., it can be argued that two more should be considered: Soft Skills Clinic and Tech & Digitalization Clinic.

The following Table 1 contains the main structural departments of the proposed USCs, main tasks and directions of consultations provided.

**Table 1.** Structure of University Startup Clinic and priority tasks for its departments.

| Departments | Departments' tasks and priority fields |
|---|---|
| Law Clinic | To work on providing legal information, consultations and clarifications on legal issues; assistance in drawing up documents, legal education, for instance, in copyright or data protection law |
| Business Model Innovation Clinic | To work on revenue models, products and services, customers, and the value chain, as well as how to pitch their business models to investors and interested parties |

(*continued*)

**Table 1.** (*continued*)

| Departments | Departments' tasks and priority fields |
|---|---|
| Finance Clinic | To work on business case standards and frameworks, availability and access to funding sources, structure and layout of pitch decks, performance management, follow-up and bridge financing |
| HR & Culture Clinic | to work on an effective HR strategy that includes on boarding, leading, managing, developing and retraining employees, as well as on building a corporate culture |
| Sales & Marketing Clinic | To work on approaching the market in the right way, developing an effective sales and marketing strategy; strategies for attracting first customers and identifying the best customer acquisition channels; developing one or more of the basic marketing 'Ps' |
| Soft Skills Clinic | To work on basic soft skill development such as talent development, emotional intelligence, leadership, teamwork, communication skills, creativity, etc |
| Tech & Digitalization Clinic | To work on use of modern digital tools in various fields of activity from the stage of starting a startup project, its formation and development, including an issue on using an artificial intelligence (AI) and AI based technologies |

### 2.2 University Startup Clinics Actions Algorithm

The process of opening and launching USCs is new not only for Ukraine, but also for other countries in the world. Therefore, the formation of the activity algorithm of such clinics is based on certain assumptions, namely: (1) the university is an integral part of the entrepreneurial ecosystem; (2) universities have enough capacity to cover requests for each department of the clinic (availability of relevant specialties and lecturers able to provide consultations, be mentors and supervisors for students and other residents; (3) Ukrainian business is gradually ready to support universities and their initiatives; (4) startup ideas generated by students or residents of various university spaces are in the early stages of development with a high level of uncertainty; (5) a synergistic effect is achieved from combining the efforts of lecturers, students and business, which are all actors of startup ecosystems and drivers of development.

The authors suggest an approach like the startup clinics that is based on the effectuation logic. It shapes the startups understanding of strength and weaknesses, supports to expand the personal network and introduces external creativity and resources. It also supports to find courses of action and enables an interaction with mentors and experts from different fields.

Figure 1 illustrates the general sequence of actions for various parties entering the USCs, the "protocol of actions" for testing projects in the early stages (stages of uncertainty) and in the stage of detection of "ailment" symptoms, short-term and middle-term benefits for each of the parties involved, and areas of further long-term sustainable development.

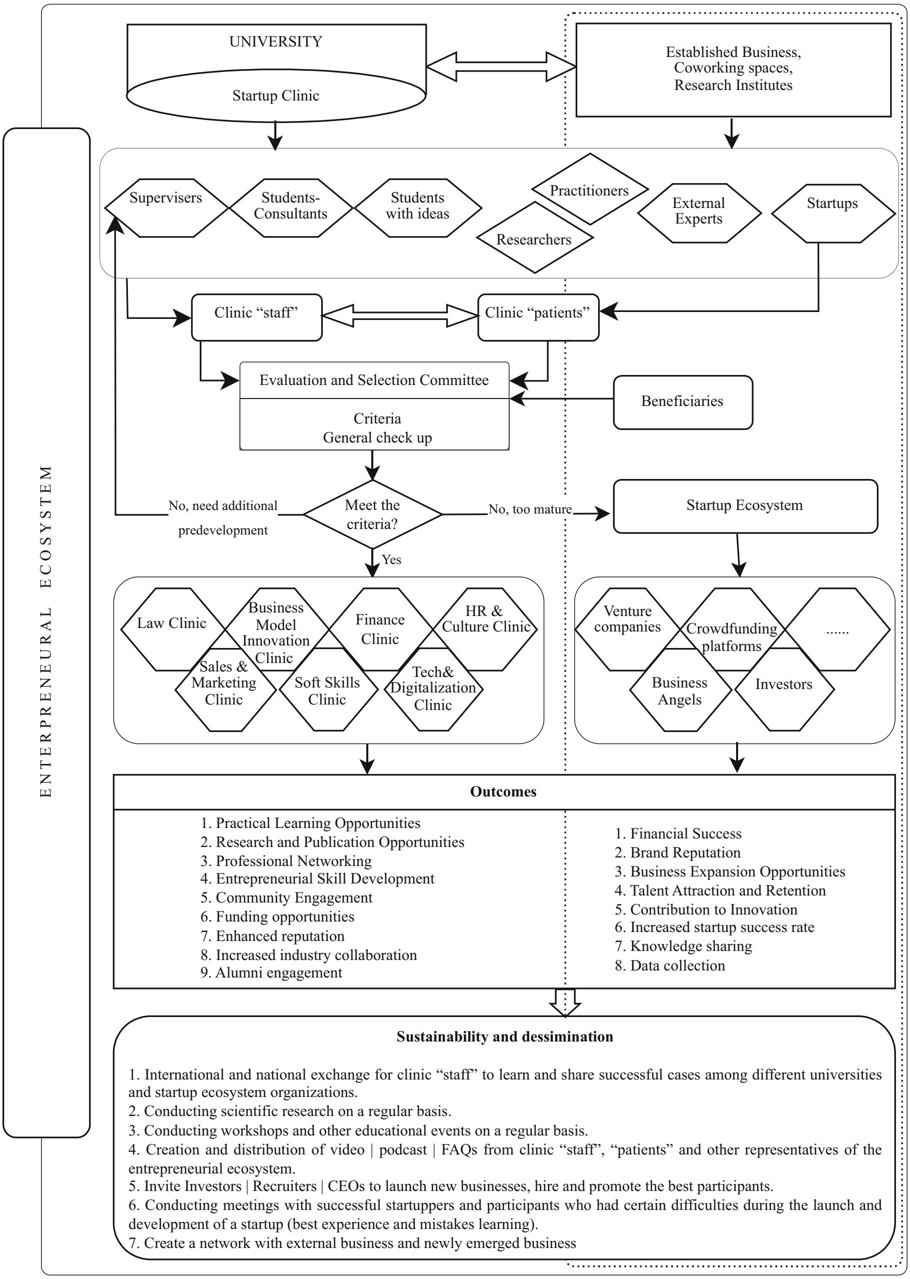


**Fig. 1.** University Startup Clinic’s actions algorithm.

The USCs offer face-to-face sessions to discuss challenges with founders and introduce them to a network of high-level experts. Startup Clinics are a university service offered to startups free of charge. Founders can attend one-on-one sessions with university experts to help solve specific challenges. Startups can register for the different Startup Clinics sessions on a website. During the sessions, the Startup Clinics mentor collects relevant data about the startup's stage, enabling and inhibiting factors, business model and team. After the clinic session, the mentor receives feedback from the startup to further guide the early stage company through the uncertain process of starting a business. Finally, after a period of time, the startup is contacted to ascertain how things have progressed. Specific workshops with partners support knowledge generation and transfer.

In Fig. 1 states that "patients" of clinics are selected according to the certain criteria. For each idea the criteria may depend on the expertise of the involved stakeholders and experts, the specifics of host HEIs, regional needs, and requests on the ground, etc.

University start-up clinics will contribute to the creation of a significant number of real cases, educational videos, podcasts, FAQ series, etc. In order to share knowledge with the community of founders and to better understand their learning needs, a digital 'knowledge base' for entrepreneurs is being set up. These can be used for educational purposes, achievements dissemination and experience transfer. An example of such a case can be found in [12].

The USCs support startups in reducing uncertainty and guide them through a process of iteration, with the aim of increasing confidence in their final product or service before or during market entry.

### 2.3 Peculiarities of Interaction Between University Startup Clinics' Parties

In Ukraine, there is a problem of low business interest in the integration and support of universities, which are the main "educators" of personnel for various fields. Moreover, sometimes the quality or direction of the acquired knowledge and competences does not meet the real business need. The launch of USCs will shorten this distance due to additional benefits for business: a data source, a base for recruitment, access to innovations and new ideas without funds investing, brand and reputation formation, bases for testing ideas.

From the point of view of pedagogical and methodological approaches, lecturer-student interaction is built according to the principles of project-oriented learning, namely based on supervising, mentoring, project management and internship as an educational component for students.

The process of building lecturer-student-business interaction looks more complicated, since Ukrainian universities, unlike European and world ones, do not have a stable link with business, neither in practical matters, nor in the field of science and innovation. The USCs will allow creating such a linkage due to the benefits described above, as well as establishing the transfer of knowledge, experience, expertise, ideas, innovations, data, etc. (see Fig. 2). The main synergistic effect of such interaction is the creation of a favourable environment for the birth of promising innovative projects (IPs).

For several decades, the issue of the development of the universities' commercial component, the creation of models and conditions under which they become full-fledged

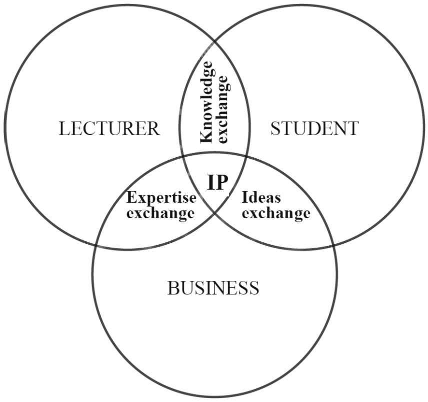


**Fig. 2.** A Lecture-Student-Business interaction circle at University Startup Clinics, where IP stands for an innovative project.

market actors and can "earn" funds to support their activities has been discussed [13]. Accordingly, it is not possible to avoid the issue of implementing an effective financial model for the USCs existence. Taking into account the peculiarities of financing the universities activities in Ukraine and the world, the opportunities that the startup ecosystem has, it is reasonable to predict that financing can be provided from the following sources: (1) university funds to cover the costs of maintaining the premises and the staff salaries that perform their duties within their main responsibilities (for instance, hours of supervision of students' practical activities and internship, covering the cost of utility services for the premises maintenance that are part of the university); (2) receiving interest from the realization of successful startups that have undergone the process of diagnosis and growth in USCs, stipulated at the initial stages of entering the clinic; (3) financial contributions from businesses for testing and "fostering" interesting from their point of view ideas (such contributions will be much smaller than the costs of covering the full cycle of startups formation).

## 3 Conclusion

Thus, in order to create the conditions for universities to enter the entrepreneurial ecosystem, to implement the principles of project-oriented learning, to maximize the involvement of students in practical activities, to create employment prospects for young people, it is promising for Ukrainian universities to transform existing hubs into multidisciplinary university startup clinics that will unite lecturers, students and businesses. Law Clinic, Business Model Innovation Clinic, Finance Clinic, HR & Culture Clinic, Sales & Marketing Clinic, Soft Skills Clinic, Tech & Digitalization Clinic are the departments that will provide consultations on certain issues within USCs activities.

Such clinics will support and develop startups in the early stages, for which there are currently limited opportunities for testing and launching, in contrast to mature startups according to the proposed algorithm. Lecturer-student-business interaction will allow the exchange of knowledge, ideas, experience and expertise and will contribute to the birth of innovative ideas that simultaneously meet market requirements, scientific achievements and social needs. To support the activities of the USCs, a financial model is proposed, which includes funding from each of the involved parties (universities, clinic "patients", and businesses).

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# Engineering Excellence for the Mobility Value Chain

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**Abstract.** Based on the project "Engineering Excellence for the Mobility Value Chain" (EE4M), this paper addresses the increasing need for training, re-, and upskilling of engineers in manufacturing enterprises in the mobility value chain. Recently, the European mobility value chain is influenced by a multitude of hyper-dynamic factors, like changing consumer behavior, disruptive technologies, etc., which leads to the fact that a continuous realignment of engineering education is indispensable. The focus is placed on operations management (OM) which is changing due to the two policy-driven and pre-dominant drivers "Industry 4.0" and "Sustainability". The implementation of smart and sustainable concepts in OM in the mobility value chain entails both a transformation of production processes and a change in the working and learning processes of the employees. Companies are increasingly required to design, manage, and integrate learning processes and learning environments to provide a lifelong learning ecosystem and to prepare employees for changes in work and tasks. Moreover, educational institutions are challenged to successfully address those demands. Therefore, this paper introduces the European research project EE4M which focuses on the professional development of smart and sustainability competences of engineers in the mobility value chain through innovative educational modules supported by a transnational platform between the main drivers of the European mobility value chain. The innovation of the project can be explained by the fact that OM serves as the basis for empirically based realignment of engineering education to create requirement-orientated competence profiles.

**Keywords:** Engineering Excellence · Competence profiles · Vocational Education and Training

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## 1 Introduction

In recent years, European manufacturing companies have constantly faced a multitude of complex challenges which are mainly triggered by exogenous influencing factors, like enhanced global competition, a tremendous change in customer behavior, the volatility and vulnerability of global supply networks, a continuous demographic change, a shifting attitude regarding the role of labor in the entire society, and an ongoing need for professionalized employability processes [1–9].

In this context, "Industry 4.0" research focuses on the usage of modern technologies which should ultimately enable manufacturing companies to develop new and better products, continuously improve their internal and external processes. Besides those developments, the research highlighted, that the transformation towards smart operations management in manufacturing companies is not possible without considering the future role of the human being and his realigned tasks in the modern socio-technical manufacturing systems. Future work will be significantly different from today´s tasks and, therefore, the skills, competences, and qualifications of the engineers of tomorrow need to be realigned by using empirical-based evidence [1, 10–14].

In this transformative society, the teaching of relevant and up-to-date skills is indispensable and thus represents a central element of the European Pillar of Social Rights [14–16]. Hence, high-quality education should be made available to all people, enabling them to make significant contributions actively and self-confidently as citizens to drive further developments and ongoing innovation [4, 17–19]. According to Tietgens [21], the expectations, needs, or wishes of key stakeholders involved in the learning process in their respective disciplines can be emphasized as an essential success factor. Only in this way it is possible to respond to current trends and challenges in practice and to equip future engineers with the necessary knowledge, qualifications, and competences [20]. In turn, these stakeholders' demands must then be fed back to guarantee professional methodological-didactic training programs [14, 21].

Furthermore, sustainable development (SD) addresses the biggest challenges facing humanity in the 21st century [22, 23]. Currently, the largest challenge is the fact that emissions of GHG have increased in constant increments since 1970, and according to the high growth scenario of the Intergovernmental Panel for Climate Change (IPCC), the present impacts could almost double by 2030 [24, 25]. Therefore, European manufacturing companies must also find new ways to respond to novel regulations regarding green and transparent operational processes to meet macro-economic targets as defined in initiatives such as the 2030 Agenda for SD and its 17 Sustainable Development Goals (SDGs), the European Green Deal or the Paris Agreement. In this context, only a handful of studies are focusing on the transition towards sustainable operations management in manufacturing companies to operate in a resource-saving and low-emission-orientated manner. According to the three pillars of sustainability (economic, social, and environmental) [26], environmental goals must be in line with economic goals and the respective impact on people and the wellbeing of society as well. Thereby, the systematic transition towards a sustainable value chain, aligned exemplary with the principles of the circular economy [27], demands a variety of complex and transdisciplinary adaptations in engineering education based on evidence-based competence profiles to contribute to the safety, health, and welfare of the public [2, 3, 28]. In this context, the Council

Recommendation of 24 November 2020 on vocational education and training (VET) for sustainable competitiveness, social fairness, and resilience [29] and the Commission Communication on "An SME Strategy for a sustainable and digital Europe" further highlight that availability of skilled staff or experienced managers is the most important obstacle to new investment across the EU. Furthermore, the beforementioned Council Recommendation defines VET as a driver for innovation and growth which equips for the digital and green transitions and occupations in high demand, consequently contributing to the achievement of the SDGs. In this context, numerous studies highlight an increased need for sustainable development education [28, 30–36]. In this context, generally, valid competences must be manifested for the entire field of engineering education to guarantee quality assurance, systematic development, competitiveness, and employability for the engineers of tomorrow [36]. Furthermore, Pacher et al. [37] investigated the educational needs in the extractive sector based on an extensive study within the framework of an EU project and concluded that the focus of higher education should lie on the training of transversal competences such as soft skills, decision-making skills, or digital competences [14, 37]. In addition, practical testing of the technical competences acquired during studies is essential for future careers, as it can be done in learning factory labs and innovation labs, exemplarily implemented for practice-oriented teaching by beneficiaries to foster VET engineering education [37].

The transformative educational processes triggered by the challenges mentioned above are influencing all societal sectors, institutions, as well as, age groups, and therefore require the long-term inclusion of new knowledge, qualifications, and competences over the entire lifespan. In this context, he pedagogical focus must not only be set on the design of suitable learning environments but also the creation of suitable institutional framework conditions [14]. With the establishment of VET platforms for a sustainable and long-term incorporation of innovative teaching and learning concepts into educational institutions throughout Europe, the EE4M project bridges this gap by combining the two components.

This research paper introduces the research project "Engineering Excellence for the Mobility Value Chain" (EE4M) which is co-funded by the European ERASMUS-EDU-2022-PEX-COVE programme under the grant agreement No. 101104549 (www.ee4m.eu). The project is focusing on the realignment and, therefore, the professionalization of engineering education in the respective focus areas of operations management in European manufacturing companies forced by the two predominant and policy-driven drivers "Industry 4.0" (smart operations management) and "Sustainability" (sustainable operations management). This transformation is further challenged by continuous demographic change, a shifting attitude regarding the role of labor in the entire society, and an ongoing need for professionalized employability and structured lifelong learning approaches [1, 4, 5, 7, 9]. The project will establish a dialogue with public and private stakeholders to (1) elaborate the needs and expectations of the industry, (2) establish a constant knowledge exchange within the knowledge triangle to foster skills ecosystems, and (3) and ensure the co-creation of educational materials, tools, and concepts. Streamlining direct stakeholder dialogue on all three sides of the knowledge triangle, with a strong focus on targeting the inclusion of female students in the training and/or workshops, underrepresentation of gender equality has the opportunity of declining.

Furthermore, interdisciplinary best practices are addressed through the unique project team composition, giving access to the latest developments in educational training [16].

### 1.1 Needs Analysis

Today, our economy and society are subject to a permanent and hyper-dynamic change as outlined in the previous section of this research proposal. To withstand this change, it requires transformational solutions that go beyond incremental innovation strategies. Therefore, business sectors need to adopt new mindsets for "breakthrough innovations" [38, 39]. Engineers play a critical role in finding innovative solutions that balance economic competitiveness, environmental protection, and social acceptance. To do so, they will need more than a strong scientific and technical background. They will need to learn to think out-of-the-box, understand how social, cultural, and economic aspects influence their work, and vice versa link science and engineering to the needs of society, collaborate in interdisciplinary teams, develop entrepreneurial systems thinking [40], propose creative and innovative solutions, and learn how to communicate the proposed solutions to the general public [41, 42]. Recent studies report a tremendous need for qualified engineers in smart and sustainable operations management. In Austria, 51% of the manufacturing enterprises expect a significant increase in the shortage of skilled workers in their sector over the next three years [43, 44], whereby, 85% of the survey responses report a tendentially strong increase of skilled worker shortage within the next five years [45]. These results are in line with the study of the recent research findings of the IW (Institute of the Germany Economy), reporting an increasing need for at least 48.300 engineers and 68.800 STEM academics per year within the timeframe 2023–2028 [44, 46, 47]. According to 42% of the companies surveyed, a (possible) shortage of suitable top specialists leads to at least minor or, according to 11% of the companies surveyed, considerable turnover losses or unrealized turnover potential for their company [47]. The predicted need for additional education in engineering is spread across all levels of education and training. Studies show the following distribution: 8% basic vocational education, 30% secondary education, 37% more tertiary education, and 25% more lifelong learning [48]. Furthermore, the implementation of smart and sustainable technologies and concepts both a transformation of production processes and the changed work and learning processes for employees as the work of the future will be more flexible, more mobile, and more digitally networked. [10, 49, 50]. In this regard, Dengler and Matthes [51] forecast that the current number of 40% of all employees in jobs with low substitutable potential will decrease to a maximum of 30% through automation. The human workforce will continue to be regarded as an essential component in global value chains. It seems to be obvious that an ongoing specialization requires adapted operational or organizational learning processes. However, these processes cannot be viewed in isolation, but they must be considered as part of organizational development [10, 51, 52]. Organizations need to transform learning organizations and employees to acquire lifelong knowledge and educational institutions are now challenged to successfully implement the demands and thus to ensure the ability to work, the understanding of the role of engineers [14, 53]. This transformation requires a new conceptualization or adaptation in a holistic way, i.e. both on the institutional level and concerning transdisciplinary cooperation with industry, as well as, a push towards national and international cooperation

[10, 14, 54]. In this context, flexibility, adaptability, resilience, and competences in smart and sustainable operations management are further regarded as essential success factors [14]. As can be derived from the challenges mentioned above, educational reforms are urgently required as of now to extend the education system and cover educational needs throughout the entire lifespan. In this context, professionally sound, competency-based, transparent, and modularized teaching and learning concepts can help to make the transition from reactive education to the proactive, future-oriented design of educational measures considering future needs for smart and sustainable operations management in manufacturing companies [55].

## 2 Research Method

The research project follows an explorative research approach. A method triangulation will be used, which includes secondary literature analyses as well as quantitative and qualitative research methods. First, the exploration of generic (competence-based) requirements for smart and sustainable operations management in the mobility chain will be investigated using a systematic literature review [56–58], extensive online questionnaires, and qualitative focus groups with experts from academia, research, and business. The same research design will be applied for the investigation of the three focus areas logistics and supply management, product development and manufacturing, and entrepreneurship and industrial marketing management. The educational services' novelty lies in the topicality of the educational content and formats conveyed. Accordingly, new educational content is to be generated based on current challenges in the economy, society, and education and addressed to specific target groups. Among other things, three essential maxims of education and educational science are to be applied—participant orientation, practical relevance, and life-world orientation—through the application of information-theoretical learning theory. The methodological approach encompasses competence-based education and training based on a modularized program architecture and supported by digital teaching and learning formats in the field of smart and sustainable operations management. These modules, based on a multi-phase teaching and learning arrangement, can be combined depending on the target group and individually adapted to their needs, as well as on the regional-specific smart specialization strategies. Thus, for the respective participants, the CoVE offers both, shorter units (Microcredentials), such as a module with a scope of 5 ECTS workshops, seminars, or trainings, as well as longer further education measures such as train-the-trainer/teacher formats, university courses (15 ECTS), up to further education master programs with 90 to 120 ECTS. These modules are methodically-didactically structured according to new findings, e.g., accelerated learning of educational research to enable holistic learning. Thus, in addition to self-learning units utilizing MOOCs [59], literature research, and online learning materials, the self-learning competence of participants is to be promoted and combined with already existing knowledge and experience. This new educational content is to be deepened, expanded, and supplemented in discussion with the stakeholders or within a group of participants to be able to guarantee the acquisition of knowledge in the long term. Finally, the consolidation of knowledge and the transfer of knowledge into practice should be ensured through case studies or best practices from the field. The modules can be offered adapted for the secondary, tertiary, and VET education levels since EE4M unites the experts on the European Qualification Framework (EQF) levels 4–8.

## 3 Impact

Overall, the development of professional and transversal skills is targeted. The innovative methodological-didactical approach of EE4M is used as a guiding principle for the development of a skill ecosystem on a regional and a European level [60]. VET teachers/trainers, practitioners, and students from all European countries within EQF levels 4–8 will be enabled to acquire (new) (inter)disciplinary skills in the fields of operations management, sustainability, digitalization, etc. through innovative teaching and learning environments to create awareness for the handling in and with the digital and sustainable world. EE4M is intended to generate added value for the European Education Area due to the multidisciplinary consortium by amalgamating various perspectives, experiences, and research results. This will ensure the exchange of experience, materials, and best practices across geographical borders and will enhance the innovative strength of all participating countries. During the four-year duration of the project, a foundation for a digital and sustainable inclusive, borderless, and integrated European VET education is to be laid to produce competent and well-trained VET students, graduates, and teachers. This will make a significant and innovative contribution to the current European social, economic, and ecological challenges. Furthermore, the project promotes the principle of lifelong learning and equal and excellent education according to SDG number 4 "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" [60]. The education system in Europe is not agile enough to adequately respond to the permanently changing needs of the labor market and societal challenges such as climate change, digitalization, etc. in the field of operations management. For this reason, EE4M represents a key action and thus a bottom-up approach to implement the facets of Operations Management digitally and sustainably in schools, higher education institutions, companies, and consequently also in society with the help of target group-specific innovative teaching and learning concepts. EE4M also enables transnational exchange with and within European member states and their populations. In addition to the professional and transversal competences, the cultural understanding (citizenship competence and cultural competence) shall be expanded, and the multilingual competence shall be promoted by providing teaching and learning concepts in the consortium languages German, Italian, Spanish, Greek, and English. Based on this, the following target groups can be identified: students (upper secondary level), students at HEIs, practitioners, professionals, and employees in operations management [61], teachers at upper secondary and tertiary level, trainers in the continuing education sector, and the broaer public.The modularized teaching and learning concepts developed will be uploaded to the European/international EE4M platform as an open-access resource to raise awareness and societal acceptance of Operations Management related topics. Thus, the developed concepts can be easily disseminated across Europe and internationally to educate current (prospective) engineers and prepare the next generations, so-called engineers of tomorrow, for the future of work. Accordingly, EE4M project partners manifest the long-term impact of the produced project results and outputs.

EE4M aims not only to promote STEM subjects and student numbers in the technical field but above all to educate the next generations transregionally with innovative, creative, and future-oriented competence profiles and mindsets. In addition, a successful regional, as well as international, skills ecosystem should be provided to increase European competitiveness, professionalize the European VET engineering education culture and increase employability and resilience.

The active dialogue and exchange partnership established within the EE4M project between all essential stakeholders from the knowledge triangle will allow to work together with a shared vision and objectives towards a more sustainable and digital operations management sector and society subsequently [60].

## 4 Conclusions and Implications

The EE4M project is based on the transparent and empirical-based investigation of future educational needs and necessary transversal key competences for the engineers of tomorrow in the smart and sustainable operations management in the mobility value chain. To ensure European competitiveness as well as the employability of European citizens, it contributes to the establishment of a culture of professional lifelong learning in the field of engineering education by focusing on the the following objectives:

- Development of European Vocational Education Training (VET) platforms for the (trans)national realignment of engineering education.
- Empowering the transition towards smart and sustainable operations management by fostering the skills of the engineers of tomorrow.
- Competence-based teaching and learning concepts for IVET and CVET learners and teachers to contribute to economic, ecologic, and social wellbeing.
- Fostering (trans)regional skills ecosystems through knowledge exchange within the knowledge triangle on the established VET platforms throughout Europe.
- Establishment and continuous development of professional teaching and learning environments for VET engineering education on EQF levels 4–8.

Through the interconnectivity within the project, educational permeability and the interlinkage between the VET educational levels on the secondary, tertiary, and continuing education levels can be generated. The educational services' novelty lies in the topicality of the educational content and formats conveyed. Accordingly, new educational content is to be generated based on current challenges in the economy, society, and education and addressed to specific target groups. During the four-year duration of EE4M, more than 1,000 VET teachers/trainers, practitioners, and students from all over Europe within EQF levels 4–8 will be enabled to acquire transdisciplinary skills in the field of smart and sustainable operations management through innovative teaching and learning environments. A foundation for a smart and sustainable inclusive and borderless European VET education is to be laid to produce competent and well-trained VET students, graduates/professionals, and teachers. Boosting (inter)national skills ecosystems will successfully increase European competitiveness and employability, professionalize the European VET engineering education, and contribute to economic, ecologic, and social wellbeing.

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# Decoding the Entrepreneurial Mindset of Engineering Education in India-A Qualitative Lens

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**Abstract.** This study explores the impact of co-curricular activities infused with Entrepreneurial Mindset (EM) on the entrepreneurial mindset of freshmen engineering students at a small private university in urban Punjab, India. We are focusing on India in the study because despite having largest demographic dividend, the entrepreneurial interest among Indian students is reported to be way below their western counterparts. However, most existing research on measuring and enhancing EM is dominated by Anglo-American perspectives and quantitative studies, calling for a qualitative approach to understanding and enhancing the EM in the context of modern Indian education system.

Using a qualitative approach, this paper aims to develop an EM model based on the experiences of successful Indian entrepreneurs and students exposed to EM growth interventions. Open-ended interviews were conducted with stakeholders, including freshmen engineering students and founders/entrepreneurs in India, to gather their perceptions of EM. Thematic analysis reveals a multi-faceted and dynamic EM model, encompassing cognitive, affective, and behavioral dimensions.

The paper also discusses the disparities in EM perceptions between student interviews and interviews with experienced entrepreneurs. These disparities highlight the need to incorporate missing EM parameters into the curriculum of India's engineering education system to enhance students' entrepreneurial mindset. Overall, this study aims to shed light on the hidden factors influencing the defining entrepreneurial mindset in Indian engineering education. It will use insights from different stakeholders and provide an opportunity for India's engineering students to explore their self-beliefs about the entrepreneurial mindset. Additionally, it aims to help students understand how the entrepreneurial mindset can be evolved in their college education journey.

**Keywords:** Entrepreneurial Mindset (EM) · Indian Engineering Students · Entrepreneurs perception

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## 1 Introduction

Entrepreneurial mindset (EM) is a highly valued and sought-after asset by organizations in the world [1]. According to the resource-based theory, organizations leverage the cognitive abilities of entrepreneurial individuals to identify market opportunities and gain a competitive advantage in the global market [2]. Entrepreneurship is now being promoted, particularly in engineering universities worldwide, to address contemporary global challenges through the development of technology-based business solutions [1]. It also aims to reduce overall unemployment rates by creating new job opportunities for others [3]. Consequently, educational institutions are actively seeking ways to cultivate an entrepreneurial mindset in engineering students from an early stage, aiming to nurture their interest in entrepreneurship and prepare them for the industry upon graduation [1].

There is compelling evidence supporting the role of entrepreneurial education in shaping the entrepreneurial mindset and entrepreneurial intention of individuals [4–6]. Research suggests that the entrepreneurial mindset mediates the relationship between entrepreneurial education and entrepreneurial intention or preparedness, strengthening the connection between the two [7, 8]. Furthermore, entrepreneurial education has been shown to enhance the entrepreneurial mindset in students. Drawing on the theory of planned behavior [1], one effective strategy is to increase entrepreneurial intention through the development of an entrepreneurial mindset. Consequently, it can effectively drive entrepreneurial behavior among individuals. [8].

Scholars have defined entrepreneurial mindset (EM) as the ability to act and make decisions in uncertain conditions. McGrath & MacMillan describe it as sensing, acting, and mobilizing under uncertainty [9]. Ireland et al. view it as a way of thinking that captures the benefits of uncertainty [10]. Shephard et al. define it as responding to judgments under uncertainty [11]. Some definitions highlight the use of the entrepreneurial mindset to adjust to situations and identify and exploit opportunities [12]. Other definitions focus on specific competencies of the entrepreneurial mindset, such as promoting flexibility, creativity, continuous innovation [13], as well as thinking, reason, make decisions, plan and set goals in a relatively unique way' [14]. A recent definition emphasizes that the entrepreneurial mindset involves reflecting upon mistakes, continuously improving skills, and confidently turning ideas into actions [15].

To facilitate the development of an entrepreneurial mindset (EM) among individuals, it is crucial for institutions to possess a comprehensive understanding of EM components. This understanding comes from EM research corpus which is currently plagued by a big problem—there is no standard, commonly accepted definition of EM [2]. Moreover, most perspectives on EM are dictated by Anglo-American perspectives and are mostly based on quantitative research. This paper aims to mitigate these barriers by using a qualitative approach to study how EM plays out in an Indian context. Results from this paper culminate in an EM model that can guide EM researchers and teachers in selecting appropriate methods to foster and evaluate EM in students.

**Need for Qualitative Assessment of EM**

Over an extended period of investigation, researchers have explored and conceptualized EM in various ways [16]. Early studies have identified two main approaches to understanding entrepreneurial mindset (EM). The first approach views EM as innate traits individuals are born with, but lacks empirical evidence [17]. The second approach, widely accepted, defines EM as a mindset that develops through interaction with the environment [18]. This mindset enables students to recognize untapped opportunities, promoting innovation through cognitive attributes like risk-taking, creativity, adaptability, growth orientation, and more. EM can be seen as a dynamic, contingent phenomenon involving psychological processes and situational factors, while others define it behaviorally as a combination of motives, skills, and thought processes that distinguish entrepreneurs from non-entrepreneurs. [2, 18].

Determining the factors that differentiate entrepreneurs from non-entrepreneurs is a contentious topic due to the diverse nature of the entrepreneurial population. To address this, entrepreneurial mindset (EM) is viewed as a dynamic and context-dependent phenomenon, influenced by an individual's psychological processes and choices in various situations [19]. To gain a deeper understanding of EM and its attributes in different circumstances, more qualitative studies involving perspectives from stakeholders such as business founders and entrepreneurs are needed [2].

Despite the need for qualitative studies to measure EM, many studies to this date report EM through surveys using quantitative approach. Students' perspective on EM has been studied via recording their perception using Engineering Student Entrepreneurial Mindset Assessment (ESEMA) [20, 21] and EM Reflections. For example, ESEMA Survey is a 34-item self-report instrument which contains 7 factors that are associated with the three Cs of EM [21]. Some other surveys such as Engineering Entrepreneurship Survey (EES) [20] have been also used by researchers to study entrepreneurial interest and engagement among the students.

While these efforts are great steps in the direction of measuring defined parameters of EM, they have limited scope in exploring culture-specific, qualitative and behavioral attributes of EM. Most of the measurements of EM come from quantitative studies within the anglo-american context that only provide a limited surface-level understanding of EM [2]. There is a high need to develop new instruments that seek to understand EM of students in heterogenous cultures via open ended questions. We find that to this day, the Indian culture packed with diversity of engineering students largely remains unexplored in terms of the EM of students, and many culture-specific insights can be gained through a qualitative study of the same.

While some researchers have attempted to capture the EM within the broader Indian education context, there is a notable lack of specific studies exploring the entrepreneurial mindset of engineering students. However, there are available studies that delve into the EM of students in business and management disciplines, as well as in students in Indian Institutes of Technology (IITs) [22–24]. These studies shed light on the entrepreneurial attitudes and intentions of students in various domains, emphasizing the need for further research to understand the distinct entrepreneurial mindset particularly for engineering students in India.

By conducting this study, we seek to enhance our understanding of EM among engineering students through qualitative exploration and contribute to the refinement of existing EM frameworks. Ultimately, this research will shed light on finding the EM of engineering students in Indian education context and exploring the factors influencing the entrepreneurial mindset in the context of a new engineering education in India through the lens of Indian entrepreneurs and engineering students.

# 2 Methods

## 2.1 Context: Nurturing Plaksha's Engineering Students to Entrepreneurial Mindset through a Summer Program

Plaksha University is a newly set up (started in Fall 2021) not-for-profit university in Mohali town of Punjab, India. It is set to reimagine engineering education via highly interdisciplinary undergraduate degrees. Each degree is unique, cutting-edge, forward-looking and aligned with the needs of the 21st century and taught by top-notch faculty from across the world. The engineering program at Plaksha is different from traditional universities in India in that it aims at developing academic depth as well as skill sets and mindsets that will stay with the students through their life to solve grand challenges in engineering via experiential learning, flexible learning paths, and 360° assessment of learning it seeks via curricular, co-curricular and extra-curricular activities.

In line with experiential learning emphasis at Plaksha from first year of engineering, Plaksha's UG engineering students undertake team-based projects as a part of the Innovation Lab and Grand Challenges Studio Course (ILGC) that continues through sophomore and junior years, culminating in capstone project in fourth year of their engineering. At the time of conducting this study, Plaksha students had completed two years of ILGC course-mediated project-based learning. After first year of the project-based learning, self-selected Plaksha undergraduate engineering freshmen who had enrolled themselves to continue their projects during summer vacation as a part of the Summer Entrepreneurship Program (PSEP) were interviewed. These students availed mentorship by Plaksha faculty and Plaksha founder-entrepreneurs, a stipend of INR 25,000 and one-on-one feedback based on their weekly pitches during the period of June 15–August 15, 2022. The PSEP program aimed at fostering Entrepreneurial Minded Learning within Plaksha's students. Total of 9 self-formed teams participated in this residential (on-campus) summer program. PSEP program conducted sessions with entrepreneurs to teach problem solving skills specific to student projects, facilitated entrepreneur and mentors' feedback on each student team's projects objectives, activities, planned milestones, outcomes in a weekly manner. It also incorporated guiding sessions with entrepreneurs talking about principles of execution through time management, prioritization and resource allocation; and encouraged collaboration and communication skills amongst teammates.

At the end of this program, all students presented deliverables to the jury consisting of faculty and entrepreneurs.

## 2.2 Data Collection and Analysis

We employed a qualitative method approach to investigate the EM in Indian context. The study consisted of semi-structured interviews and in-program observations, to qualitatively assess EM of undergraduate students and entrepreneurs. The observations and interviews were conducted within two distinct groups: the one with entrepreneurs/university founders (experienced) and the other one with engineering students (novice). This data is thematically analyzed and explores the differences between comprehension of EM between students and experienced entrepreneurs. A total of 25 interviews were taken out of which 6 were with entrepreneurs/founders and 19 were with PSEP students.

## 2.3 Sample Selection

Out of all 32 students enrolled in the PSEP (Plaksha Summer Entrepreneurship Program), a total of 19 students who had successfully completed their first year of engineering at Plaksha University voluntarily participated in the interviews. These 19 students self-selected themselves to be a part of the interview process. All 19 PSEP students had finished two semesters of their freshmen undergraduate engineering curriculum at Plaksha University, Mohali, Punjab, India. 19 students were self-selected out of all 32 students enrolled in PSEP invited to do interviews.

Entrepreneurs—6 entrepreneurs were chosen as representative of various entrepreneurial domains in India. These entrepreneurs were selected as participants in this study because they have the expertise in various domains of entrepreneurship and have demonstrated successful entrepreneurship set up in India at various geographical locations. All interviews were conducted in person with prior consent for recording and transcriptions.

This study was approved by the institutional ethics committee at Plaksha University.

**Table 1.** Questions asked in interview with entrepreneurs and students immersed in Plaksha summer entrepreneurship program.

| **Entrepreneurs:** |
|---|
| • How was your personal journey like as an entrepreneur? What inspired you to enter the field? What facilitated this journey? What were some of the barriers encountered?<br>• According to you, what constitutes entrepreneurial mindset? How can we inculcate this in Plaksha students?<br>• What is not an entrepreneurial mindset characteristic but popularly known as one?<br>• What are some of the ways in which we can inculcate EM in Plaksha students? |
| **Students:** |
| • What were some of the facilitators that helped you progress in your PSEP projects?<br>• What were some of the barriers that limited your progress in your PSEP projects?<br>• What are some of the skills in either you or your team members that helped you move forward in your PSEP projects? |

### 2.4 Interview Questions

The interviews started with a fixed set of open-ended questions (Table 1) after which the interviewer asked new, follow-up questions basis interviewees' answers to get more in-depth data on their lived experienced around EM. Grounded theory is used as a methodology to gain EM insights from collected qualitative data on student and entrepreneur perspectives. The insights were later used to build EM models based on student and founder perspectives.

## 3 Results and Discussion

### 3.1 Demographics

In our study, we gathered data from a sample of 19 first-year engineering students who had completed the PSEP program. The gender distribution of the sample consisted of 73.6% males (14 students) and 26.3% females (5 students). All these students were in the age range of 17–21 years, with a mean age of 18.17 years. The majority of respondents (79%) were from urban areas, while the remaining 21% hailed from rural areas. Only a small portion (10%) of students reported coming from families where at least one parent was an entrepreneur. Interestingly, for the majority of students (90%), the summer PSEP program represented their first exposure to entrepreneurship, and none of the students indicated that they currently owned their own business.

Additionally, we collected data from 6 entrepreneurs who served as representatives from diverse entrepreneurial domains in India. The gender distribution of this sample consisted of 5 males and 1 female. All of these entrepreneurs fell within the age range of 45–70 years. These entrepreneurs possessed expertise in diverse fields such as technology, debt financing, startup foundry and accelerators, investment firms, and education and development.

### 3.2 Model of EM Based on Perceptions of Students Who Partook in *Plaksha Summer Entrepreneurship Program (PSEP)*

To gain a deeper understanding of students' perceptions of EM, we conducted unstructured interviews with 19 students who participated in the Plaksha's summer entrepreneurship programs.

By analyzing the data obtained from these interviews and in-class observations while students were attending PSEP sessions, a Student Model for EM has been developed. This model aims to capture the unique characteristics and factors that shape the entrepreneurial mindset specifically in the context of undergraduate students. The model takes into account the distinct themes observed by the students in their entrepreneurial journey. The Student Model for EM (Fig. 1) provides valuable insights into the perceptions and experiences of first-year undergraduate students, shedding light on their mindset development, aspirations, and entrepreneurial behaviors.

The qualitative analysis of student interviews using grounded theory reveals several key attributes and factors as prominent components of their entrepreneurial mindset. Students mentioned how curiosity about problems in one's context and the zeal to explore,

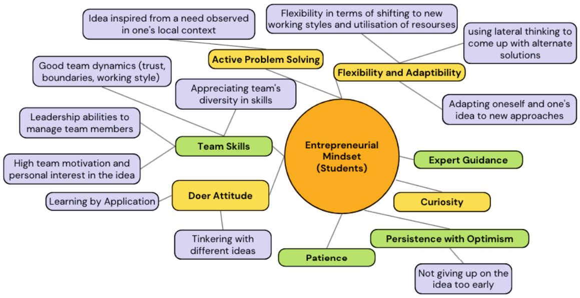


**Fig. 1.** Student model of Entrepreneurial mindset based on the interviews and in-program observations.

implement (doer attitude) and swiftly switch to different ideas (adaptability) to solve problems helped them progress in their entrepreneurial journey. They also found factors such as strong team dynamics, ability to patiently persist with optimism (not giving up early) and good mentorship (expert guidance) as key facilitators that helped them progress in their PSEP projects. The students focus less on the feeling aspects and instead prioritize the development of thinking and behavioral skills within an entrepreneurial context. As a result, the cognitive elements, such as active problem-solving, flexibility, adaptability, along with behavioral traits like expert guidance and patience, emerged as more prominent.

As we mentioned in the introduction section, the early research on the entrepreneurial mindset reveals two prevailing approaches: one focusing on innate traits that predispose individuals to entrepreneurship, while the other emphasizes the nurtured development of the mindset through environmental interaction. Both approaches highlight the interplay between inherent traits and environmental influences, with education, training, and exposure playing vital roles. An integrative view recognizes the complex dynamics between traits and the environment, contributing to a comprehensive understanding of the entrepreneurial mindset and its impact on behavior and outcomes. This holistic perspective underscores the dynamic nature of the mindset and its interaction with individual attributes and the surrounding environment. Thus, our observations and interviews were aimed at capturing the nurtured development of the entrepreneurial mindset through environmental interaction.

### 3.3 Constructing EM Model Based on Entrepreneurs' Perceptions:

The open-ended interviews with 6 entrepreneurs revealed many attributes—that were categorized between core attributes (must haves to enter/start in the entrepreneurial space) and facilitators (help improve chances of sustaining in the entrepreneurial space and can be learned with time and experience, while working with peer entrepreneurs). Figure 2 represents our model accounting for the core attributes of EM on upper side with sub themes that emerged; as well as the facilitators/enablers of EM on the lower side of figure, that were captured out of founder/entrepreneur interviews.

We found that the core attributes represented on top side of Fig. 2 can further be classified in themes of cognitions, behaviors and feelings.

1. The cognitions in our model represent different mental models that entrepreneurs might use to advance their entrepreneurial journey. For instance, a person with entrepreneurial mindset is on a constant search for opportunities to capitalize (curiosity and active problem solving) and ideates using lateral thinking (building novel, distant connections) to come up with creative solutions.
2. Behaviors represent ways in which entrepreneurs engage/act when working with entrepreneurial opportunities. People with EM exhibit behaviors where they don't give up early on their ideas (persistence), continuously tinker and iterate (doer approach), and simultaneously adapt their approaches to avoid roadblocks (knowing when to pivot) in their journey.
3. Feelings represent emotions/internal drives that entrepreneurs experience when working in an entrepreneurial space/environment. Entrepreneurs commonly experienced emotions such as a desire to change/improve the status quo, enthusiasm for taking calculated risks, and perceiving failures as learning/growth opportunities.

The second part of the EM model (Fig. 2) reveals the themes contributing as Facilitators to the Entrepreneurial Mindset as mentioned by interviewed entrepreneurs. These are the factors that help to improve chances of sustaining in the entrepreneurial space and can be learned with time and experience, and peer entrepreneurs.

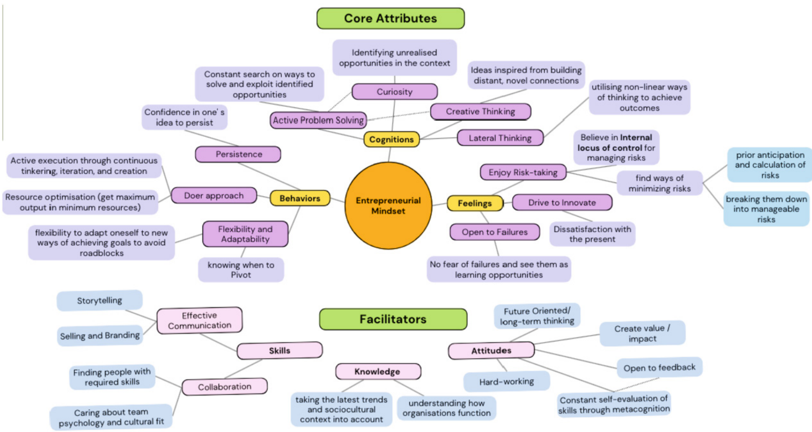


**Fig. 2.** EM model based on the interviews and observations with 6 entrepreneurs participating in summer entrepreneurship projects.

They are categorized in the bottom part of Fig. 2 into Knowledge, Attitudes and Skills.

1. Knowledge refers to the information, understanding, and expertise acquired through education, experience, and research. A deep understanding of the industry or market they operate in.
2. Attributes are personal characteristics or qualities that are commonly associated with successful entrepreneurs. When it comes to attributes in the entrepreneurial mindset,

three important qualities are being hardworking, having long-term thinking, and being open to feedback.
3. Skills are practical abilities that entrepreneurs develop through learning, practice, and experience. Skills like effective communication and collaboration or relation building are the valuable assets for developing an entrepreneurial mindset.

These are the factors that help to improve chances of sustaining in the entrepreneurial space and can be learned with time and experience, and peer entrepreneurs.

### 3.4 How do Different EM Core Attributes in the Model Work Together to Support an Entrepreneur's Journey?

Based on interviews with entrepreneurs, we have identified ways in which different EM attributes drive/enable each other. Using the concept of reinforcing feedback loops from system thinking research [25], here we explain various associations to provide a better understanding of how the proposed EM model functions in an actual entrepreneurial space. The idea revolves around how increase in one EM attribute positively drives growth in other attributes. The first word below states the Enabling parameter, and the second word shows what it enables.

1. Drive to innovate → Persistence: Entrepreneurs persist with their ideas because they are dissatisfied with the way current systems work in their context and have a strong zeal to bring a positive change/improvement.
2. Enjoy Risk Taking → Doer Approach (mediated by Openness to failures): Entrepreneurs enjoy taking risks as they believe that they have the ability to control/minimize them (internal locus of control) which enables them to continuously tinker/experiment in the field (doer approach) without worrying about failures. This relation is further strengthened by their openness to failures as they don't fear them and instead, see them as learning opportunities.
3. Lateral Thinking → Adaptability and Flexibility: Since lateral thinking involves constantly exploring and combining different, unrelated ideas to solve a problem in a non-linear manner, having a knack for it allows entrepreneurs to stay flexible and easily adapt to different situations/systems to get their task done.
4. Drive to Innovate → Active problem solving (mediated by creative thinking): Entrepreneurs are always on the lookout to solve problems they find in their local context because they have a strong dissatisfaction with the current state of things and want to improve them through innovation. This relation is further strengthened by creative thinking as it gives them an edge as entrepreneurs to ideate innovative ideas to bring successful changes to their current systems.
5. Curiosity with Problem-Solving: Entrepreneurs succeed not only being curious about problems they find in their local context but by also actively striving to solve the identified problems. It is only when they combine curiosity with problem solving, they are able to achieve their entrepreneurial goals.
6. Persistence with Ability to Pivot: For entrepreneurs, simply persistently working towards their ideas is not enough for them to succeed. They should be good at calibrating situations when pivoting is required to successfully move forward in their entrepreneurial journey.

The above EM core attributes work together in positive feedback loops where cognitions and feelings drive behaviors and successful outcomes of behaviors further strengthen entrepreneurs' feelings and cognitions [26], [25]. Overall, the thematic analysis revealed a multifaceted and dynamic entrepreneurial mindset model which not only highlights different crucial attributes but also present ways in which they interact with each other to support an entrepreneur's journey. The model clusters EM attributes as behaviors, cognitions and feeling and shows how they work together to help an entrepreneur use their EM to establish successful businesses and bring positive reforms in the world.

### 3.5 Disparity in Students Versus Entrepreneurs' Perceptions of EM:

We realized through program observations and interviews that the entrepreneurial mindset (EM) of an undergraduate student differs from that of experienced entrepreneurs involved in startups or business ventures. Some of the key EM attributes like Enjoy Risk-taking, Creative Thinking, Drive to Innovate and Open to Failures were not brought up by students in their interviews when asked about their EM experiences. EM attributes related to feelings around risk taking and failures that were mentioned by entrepreneurs in Fig. 2, were missing in student interviews pointing that perhaps these crucial factors are realized later on once someone has accumulated many entrepreneurial experiences. This informs us that the people's understanding of EM changes with experience, and particularly, it is important to widen students' perception of what constitutes entrepreneurial mindset as they are being shaped as engineers across 4 years of their program. From an educational perspective, students can early on be taught about such attributes through simulated experiences and encouraged to inculcate them in order to increase their probability of succeeding in their entrepreneurial endeavors.

Table 2 summarizes the difference in the perception of EM between founders and students based on the semi-structured interviews and data collected from students as well as the founders.

**Table 2.** Differences between founders and student's perceptions of EM

| **Exposure to EM attributes** | **Founders** | **Students** |
|---|---|---|
| Persistence | ✓ | ✓ |
| Active Problem Solving | ✓ | ✓ |
| Lateral Thinking | ✓ | ✓ |
| Flexibility and Adaptability | ✓ | ✓ |
| Enjoy risk taking | ✓ | |
| Doers attitude | ✓ | ✓ |
| Creative thinking | ✓ | |

(*continued*)

**Table 2.** (*continued*)

| Exposure to EM attributes | Founders | Students |
|---|---|---|
| Drive to innovate | ✓ | |
| Open to failures | ✓ | |
| Curiosity | ✓ | ✓ |

## 4 Conclusions

This study explores the significance of fostering an entrepreneurial mindset (EM) among engineering students and emphasizes the need for a holistic understanding of its constituents. It analyzes perspectives from Indian freshmen students and experienced entrepreneurs, providing non-western insights on EM. The study acknowledges the dynamic nature of EM, where psychological processes and situational factors influence entrepreneurial success. Preliminary findings reveal that students perceive EM as consisting of attributes like doer attitude, flexibility, active problem-solving, and curiosity, along with factors like patience, persistence, optimism, team skills, and expert guidance. Entrepreneurs highlight core attributes such as risk-taking, creativity, adaptability, opportunity recognition, innovation, and growth orientation, along with facilitators like knowledge, skills, and attitudes. The study uncovers symbiotic relationships between different attributes, emphasizing their interactions in the entrepreneurial environment. Differences in perceptions of EM between students and entrepreneurs are also noted, suggesting the influence of entrepreneurial experience on conceptualization. The paper presents the components of EM and its development among engineering students in an Indian university, highlighting the importance of nurturing an entrepreneurial mindset and providing insights for educational institutions.

**Limitations and Future Scope**

Through qualitative research, we gained insights from different stakeholders, including experienced entrepreneurs and undergraduate engineering students. However, these findings are limited to researcher's interpretations from analysis of a small sample size that was availed for this study. Data might be also constrained by the type of sample self-selected for this study. Being predominantly from the founding batch of a new university, the selected students come from a unique institutional ecosystem set to reimagine engineering education. Through data collected, many other research questions can be also studied that were not the focus of this study for e.g., what attracts one to entrepreneurship, and how might we inculcate entrepreneurial mindset effectively in India's engineering students.

Building upon the limitations of existing instruments, future research should focus on designing and validating a new instrument that comprehensively measures the entrepreneurial mindset in Indian context. This instrument should encompass the core attributes and enabling factors/facilitators identified in this study and should be sensitive to cultural and contextual variations, particularly in the Asian context and among students.

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# Survey-Based Measurements of the Entrepreneurial Mindset of Indian Engineering Students

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**Abstract.** This study evaluates the entrepreneurial mindset (EM) among Indian engineering students and assesses the effectiveness of existing measurement frameworks in the Indian context. EM is recognized as a valuable asset for engineering students, enabling them to tackle global challenges and gain a competitive advantage. Incorporating entrepreneurship education is a common practice worldwide to cultivate EM in learners. However, assessing EM development is challenging due to its complexity.

The study applies EM measurement frameworks, validated in Western education systems, to assess EM of engineering students at a small private university in India. Quantitative assessments through online surveys are conducted at various points in the students' engineering course through first and second year of engineering.

This study recognizes the significance of measuring entrepreneurial mindset in preparing engineering students to address contemporary engineering challenges and foster such mindset for creating innovative solutions. To enhance the EM, it was found necessary to evaluate it in terms of students' self-reported values for parameters such as growth mindset, altruism, empathy, help-seeking, ideation, interest, open-mindedness, entrepreneurial interest, and entrepreneurial self-efficacy arising in Indian educational ecosystem context. This research thus seeks to provide insights into the EM of UG engineering students at a small university in North India, while discussing the applicability of existing EM measurement frameworks to this research.

**Keywords:** Entrepreneurial mindset (EM) · Indian engineering students · Measurement frameworks · Entrepreneurship education · Assessment Introduction

## 1 Introduction

Entrepreneurial mindset (EM) is an asset for engineers in solving global challenges and gaining a competitive edge in the market. Institutions across the globe are making an effort to infuse entrepreneurial mindset in engineering curriculum. However, the

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concept of EM is complex and elusive, making it challenging for institutions to assess its development in learners.

Early research on the entrepreneurial mindset (EM) has identified two prevalent approaches. The first approach views EM as a set of innate traits or characteristics that individuals possess, which predispose them to engage in entrepreneurial activities (Muller, 2001). These traits include proactiveness, risk-taking propensity, and opportunity recognition skills. This perspective suggests that certain individuals have an inherent entrepreneurial personality that drives their behavior and success. The second approach defines EM as a mindset that is nurtured and developed over time through interaction with the environment (Obschonka, M., 2016). This perspective recognizes that while certain inherent traits may provide a foundation, the development of an entrepreneurial mindset is influenced by experiences, education, and exposure to entrepreneurial contexts. It suggests that both inherent traits and environmental influences contribute to the formation and development of the entrepreneurial mindset.

Though EM is traditionally associated with business ownership, it is now also highly valued by large corporations who perceive entrepreneurially minded employees as a strong asset (Bosman & Fernhaber, 2018). As per the resource-based theory, organizations utilize entrepreneurially minded people as resources possessing enhanced cognitive ability to exploit identified market opportunities and gain a competitive edge in the global market (Naumann, 2017). Entrepreneurial mindset preparation is closely tied to the level of preparation that the individuals undertake in their pursuit of becoming entrepreneurs. This readiness is defined by a distinct set of personal traits that set individuals apart in their efforts to prepare for the business world (Ruiz et al., 2016).

In today's world that requires dynamic problem-solving for grand challenges we are facing, engineering graduates will need to possess entrepreneurial mindset. Incorporating entrepreneurial learning into their education will provide great emphasis on exploration, identifying opportunities, and creating value while solving a problem. Graduates who embrace this approach experience various advantages, such as the ability to assess market demands, societal trends, and technical feasibility. Even the companies hiring graduates are looking for individuals equipped with a diverse range of skills, including not only technical expertise but also professional skills. Engineering unleashed community rightly captures this as " an entrepreneurial mindset provides a deeper sense of meaning for the students. They won't just deliver a product. They'll create value." (Entrepreneurial Mindset | Engineering Unleashed, n.d.).

However, whether ways of inducing EM are effective or not also needs to be assessed. Researchers have employed various instruments to assess the entrepreneurial mindset (EM) in engineering students. These instruments include comprehensive assessment surveys, frameworks mapping to the 3Cs (Curiosity, Connections, Creativity), and models based on the concept of a growth-oriented mindset (Kaitlin Mallouks, 2019). The studies focused on different aspects, such as examining the outcomes of entrepreneurship education, measuring entrepreneurial behaviors as learning outcomes, and evaluating the impact of entrepreneurial interventions on mindset changes. Overall, these research efforts aim to understand and cultivate EM among engineering students by assessing their status via survey.

Our understanding of EM remains restricted to these instruments predominantly applied in western engineering education systems. How these instruments perform in Indian engineering education context and how do the Indian engineering students' EM look like when these instruments are applied, is largely unknown. Thus, despite extensive research on entrepreneurial mindset (EM) and the development of various tools to measure it, there is still limited exploration of the effectiveness of these tools in quantifying the EM of students. Literature is scanty in reporting the application of existing frameworks in evaluating the entrepreneurial mindset of engineering students in India. This research paper aims to address this gap by evaluating change in entrepreneurial mindset of first- and second-year engineering students of a small private university in India as result of exposure to entrepreneurial activities, by applying selected relevant existing EM measurement frameworks developed by others.

## 2 Literature Review

Entrepreneurship is now promoted, especially in engineering universities, across the globe as a way to solve global challenges of contemporary relevance by building new technology-based business solutions (Bosman & Fernhaber, 2018) and decrease overall unemployment rates by creating new job opportunities for others (Kriewall, 2010). This has led many education institutions to find ways of instilling entrepreneurial mindset in engineering students early-on for building their interest in entrepreneurship and preparing them for industry after graduation (Bosman & Fernhaber, 2018). In the field of engineering education, universities have acknowledged the importance of integrating entrepreneurship education into their existing curriculum to foster an entrepreneurial mindset. This has led to the incorporation of courses and modules specifically focused on entrepreneurship. Examples of such integration include the Lean Startup Method (LSM) and Business Model Canvas (BMC).

There is also strong supporting evidence for the role of entrepreneurial education in shaping EM and entrepreneurial intention in people (Ngek, 2012; Jiatong, 2021; Roeslie & Arianto, 2022). Research suggests a mediating role of entrepreneurial mindset in strengthening the relationship between entrepreneurial education and entrepreneurial intention/preparedness (Saptono et al. 2020; Liao, Nguyen, & Nguyen, 2022).

For assessing the Entrepreneurial Mindset, researchers have reported various instruments. For example, Nathalie Duval-Couetil et al. described the development of a comprehensive assessment instrument to examine the multiple outcomes of entrepreneurship education for engineering students. The survey was targeted at senior-level students enrolled in capstone engineering design courses. Similarly, based on the framework established by the Kern Entrepreneurial Engineering Network (KEEN), Li et al. developed an assessment instrument to measure the entrepreneurial mindset of engineering students via entrepreneurial behaviors (engineering thought and action, collaboration, communication, and character) as the learning outcomes of the course. London et al. developed a framework to measure EM through twelve attitudes and seventeen behaviors that map to the 3C. Kirkpatrik et al. applied the 3Cs (Curiosity, Connections, Creativity) from keen framework to Grand Challenges course in engineering (Kirkpatrik et al., 2001). Reid et al. reported a baseline mindset study to measure the impact of entrepreneurial interventions within first-year engineering courses on changes in the mindsets of engineering students. Entrepreneurial mindset in their study is operationally defined as a more growth-oriented mindset versus a fixed oriented mindset. Bandaranaike et al. also introduced EM to students at a Mexican University and presented EM model based on Carol Dweck's "growth mindset" concept, where an individual believes you can learn and grow even by making mistakes and remaining positive (Bandaranaike et al., 2008).

These examples have successfully illustrated researchers' efforts in measuring impact on entrepreneurial mindset as a result of curricular/co-curricular activity interventions. Nevertheless, these instruments are primarily applied and tested in Western engineering education systems. The applicability and outcomes of these instruments in the context of Indian engineering education and the change in EM of Indian engineering students as result if curricular/co-curricular interventions remain largely unexplored.

## 3 Methods

This study employs a quantitative assessment using existing EM instruments described in Sect. 3.1. To explore how variables linked to EM changed as engineering students were exposed to EM activities throughout their first to fourth semester, we offered an online survey titled Student Perceptions Survey. Items within each variable are randomly ordered in the survey. A Likert scale was provided to collect responses for different variables constituting EM, as indicated in Sect. 3.1.

The surveys were conducted with two distinct groups: the one who participated in EM development programs in their curriculum and those who did not participate. This data was used to analyze the differences between students' comprehension of EM throughout their engineering course. The project invited freshmen undergraduate engineering students studying at Plaksha University, Mohali, Punjab, India to fill the survey at various time points as they were exposed to EM interventions.

The EM survey was offered at various time points during four semesters that happened between Fall 2021-Spring 2023 as indicated in Table 1.

**Table 1.** Description of time points used in EM survey.

| Time point | Description | Number of survey respondents |
|---|---|---|
| T1 | Oct 2021: A baseline assessment conducted at the beginning of their 1st semester in engineering at Plaksha | 57 out of 86 students in the class |
| T2 | Jan 2022: End of first semester in engineering at Plaksha | 57 out of 86 students in the class |
| T3 | May 2022: End of second semester in engineering at Plaksha | 57 out of 86 students in the class |

(*continued*)

**Table 1.** (*continued*)

| Time point | Description | Number of survey respondents |
|---|---|---|
| T4 | August 2022: End of Plaksha Summer Entrepreneurship Program | 23 out of 37 students who were part of PSEP |
| T5 | May 2023: End of fourth semester in engineering at Plaksha | 46 out of 86 students who were part of the class |

### 3.1 Assessments Used in Tracking Change of Entrepreneurial Mindset

We measured EM via survey asking questions about EM related variables reported in literature (explained below) to find out baseline and to study whether entrepreneurial exposure activities (like summer programs) as interventions affect the level of these variables in students. To get a holistic view of EM, we assessed students EM from multiple perspectives related to attitudes such as curiosity, ability to make connections, and creating value (captured via ESEMA survey application); students' entrepreneurial interest, entrepreneurial engagement, entrepreneurial self-efficacy, and growth mindset. These are described below.

**Growth Mindset:** We applied Carol Dweck's 3 item Growth Mindset Scale (Stanford University) to study the extent to which students perceive their own intelligence as malleable and how that affects the growth of their entrepreneurial mindset (Carol S, 2016).

**Engineering Students' Attitudes Related to EM:** To identify student perspectives, we record their perceptions using Engineering Student Entrepreneurial Mindset Assessment (ESEMA) (Duval-Couetil et al., 2011). ESEMA Survey provides a 34-item self-report instrument which contains 7 factors that are associated with the three Cs of EM (Brunhaver et al., 2018). These translate to Altruism, Empathy, Help-seeking, Ideation, and Drive (Interest) and Open-mindedness, as described in Annexure 1. Since we use the 3 Cs of EM framework in our EM-boosting interventions, this survey is considered as a suitable tool to measure EM for this study. We adapted the scale from a 5 point to a 6-point likert scale to avoid response bias towards neutral options in participants. Research supports the usage of 6-point likert scales for better reliability and discriminant validity (Chomeya, 2010; Leung, 2011).

**Entrepreneurial Interest:** To assess students' interest in entrepreneurship, we adopted items from the 'INTEREST' section of Engineering Entrepreneurship Survey (EES) (Duval-Couetil et al., 2011). Items were used to measure the general interest of engineering students in learning/applying entrepreneurship. The items were condensed into fewer items in order to keep the survey brief.

**Entrepreneurial Self-efficacy:** We devised three new items to measure how confident students feel about their capability to apply the 3 Cs of EM: 1) Having a constant **curiosity** about our changing world and employing a contrarian view of accepted solutions. 2) Habitually **connect**ing information from various sources and inferring insights as well as managing risks. 3) Creat**ing value** for others from unexpected opportunities as well as persist through, and learn from, failure.

Since our in-class interventions stemmed from the 3 Cs of EM, measuring entrepreneurial self-efficacy in this way seemed apt for this study.

## 3.2 EM Development Programs

We introduced a project-based course and several entrepreneurial exposure activities throughout their engineering curriculum as interventions to boost EM in students. These activities centered around EM enhancement included the Innovation Lab and Grand Challenges Studio (ILGC), Plaksha Summer Entrepreneurship Program (PSEP), Plaksha Summer Innovation Program, Exploring Minds Podcast, Speaker Sessions & Workshops, and Plaksha Pitch Day. This section provides a brief introduction to these course and activities:

**Innovation Lab and Grand Challenges Studio (ILGC):** This is a 2-credit lab course mandatory in all semesters of students' engineering journey. ILGC exposes students to design thinking, engineering design, human centered design, puts various global challenges in engineering perspective, and teaches them ways to tackle these challenges with an entrepreneurial mindset. Students work in diverse teams on projects where they identify innovation opportunities in their surroundings, connect them with in-class learnings and work in teams of 2–5 students to develop sustainable solutions.

**Plaksha Entrepreneurship Support Program (PESP):** PESP is a 2-month in-residence entrepreneurship program focused on idea-incubation, for Plaksha undergraduates to start their entrepreneurial venture. Guided by eminent startup founders and experienced mentors, the program is a launchpad for budding entrepreneurs. The program offers access to leading venture partners and experts of the and provides Workspace, seed funding and mentoring to students by expert entrepreneurs and faculty in the area of their project.

**Other Entrepreneurial Activities Available via Campus Ecosystem:**

**Exploring Mind Podcast:** The Plaksha University Entrepreneurship Cell hosts a podcast series that brings together students, venture capitalists, and founders to discuss various aspects of entrepreneurship. This podcast serves as a platform for insightful conversations, knowledge sharing, and fostering connections between the student community and industry professionals.

**Speaker Sessions and Workshops:** Plaksha University Entrepreneurship Cell organizes engaging and informative speaker sessions and workshops throughout each semester focused on entrepreneurship to nurture the entrepreneurial mindset and provide students with practical knowledge and skills in this domain. These sessions cover a wide range of topics related to entrepreneurship, including idea generation, market analysis, business models, funding strategies, scaling ventures, and navigating challenges.

**Plaksha Pitch Day:** Entrepreneurship Cell hosted its first startup pitching competition at Plaksha University, Mohali, India. The event entailed a great fireside chat by some virtuoso angels and entrepreneurs, a keynote speech and live pitching session by the undergraduate students as well as top start-ups around tricity (Chandigarh, Mohali and Panchkula) in India.

# 4 Results and Discussion

As indicated in Table 1, we have conducted the EM survey five times during different periods of the students engineering educational journey so far at Plaksha University. The baseline assessment was conducted at the beginning of their 1st semester (T1) followed by a second round at the beginning of the 2nd semester (T2), a third assessment at the end of the 2nd semester (T3), a follow up assessment at the end of the Plaksha summer entrepreneurship program (T4) and a fifth assessment at the end of their 4th semester (T5) where students were exposed to other EM activities happening as a part of campus ecosystem. To complete this longitudinal study, from T5 onwards, we plan to take measurements at the end of every year in engineering.

## 4.1 Effect of Exposure to Plaksha Summer Entrepreneurship Program

Our first objective was to evaluate whether any change was reported in the EM factors of the surveyed students across their time journey so far at Plaksha. We compared baseline (T1) with their 1$^{st}$ semester-end (T2), 2$^{nd}$ semester-end (T3), and 4$^{th}$ semester- end (T5). The third semester data was not collected because we wanted to shift the measurement at the end of every year than every semester and avoid bombarding students with survey each semester. T4 was not included in this analysis as the respondents of T4 are only a few students who underwent the summer PSEP intervention.

Results are indicated in Fig. 1. The analysis shows that no significant variation of the EM variables can be observed across the timelines indicating any positive trends of enhancement of EM despite the students being exposed to several EM enhancing activities.

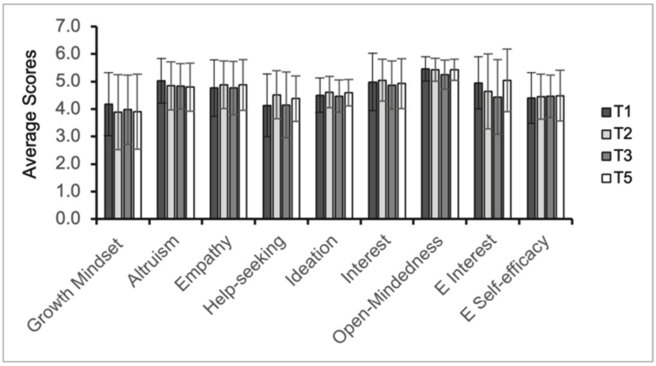



**Fig. 1.** Comparison of EM variables for T1, T3, T3 and T5. Bar graphs represent mean variable scores of all participants in the study. (N = 57 for T1, N = 57 for T2, N = 57 for T3 and N = 46 for T5).

As we did not see a general increase in all students, we were then looking at whether specific activities were generating impact. For this, timepoint after the EM enhancing activity of PSEP was selected. We looked at if PSEP generated any difference in the self-reported perceptions of EM of students. Figure 2 indicates the results.

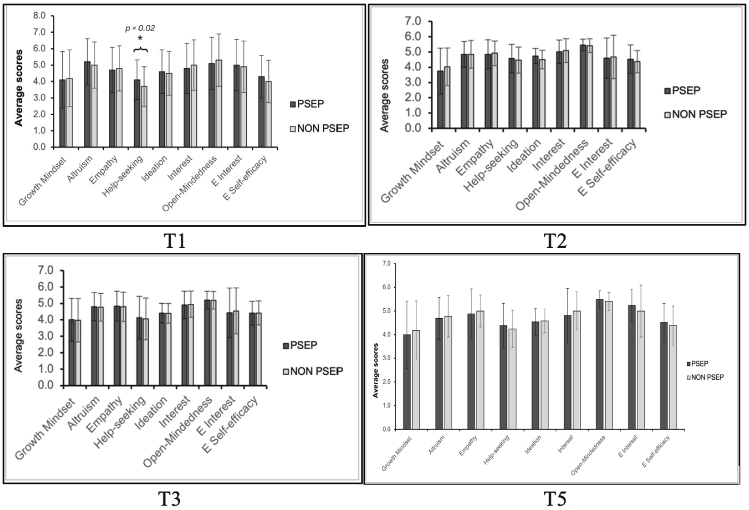
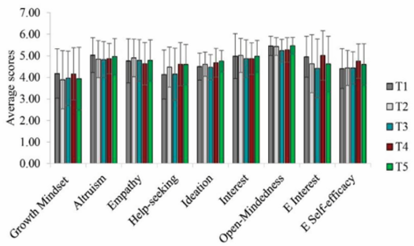



**Fig. 2.** Comparison of EM variables for PSEP and non PSEP students at various assessment periods. (N = 57 for T1, N = 57 for T2, N = 57 for T3 and N = 46 for T5).

Analysis shows that interestingly, of the various parameters, “help-seeking” parameter showed a significantly lower mean for non-PSEP students in T1 compared to those who went on to do PSEP. Perhaps this finding is linked specifically to Indian education system, as typically help-seeking is not intentionally encouraged in India’s conventional educational setting (it is observed as being limited to asking to teacher/authoritarian figure), and undergoing the PSEP entrepreneurial learning fostered this attribute. It appears that help-seeking might be an inherent trait associated with EM as this change was observed at the baseline (T1). Our claim rests on the literature point that EM is linked with some inherent traits (Naumann, 2017).

Apart from help-seeking, there was no significant difference reported in the EM factors between PSEP and Non PSEP students across any other assessment periods. Although no other difference was observed after PSEP program exposure, we believe this methodology for assessment can be repeated with other EM exposure in campus ecosystem that students at Plaksha are currently undergoing, to know the specific activities’ impact on various parameters of EM.

Analysis was further carried out comparing the change in EM variables for participants across T1, T2, T3, T4, and T5 (Fig. 3). When answering the research question whether exposure to various EM activities enhanced students' EM, we found surprising results. No significant change between T1 (baseline EM) to T5 (end of semester 4) timelines in any EM variable was observed from this, indicating any positive trends of enhancement of EM despite the students being exposed to several EM enhancing activities.




| Group | Altruism | Empathy | Help-seeking | Ideation | Interest | Open-Mindedness | E Interest | E Self-efficacy |
|---|---|---|---|---|---|---|---|---|
| Growth Mindset | 0.85 | 0.76 | 0.34 | 0.55 | 0.92 | 1.35 | 0.79 | 0.49 |
| Altruism | 0 | **0.089** | 0.52 | 0.3 | **0.067** | 0.5 | **0.057** | 0.36 |
| Empathy | **0.089** | 0 | 0.43 | **0.21** | **0.16** | 0.58 | **0.033** | **0.27** |
| Help-seeking | 0.52 | 0.43 | 0 | **0.21** | 0.58 | 1.01 | 0.46 | **0.15** |
| Ideation | 0.3 | **0.21** | **0.21** | 0 | 0.37 | 0.8 | **0.25** | **0.06** |
| Interest | **0.067** | **0.16** | 0.58 | 0.37 | 0 | 0.43 | **0.12** | 0.43 |
| Open-Mindedness | 0.5 | 0.58 | 1.01 | 0.8 | 0.43 | 0 | 0.55 | 0.86 |
| E Interest | **0.057** | **0.033** | 0.46 | **0.25** | **0.12** | 0.55 | 0 | 0.31 |

**Fig. 3.** Comparison of EM variable means for T1, T3, T3, T4 and T5 time points. Bar graphs represent mean variable scores of all participants in the study. (N = 57 for T1, N = 57 for T2, N = 57 for T3, N = 23 for T4 and N = 46 for T5). Table on right shows the p vals for comparison of means of each factor (eg. Growth Mindset means for T1 through T5 compared with Altruism means for T1 through T5). Numbers in bold represent difference in means that are not significantly different from each other ($p > 0.05$).

We carried an ANOVA to determine the differences between mean scores in each of the 9 variables. Figure 3 has a chart of absolute difference between means of each factor across T1, T2, T3, T5 time points. The results indicated some of the factors were significantly different from each other as bolded, but many factors were not different in means.

Since the EM factors that were assessed using these existing frameworks did not show significant changes across time frames despite the students being continually exposed to EM enhancing activities, we think the following possible cases might be playing a role: 1) instruments that were validated for these factors in Western context might have limited applicability in Indian context. 2) survey captured students' self-reported measures of the factors, which is subjective from student to student. 3) The students could also have been exposed to factors due to activities outside of their educational curriculum, such as seminars, conferences, interaction outside the campus which we are not sorting out. 5) the assessment is still a snapshot into the initial 2 years of exposure during their engineering educational journey. EM formulation might be different as a result of capstone and Entrepreneurship minor that they will be part of in the next 2 years. A clearer picture might be available after they finish their 4-year Engineering educational journey.

This study attempts to fill the gap that studies reporting EM of Indian engineering students measurable via an instrument are lacking in the literature to date. While this was only measuring effect of one entrepreneurship activity (PSEP) as a proof of concept, this can be repeated with other factors that students are being exposed to know the specific activities' impact on various parameters of EM.

## 5 Conclusion and Future Scope

The study aimed at reporting the EM mindset of engineering students at a private university using existing frameworks and to understand their effectiveness in evaluating EM of Indian students. Findings from the study show that existing frameworks did not reveal any change in EM within Indian educational setting. No significant change in EM was seen over a period of 2 years except for help-seeking parameter being different between students exposed to Summer Entrepreneurship Program. We believe a better model to correlate the EM with independent exposures need to be developed.

We have also seen that there are several limitations of these existing EM models as they are not capturing all the attributes shaping the EM of an individual from a qualitative perspective. To identify the gaps in students' perceptions of EM and entrepreneur's perceptions of EM attributes, we conducted a parallel study of qualitative nature using student's and entrepreneurs' perception of EM that we are reporting in another paper.

We propose that the new instrument for measuring EM should be more comprehensive of the core attributes as well as enablers of EM, via observing behaviors, cognition, feelings, attitude, and skills. It is hard to measure such parameters using a quantitative instrument alone, hence it is worth looking into developing a new tool which more accurately captures the EM using mixture of quantitative and qualitative approaches. Additionally, an attempt should be made in new instrument to also measure experts' analysis of students' EM. Existing studies on EM predominantly measure EM as perceptions of students new to entrepreneurship, disregarding the perspectives of other stakeholders such as entrepreneurs and teachers in assessing change in students' EM. Thus, to attain a comprehensive assessment of EM across diverse contexts of educational system, such as in India, qualitative studies are imperative to be included in future.

# Appendix: EM Survey Questionnaire

1) Demographic Information in terms of gender (M/F/Other), age.

2) Think about your experience and rate your level of agreement to the following statements:

Response scale used:

| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| Strongly Disagree | Disagree | Somewhat Disagree | Somewhat Agree | Agree | Strongly Agree |

| | | | |
|---|---|---|---|
| 1 | I like to reimagine existing ideas | 13 | I am willing to learn from others who have different area of expertise |
| 2 | I like to thinks of ways to improve existing solutions | 14 | I recognise the importance of other fields even though I don't know much about them |
| 3 | I like to think of crazy and wild ideas | 15 | I am willing to update my plans in response to new information |
| 4 | I tend to challenge things that are done by the book | 16 | I tend to get involved in a variety of activities |
| 5 | Other people tell me I am good at thinking outside the box | 17 | I enjoy being involved in a variety of activities |
| 6 | I prefer to challenge adopted solutions | 18 | I participate in a wide range of hobbies |
| 7 | I tend to see my ideas through even though there are setbacks | 19 | The idea of tackling societies' problems do not motivate me |
| 8 | I look for new things to learn | 20 | I believe that is important I do things that that fix problems in the world |
| 9 | I am willing to consider an idea put forth by someone else | 21 | I am driven to do things that improve lives of others |
| 10 | I am willing to compromise if ideas seems better than mine | 22 | I can easily tune into how someone else feels |
| 11 | I appreciate the values that different kind of knowledge can bring about | 23 | Other people tell me I am good at understanding their feelings |
| 12 | I appreciate the value that different strengths brings to the team | 24 | I know when I need to ask for help |

| | | | |
|---|---|---|---|
| 1 | You have a certain level of intelligence and can't do much to change it | 4 | I am interested in entrepreneurship and would like to learn more about it |
| 2 | Your intelligence is something that you can't change very much | 5 | I want to become an entrepreneur |
| 3 | You can learn new things but can't really change your basic intelligence | 6 | I would like to know what it takes to be an entrepreneur |

Response scale used:

| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| Strongly Disagree | Disagree | Somewhat Disagree | Somewhat Agree | Agree | Strongly Agree |

| | |
|---|---|
| 1 | Identify innovations and opportunities in my background and act on them |
| 2 | Connect and identify issues in my local context with global economic |
| 3 | Evaluate how different innovations and business ideas create social economic and environmental values to society |

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# Innovation and Entrepreneurship Integrated to Introductory Programming Courses: An Experience Report of a Brazilian Case

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**Abstract.** This work reports the experience of integrating aspects of innovation and entrepreneurship in introductory programming courses (IPC) in a Brazilian context. This action research involves 53 students enrolled in basic and advanced IPCs in a Computer Science program at the Federal University of Jataí, Brazil, in 2022. From the concepts in the room/laboratory, the students collaborated to co-create a computational solution that impacts society. As results were achieved, it is possible to mention that students had experiences promoting soft skills development.

**Keywords:** introductory programming · entrepreneurship · education

## 1 Introduction

With the advent and implantation of Industry 4.0, a profound change is expected concerning the professional profile. It desires them to be able to deal with computing subjects. However Computing area is in open growth, the Brazilian Association of Information and Communication Technologies Business (BRASSCOM[1]) highlights that Brazil has a deficit in relation of formation of ICT[2] professionals, being the high dropout rate in programs one of the main reasons for this phenomenon [1].

Some works focus on identifying factors by students giving up computing programs [2–5]. Among several pieces of evidence, it points out the student's difficulties in assimilating programming logic. In [6], the authors add that the

[1] BRASSCOM stands for *Associação Brasileira de Empresas de Tecnologia de Informação e Comunicação* in Brazilian Portuguese.
[2] ICT stands for Information and Communications Technology.

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source of problems concerning retention and dropout in introductory programming courses (IPC) are related to students, professors, and even the adopted methodologies. They list some factors that contribute to this phenomenon like (i) lack of a logic-math background of students [7]; (ii) lack of dedication when conducting their studies; (iii) professor limitations; (iv) inappropriate textbooks and other support resources [8]; and (v) non-efficient teaching methodologies [9], among others.

Last years, and accelerated with digital transformation, there is an imperative to form professionals that can adapt to fast changes [10]. In this context, *Association for Computing Machinery* (ACM) [11], the Brazilian National Curricular Guidelines of Computing Programs [12], and Brazilian Computer Society (SBC) [13] present guidelines and references for computing curricula. A concern is common in all of these documents: the need to prepare conscious egress of ethical issues [14], with a focus on creativity, innovation, and entrepreneurship.

Developing the student protagonism, the agenda explores skills linked to their behavior and human aspects, i.e., soft skills [15]. Thus, during this professional journey of formation, it is necessary to cultivate aspects like collaboration (group work), resilience (ability to adapt to obstacles), and effective communication (sharing ideas with clarity).

Costelloe [16] defines several approaches for teaching programming, such as lectures & labs, software visualization, robots, problem-based learning, cognitive apprenticeship, and a miscellaneous of these approaches. Santos and colleagues [17] emphasizes PBL adoption as one of the approaches with more evidence in teaching programming. Considering PBL in a single discipline or course, it is common its adoption as an experience based on the "capstone" project, a final project undertaken in a program of study designed to assess the skills, knowledge, and expertise acquired by the student. In [18], for example, the authors carried out a course in which small multidisciplinary teams of students created web-based games as a final project.

This current study designed a teaching project called "Integrating the Startups Culture into IPCs" to merge concepts associated with innovation and entrepreneurship into these courses in a "capstone" style. This work reports the experience obtained during this project execution. This project was in-person in classes of IPC and Entrepreneurship courses at the Federal University of Jataí (UFJ), Goiás (Brazil), under the professor's perspective in 2022.

This paper is divided into five sections. After this introduction, Sect. 2 contextualizes the IPC offered in the computing program at UFJ. Section 3 presents details concerning the planning and conduction of this teaching project. Section 4 reports this experience *per se*, scrutinizing the performed activities. Finally, Sect. 5 points out the final remarks about the challenges, strengths, and limitations, prospecting future perspectives.

## 2 Context

The Introductory Programming is divided into two courses at UFJ: basic and advanced. This computing program offers basic introductory programming (BIP) in the first academic semester and advanced one (AIP) in the second [19,20]. Both courses have 64 h (4 h/week). We can mention algorithm notions (natural language, flowchart, and pseudo-code), loops, and homogeneous data structures (array, strings, matrices) among the BIP curricular content. And we can cite heterogeneous data structures, modules, use of parameters by value and reference, pointers, recursiveness, and file manipulation among the AIP curricular one.

A relevant aspect is BIP is a prerequisite of nine in 49 courses necessary to conclude the program [19]. According to data extracted from the academic system of UFJ between 2013 and 2018, BIP and AIP had 407 enrollments with an average approval rate of 58.06%. The average retention rate is 41.4% in this period, among those reproved by the class absence or by performance.

Table 1 presents a data compilation extracted from diaries of BIP and AIP courses between 2019 and 2022. Due to the Covid-19 pandemic and the suspension of the academic calendar, it is important to highlight that the current academic term is 2022.2 (in the publish moment of this report).

**Table 1.** Student status in BIP and AIP in UFJ between 2019 and 2022.

| Year | Format | Course | Enrollments | Approvals (%) | Perf. Retained (%) | Perf. & Abs. Retained (%) |
|---|---|---|---|---|---|---|
| 2019 | In-person | BIP - A | 27 | 51.93 | 25.93 | 22.20 |
| 2019 | In-person | BIP - B | 22 | 40.91 | 31.82 | 27.27 |
| 2019 | In-person | AIP | 34 | 67.65 | 17.65 | 14.71 |
| 2020 | Remote | BIP | 50 | 60.00 | 4.00 | 36.00 |
| 2020 | Remote | AIP | 33 | 81.82 | 9.09 | 9.09 |
| 2021 | Remote | BIP | 53 | 69.81 | 7.55 | 22.64 |
| 2021 | Remote | AIP | 33 | 81.82 | 9.09 | 9.09 |
| 2022 | In-person | BIP | 53 | 60.38 | 18.80 | 20.75 |
| 2022 | In-person | AIP | 38 | Ongoing | Ongoing | Ongoing |

*Source*: BIP and AIP diaries (UFJ).

It is possible to note in Table 1 that the courses were offered in-person or remotely. The remote courses needed to be remote due to social distancing policies imposed by the Covid-19 pandemic. In Brazil, the pandemic affects all education levels of computing education, including graduate studies [21]. In this period (and also during the in-person return), it is a notorious increasing number of mental illness reports of students in these courses.

Aiming to mitigate this scenario, this teaching project was redesigned to support these students. Thus, the professors efforted to close to students through initiatives UFJ offers, like psychology and psychopedagogy services (both linked to official university departments) [22]. The understanding is there is a negative correlation between psychological vulnerability and the quality of academic experiences, mainly concerning undergraduate self-efficacy [23,24].

## 3 Integrating Startup Culture

Concerning undergraduate activities, the teaching project aimed to improve the quality of the learning-teaching process. At UFJ[3], the teaching project is described as a set of pedagogical support actions to amplify the chances of academic development, enhance undergraduate formation and guarantee their inclusion and stay [25].

In this context, this project emerges of the need to engage new students in computing programs to mitigate retention in BIP and AIP courses and, consequently, the dropout. In 2022, the project came to include the Entrepreneurship course developed transversely with BIP during the first academic semester.

It is essential to highlight the idea of a startup culture concerning student protagonism in knowing the next's (and theirs') pain and propose an innovative solution. In this way, they are guided to build compatible solutions to their studies during the academic semester, generating value and improvements for society. In other words, they are provoked to seek a purposeful sense in their careers. Besides this, some characteristics are covered during the project as agility and flexibility, typical to the innovative and entrepreneurial ecosystems. The project is developed in yearly cycles and foreseen a sequence of steps (see Fig. 1).

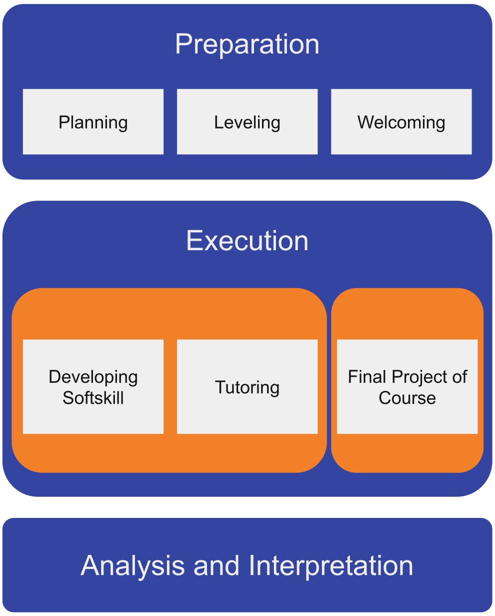


**Fig. 1.** Steps of teaching project "Integrating the Startups Culture into IPCs".

[3] Federal University of Goiás (UFG) is the university tutor of UFJ, that was created by the break-up of UFG, according to Brazilian Law No. 13.635 of March 20, 2018.

The preparation consists of class planning using a semester teaching plan. In the first days of classes, students answered a questionnaire aiming to provide a diagnostic evaluation of the content. During the welcome, a set of actions was performed, enabling the well-being of students at the university. Thus, besides the presentation of the teaching plan and UFJ culture, this step consists in presenting places like the library, the business incubator, psycho-pedagogical support, among others.

In the first meeting, the project is already presented to students. It is part of the course evaluation called the Final Project of Course (FPC). FPC consists of steps from problem identification to the proposal of a computational solution conceived from required content in courses employing learning by doing [26].

During the semester, the student doubles are composed to conduct the tasks from leveling and observation data. Using an active methodology, the doubles develop pair programming [27] with the navigator and pilot roles. In this setting, the most experienced student acts as a navigator (making suggestions), and the less one codes.

Still, special attention is given to the monitor practice during the semester. In this approach, the students attend the second shift to reinforce the lab contents or conduct activities concerning FPC. As there is a knowledge unevenness among students, the most experienced students help the monitor to solve the doubts.

Finally, at the end of the execution step, it happens the FPC evaluation. The teams present a pitch and all software artifacts produced to an examining committee composed of experts that assess the dimensions of innovation, business, and technology. Soon after, the analysis and interpretation step concerns tabulation and data analysis from leveling form filled out during observation and expert assessments. It is essential to highlight that the records are made in each class and monitor meetings, occurring the developing following of students.

## 4 Experience Report

This report presents the challenges and surpassing lived by the participants of the teaching project under the teacher's lens. Aiming to allow future replications and comparisons of activities offered in case studies, it suggests the reports identify some central elements of intervention [28]. In this way, we describe the demographic dimensions of both teachers and students that make up part of the intervention. This information is available in detail on the online repository of this project[4].

The preparation consists of elaborating, approving, and disseminating teaching plans for BIP and AIP. The documents approach the curricular content and comprise theoretical and practice classes, bonus activities, and FPC. This step occurs before the beginning of classes.

In the first BIP classes, we ask students to fill out a form to identify their knowledge level about programming (e.g., "What are loops"?). Beyond this,

[4] Available in https://github.com/bispojr/ufj-teaching-project.

observation notes are made of students during the classes, besides monitoring activities to situate their maturity level concerning the content. This is a fundamental step because there is considerable difficulty in teaching BIP and AIP due to students' heterogeneity. Although some students dominate programming, others are in touch for the first time.

The newcomers' welcome is another crucial point during the BIP course especially. For many students, this is a critical period when profound transformations occur (like city moving, establishing new relationships, knowing the university culture, etc.).

Unfortunately, after the pandemic, it noted a decrease in students' mental health. In 2022, a project reformulation included a set of actions concerning welcome and integration. Among these actions, we can list: (i) a guided visit to *Flor do Cerrado* library (UFJ), (ii) a lecture entitled "Care of Mental Health", and (iii) a set of lectures related to entrepreneurship and innovation. Figure 2 refers to students' visit to the library to learn how to access it in a traditional way (e.g., studying, getting books) and in an alternative one (e.g., resting, playing chess, watching a movie from the catalog).

**Fig. 2.** Lecture for students in the *Flor do Cerrado* library (UFJ) on March 26, 2023, in a different schedule of their classes.

In respect of the care of mental health, there is a significant concern about BIP students' welcome. The BIP target public is composed of newcomers in the majority. After the sixth week of classes, a "chat circle" with the psychology and psycho-pedagogy service team of UFJ happens. This date is chosen intentionally to guarantee simultaneousness with the first exams of students. Figure 3 registers the moments when this chat circle occurred in 2022.

**Fig. 3.** "Chat circle" about mental health conducted by the psychology and psychopedagogy service team of UFJ on September 19, 2022.

In the execution phase, besides teaching content to form hard skills of students, emphasis is also given to soft skill development. During the practical classes, the pair programming method was adopted, consisting of an agile technique when two students work together in the same workstation. The pilot student (lesser experienced) codes while the navigator one (most experienced) observes and suggests improvements (see Fig. 4). There was a rotation among students for different colleagues that allowed a socialization throughout the semester. Beyond this, the lab activities included challenges, promoting more complex tasks to students with an advanced level of programming.

**Fig. 4.** AIP students are doing pair programming activities on February 27, 2023.

Still, during the execution phase, another important aspect to highlight is the monitoring practice. It consists of the selection of student-monitor and the elaboration of their activity plan. This plan comprises activities like (i) helping during lab classes, (ii) giving support to low-performance students in counter shift, (iii) participating in weekly planning meetings with the professor-tutor, (iv) assisting in the preparation of exercise lists, and (v) aiding in student advising on potential participation in scientific events as both listener and author.

It was offered a bonus in the final grade of students that participated in 100% of monitoring meetings. This is a strategy to promote more student participation. It is important to make some considerations about this bonus: (a) there was a significant increase in looking for monitoring meetings with an average presence of 30% of students, being half obtaining the extra grade; and (b) there was a large participation of students that dominated and/or had more easily to learn the content (they attended aiming to help the monitor to assist low-performance students and interesting in applying for the monitor selection next semester). Figure 5 registers BIP students participating in monitoring meetings.

**Fig. 5.** BIP monitoring meeting on September 2, 2022.

For the co-creation of FPC, strategies and methodologies of agile development (like Scrum) helped in soft skills and competency improvement (e.g., learning to manage time, establishing appropriate communication, and increasing resilience). The final moment of the teaching project occurs when students present the FPC in a demo-day style. Students are guided about the project from the first class and stimulated to form teams. Throughout the years, it noted several students dropped out of the course, leading, by consequence, to discourage other team members from continuing. Due to this, in BIP 2022, it was careful to establish teams only after the grade publishing of the first exam (about loops). It was interesting because a group created in the later future in introductory courses has more chances to persist to the end.

In methodological terms, definitions of problems/pains to be approached are already worked on from the first weeks, including entrepreneurship courses. Yet at the beginning of FPC development, a presentation about Scrum [29] pointed out notions about development teams, deliveries, and deadlines. Thus, during the FPC conduction, a period was dedicated to building software artifacts and short meetings (sprints) between each group and the professor to discuss the project development progress, allowing us to see the deadline fulfillment. During the FPC algorithm building, students were provoked to look for solutions from the perspective of learning by doing. In other words, given a functionality that needs to be implemented, they looked to reinforce the concepts presented in the classroom or even develop a proactive attitude to learn the new and necessary knowledge to assist in their project.

At the end of the semester, the minimum viable product (MVP), pitch, runnable code, source code, and pseudo code are presented in a demo-day format. Thus, students are assessed by an examining committee composed of three members responsible for three distinct and complementary dimensions: technology (computing professor), business (software factory representative), and innovation (member of innovation and research sector of UFJ).

Figure 6 registers a student moment during their pitch presentation, englobing the problem/pain, business model, and the differential of the proposed solution. About MVP, it is a solution prototype and is composed of algorithms and software built throughout the semester, being evaluated only by technology experts. In this case, it is important to emphasize that algorithms are received in advance, and previous code analysis is performed due to the limited presentation time.


**Fig. 6.** BIP student was presenting the FPC pitch to an examining committee in technology, innovation, and business on December 5, 2022.

On October 31, 2022, students presented their team composition during a theoretical class. The team themes/titles are (i) Any Animals (pet manager), (ii) classroom allocation, (iii) Hassie-freeing BIP (teaching platform with BIP contents); (iv) E-commerce for rural manufacturers, (v) Bus queue manager, (vi) Child hall manager (with emphasis to disability children), (vii) routine manager (similar to agenda), (viii) smart wardrobe, (ix) platform for teaching of programming logic, (x) Auto Info Portal (solution to choosing a car).

It is essential to highlight that students were free to choose the theme and the solution name. The only reservation was the subject should be relevant and evoke interest for all team members. Thus, the proposed solutions approached the familiar pains of scheduling a type of service for disabled children. This solution aimed to identify the hairdresser the child had more confidence in, for instance. Although some titles could suggest using a web platform (like e-commerce for rural manufacturers), the solutions were limited to the content of the courses.

Due to the high number of teams, it defined that each group would have a maximum of seven minutes to present their FPC, approximately two minutes for the pitch, and five minutes for the code. Next, the examining committee would have five minutes to discuss their solution.

All presentations occurred on December 5, 2022, and students were assessed in (i) a collective (by innovation and business experts) and (ii) an individual way (by technology one). A raffle defined the presentation order before the first presentation. Each committee member completed a form with questions about each dimension (innovation, business, and technology). This information also is available in detail on the online repository project (See Footnote 4).

## 5 Final Remarks

This paper reported the teaching project 'Integrating the Startups Culture into IPCs" from the professor's perspective. This project aimed to support students and, as a consequence, reduce retention and dropout. This project is developed yearly, but it began to be developed transversely, including AIP, BIP, and entrepreneurship courses since 2022.

With the return of in-person classes, it noted a decrease in students' mental health. From this finding, in 2022, it was a project redesign to include a psychological welcome. Beyond this, it established partnerships with the library sector and business incubator for providing lectures or doubt clarifications to project participants, aiming to offer a welcoming environment.

About pair programming, almost all students participated spontaneously. But it is essential to highlight that two students requested not to participate in pilot-navigator activities. We suppose they did not occupy the navigator role because they had programming skills. According to the report of one of them, he would not have the patience to teach and prefer not to participate. However, they did the FCP with their team, and the activity division was successful. A possible hypothesis is that team members had a more homogeneous knowledge, and they did not force themselves to teach their colleagues.

Regarding the bonus (extra grade) to participate in monitoring meetings, there was a high looking for by students. In AIP, students had at their disposition two monitors with scholarships, and 100% of the students who got extra grades were successful in the course. In some cases, a student achieved the maximum grade after receiving the extra grade.

The projects were relatively simple from a computational viewpoint justly because these students were newcomers. However, the proposed solutions were sophisticated for students in introductory courses. In other words, given a limited set of computational resources and concepts, they got to develop satisfactory solutions for self-suggested scenarios.

Therefore, it is possible to conclude that this teaching project promoted a learning environment that allows students to assimilate computational concepts to solve real problems. Moreover, from data disposed of in Table 1, there was an increase in approval numbers, converging for one of the purposes of this project.

At last, from chosen themes and talks to students, it noted attitudes more engaged in the entrepreneurial profile and, in a certain perspective, ethics. They put themselves in a protagonist condition, looking for and proposing solutions to a problem and contributing to the well-being of individuals in society. It is possible to assert that this project contributed to the formation journey of professionals more adapted to a fast-changing world boosted by digital transformations.

From future perspectives, innovation and entrepreneurship concepts can also be explored in complementary activities, aiming to develop and improve other skills and competencies. We see potential to prepare our students from the program beginning to glimpse future possibilities to incubate a startup idea in our technological park.

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# Academia-Industry Partnerships

# Managing Students' Expectations in a Challenge-Driven Learning Environment

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**Abstract.** Understanding students' learning experiences is valuable for educators to correctly manage and adjust students' expectations towards their learning [1], especially when working in a challenge-driven learning environment. Moreover, within higher education exploring undergraduate students' expectations and preferences in teaching, learning, and assessment can support teachers in exploring different learning methods and techniques, which can reduce the gap between theory and practice, creating a balanced and engaging learning environment. Current challenges in higher education include reducing the gap between academia and industry, using challenge-driven learning, flipped classrooms, and student-centered learning with real-life problems has become a method to deal with such challenges. However, such approaches do not come without new challenges, such as an increasing gap between the student's practical approach to completing a specific project, and the general theory essential to the profession. This study aims to gain a deeper understanding of students' perspectives and expectations when learning theoretical aspects of software engineering in a challenge-driven flipped learning environment over a period of 6 months at a 25% learning pace, the learning environment also consists of several different elements including student peer learning and incremental assignments. By benchmarking student-learning expectations during several surveys, what can be indicated is that students' expectation early in a course relies mostly on presumptions based on previous course assessments and students' current knowledge. Early results indicate that student learning preferences and expectations include that 75.6% of the students expect to learn as much as possible new things about software development via solving real-life problems. As a conclusion, the results indicate the driving forces behind utilizing challenge driven in an educational learning environment and the potential obstacles met by learners. Relies mostly on the learner's expectations, therefore, managing these expectations has the potential to reduce the barriers between theory and practice, which can lead to creating a balanced learning environment.

**Keywords:** Challenge Driven Education · Flipped Classroom · Students' Expectations

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## 1 Introduction and Background

There has been a growing interest in learning approaches where students are collaborating and interacting with external stakeholders, in which collaborative and cooperative learning are key elements in the process of successful knowledge and practical experience acquisition. To do so previous research [2–6] has investigated the various pedagogic format that can be used to support this learning approach, such as flipped classrooms, peer learning, and agile learning. It can be established that these various approaches are associated with challenges [2, 7, 8], including limited student preparation before class, time-consuming, difficulty in managing tasks, etc.… However, a common challenge that these various approaches can have in common is managing student expectations and its impact on both the student's educational experience and teaching effectiveness. This paper presents findings from an ongoing case study involving in an engineering education challenge-driven course, where student groups collaborate on a software engineering project in a flipped classroom-learning environment. The course is part of the second-year bachelor program in Computer Science at the KTH-Royal Institute of Technology, Sweden. The course has undergone different iterations to increase attendance rate and student engagement, and motivation, and close the gap between theory and practice. The case study presented in this paper focuses on presenting students' expectations both before and after participating in the course, concerning the course learning goals and learning environment. The process of learning software engineering skills can be abstract and in some cases not applicable for students to learn [9]. This could be due to different aspects of the learning environment, such as the choice of assessment methods and course syllabus.

The Software Engineering course included in this case study consists of 211 computer science students in their second-year bachelor program for six months, starting at the end of the fall and spring semesters. The course aims to introduce students to the theory and practice of software engineering; the main activities are formal lectures and a group project. The course learning outcomes include

- Describing different development methods for software.
- Appling appropriate methods for design and implementation in modern software development.
- Appling established principles of production of the documentation necessary for planning, implementing, and delivering software development projects.

To achieve these learning outcomes and to reduce the gap between theory and practice, the course has introduced in recent years a flipped and student-centered learning approach, where all course theoretical material is recorded and available for students with the course learning management system LMS. Moreover, during the course, students have the opportunity to choose both their group members (creating groups of 7/8 members) and the company client which are selected by the course responsible and presented to the student groups in a course catalog. The catalog consists of various clients and organizations with various projects ranging over different scopes in the field of software development. Moreover, students are assessed as a group and no individual grading, this is done with the support of a team of teaching mentors, where an average of 10 mentors are required, and mentors are assigned an average of three groups. The role of the mentor is to support the groups during the duration of the course, offering technical and planning advice, in addition to giving feedback on different course assessments. The course assessment consists of three main elements, which are:

1. Iterative written project reports, using an agile assessment approach [10, 11], which promotes communication, collaboration, and continuous improvement. The approach also fosters self-managed teams where student groups work on one main project report that is assessed over three milestones during the course duration.
2. The second form of assessment includes student groups presenting their project work twice during the course durations, where groups focus on two main aspects in both presentations which are a) the product; in which groups include enough models/information to make the customer/audience understand their product. In addition, b) the process; where groups explain the execution process/method used, how they implemented it, and how they perceived it. This assessment aims to focus on group communication and presentation skills.
3. The final form of assessment during the course is in the form of Student Conference Seminars (SCS) [12]. The objective of these SCS is to create a self-directed learning environment for the students, where groups choose a single SCS topic from a scheduled list of topics that are based on software engineering activities that are relevant to all groups. All SCS are organized into one-hour sessions where students are not meant to focus on theory, but instead the practical plans and experiences from the groups' perspective. And draw on examples of how and why the topic was included in their project work, relating their own group experience to the topic and interacting with the student audience participating with questions and feedback in a relevant way [12]. Hence, these various assessments aim to support both students and mentors to deal with the various challenges associated with external stakeholders and support the student's ability to handle wicked problems. Therefore, during the case study it was important to understand the students' experiences working in groups, how would they rate their overall ability to work in groups? Moreover, reflect on their group learning activities and on learning software engineering topics.

## 2 Method

The case study presented here is part of an initiated of an earlier case study which accumulated reflections and observations made while teaching students software engineering practices in higher education. Moreover, this case study is part of a larger study investigating the various elements such as to test and evaluate the effects of changing the learning framework of the course from a traditional lecture environment with project-oriented assignments to an agile/self-directed learning environment, with a project accumulative knowledge assessment. The following represents an overview of the proposed study framework that was used in the overall study (see Fig. 1):

1. Exploratory phase of design concepts, including the proposed learning techniques, and methods used in the course with the focus on creating an agile learning environment.
2. Analysis phase of the design process, or methods to capture the experience of the students while being exposed to this new learning environment

3. Evaluation phase and reflect on the different reflections captured, to identify the potential result [12].

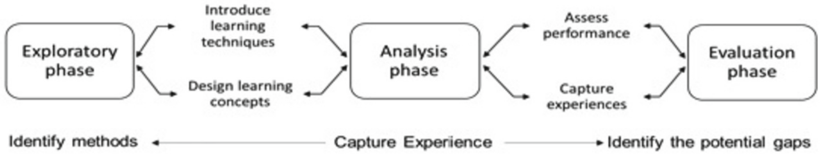


**Fig. 1.** Study framework that was used in the overall study.

As illustrated in Fig. 2, the current case study focuses on the analysis phase, hence the focus is to understand students' experiences during the software engineering course, their attitudes towards different learning methods, and their understanding of different skills and knowledge required in software development. To do so it was important to understand the student's perspectives regarding the main components that the flipped classroom consists of which are; a) the student communications skill within a group project b) the student group seminars and c) the overall course structure. Therefore, the analysis was divided into two main stages, which are:

- Stage one: Assessing Performance; capturing the student's self-assessment
- Stage two: Capture Experiences; gaining a deeper understanding of the student's learning preferences

## 2.1 Data Collection

The following section describes the data collection used during this case study the survey questionnaires were organized based on the two stages mentioned earlier and digitally distributed to 212 potential participants. To capture and understand the important aspects and challenges, the students encountered when learning in an agile learning two voluntary anonymous surveys were conducted. The first was conducted before the course student and the second follow-up survey including the same questions was conducted after the course ended. In an initial survey before the course started 212 students, 55% (117) responded to the survey, while 46.2% (98) responded to the survey at the end of the course.

- Stage one: During the first stage of the data collection, the survey focused on capturing the student self-assessment by focusing on; a) their perception of their communication skills, and b) their group skills including the ability to work in a team and their ability to learn from their peers. The aim of capturing this data was for students to self-reflect on their individual skills and preferences, such as what they valued the most when working on the project in groups during the course. Hence, capturing the student's learning expectations can rely on the various group dynamics and therefore can influence the student learning experience.
- Stage two: During the second stage of the survey, it was important t to gain a deeper understanding of the student's perception of learning software engineering skills

before the course started and to capture their experience when the course ended, such as what they consider to be important to learn regarding software engineering. While at the end of the course, students were also asked to give feedback regarding the course layout including (Projects, Student Seminars, learning material, etc.). In addition, to what degree they thought the course layout is suitable for learning software development?

## 2.2 Data Analysis

The survey results were analyzed using an inductive quantitative method, where data coding is performed in a bottom-up approach starting with no codes and developing codes during the analysis of the datasets, allowing the theory to emerge from the raw data itself [13–16], Fig. 2 illustrates an overview of the data analysis method.

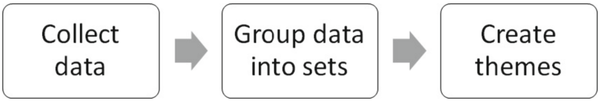


**Fig. 2.** Overview of the data analysis process.

To create coding themes the survey data needed to be grouped into data sets, which were;

4. Detect changes in attitudes and perceived communication skills.
5. Investigate the different experiences of learning in a group.
6. Capture students' learning experiences.

Figure 3 illustrates the coding theme created and how aids the case study in gaining a deeper understanding of the students learning expectations.

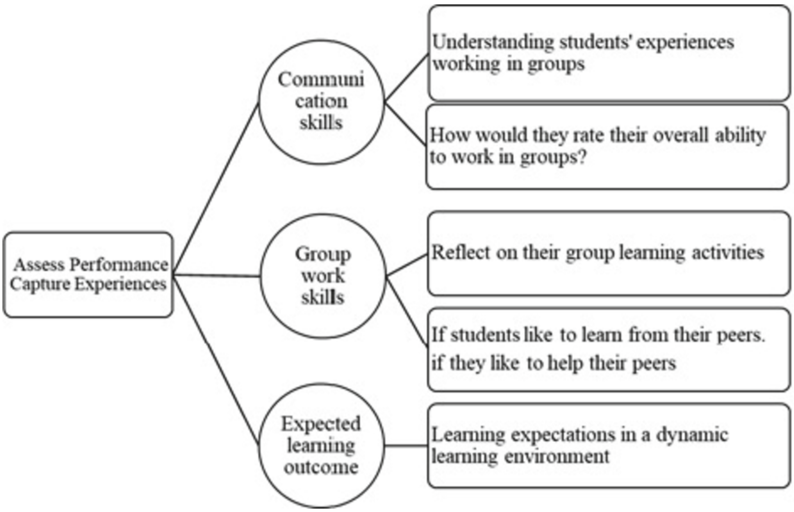


**Fig. 3.** Overview of the data sets and themes

## 3 Results and Discussion

Measuring students' expectations is the focus of this case study and is based on the coding map explained in 2.2 of the method section, focusing on students' communication skills, group work, and expected learning outcomes. The data was analyzed by investigating the student's reflections when the course had ended and comparing them to their perspectives before the course started.

### 3.1 Communication Skills

To gain a deeper understanding of the student's reflections on their communication skills, which is a core aspect of collaboration in a challenge-driven learning environment, where students work in groups; students were asked to reflect on their overall ability to communicate with others. As illustrated in Fig. 4, initially what can be observed in the survey data is that the majority of the participants (20.5%) with a score between the ranges 7 to 10.

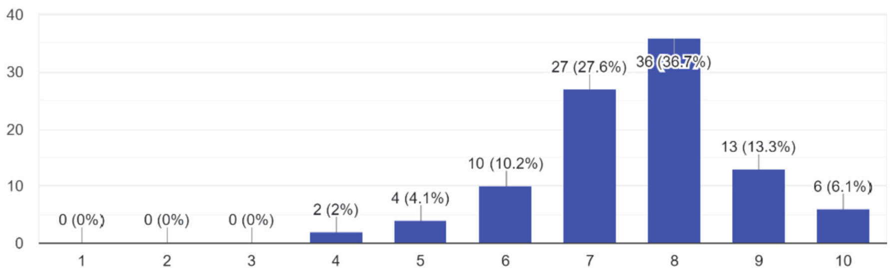


**Fig. 4.** Student reflections when asked how would they rate their overall ability to communicate with others.

When in compression to before the course started and when asked the same question, the average response was 21.25%, thus students overall had higher expectations of their ability to communicate before the course started. Furthermore, students were asked to leave anonymous comments in the survey after the course ended, what can be highlighted is that several students emphasized this question and reflected with the following comments:

– *"It has been nice and has required a lot of communication on all parts."*
– *"I learnt a lot about how to work and communicate in a group, the benefits, and challenges that come with it, which I believe are valuable lessons for the future."*
– *"The aspect I learnt the most about was communication with clients and the balancing act that has to be performed by engineers caught in a crossfire of politics, different ideas, and aims for a project."*
– *"Being 8 really made a difference. Not only do you have to adapt to other peoples working methods but also learn how to structure, plan and communicate within the project. You realize how important those factors are."*

### 3.2 Group Work Skills

When capturing student reflection on group work and their experiences before the course started and again at the end of the course, taking into consideration that the course extends over a period of 6 months at a 25% learning pace. This aspect of the learning environment was divided into several different questions. The first question focuses on students' perspectives if interacting and learning from their peers is important when provided with the options: Strongly disagree, Disagree, Neutral, Agree, and Strongly agree. An average of 49.6% strongly agreed before the course started while only 44.9% strongly agreed when the course ended. Indicating that student expectation regarding peer learning has decreased. It can be interoperated that peer learning is difficult in a challenge drive learning environment and could need more support, (See Fig. 5).

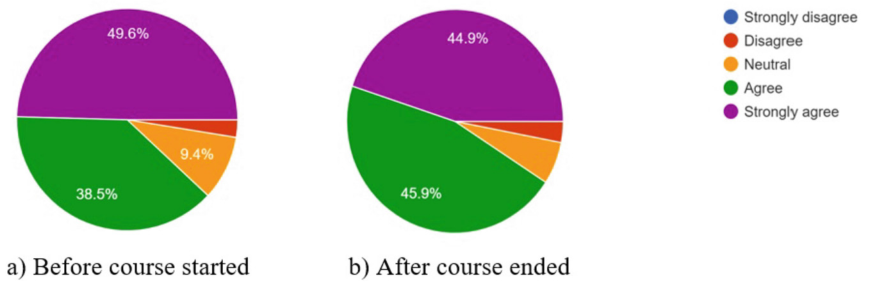


**Fig. 5.** Benchmarks students' reflections, when asked about their preferences when learning from peers

The second question focused on whether or not they like to collaborate in groups, a majority before the course started had a positive attitude associated with 61.5% agreeing and strongly agreeing to work in groups. 30.8% were neutral in their opinion and an average of only 6% had a negative perspective on working in groups. While after the course, 63.2% agreed and strongly agreed to work in groups, and 5.1% with a negative response, as illustrated in Fig. 6.

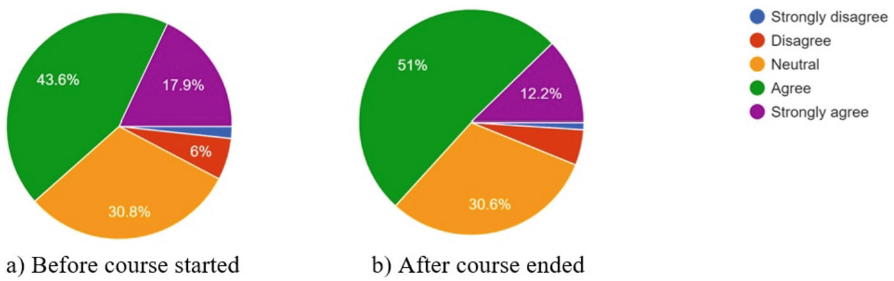


**Fig. 6.** Illustrates students' reflections when collaborating in a group.

Indicating a majority of the student's expectation of collaborating in a team environment was higher than what they expected in the presented learning environment. Further results indicated that an average of 81.6% found that working with others supported their learning, which was less than 80.3% before the course started. In the anonymous comments, what can be highlighted is that several students commented on the impact of group collaboration as a fundamental software engineering skill, as presented in the various comments below:

- "I learnt a lot about working in a team and collaborating with others, and also how to use software methodology to work on a software project."
- "Most importantly this was the first time I got to work in a group that was larger than four people and the mechanics are completely different when you are 8 compared to when you are 4. This really gave me a feel of how software development might look like in the future ".
- "I also learned about agile development and feel confident about joining another team project."
- "The process of cooperating with group members, dividing up work, communicating with a client, making a report and presentation was all very relevant and valuable"

Indicating overall that the course learning environment and course elements support group learning.

### 3.3 Expected Learning Outcomes

To gain a deeper understanding of the students with a focus on learning software engineering topics. To do so three main questions, providing students with options the questions were:

1. What students' preferences were to learning software development?
   Introducing a different course setup and introducing new learning activities they thought would support them in learning software engineering concepts. Students were asked to choose only one of the options provided. The result of the surveys illustrated before the course started was that students' expectations to learn from solving real-life problems was 65.8% where that percentage decreased to 63.3% after the course ended, indicating that the project alone is not the only source for learning. It can also be noted that the percentage of learning by traditional lecture decreased from 5.1% to 3.1% indicating that students agree with the flipped classroom since the course had removed all traditional lectures and provided other forms of lecture material, such as recorded lectures, lecture notes and web links, etc… Finally, what could be indicated that googling information as an option increased from 4.3% to 10.2% indicating the need for the course to include more web links, learning material and useful tips to support students in their learning, details in Fig. 7.

1. From the comments collected from the students, what can be noticed was that students had a positive attitude toward the learning environments, emphasizing the course setup, as shown in the anonymous comments below:

   "It was an interesting and good way of learning about software development, instead of traditional lectures about it."

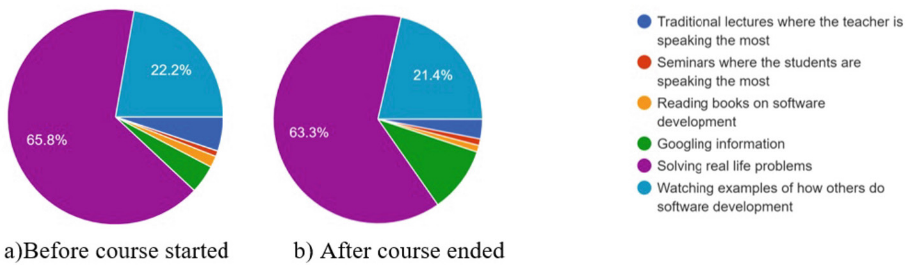


**Fig. 7.** What do students think is the best way to learn software development topics?

"I think it was a good way of learning about the topics. It was also nice to see how the other groups had done and take inspiration from them."
"It was fun. Not only did you learn much about different topics but also what other people have done in their projects and how they solved problems and worked as a team"
"Interesting but probably missed a lot of information about other topics since I only went on the obligatory ones but I believe that this was very common though."

2. What students thought they valued most when working on a group project. The objective of this question was to capture the students' attitudes and learning expectations students were asked what they value the most, and given the option of choosing three alternatives that they thought were necessary to have. The three options that showed an increase after the course ended were.
   a. Developing a functional product which increased by 18,6%
   b. Pleasing the client, had an increase of 11,4%
   c. Passing the course increased by 24%
      When taking a closer look at the student comments what can be highlighted was that students valued learning from other groups, this occurred during group presentations and group seminars. As listed in the anonymous comments below:
   d. "It was interesting to learn how other groups work and the differences from my group's experiences."
   e. "You get a better idea of how to do your group project based on real theory and not just based on what you already know about working in teams"
3. The final question, focused on what student's thought were the most important qualities of software engineering. This question aimed to identify the student's expectations when learning software engineering topics, and which skills they thought were important. Students were provided with a list of options that they chose the three most important qualities from their perspectives. When comparing students' responses before and after the course, what can be noted is that the following qualities had a higher percentage at the end of the course.
   a. Being able to learn new things increased by 6,2%
   b. Being able to plan the work well and keep deadlines, increased by 3.1%
   c. To work well with others in the group, increased by 1.5%
      What was interesting what students valued less as a software engineering quality, included:

d. Knowing how to code in many programming languages, decreased by 0.7%
e. To deliver exactly what the client wanted, decreased 10%

From the collected comments what can be observed that students were able to comprehend the course learning goals better at the end of the course, as presented in the comments below:

f. "I learned about what it takes to develop software, it's not about just coding, it's about collaboration, mutual work and understanding, planning and executing. It's a complex process"
g. "It's been useful to have a mentor that can guide us through the development and let us independently learn methods and apply them to our project so we can naturally learn how to use these well. It has been nice and has required a lot of communication on all parts. I have learned a ton of leadership and such."
h. "It was a fun experience. Both to meet and connect with new people and to be a part of something bigger than just pure schoolwork with real-world impact. I learned new skills and aspects about both front and backend, but also how to work in a big group of people in a proper and organized way."

Overall results of the survey indicate that students' expectations of the course were overall positive and the comments indicate that a majority of the student agreed with the learning environment and that it supported their learning expectations regarding the topic of software engineering.

## 4 Conclusion and Future Work

The overall aim of this case study was to measure student expectations when being introduced to this new learning environment. Moreover, if it supported students learning, bridging between theory and practice, and focusing on learning software engineering skills, students worked in groups of eight with the support of mentors to follow up on their project progress and project challenges. By introducing a flipped classroom and peer learning as an approach to reduce the gap between theory and practice, what can be concluded is that the course-learning environment did have a positive impact on the student learning experiences, and overall did meet their expectations, students' reflections emphasis and various software engineering practices such as implementing risk analysis, planning and collaborating. In addition to group presentations and seminars, students reflect on theoretical topics from their own project experiences. Future work will investigate deeper the role of the mentors, and clients on students' experiences when learning in a challenge-driven environment. Moreover, future work aims to investigate the impact of the seminars as an approach to peer learning in a flipped classroom.

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# Strategic Design Under the Vision of Students, Companies, and Experts. A Teaching Process in Higher Education

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**Abstract.** This article describes a new Strategic Design teaching process for students in the Bachelor of Design program at Tecnologico de Monterrey, Campus Monterrey. We developed the process to have three stages: Situational Analysis, Foresight, and Generation (SAFG), and an application sequence in which students developed a project for a real client, which in this case was a product or services company. As part of the methodology, we proposed the process to three professors who teach the subject of Strategic Design and two experts in the subject to adapt and validate the stages. Next, we implemented the proposal during a semester to a group of 25 students, divided into 8 teams. At the end of the course, the students answered a survey instrument. To complete the investigation, student teams interviewed a representative of the company involved in their projects. A correlational analysis of the student survey was compared with the company representatives' opinions to corroborate the process's value. Also, the results were contrasted with the information obtained from the experts to corroborate that the process did have the expected impact. The conclusion was that the students and companies found significant value in the process. The students identified the Foresight stage as the most difficult and the one they appreciated as the most valuable in the process. However, company representatives found greater value in the Generation stage.

**Keywords:** Strategic Design · Higher education · Educational innovation · Academic/Industry Partnerships

## 1 Introduction

Over the years, companies have adopted different approaches to design, perhaps because they must define the activities the designers will carry out and how they will insert the design into the company's organizational structure. The peculiarities of the designer's profile and the design's importance to the company are major considerations. Perks et al. [1] investigated how the activities of the designer could become incorporated into the company, resulting in (a) design as an element within a set and as part of a process; (b) design (or designer) integrated into a multifunctional team, where each member has a similar value, and the result is due to the synergy of teamwork; and (c) a guide for the

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product innovation process, where the design directs the actions and all the decisions revolve around the values and principles proposed. Design participation penetrates the company, going from less to more, impacting its organizational structure and strategic vision.

Claudia Acklin and Hans Kaspar [2] proposed an interesting approach, suggesting three levels of design to be present in a company, which constitute the main ways to incorporate it. The levels are a) corporate strategy level, where incorporation occurs through design planning after market research and analysis of user/consumer needs by qualitative or quantitative methods; b) corporate culture level, where the attitude towards design can be built through awareness of the strengths of design as a strategic resource. It involves fostering a climate of innovation and creativity within the company, where design can coordinate all the expressions of the company at the points of customer contact; c) new product development level, where design managers include design competencies in the early phases of the project plan and manage the interface with other departments such as marketing, production, and sales. Once the design has passed through these different levels of penetration in the company, the strategic perspective emerges [3], and the adjective "strategic" is added to the design.

Under the above context, Strategic Design (SD) is an area within the design discipline where designers practice their knowledge and skills in strategic decision-making within companies or organizations [4]. However, it implies establishing the objectives to guide decisions, prioritizing between desirability and possibility [5], and expressing the vision of the future impact. This approach becomes complex when the designers' contributions to strategic decisions must consider what users or people want or could want, what is technologically possible now or in the future, and what the company can offer through its available resources [4]. The visualization of alternative possible future scenarios supports strategic decisions [6]. Also, the company must have various tools that help it prepare for unexpected events and face uncertainty, as in the Scenario Analysis method [7], which helps companies anticipate the changes that can occur in industry [8].

Notably, the strategic design (SD) comes from the company's strategic planning, giving it two advantages during its implementation: differentiation and competitiveness, which align with the organizational strategic objectives in an innovative approach [9]. Hence, Calabreta and Gemser [10] differentiate SD from other designs by its inclusion in formulating and implementing the company's strategies. If the design focuses on the result without considering a strategic vision, it triggers a short-term result that tends to be inertial and reactive concerning the market and the competition [11].

According to McCullagh [12], several misconceptions about SD include that designers intend to assign the label "strategic" to any design project just because it involves a vision of the future. Another misconception is that the SD is based solely on a market trend or visual language which can be developed without being linked to the company's strategy. In this sense, McCullagh [12] proposes that the SD must have five key elements, including first, a perspective of the general panorama of what is happening with the industry, technology, the consumer's point of view, the state of the technique, and other aspects with which the designer must be familiar; second, a rigorous analysis of information or data that supports a credible strategy; third, a correct synthesis that creatively fuses the information, knowledge, ideas, and assumptions within the core of strategic thinking; fourth, a framework to structure the problem with all its constituent elements in a way that generates a common point of view for all involved and enables sound decisions; and fifth, a real implementation plan that puts the strategy into practice and considers all the steps.

Based on the above, SD should involve full co-knowledge of the company's capabilities [13] in terms of strategic planning, i.e., goals, objectives, and deployment of resources in the short, medium, and long term, to ensure that the design response is forceful and has a lasting effect that generates greater business development. In the same vein, Caliskan and Wade [14] propose an update of the Actor-Network Theory in which they suggest that the analysis of the interactions among devices, actors, representations, and networks supports the operability of strategic design in organizations so that challenges can be resolved consistently, obliging designers to clearly understand what the company considers important, identify how they can contribute, and effectively communicate the potential of their contributions [15].

Beyond the importance and key aspects of SD, many approaches to its teaching and methodological considerations contribute to achieving the expected results. Reviewing some of the curricula of different universities worldwide, both at the undergraduate and graduate levels, reveals significant variations in the topics addressed, the magnitude of the projects, the methodological approach, and the duration, among others. Thus, university learning experiences must link effectively with reality [16, 17]. It is even sought that design students become familiar with the language companies use to refer to organizational issues. However, the main co-knowledge that students receive in universities is about the design process and not about how their designs contribute to the company that commissions them or the main objective of the product, service, or experience they were commissioned to design, especially at the undergraduate level.

Based on the above, we created a process that would allow product design students to develop an SD project linked to a real company with the support of the professor, addressing at different stages throughout the semester whether it is possible to generate a realistic learning experience that would provide sufficient value for the company, thus reinforcing different learning alternatives [18]. This proposal also aimed to identify the key elements considered by the companies for the project to contribute to decision-making or the achievement of strategic objectives. Additionally, this research aimed to check whether the timing of connections and feedback with the company is adequate and relevant for the project's impact.

## 2 Methodology

### 2.1 Description of the Process Proposed in This Research

The proposed research method is called SAFG, an acronym for its three stages: Situational Analysis, Foresight, and Generation (see Fig. 1).

**Situational Analysis Stage**

In the Situational Analysis stage (Stage 1), the customer (a company or organization) is identified. Then, the elements of strategic planning [19] are analyzed (mission, vision, competitive advantage, values, scope, objectives, and strategies), and also the competitive

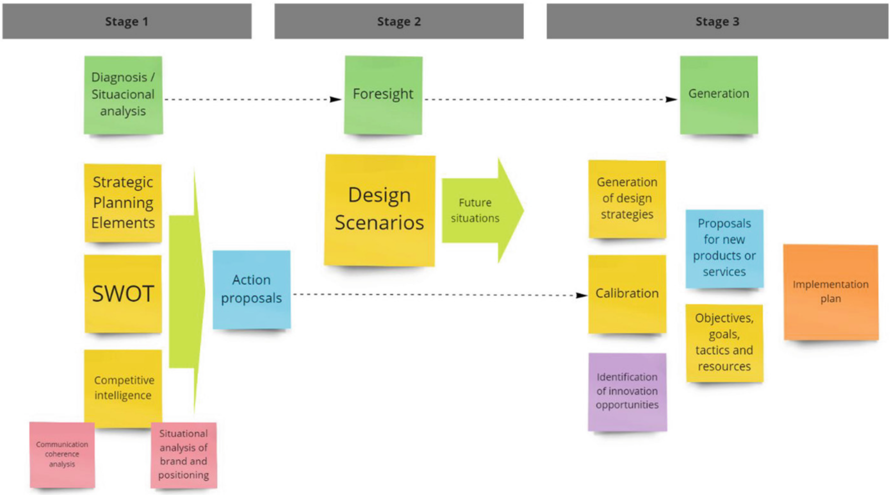


**Fig. 1.** Diagram of the SAFG process.

position, considering the brand and the products or services to then apply a SWOT analysis with a cross-checking of variables that make it possible to generate actions to address threats and minimize or overcome weaknesses. This analysis diagnoses the company's current situation [20].

**Foresight Stage**

In the Foresight Stage (Stage 2), we used the proposal of Gutierrez et al. [9], suggesting executing this process in three stages. In the first stage (Visualize), the participants identify and analyze the key elements of the company's strategic planning and PESTE analysis. They set guidelines on the approach to take in the process and visualize the future context of the PESTE dimensions within the year of study [8, 21]. In the second stage (Connect), it is necessary to understand how people would live in such contexts within a determined period and their interactions within the system, and identify user needs independently from economic and technological parameters to focus the system on those usage needs from the human perspective. Finally, in the third stage (Proposal), they suggest design solutions for the users' needs, integrating technology and materials and creating new design languages. With the execution of this process, it is possible to establish the future situations the company could face to have the basis for the next stage [22].

**Generation Stage**

In the Generation stage (Stage 3), the aim is to develop part of the strategic actions related to the designer's competencies [22] by calibrating the actions derived from the SWOT in Stage 1 and the results of Stage 2 for future situations. This makes it possible to define which actions will impact the strategic objectives and achieve the company's vision [4]. On the other hand, innovation opportunities are identified that the company can leverage with the rest of the actions. In Stage 3, the participants outline the design strategies [23, 24] and develop the product or service concepts that emerged in Stage 2. These concepts involve basic design actions such as user understanding, requirements definition, collaborative work, prototyping, and validation [25, 26]. Likewise, the concepts developed in the stage or timing of the strategic planning become executed.

At the same time, the strategy implementation plan or tactical plan is developed [12, 27], which aligns the strategic objectives with the goals, actions, resources (material and human), and costs; these are scheduled in a Gantt chart.

## 2.2 Implementation

The implementation of the process occurs in three moments: Previous, During, and After (see Fig. 2 diagram of the process). First, (Previous) a literature review allows for generating an updated proposal of the process to follow [28]. In our study, the initial version of the generated process was presented through semi-structured interviews with three professors who teach SD at Tecnologico de Monterrey and two experts to validate the stages and activities and make adjustments [29]. In these interviews, the professors and experts answered questions about their professional experience, their conception of SD, how it can be differentiated from other types of design [17] (such as user-centered design), and specifically, about the stages of the process, the extension, the number of aspects considered, and the differences that could exist between an educational approach versus professional practice.

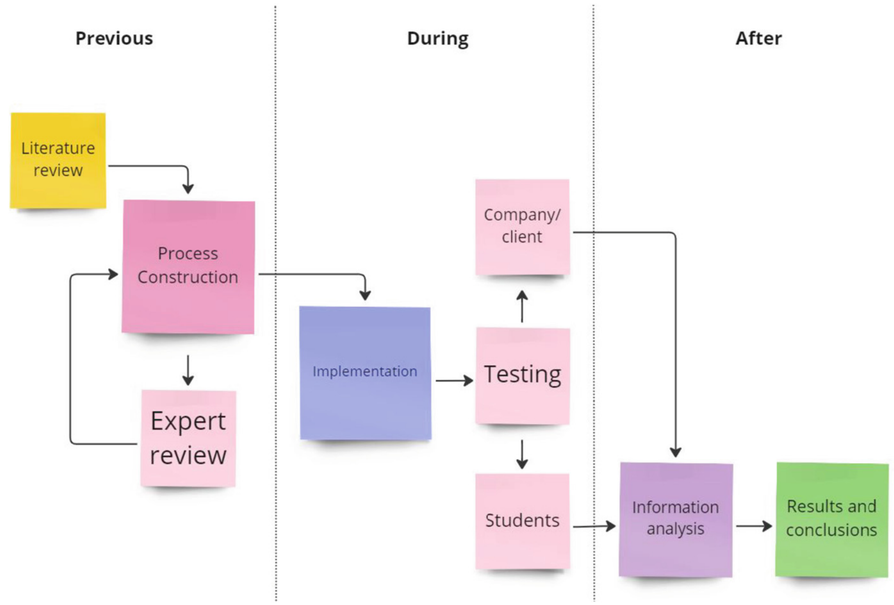


**Fig. 2.** Methodology sequence diagram

The proposal was then applied during a semester to 25 students in the Bachelor's Degree in Design program at Tecnologico de Monterrey, Campus Monterrey, in the

Strategic Design course (During), who grouped into 8 teams [30]. Each team contacted a company or organization willing to follow the process throughout the semester and carry out the project. The project had to consider the generation of products or services as part of the result. In addition, students had to present progress reports and ask for feedback from the company at the end of Stages 1 and 2, after the calibration of the strategic actions, and at the end of the process as a final presentation or closure of the project, so that the project became a theoretical and practical learning experience [16]. Throughout the semester, students received theoretical information (through lectures, reading articles, reading cases, and internet searches) and advice from the professor on the topics required for each stage and activity of the process [31].

### 2.3 Evaluation

The students answered an online survey instrument with dichotomous and Likert scale questions [29] at the end of the course [30], which sought to measure the impact on their learning, the value of the project linked to the company, the difficulty of the stages, the notion of knowledge about the SD, the general appreciation of the process, among other aspects.

A semi-structured interview [11] was conducted with the company representatives (eight people, one for each company) at the end of the semester. During the final presentation, the students asked them about their appreciation of the SAFG, the dynamics of activities and stages, the follow-up, the veracity of the diagnosis made by the students, the congruence of the proposals generated by the students with the company's plans, and the feasibility of implementation. The interviews were transcribed and analyzed using an affinity diagram [28].

Finally, a correlational analysis [30] was applied to the students' survey and compared with the companies' representatives' opinions to corroborate the process's value. The results were contrasted with the information obtained from the students, the company representatives, and the opinion of the experts from the previous stage.

## 3 Results

**Results of Student Surveys**

First, we analyzed the information obtained from the student surveys to establish the research results. One of the first aspects to investigate was their prior knowledge about DS, and 85% said they did not know what it referred to. Then on a scale of 1 to 5 (where 1 represents "not at all" and 5 represents "a lot"), the students answered how much they had learned strengthened their knowledge on the subject; 25% responded 5, 50% rated it 4, and 20% answered 3, which clarified their perceived impact of what they had learned versus what they knew before starting the course.

The students were asked which of the stages they considered to be of greatest value to complete the process successfully, and 55% stated that all stages have the same value; in second place was Stage 1 with 25% value. This result became more relevant when the students were asked which stages presented the greatest challenge, and 50% answered Stage 3, where they must synthesize all the information and generate proposals for new products or services. Other questions about the time and activities for each stage (see Fig. 3) resulted that for Stage 1, 85% thought that everything was correct, and similarly, for Stage 3, where 80% had the same opinion. However, there was a difference in Stage 2 (Foresight), where the percentage of positive perception dropped to 75%. This result aligned with the responses about which stage they would change or modify; 40% stated that they would modify Stage 2, while 30% stated that they would not change any of the stages.

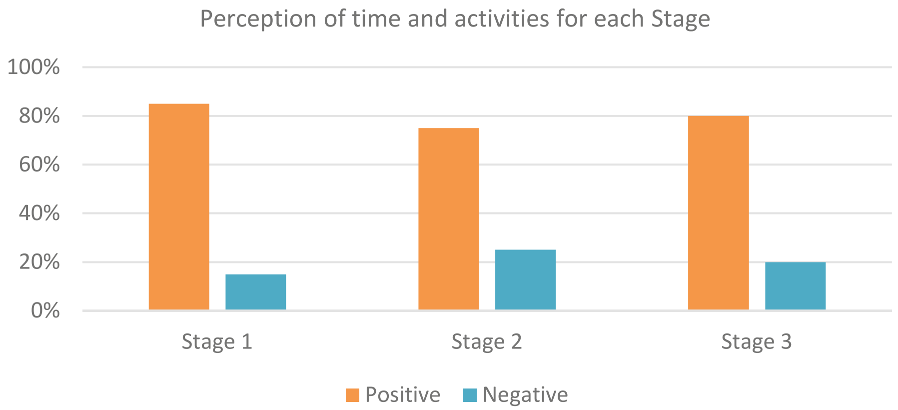


**Fig. 3.** Comparison of perception of time and activities in each process stage.

The students were asked about their perceived complexity of the whole process on a scale of 1 to 5 (where 1 is not complex at all, and 5 is very complex), to which 40% rated it 5 and 25% rated it 4, reflecting a very high perception of complexity, since 30% rated it 3 and only 5% rated it 2. Despite this result, when asked about their satisfaction and preparation level to face new strategic design projects, the students evaluated them very positively; the majority rated these between 4 and 5, as seen in Fig. 4.

On the other hand, the students were asked about the impact of the company's participation in the project's development. In this regard, they responded to the value they gave to the company's participation and the feedback they received in the project's final presentation. In participation, on a scale of 1 to 5 (where 1 is not at all valuable and 5 is very valuable), 60% rated it 5, 25% rated it 4, and 15% rated it 3. Regarding positive feedback, the responses improved (see Fig. 5): 65% rated it as 5, 30% as 4, and only 5% as 3. As can be seen, no responses were negative, and the value of the process stood positive.


**Fig. 4.** Comparison of the level of satisfaction with the result and the level of preparation to solve strategic design projects.

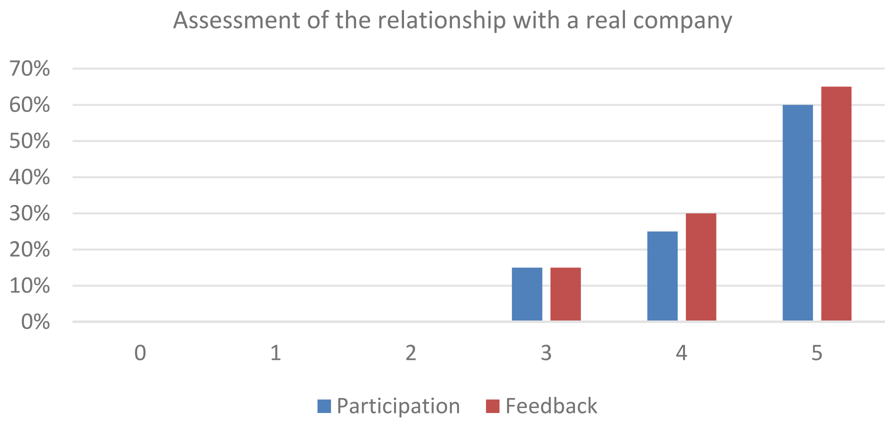


**Fig. 5.** Relationship between the assessment of the company's participation in the project and the feedback.

Finally, despite the sample size, the students who said they knew about SD considered Stage 2 negatively and stated that Stage 1 was of greater value. Likewise, the students who rated with the highest score that SAFG strengthens their knowledge stated that they would not change or repeat any stage of the process and that they would do everything the same in a new project.

**Results of Interviews with Company Representatives**

In the case of the interviews conducted with the representatives of each of the eight companies that participated, all agreed on a positive assessment of the process, highlighting the different stages and how they allowed progress from one to the next. However, two companies stated that they used other methods to analyze the competition and were not necessarily aware of market trends.

When asked about the follow-up given to the project, the majority (six of the companies) agreed that they had difficulty scheduling meetings with the students and, in some cases, had to send the information by e-mail first and then hold the meeting. Regarding the process stages, five companies identified Stage 1 as being of great value because they had not noticed all the issues that arose in the situational research. Likewise, all of them considered Stage 3 very relevant because this is where the proposals for action and the implementation plan generate.

Notably, four companies said they had never analyzed the future to identify new opportunities, so the scenario design seemed very timely. All the companies agreed that the proposals were very relevant and aligned with the company's capabilities, so they were feasible to carry out. However, only three stated that they would follow up to implement those actions they considered most relevant in the short term. Nevertheless, the companies said they were very pleased with the professional level of the students and the quality of the work presented and were grateful for the commitment shown throughout the process to achieve success.

## 4 Discussion

The results indicated that the students and companies found significant value in the SAFG process. The students identified, among other things, that the Foresight stage (Stage 2) presented greater difficulty than the others; however, they still assessed it positively, although lower than the other stages. The students' perception of complexity seems biased by the topic's novelty because 85% had commented that they did not know anything about it; therefore, the topics and the SAFG process challenged their efforts to comply with the activities.

The results also showed that the linking of the projects with real situations was of great value for the students, highlighting the weighting assigned to the participation of the company representatives and the feedback received from them, which aligns with the work of Vignati et al. [16] and Brown [17].

Concerning company representatives, they found greater value in Stage 1 for all the situational research and in Stage 3 for the relevance of the results presented by the students. Still, it is striking that some companies said that they did not perform analyses of the future, which may be related to a lack of knowledge of these analyses' value, or perhaps they lack personnel dedicated to identifying opportunities for new products and services. It was possible to identify a relationship between the opinion of the professors interviewed and that of the students and companies concerning the relevance of knowing the current situation of each company and their growth objectives and the importance of a sequence of actions following a logical order to reach a valuable result.

## 5 Conclusions

This research determined that the SAFG process provides Strategic Design with a fundamental approach. On the other hand, the participation of the companies in the Strategic Design teaching process is key for the projects to end up with viable proposals that the companies can easily adopt. It is important to emphasize that although the research continues with other groups of students to expand the sample, the results generated up to this point give certainty to the proposed process, but further analysis of the data collected by the applied instruments (the student surveys and the interviews with company representatives) can shed light on other correlations that were beyond this level of the research.

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# Hackathon Approach for Students Evaluation at a Software Engineering Course – Preliminary Results

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**Abstract.** This paper explores hackathons as an evaluative tool and their contribution to students' learning. Mixed-data collection methods/qualitative and quantitative data collection were used by conducting a survey among students and semi-structured interviews among hackathon juries and organizers. Results have demonstrated that hackathons can be used as evaluative tools alongside exams. From a student's perspective, hackathons supply positive motivation and are less stressful while enabling students to demonstrate their knowledge in a work-like environment. From the organizer's perspective, hackathons require more effort in terms of organization whereas less effort is needed in handling of evaluation and grading. This work provides guidelines to address potential challenges and organize a hackathon as an exam replacement or part of the exam. This study advocates that the evaluation steps described in this paper could constitute a solid basis to develop a formal evaluation strategy to be applied to similar future events. The paper provides preliminary results that were collected in a rigorous manner. Future work should target a larger sample size to draw more firm conclusions and generalize to wide academic settings of software engineering programmes.

**Keywords:** hackathon · students evaluation · motivation · software engineering education · survey

## 1 Introduction

Hackathons are *hack marathons*, i.e., events where computer programmers and other IT experts collaborate on the design and development of software projects. The objective of conducting a hackathon is to create functioning software within a limited time, i.e., hours or days, via intense teamwork. In our educational practice, a hackathon is an intensive team exercise dedicated to reveal student's creativity, to energize learning and to practice course methods and tools in an industry setting. We name this event a *hackathon* with the goal to motivate students through gamified exercises and an encouraging environment, friendly competition among the teams, an award ceremony, and an after-party.

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The systematic literature review performed by M. Tikka [15] demonstrates the growing interest in hackathons in academia. Given the massive and sudden changes that have appeared in the educational field since the year 2020 [9], it is natural to start investigating what the roles of such events could be in the educational process. Many studies report positive results from incorporating educational hackathons into software engineering curricula; however, little focus has been given on evaluating hackathons as an evaluation technique. This study investigates the extent to which hackathons could be effective in assessing the knowledge and learning skills of students in higher education. We particularly focus on two research questions (RQ):

– RQ1: Can hackathons replace exams for the course's final evaluation?
– RQ2: What are the benefits and limitations of hackathons as compared to exams?

We analyze the perception of participants towards hackathon events via a survey. The survey participants are students who responded to questions aimed at revealing their attitude towards the hackathon they attended in an academic setting at an information technology university. Furthermore, the survey aimed to uncover students' understanding of hackathon's effectiveness for learning and evaluation purposes.

The results of this study serve a dual purpose. Firstly, understanding the perception of hackathons in the target academic setting will provide valuable insights for effectively integrating hackathons into the educational process. This understanding can contribute to enhancing the educational experience. Secondly, sharing these findings with the scientific community will enable other organizations to contemplate the potential of hackathons and consider embarking on their own experimental courses.

The paper is organized as follows. Section 2 provides an overview of the relevant literature and previous research. In Sect. 3, the motivation behind considering hackathons as a replacement for traditional exams and the setup of hackathons are discussed. Section 4 presents the examination of hackathons from both the perspective of organizers and students, along with preliminary findings. Guidelines for organizing hackathons are outlined in Sect. 5, and the discussion and conclusion are presented in Sect. 6.

## 2 Related Work

Hackathons have been used by colleges and universities as an innovative educational and promotional tool. Hackathons, run before the course start, raise the interest of prospective students and attract them to join a college program [8,17]. Hackathons as part of the course can be organized as a one-time event to motivate students and boost their performance [3]; as a series of hackathons being integral part of a course aimed to foster understanding course material and enforce its practical application [1]; as an integral part of a capstone course to facilitate capstone projects completion [16]; as a one-time condensed 24-hour event where students develop their final course projects [4]; as an extracurricular activity, aimed to improve students soft skills and employability [5].

Using hackathons as an educational technique has been researched from several perspectives. Porras et al. [10] discuss their experience organizing educational hackathons and reflect on the role of hackathons in software education as well as the benefits that educational hackathons provide to their stakeholders. The authors conclude that educational hackathons teach students real project skills. Moreover, the authors argue that hackathons can be used as an evaluation method, yet the idea is not explored. Steglich et al. [14] use hackathons as a pedagogical strategy aimed at engaging students in software engineering practices. Gama et al. [4] suggest a methodology for organizing educational hackathons. Krüger et al. [6] have analyzed the outcomes of a large hackathon event and concluded that digital hackathons have substantial learning outcomes. Steglich et al. [13] highlight that hackathons can be used to practice knowledge and skills that students have previously developed while providing significantly limited opportunities for developing new skills. In another study [14], the authors conclude that hackathons are suitable for the evaluation of student's knowledge in a real project setting. Affia et al. [1] studied integrating several hackathons into a semester-long educational course. Although many researchers have studied the organizational aspects of hackathons and the advantages they bring to the educational process, their focus on using hackathons as course evaluation events has been limited. In the work of Affia et al. [1] a final report on all three hackathon results contributed to the student's course grades, however, the hackathons served as an integral part of the course rather than an evaluation event. Porras et al. [10] argued that hackathons may serve as an evaluation tool, yet do not elaborate further on how to do so. We aim at closing this gap and investigate whether hackathons can replace course exams and what the advantages and limitations of hackathons can be compared to exams.

## 3 Hackathon as Exam

While teaching graduate programs in software engineering, we noticed a disconnection between evaluation methods, such as exams, and effective motivation strategies for technical individuals. As students progressed in their graduate-level courses and gained industry experience, their motivation to prepare for exams dwindled. In response, our objective was to explore methods for revitalizing the final evaluation of the course, transforming it into a memorable event that would inspire students to showcase their abilities and skills. Drawing from both the literature review and our own positive experiences in organizing research project hackathons [12], we believe that hackathons have the potential to create an engaging and invigorating learning environment.

Over the course of four consecutive years, we conducted a series of hackathons, and now we aim to generalize this experience by proposing the idea of replacing exams with hackathons. To exemplify this concept, we present the case of the "Quality In Use" hackathon [11] that we organized in April 2022, which embodies our best practices and methodologies.

**Outline.** In the context of the Quality In Use hackathon, students conduct an audit of an open-source project. Nowadays, open-source software components are deployed in the majority of industrial projects. We engage with the industrial customers by offering them an audit for open-source components of their interest. We collect and shape industrial cases, so that they fit to the course context and are feasible for students. We gather the information about the customer's primary focus for the quality requirements such as, for example, performance, security or maintainability.

The topics are published one week before the hackathon. Students register their teams of 4–5 members and select a case. They are encouraged to start as soon as possible and contact the customer of the case in order to get familiar with the context and the quality requirements that apply to the case.

On the hackathon day, we gather all teams for 4 h of continuous effort to conduct the experiments and prepare an analysis. This is followed by an audition in front of a jury represented by customers, course instructors and external experts. We ensure that at least three jury members evaluate each team. Teams give a 10-minute presentation and reply to questions. The work is evaluated by the jury with the following criteria:

1. Understanding of the business context and quality requirements;
2. Technical findings through applying the course methods and soundness of analysis;
3. Quality of presentation.

The proposed event provides plenty of opportunities for collaboration between students and industry. In the same time, the audit analysis requires creativity in many tasks including:

– Developing quality requirements based on quality attributes and properties specified by customers.
– Choosing methods and tools for experiments to verify quality of open-source components and conduct an analysis. This choice is not predefined.

**Duration.** Porras et al. [10] indicate that hackathons may exercise an extreme pressure on participants that can even be harmful to participants' health. In order to cope with this issue, we deliberately limited the whole event to one working day, i.e., 8 h in total, including an introductory session, 4 h of team work, breaks, presentations and award Ceremonies. The teams are invited to start working as the cases selection is published, so that they have a time to prepare at a slower pace. However, due to high load during the preceding week the main experiments and analysis activities are conducted during the 4 h of intense work at the hackathon day.

**Organization.** We set the hackathon date as a major event. We organize breakout rooms, coffee breaks throughout the day, and a pizza party at the end of the event. All participants receive certificates of participation. Customers distribute companies' branded perks. The winning teams receive symbolic prizes like t-shirts with the course quotes.

Our goal for this setup is to shift the perception of the final evaluation from an exam style to a memorable event style. Hence, we motivate the students to give the best of their efforts, show their knowledge of the course material and beyond, as well as practice soft skills like communication, teamwork, time management, and presentation. Therefore, the objective is to replace the anxiety of an exam with a positive excitement for creative task solving in a friendly team competition.

**Course Grade.** The hackathon is integrated in the overall course grading in the following way. We evaluate students on the course with lecture quizzes, individual labs and course-long group project. The hackathon is the final group assignment that represents 20% of the total course grade. Overall, we balance individual and group assignments on the course to avoid the group bias. Students are free to choose individual only or group assignments, since it is possible to validate the course without participating in group assignments. However, they are highly encouraged to participate in group exercises to practice team work and communication - the essential skills in software engineering.

## 4 Examining Hackathon - Perspective of Students and Organizers

We evaluate the perception of hackathons from the perspectives of the organizers and students. For that, we collected both qualitative and quantitative data and assess them in their context to draw conclusions. We conducted face-to-face interviews with hackathon participants, in addition to a survey with the students who participated in the hackathon.

### 4.1 Preliminary Findings

This section provides preliminary results, collected in a rigorous manner. These initial findings are based on the feedback collected from the students and organizers of the hackathon and are stated in detail as follows.

This current study analyzes quantitative and qualitative data obtained using a survey conducted with the student participants of the hackathon and interviews with hackathon instructors and mentors [2]. In total, 102 students participated in the hackathon. 70 bachelor's students in their fourth year took the course Software Quality, Reliability, and Security, and 32 master's students in their first year took the course Analysis of Software Artifacts. Out of 102 participants, 60 (59%) filled in the questionnaire.

Questions were designed to evaluate assumptions that our team formulated before the hackathon. In essence those assumptions are:

1. Hackathons provide higher motivation to students to recap and apply their knowledge as compared to exams.

2. Hackathons help to practice soft skills.
3. Hackathons better prepare for future job in industry.

On the negative side, we had concerns that hackathons may be more effort-consuming for students and the evaluation may be more biased and subjective than those of exams.

The survey for the students included 25 questions, the first of which was a qualifying question about the level of study of survey participants. The further 20 questions were single-choice questions, most of which were using a Likert scale ('Strongly disagree', 'Disagree', 'Agree', 'Strongly agree', 'No opinion' choices). The rest of the questions were open questions to collect additional qualitative information from the students on the skills used during hackathons, their feelings experienced during hackathons compared to their feelings during exams, and feedback on further improvements to the hackathon.

Personal interviews with hackathon instructors and mentors had a semi-structured form and aimed to reveal insights on the effectiveness of hackathons as course exams. Collecting data both from the participants and organizers assists in establishing connections between the needs and wants of the students and those who could potentially implement the hackathon method as a course exam practice. Identifying the factors that may be critical for students in the transition from traditional exams to hackathons as exams and matching them with the factors that assist the organizers to adapt such a practice can establish a hypothesis for further research of the feasibility of the adoption of hackathons by academia.

In addition, the qualitative method provides a better understanding of the implementation features of hackathons as course exams, as the organizers have met the challenges of conducting a hackathon. Thus, they share their insights, especially as applied to the realities of academic exam practices in terms of knowledge evaluation, resources, and time needed.

### 4.2 Survey Data Analysis

This section summarizes survey data containing participants' feedback on the hackathon [2]. 90% of participants considered the hackathon overall a positive experience. One participant was indecisive and one disagreed and did not consider it a positive experience. 78% report having more motivation to learning/revising course concepts compared to exams.

Mostly, the hackathon was appreciated for its various benefits, elaborated as follows. We asked participants if hackathons helped them practice content that the traditional classroom environment usually does not cover. 70% have learnt new material related to the course.

All students have practiced soft skills. These include team management, communication, collaboration, and negotiation. In particular, 68.3% report applying creative thinking. Participants also agreed to a greater extent that they could avoid the topics that they did not know well in the hackathon. Traditional exams reduce this possibility.

In regards to emotional experience, 37.7% of respondents report their motivation as high at the hackathon compared to 10.3% at exams (6.8% for negative motivation at the hackathon vs. 51.7% at exams). Participants listed all sorts of emotions, from excitement, motivation, and relaxation to stress, boredom, and challenge. The participants who felt stressed highlighted their dissatisfaction with the task they performed. Some stated that they felt the task was more theoretical than practical. Therefore, we realize that there is a need to concretely study the task from both theoretical and conceptual dimensions as well as the practical workload before finalizing it for the hackathon project. Students felt anxious as they knew that a part of the grade is dependent upon their successful completion of the task. Additionally, students stated that they would prefer lectures to include a greater emphasis on practical topics. Hence, students would feel more prepared for the hackathon exam. For upcoming hackathons, the presence of lectures that demonstrate engaging projects for participants is essential during the hackathon exams.

Based on the analysis of questionnaire responses, we evaluated our assumptions about the potential benefits and limitations of hackathons versus course exams. Responses regarding hackathons' benefits are in line with previous studies and declare that hackathons facilitate learning through positive motivation, provide opportunities to develop soft and hard skills, and improve students' self-confidence and employability. 78% consider that the hackathons prepare for a future job, while 66.7% report to gain confidence in applying course methods in industry. These benefits pertain to hackathons in general, and go beyond those that serve as course exams.

At the same time, we evaluated the potential benefits and limitations that hackathons serve as an evaluation tool. For students, hackathons take less time for preparation and participation and are less stressful compared to exams as 81.7% report they spent less time preparing to the hackathon. Hackathons' grading can be considered subjective, but so does an exam's grading. In hackathons, students may pick the topic they like and focus on the material they know better. However, the majority of students could not avoid using the methods they do not know well.

### 4.3 Interviews with Organizers

The study involves conducting semi-structured interviews [7], as a qualitative research method. Three hackathon organizers provide their insights on the hackathon experience as an alternative to exams. The participants have an academic and industrial background; they are university lecturers in CS and have experience as hackathon jury members. Figure 1 demonstrates the main distinctive features covered during the semi-structured interviews that highlight the main distinctive features between hackathon and exams. We may highlight the positive effect of hackathons as it appears less effort consuming to source cases from industry than prepare tasks for an exam. In addition, the grading is available on the spot and does not require a specific effort by the faculty. As the challenge the organizers mention the effort required for the event organization.

There is a chance that the cases do not fully cover the course material and thus some of expected course learning outcomes may not be verified. The organizers mentioned that hackathon form suite when certain areas such as software engineering courses, however this method may not be applicable to a large number of course e.g., Calculus.

## 5 Guidelines for Hackathon Organization

The interviews with organizers highlighted certain challenges for integrating hackathons as part of the exam. This section discusses how to address these challenges, to allow for designing a hackathon as an exam replacement.

***Right Topics:*** From our experience, one of the major challenges is the selection of the right format for the hackathon topics. The output of the hackathon must be related to the course objectives, the student's work must have a concrete deliverable after the hackathon; and the results must be interesting to industrial customers so that they will willingly engage in the hackathon. Many hackathons target a minimum viable product or prototype development. Our assumption is that this is unrealistic in the educational hackathon due to time limitations - 4 h for teamwork. Instead, we focused the hackathon topic on critical analysis tasks, with the presentation as the final output. We believe that critical analysis is suited for teamwork - various types of analysis can be run in parallel and combined into a set of convincing arguments for a presentation. In addition, several students' presentations may cover various analytical aspects and provide significant value to the customer.

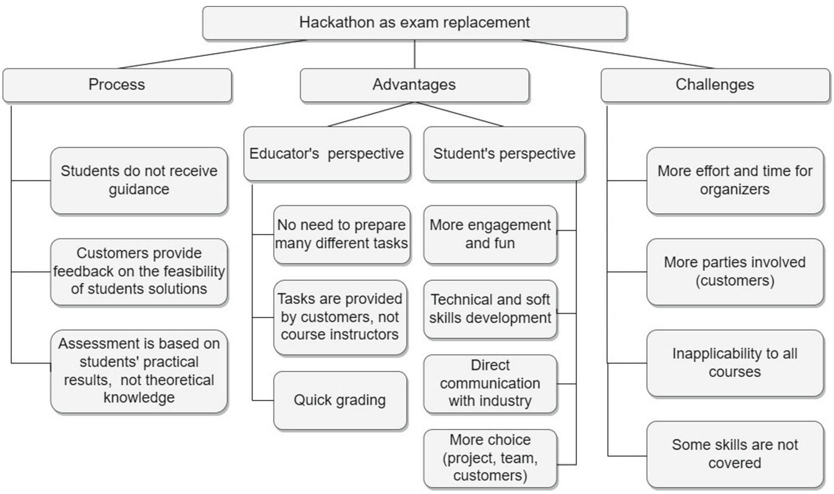


**Fig. 1.** Summary of semi-structured interviews with hackathon designers on hackathon's potential as an exam replacement

***Evaluation Procedure:*** Designing the hackathon evaluation procedure is another significant challenge. We deliberately limited the presentation time by 10 min. Therefore, the whole evaluation phase requires 2 h approximately. In addition, when a large number of teams participate, we also conduct evaluations in parallel sessions to keep the total time in a reasonable range. Moreover, we simplified the criteria to more qualitative parameters such as "soundness of analysis". This type of evaluation reveals a perception by the jury rather than an objective judgment. We believe that this is still valuable feedback and has a certain level of objectivity since the jury may compare teams pairwise. Simplifying the criteria allows the evaluation process to take place at a faster pace.

***Hackathon Versus Project-Based Evaluation:*** Our event shares characteristics with course projects. The projects are arguably much lengthier in time. We consider hackathons as a supplement to the project-based evaluation - a paramount event that concludes the course and makes students practice skills on an industry case in an engaging and motivating format.

To give an example, the bachelor students who participated in the hackathon had a semester-long project in the same course and they gradually learned and applied methods and tools. The event helped them to apply and validate their knowledge and skills in a case provided by a real customer. For the master students who participated in the event, the course load was so high that there was not even a place for project-based learning within the course timeline. With the event, our goal was to mobilize their knowledge and provide them confidence to apply methods they learned, without overcharging the course curriculum.

***Integration of Hackathon in the Course Grading:*** The last challenge is the integration of a hackathon into the course grading system. We identified the risk that the hackathons may not be fully suited as the only grade in the course due to the setup and limitations that we have briefly mentioned above. Therefore, we combine the hackathon with traditional methods of continuous evaluation with weekly quizzes and other individual assignments. Hence, hackathons can provide a complementary approach for learning and evaluation beyond traditional means.

## 6 Discussion and Conclusions

Analyzing the collected data supports our inquiry, *Can hackathons replace exams for the course final evaluation?* Hakathons can replace exams for the course's final evaluation in software engineering. Hackathons can be a form of course exam practice that allows educators in software engineering to select, when applicable, to test specific learning outcomes. This study represents a response to the growing interest demonstrated in the existing literature on the increasing interest in integrating educational hackathons to have an active contribution to the academic in software engineering.

The second research question is *What are the benefits and limitations of hackathons as compared to exams?* The integration of hackathon, as an educational tool to examine the skills of software engineering students seems to provide several benefits. A hackathon can measure and assess students' soft and technical skills; can represent a motivational tool for students to collaborate and communicate to address and provide solutions to proposed problems; can be more fun and less stressful than classical exams, as stated by a hackathon organizer *"students learn more when they have fun, and hackathons have more fun than exams"*, and can introduce a new format for testing certain skills in software engineering, when exams are unable to test, *"exams cannot test everything"*, from the perspective of an educator and hackathon organizer.

This study unfolds the limitations of hackathons as compared to exams. Hackathons do not seem to be applicable to all courses, as they cannot be the only variant to test the target skills in software engineering. Therefore, hackathons are provided as a new variant for educators to implement when exams cannot measure the attained learning outcomes. This work is important for educators in software engineering to reflect on the educational role of hackathons and investigate their potential and positive contribution to be integrated into assessing students' analytical and soft skills in software engineering. The positive feedback on the hackathon is a motivating factor for the authors to continue investigation of hackathons as exams' replacement. Other universities can also be open to reflecting on energizing their exams and utilising educational hackathon.

### 6.1 Threats to Validity and Ethical Considerations

The survey data was collected over a several-day period with the majority of participants. However, the organizers had to remind the students about the importance of the survey for the research. While everyone was explicitly informed that the survey had no bearing on the hackathon or the course grade, the flow of notifications could be interpreted as a pressure to respond.

In addition, this research can benefit from an increased sample size. The conclusions drawn are applicable in a similar context; however, the findings need to be specific to provide concrete guidelines in terms of this event's organization. Additionally, conducting several future hackathons will provide the educators and organisers with more awareness and understanding of additional challenges that both the organizers and students can experience.

An ethical consideration to address upon proposing a hackathon to replace exams in software engineering is the voluntary participation of students. Hackathon takes place on the basis of inviting students to participate in the event voluntarily. However, exams do not have the same ground rules. Therefore, proposing such a replacement should take into consideration that students will have mandatory grounds to participate. The concern, hence, can be whether this factor might influence students' motivation and consequently have a less engaging experience, providing that this freedom has been a determining factor that has contributed to making hackathons more motivating than exams from students' perspectives as reported in the study.

### 6.2 Recommendations and Future Work

This work suggests guidelines for organizing a hackathon as part of the exam and conducted a preliminary assessment of this process for its benefits and limitations. However, further studies are required to be conducted to provide larger data sets. Another recommendation is to study cross-course hackathons that rely on the knowledge and skills that students gain over several courses in the Software Engineering curriculum.

### 6.3 Conclusion

With the onset of the fourth industrial revolution, various aspects of the present educational system have been shown to be outdated. Life-changing events have occurred in the year 2020, affecting a wide range of professional fields. One of the most affected areas has been education. Institutions all across the world had to make the transition to online education in a matter of days. After this period, several teachers (including those authoring this article) have realized how crucial it is to find a different and more resilient method of assessing skills that can offer alternatives to final exams. This involves continuous assessment instead of a heavy final monolithic-grading item, typically represented by a written or oral exam. Hackathons may represent a powerful instrument in the hands of educators when efficiently utilized. This understanding has to be clearly shared by the recipients, i.e., the students. This research study examines the educational contribution of hackathons as a replacement for exams in software engineering in higher education. We propose hackathons as an integral educational tool for evaluating learning in software engineering due to the increasing positive role hackathons seem to currently play. In this article, we have conducted a preliminary study in this direction and identified a tentative positive reception by the students at an IT university. The study is based on survey involving 60 respondents. While the dataset may appear limited it provides solid insights for our research questions and deserves further investigation to reach more conclusions. So far we can safely claim that hackathons suite well for the final evaluation at the Software Quality courses, as hackathons definitely provide positive motivation to students to learn the material even beyond the course curriculum, as well as confidence to apply the learnings in industry settings. We would highly recommend to experiment with this format of final evaluation in other software engineering courses.

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# Co-creation of Interactive E-Courses by Multidisciplinary Teams of Educators-Researchers-Practitioners-Stakeholders

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**Abstract.** The article proposes model of human-centered and impact-oriented e-training course development. Multi-actor, multi-sector and multidisciplinary co-creation is considered a key factor of efficient interactive e-course development. Eco-humanistic model gives understanding HOW to manage e-course co-creation based on understanding system forming factor, content-structure pattern and mechanisms. This allows involvement, management, modeling, digitizing, simulating, piloting, demonstrating and duplicating the co-creation process. Eco-humanistic model triggers qualitative changes by ensuring synergetic interaction of diversities in multi-actor/sector/disciplinary interaction based on: a) awareness of the value of diversities for synergetic development, b) strategic orientation mechanism that integrates personal senses (needs) into a unifying goal of mutual development and optimizes the process; c) digital support system modeling existential process of multi-actor/sector/disciplinary co-development through interaction (co-creation); d) digital tool allowing to combine the diversities of individual visions reflected in the format of Ideal and Real profiles into Synergetic profile based on the innovative technology of cognitive schemas overlay. This allows creating: efficient system of digital support, multi-scale measurement of e-course efficiency; eco-humanistic developmental training programs. The digitized toolkit includes: "OmniBase" compendium of information presented in different formats with search engine based on content-structure pattern as a tool for sense-cognitive orientation both in training and co-creation activities; e-set of tools for multi-actor/sector/disciplinary interaction for synergistic solutions including Ideal, Real and Synergetic profiles of e-course; evaluation toolkit including "Multiscale filter" for assessment of solutions efficiency in terms of training environment developmental capacity and personality development efficiency.

**Keywords:** multidisciplinary team · interactive e-courses · interactive developmental e-courses multidisciplinary co-creation

## 1 Introduction

The situation being studies in the paper deals with the dependence of the e-courses developmental efficiency on the conceptual model it is based on [1]. It is urgent need to focus e-learning on the patterns of students' cognitive and personal development that requires

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multidisciplinary research [2]. It should provide understanding of the system-forming factor, content and structure in their synergy (the structure is meaningful, and the content is structured), the mechanisms of the purposeful developmental process of e-learning provided by multidisciplinary team [3]. This is the research prerequisite of the process modeling, which will allow creating an efficient e-course aimed at developing students as agents of positive changes in a new dynamic world full of ambiguity and crises [4]. Original Eco-Humanistic Model is proposed for co-creating multi-actor/sector/disciplinary human-centered impact-orientated e-course of new generation.

Unfortunately, in the field of e-learning, we are not aware of works that would investigate the problem of synergistic co-creation of diversities at the level of specific activities, based on a scientific understanding of the process of living systems development in interaction with each other and with the virtual environment. Therefore, we refer to studies that are only indirectly related to this problem in its individual aspects.

## 2 Contextualization

**Goal.** When creating developmental e-courses, the main problem is access to a "common language" between representatives of the subject area and IT developers of the course [5]. The problem is explained by different entry points to the process, due to the diversities of participants' cognitive schemes [6]. Today, this problem is even more acute, as the modern understanding of the multidisciplinary approach has been expanded significantly. The requirements for learning in general and for e-learning in particular have changed [7]. For the development of human-centered and impact-oriented training courses, it is required the involvement of not only educators, but also practitioners from the relevant sector of production or business, researchers in areas related to the subject and developmental psychology, stakeholders in relevant areas of subject knowledge and IT experts who, in turn, are also divided into developers and researchers. So, there is an urgent need for a methodology that would allow for efficient multi-actor – multi-sector – multidisciplinary interaction without losing the unique contribution of each participant in the process. The goal of the study is to create a methodology for synergistic multi-actor/sector/disciplinary interaction of educators-researchers-practitioners-stakeholders for the development of a new generation developmental e-courses. Such a methodology can become the basis of co-creation, determining the multi-impact of education on the socio-economic sphere at national, regional and institutional levels.

**Approach.** The key methodology is based on the assumption that efficient e-training interactive course is a "living" dynamic system representing developmental environment where student-environment interaction causes both the development of the training environment and a student [8]. Interaction is an engine and a system-forming factor of co-development represented by eco-humanistic model based on a holistic view of development as an existential process with its own laws and mechanisms [9].

Multi-actor, multi-sector and multidisciplinary co-creation is a key factor toward a successful interactive e-course development [10]. With the aid of scientific know-how and technology, a diversity of developers' individual cognitive schemes and practices are integrated by strategic orientation toward the cooperative development of training course as inclusive environment. The very process of multi-actor/sector/disciplinary interaction within eco-humanistic framework provides developing students' consciousness and behaviour with consideration of human-environment interdependence.

Student-developmental environment synergetic interaction is an engine of efficient co-development that demands understanding its nature, patterns and mechanisms. Cocreation content-structure pattern – a kind of symbiosis representing structure that is meaningful and content that is structured – is shown in the Fig. 1 below.

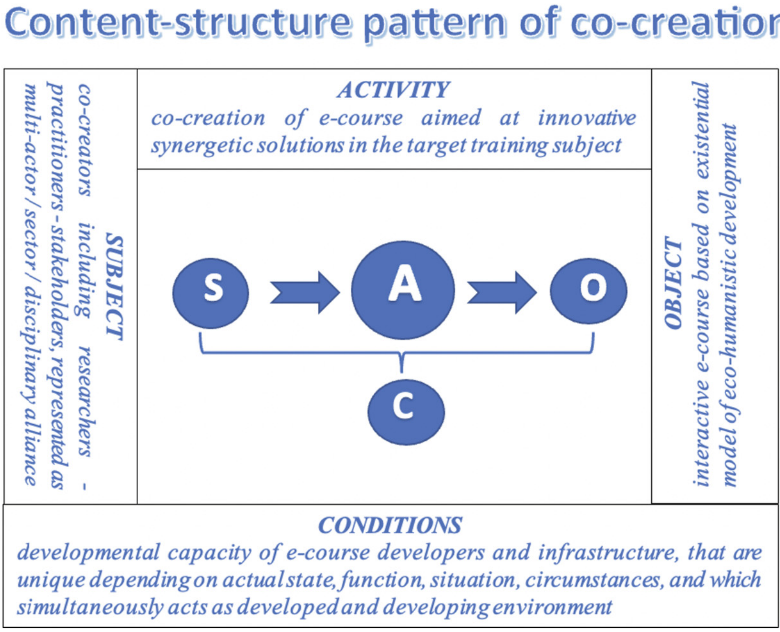


**Fig. 1.** Content-structure pattern of co-creation

In order to create the developmental environment of such complexity it is proposed the structure of multi-actor/sector-disciplinary interaction of developers that includes: (A) activity – co-creation of e-course aimed at innovative synergetic solutions in the target training subject. In our case it is proposed training by the tasks of solving problems of relevant field within project work approach [11]; (S) subject of activity – co-creators including researchers-practitioners-stakeholders, represented as multi-actor/sector/disciplinary alliance; (O) object of activity – interactive e-course based on existential eco-humanistic model realized as student-developmental environment interaction; (E) conditions of activity – developmental capacity of e-course developers as well as infrastructure, that are unique depending on actual state, function, situation and circumstances [12], which simultaneously acts as developed and developing environment. Both developmental capacity of developers and infrastructure can be improved by training-of-the-trainers intensive e-course [13].

**Actual Outcomes.** The very process of interactive developmental e-course multi-actor/sector-disciplinary co-creation needs digital support development. Eco-humanistic model allows modeling the existential process of co-creation for producing an efficient digital support system for co-creation through multi-actor/sector/disciplinary interaction, which, in turn, allows creating efficient support tools at each stage (see Fig. 2): 1) OmniBase – e-tool for sense-cognitive orientation in the activities of training and co-creation including compendium of information presented in a range of formats (text, graphic, audio, video) relevant to the subject and search engine; 2) Ideal, Real and Synergetic Profiles – e-set of tools for supporting multi-actor/sector/disciplinary solutions of the interactive developmental e-course; 3) Multiscale Filter and Motivation Matrix – e-set of tools for evaluation based on multi-scale assessment of the multi-actor/sector/disciplinary solutions efficiency in terms of environmental and personal development; 4) Continuum of Sequential Tasks – e-tool for action planning based on system organization of co-creation processes and activities; 5) Lighthouse and Demonstrator – e-set of tools for dissemination of results including their demonstration and multiplication, Manual for experts providing methodology – tools – instructions, Film – for general auditorium presenting information revealing challenges – solutions – impact.

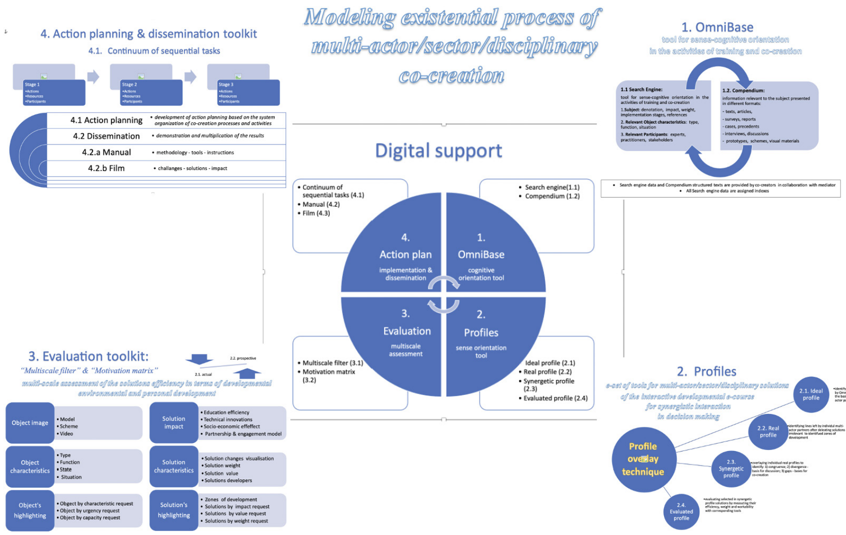


**Fig. 2.** Modeling existential process of multi-actor/sector/disciplinary co-creation

## 3 Discussion

Let us take a closer look to digitized toolkit in the logics of co-creation stages. The key problem of multi-actor/sector/disciplinary interaction of co-creators is difference in their cognitive schemes, both in terms of content and level of development. In traditional approaches, finding "common language" is time and labor consuming procedure. The eco-humanistic methodology offers a scientifically based approach to efficient synergistic co-creation through the development of co-creators' cognitive schemes within process of solutions co-creation. This development is supported by the digital instrument that sets strategic orientation to eco-humanistic development of solutions having stood the test of time and presented in the format of the co-creation process structure. "OmniBase" (see Fig. 3) – interactive cognitive resource for co-creators' orientation in the target area based on summarizing experience for co-creating multi-actor/sector/disciplinary solutions comprises: (1) search engine to find solutions in correlation with their efficiency, specified objects and HR needed. Search engine provides information by request of: (a) activity objects (O): solutions in correlation with their efficiency, specified objects and HR; (b) activity subjects (S): HR including multi-disciplinary experts – multi-sector practitioners – multi-actor stakeholders relevant to target field; (c) activity conditions (E): type, function, state, situation, circumstances. (2) Compendium of information relevant target area presented as articles, reports, case studies, interviews, precedents structured in the logics of search criteria. "OmniBase" is developed by researchers, educators, practitioners and stakeholders having unique experience, the diversity of which provides synergistic solutions in collaboration with IT experts [14].

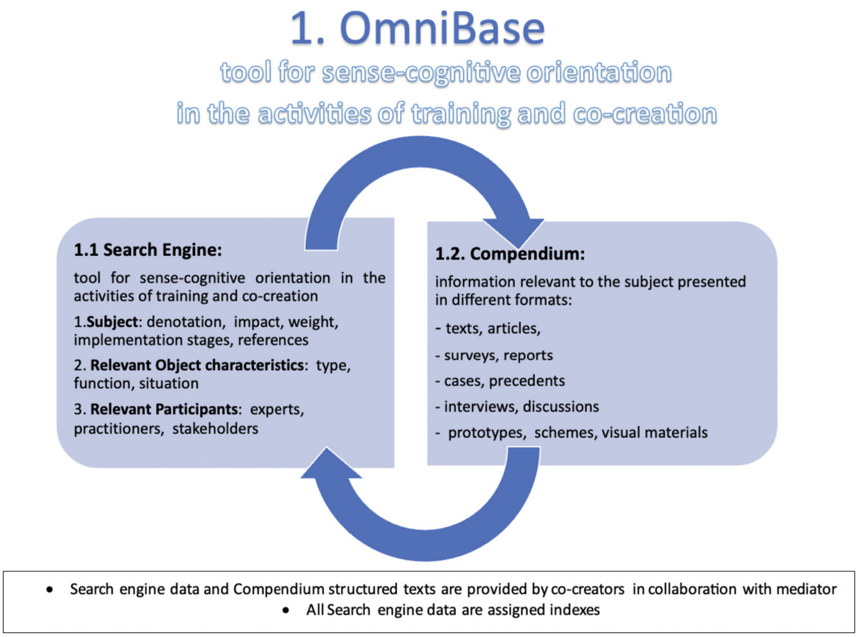


**Fig. 3.** OmniBase – tool for sense-cognitive orientation in the activities of training and co-creation

The challenge in ensuring true inclusiveness is to provide not just formal participation in surveys and discussions, but co-creation, which is possible only through real efficient motivated activities of all participants. The organization of such activities is possible within the framework of the proposed methodology, since it is based on scientifically based patterns of eco-humanistic development. Initially, a strategic sense-cognitive orientation is provided, determining the efficiency of solutions and their co-creators' development. Participants creating "Ideal profile" not only set a strategic sense-cognitive orientation but are personally involved into the process of co-creation through the specific task of building ideal and real profiles. In fact, this involvement turns participants into co-creators, identifying themselves with solutions. All this contributes to the immersion in the solutions and stimulates motivation throughout the whole process of developing and implementing solutions. Building "Real profile" allows realistic solutions through a detailed acquaintance with the conditions of the specified object, simultaneously developing the critical thinking of co-creators. Thus, activity develops the co-creator's cognitive and sense resources, thereby determining the quality of solutions.

The methodology also allows solving a complex problem that arises with collective solutions [15]: how to systematically combine different solutions into a single synergistic structure without losing the unique value of individual solutions. Within the framework of the proposed methodology, it is possible due to the original digitalized technology of cognitive schema overlay allowing to transform individualized Ideal and Real profiles into the "Synergetic profile" without losing the unique contribution of each co-creator. So, an innovative digitized technique of cognitive schemes overlay is aimed at identifying and evaluating co-creators' individual or synergetic solutions based on their attitudes, competences and needs. Profiles are reflected in Fig. 4.

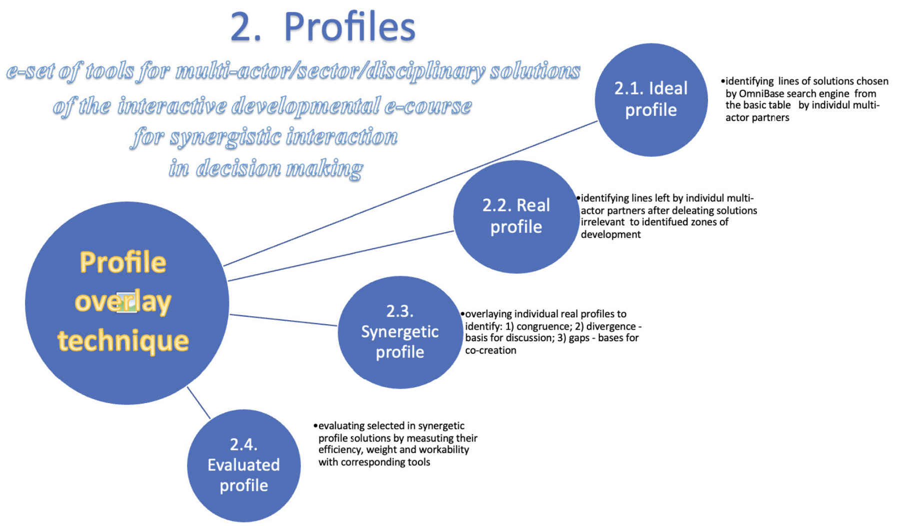


**Fig. 4.** Profiles – a set of multi-actor/sector/disciplinary solutions of the interactive developmental e-course for synergetic interaction in decision making

Stakeholders are key actors to boost tailor-made and fit for purpose solutions by developing gradually Ideal, Real and Synergetic profile in collaboration with experts and practitioners. Following the stages of solutions co-creation the experts, practitioners and stakeholders relevant to target area develop: (1) "Ideal profile" – a graphical reflection of multi-actor partners individual vision by choosing lines of solutions from "OmniBase" basic table by request supported by search engine; (2) "Real profile" – a graphical reflection of multi-actor partners individual vision by identifying lines left after deleting solutions irrelevant to the identified zones of development; (3) "Synergetic profile" – a graphical reflection of multi-actor partners integrated vision developed on the bases of overlaying individual real profiles to identify: 1) congruence; 2) divergence – basis for discussion; 3) gaps – bases for co-creation. The profile overlay technique makes it possible to identify similarities, differences, and lack of solutions. The similarity of solutions opens the way to their evaluation, implementation and dissemination. Contradictions are considered as a signal that there is a problem that can be solved within the framework of a cooperation strategy the gaps found indicate the absence of solutions that can be developed using the proposed methodology. To do this, it is proposed to resume the selection, starting from the first stage, but in application to a specific object that has not received a solution. Thus, a cyclic process of selecting solutions will fill the identified gaps in the synergistic profile and get the final solution.

Evaluation toolkit for multiscale assessment of the solutions efficiency is in Fig. 5.

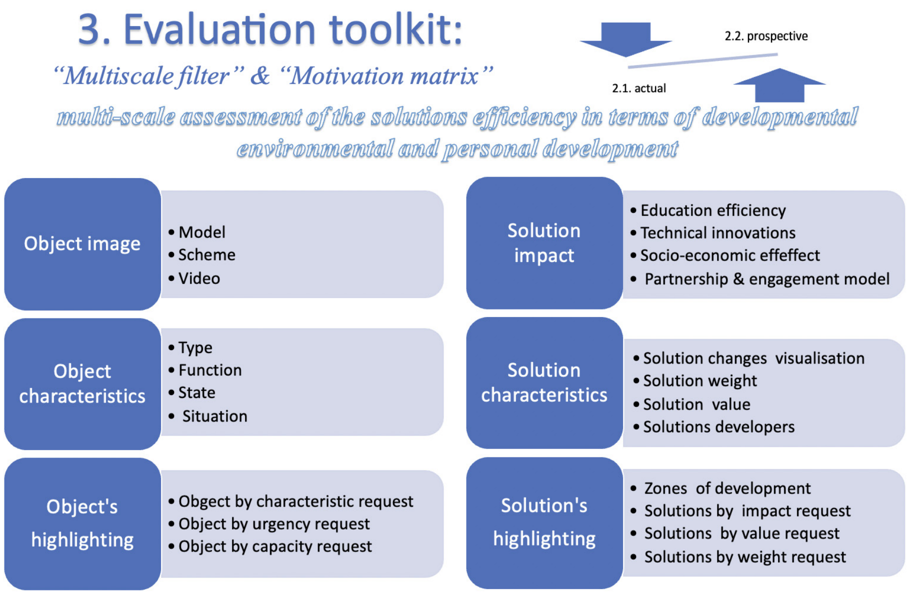


**Fig. 5.** Evaluation toolkit for multiscale assessment of the solutions efficiency

Holistic approach introduces multiscale measurement [16] of interactive e-course as a dynamic "living" system of student-developmental environment interaction causing co-development. In addition to measuring students cognitive and personality development in terms of solving subject tasks efficiency based on formula, including parameters of accuracy, velocity and completeness; cognitive scheme complexity; professional, social and existential senses as well as meta-abilities including metaqualities (proactivity, autonomy, objectivity, responsibility, flexibility, creativity and empathy) it is used measurement of innovative solutions aimed at estimation of their quality and efficiency including engagement, impact and achievements by milestones. The data obtained are processed by statistical methods [17], including correlation [18] and factor analysis [19], which determines the relationship indicating possible causes that are verified in the course of a scientific developmental experiment.

Evaluation and dissemination toolkit are presented in Fig. 6. A multiscale dimension characteristic for existential holistic processes determines a range of selection and evaluation criteria for "OmniBase" search engine and solutions evaluation. "Evaluated profile" reflects experts' vision of solutions efficiency, relevance and workability by multiscale measurement with corresponding tools including: (a) "Multiscale filter" – original tool based on profiles overlaying technique allowing multiscale measurement of impact, efficiency, weight and workability of solutions; (b) "Motivation matrix" – original tool based on profiles overlaying technique reflecting the hierarchy of human needs [20] – existential senses of survival, quality and sense of life.

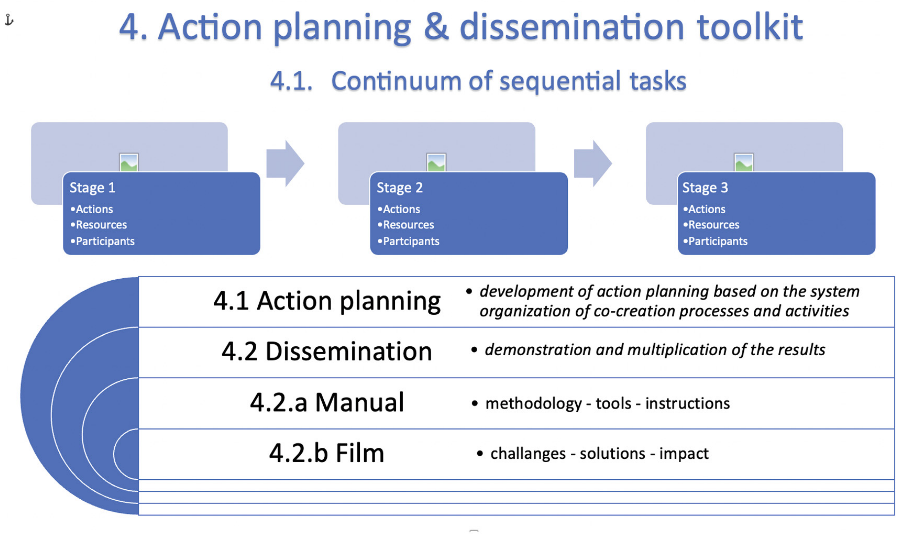


**Fig. 6.** Action planning and dissemination toolkit

The evaluated synergistic solution profile is transformed into action planning in the format "Continuum of sequential tasks" – an interactive instrument for visual arranging in time the process of implementing selected solutions, setting tasks and distributing responsibilities among participants. Continuum is built to demonstrate and multiplicate solutions in terms of technological, socio-economic, social innovations. Universal in format and unique in content, Continuum reflects the specifics of solutions implementing in the context of available conditions and resources.

Dissemination toolkit includes "Manual" – interactive instructions in e-learning mode based on metacognitive approach realized as eco-humanistic model of self-development; "Film" for disseminating experience among general audience.

## 4 Conclusion

The eco-humanistic model gives an understanding of HOW to manage the process of interactive developmental e-courses multidisciplinary – multi-sector – multi- actor co-creation, highlighting the system-forming factor, structure and content as well as mechanisms of the co-development process. A scientifically based system representation allows modeling this process as an existential one. This makes it possible to create: a) an efficient system of digital support, b) multi-scale measurement of e-course efficiency; c) eco-humanistic developmental training programs.

An eco-humanistic model triggers qualitative changes at several levels. It ensures synergetic interaction of diversities which is of exceptional importance in multi-actor/sector/disciplinary interaction based on: a) awareness of the value of diversities for synergistic development, b) strategic orientation mechanism that integrates personal senses (needs) into a unifying goal of mutual development and optimizes the process; c) digital support system modeling the existential process of multi-actor/sector/disciplinary co-development through interaction (co-creation); d) digital tool allowing to combine the diversities of individual visions reflected in the format of Ideal and Real profiles into Synergistic profile based on the technology of cognitive schemas overlay.

Eco-humanistic model also ensures managing the process of co-creation on the basis of understanding its system forming factor, structure and content as well as mechanisms. System understanding allows: a) process modelling, c) managing purposefully, consciously and efficiently, c) demonstration, d) multiplication (Fig. 7).

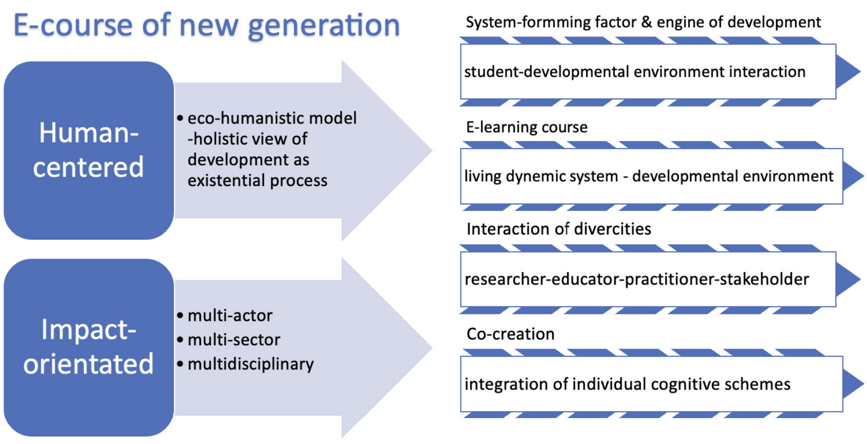


**Fig. 7.** E-course new generation

If the above can be attributed to the strength of the research, then the lack of experts who understand the structure and mechanisms of the co-creation by diversities in order to manage efficiently can be considered not so much a weakness as a problem. Obviously, the education system should include the development of this important multidisciplinary competence in its curricula.

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# A Method of Generating 'Smart' Blocks of Test Questions in the Learning Process, Adaptable to the Learner's Personality, Using Neural Network Technology

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**Abstract.** The intermediate and final assessment of students' (learners') knowledge has a significant role in the learning process. Given the rapidity of life and changes in the environmental context, the educational ecosystem needs additional tools for assessment of learners' knowledge, adapted to their personality. Each learner has personal characteristics which affect the pace, percentage of absorption and comprehension of information. The purpose of the study is to describe a method for generating smart blocks of test questions in the learning process, which are adapted to the learning individual using neural network technology. By introducing adaptive tests in the form of smart blocks of test questions we can take into account the personality characteristics of the person being tested. This allows an individual assessment methodology to be formed for each learner.

A broader objective is additional adaptability, in the context of inclusive and open education. As a result of applying the method of forming smart blocks of test questions in the learning process, adapted to the learning personality, using neural network technology, the level of students' interest in learning courses related to information technology, both direct and non-direct specialties was increased. The method can also be applied in other systems and for other subject areas, i.e. it can be considered universal and one that ensures inclusion.

**Keywords:** adaptive learning · smart blocks of test questions · neural network · artificial intelligence · inclusive education

## 1 Introduction

None of us expected, much less were prepared for a russian invasion on 24 February 2022. The war affected the internal state and emotional stability of Ukrainians. Despite the difficult situation in the state, within weeks of the attack, students were already continuing their study online or in a mixed online/offline mode. It should be kept in mind that many learners and educators are located in other cities in Ukraine or abroad. It

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is important for learners to adapt to the situation and understand – the learning process will not be easy.

The unfolding events have had an extremely negative impact on the quality of education: lack of the usual safe environment, sometimes excluding interpersonal relationships between students; quality of communication, availability of lighting; stress, increased anxiety, chronic depression. Stress, anxiety, depressive states significantly interfere with students' learning process. In such a situation, you should learn to control your emotions, react adequately to events, not to make long-term plans, maintain a sufficient level of self-motivation to study. Without sufficient rest (constant air raids at night, the need for funds to support oneself in the new environment of temporary residence), neither good work nor effective learning is possible. This is a basic rule. Nevertheless, awareness of the problem is 50% of the solution. And this is where innovative technology, artificial intelligence, comes in to help us adapt to the situation at hand.

In English, the term "Artificial Intelligence" does not have the anthropomorphic connotation that it has acquired in the traditional Ukrainian translation: the word intelligence in context means "the ability to reason intelligently" rather than "intellect". From the point of view of natural sciences, intellect can only be a biological phenomenon, and it is the subject of debate among the scientists of the world.

The research proposes to look at the use of artificial intelligence to improve the performance of adaptive learning systems.

At present the following definitions of artificial intelligence are given, let us enumerate some of them:

– A scientific field in which the tasks of hardware or software modelling of those human activities that are traditionally regarded as intelligent are posed and solved [1].
– The property of intelligent systems to perform functions (creative) traditionally considered to be the prerogative of humans. In this case, an intelligent system is a technical or software system capable of solving tasks traditionally considered creative, belonging to a specific subject area, the knowledge of which is stored in the memory of such a system. The structure of intelligent system includes three main units – knowledge base, solver and intelligent interface, which allows to communicate with computer without special programs for data input [2].
– A branch of computer science and information technology whose task is to reproduce, through computing systems and other artificial devices, intelligent reasoning and action [3]
– The ability of a system to interpret external data correctly, to learn from that data, and to use the knowledge gained to achieve specific goals and objectives through flexible adaptation.

The purpose of the research is not just to examine the interaction between a machine and a human-biorobot, but a human being with emotions, so several definitions related to emotional state need to be provided.

Application of the term "ability" [4] to a certain computer technology is identical to the meaning of "capacity", which is conditioned by its technical characteristics. Ukrainian explanatory dictionary offers two definitions of "ability": (I) – property; (II) – natural talent, ability [5].

It is known that ability and learning capability determine a certain level of perception, assimilation and processing of the received educational information. As for capabilities, they are individual-psychological features of an individual which may be genetically conditioned and have their own determinants. Therefore, mastering the same learning material, skills and abilities of each individual person is strictly individual.

Differences in ability between individuals can be qualitative and quantitative. A person's abilities are manifested in the way he/she uses his/her existing knowledge and acquires new knowledge, skills, and abilities needed to solve the tasks that life puts before him/her. The qualities of thinking and associated language occupy an important place in the structure of abilities for scientific, technical, industrial, inventive, literary, artistic and other activities. Quantitative measures of aptitude describe the degree of expression. Tests are the most common form of assessing the degree of ability expression.

In studying the abilities Ukrainian psychologists used a system of tests, gradually increasing in complexity. Intelligence tests [6] form a special group of techniques aimed at measuring the level of intellectual development and establishing individual differences between people on this psychological trait (R. Amthauer's intelligence structure test [7], R. Meili's analytical intelligence test [8]).

The application of adaptive testing to determine the knowledge level of learners allows evaluating it and selecting the appropriate test level. Works [9–13] describe the importance of individual approaches in learning and project implementation.

The model proposed by the authors allows for an individualised approach to the individual learner [14] in the ongoing study of topics. The topic of adaptive learning is relevant and undergoing change due to the development of information technology.

The implementation of neural networks in the adaptive learning system makes it possible to teach the system to select appropriate questions during the test question generation phase.

The purpose of the study is to describe a method for generating smart blocks of test questions in the learning process, which are adapted to the learning individual using neural network technology. To reach the study's goal it's needed:

- to consider possible stress conditions and their identification by means of a psychological test;
- to formulate a method of forming "smart" blocks of test questions in the learning process, adapting to the learning personality;
- describe the work of the logical unit of formation of adaptive tests based on neural network technology;
- describe the architecture of the adaptive learning system;
- perform data verification.

## 2 Description of Key Terms and Statements

For the process of research, we will use the term "learner" and see it as a holistic object with individual characteristics. That is, we are not dealing with a single-type actor, but with a personality subject to external influences. The learner has his or her own personal characteristics which affect the pace, the percentage of learning and perception of information.

By "pace" of learning we mean the time taken to review material on a topic, interim testing on subtopics, completing practical work and receiving a grade for the final exam.

The "information assimilation percentage" will be understood as the percentage value of the final exam grade.

Under "perception of information" in a stable psychological state we will consider a qualitative indicator 'excellent', 'good' and 'satisfactory', based on quantitative indicators of the percentage value of interim testing on subtopics and exemplary attempts to pass this test. The maximum number of attempts at intermediate testing is 3. The final test has one attempt. Table 1 shows the relationship between the qualitative and quantitative indicators.

**Table 1.** Table of formation of qualitative indicators of "information perception" in a stable psychological state.

| Quantitative indicators | Qualitative characteristics | | |
|---|---|---|---|
| | Excellent | Good | Satisfactory |
| Percentage value of interim testing on subtopics | 90–100 | 75–90 | 60–90 |
| Maximum number of attempts to pass the interim test | 1 | 2 | 3 |

According to the table, if a student scores 90 points on the third attempt, his/her "perception of information" level is 'satisfactory'. If the student scored less than 75 points on the 2nd attempt, his/her "perception of information" level is 'satisfactory', if between 75–90 points, his/her level is 'good'. A score of 'excellent' is given to a person who scores between 90 and 100 on the first attempt.

If a person being tested is under the influence of stress, he or she assimilates information more slowly due to his or her own psychological state. Therefore, "perception of information" indicators have shifts in both the quantitative value of the interim test percentage by subtopic and the quantitative value of attempts to pass the interim test (Table 2).

**Table 2.** Table of formation of qualitative indicators of "information perception" for the stressed individual.

| Qualitative characteristics | | | |
|---|---|---|---|
| | Excellent | Good | Satisfactory |
| Quantitative indicators | | | |
| Percentage value of interim testing on subtopics | 90–100 | 75–89 | 60–74 |
| Maximum number of attempts to pass the interim test | 2 | 3 | 3 |

According to the table, if a student scores less than 75 on the third attempt, his/her "perception of information" level is 'satisfactory'. If a student scores between 75 and

90 on 2 attempts, his or her "perception" level is 'good'. A score of 'excellent' is given to a person who scores between 90 and 100 on the first or second attempt. A score of 'excellent' is not reduced, as it guarantees a high level of knowledge of the topic.

The detection of the presence of a stressful state takes place at the stage of the input survey, containing characteristic questions that are markers for the identification of the psychological state of a learner using neural network technologies.

According to A. Maslow's model, in the hierarchy of basic needs the need for safety [15]. Everyone experiences fear and anxiety from time to time during their lives. Fear is an emotional, physical and behavioural response to an external threat that is immediately recognisable (attack by an intruder, explosion of a shell, mutilated bodies) [16].

Anxiety is a state of oppression, an unpleasant emotional state of nervousness and worry. To find out the level of anxiety, it's possible to use the test. The "Anxiety, Stress and Depression Test" provides insight into the underlying causes of anxiety, stress and even depression; allows their level to be determined. To determine the level of students' anxiety, we have chosen a test with 30 questions [17]. The chosen test determines mental state by using scales corresponding to states of anxiety, stress and depression. Using the results obtained, it is possible to divide the respondents into several groups: stressed learners, learners with a certain level of anxiety and depressed learners.

## 3 Actual Outcomes and Summary

The adaptive learning system taken as the basis of the research has a client-server architecture and provides access to self-study in 24/7 format and consultation with the tutor at specific intervals. Fig. 1 shows the architecture of the adaptive learning system.

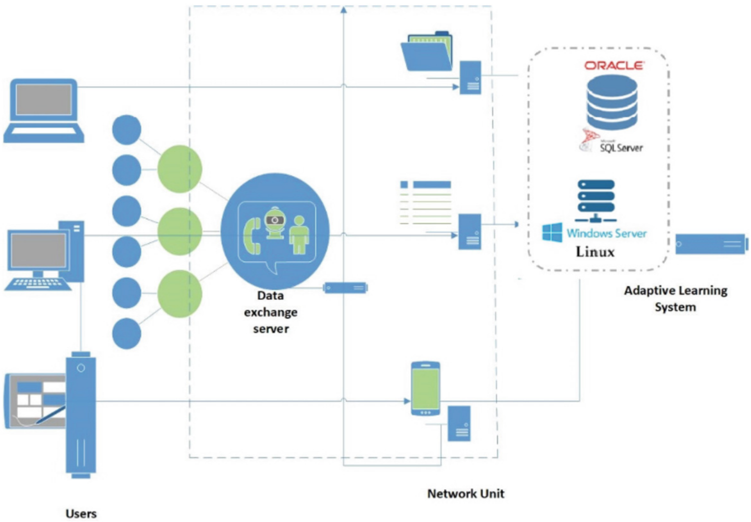


**Fig. 1.** Architecture of the adaptive learning system

According to Fig. 1, users interact with the adaptive learning system via a network unit. The communication is through a remote server. The user interaction with the learning system is based on TCP protocol, which ensures that both the user and its response are delivered to the server.

The adaptive learning system hosted on the server contains the Adaptive Decision-Making Unit. The adaptive learning model contains a test generation programme based on the principle of modular knowledge control taking into account the psychological state of the learner using neural network technologies, an explanation module and a decision-making unit with the assessment of test difficulty, taking into account the learner's capabilities. The communication of the trainee with the neural network technology system takes place through a user-friendly interface. Let us describe a method to generate smart blocks of test questions. The neural network technologies used in the training process of the system should determine the psychological state of the trainee.

### 3.1 Description of a Method for Generating Smart Blocks of Test Questions in the Learning Process, Which are Adapted to the Learning Individual using Neural Network Technology

Step 1 Registration of a person enrolled in a thematic module.
Step 2 The registration process involves answering standard questions that determine the psychotype of the person who plans to learn.
Step 3 To determine the individual's reaction speed and perception of information, the learner is given a puzzle picture test.
Step 4 The results of the test and the puzzle game are determined by the input to the perceptron to determine the state of the person about to be trained.
Step 5 The neural network receives preliminary results to determine the learning rate and adjusts them each time the trainee undergoes an intermediate test.
Step 6 The Adaptive Decision-Making Unit decides, based on the calculated personality and training data, to provide a level of test questions and to generate a score.
Step 7 Based on the pre- and post-assessments, a coefficient of proficiency of the person being tested is calculated.
Step 8 Based on the learning rate and "perception of information" data, a final test on the subject module is generated.
Step 9 A questionnaire test to determine the level of satisfaction with the selected course.

In accordance with the method of forming "smart" blocks of test questions in the learning process, which are adapted to the learning personality, let's depict the algorithm of the adaptive learning system (Fig. 2). The work in the system starts with checking the availability of the user of the system. If the user is registered, he is logged in, if not, he is registered. After logging in, there is an input testing process where the psychological state of the trainee is determined. The next stage is a cyclical process of training and testing within a framework defined by the system. When the testing process stops, the decision-making unit makes a decision based on the receipt of test data to calculate the test results which are output to the user of the system. If the user passes the final survey, the system action stops. If not, it goes back to the Decision Unit operation.

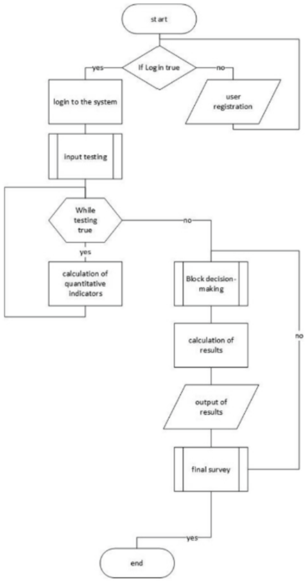


**Fig. 2.** The algorithm for an adaptive learning system

The decision-making unit operates on the basis of embedded rules described in the neural network to calculate the stress quotient, which affects the production of a qualitative measure of "perception of information" and "pace". One of the ideas for the application of this technology is to generate a sense of enjoyment for learning on the chosen course [18].

According to Weber-Fechner's law [19], a neural network learner will attempt to gain maximum knowledge for a sense of confidence, but will also run the risk of not completing the course if the stressful situation is not overcome.

"Transactional utility" is the difference between the emotional state of the learner at the time of learning and the typical emotional state of the learner [20].

### 3.2 A Mathematical Model for Calculating the Satisfaction Function of Learning Outcomes. Data Verification

The general solution to the problem of investigating learner satisfaction with the course will be found in the form of the solution to equation (1)

$$W = f(w_i, p_j, U, T) \tag{1}$$

where $w_i$ is the value of the psychological state of the learner at time $t_0$; $p_j$ is the "perception of information" indicator; $U$ is the amount of training material broken down into subtopics; $T$ is the pace of learning. These parameters are fuzzy.

The solution will be sought using the perceptron model (Fig. 3).

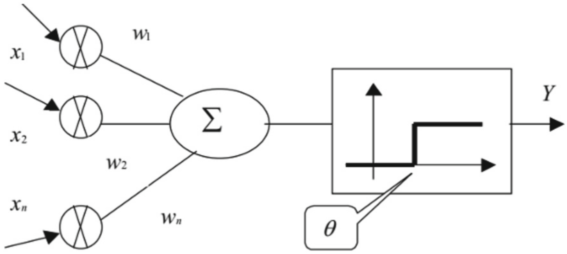


**Fig. 3.** The perceptron model

The set of associative elements $x_i$ ($i = 1, n$) will be the test data on the topics of the discipline ("perception of information" and "pace"), and the weights $w_i$ – the value of psychological state of the learner at time $t_0$.

The sum of products of associative elements by their weight coefficients forms

$$a = \sum\nolimits_{i=1}^{n} x_i w_i \tag{2}$$

Output Y is calculated according to the formula

$$Y = \begin{cases} 1, \mathit{if} \ \ a \geq \theta \\ 0, \mathit{if} \ \ a < \theta \end{cases} \tag{3}$$

where $\theta$ is the threshold. In our case it is equal to zero, as we are aiming for the smallest number of dissatisfied with the course and those who did not hand in on time.

If "$a$" exceeds the threshold, $Y = 1$. Otherwise, it is equal to zero. If $Y$ is true, go to the next step. If $Y$ is false, calculate the difference between the obtained value of $Y$ and its correct value:

$$\delta = T - \mathrm{Y} \tag{4}$$

Calculate

$$\Delta_i = \eta \delta x_i \tag{5}$$

where $\eta$ is the learning rate coefficient of the neural network.

Find the correction values of the weighting coefficients

$$w_i(n+1) = w_i(n) + \Delta_i, \quad i = 1, n \tag{6}$$

where $w_i(n+1)$ is weighting factor value after correction, $w_i(n)$ is weighting factor value before correction.

The procedure is performed for each input image.

For the adaptive testing system, the neural network was trained through programming (Fig. 4) and a table of coefficients (Table 3) was obtained.

```
input [0 0 0];actual [0.]  expected 0 delta= [0.02814229]
input [0 0 1];actual [0.]  expected 0 delta= [0.05754608]
input [0 1 0];actual [0.]  expected 0 delta= [0.00946266]
input [0 1 1];actual [0.]  expected 0 delta= [0.02607509]
input [1 0 0];actual [1.]  expected 0 delta= [0.03449891]
input [1 0 1];actual [1.]  expected 1 delta= [0.03238184]
input [1 1 0];actual [0.]  expected 0 delta= [0.17848149]
input [1 1 1];actual [1.]  expected 0 delta= [0.0425746]
input [0 1 1];  expected 0
```

**Fig. 4.** The result of perceptron training

**Table 3.** Neural network training table with initial values of test results and weights

| w1 | w2 | w3 | Ø | x1 | x2 | x3 | a | Y | T | n | oW1 | oW2 | oW3 | oØ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0,52 | 0,24 | 0,17 | 0,5 | 0 | 0 | 0 | 0 | 0 | 0,9438 | 200 | 0,029224 | 0,013488 | 0,009554 | **0,0281** |
| 0,52 | 0,24 | 0,17 | 0,5 | 0 | 0 | 1 | 0,17 | 0 | 0,885 | 180 | 0,0598 | 0,0276 | 0,01955 | **0,0575** |
| 0,52 | 0,24 | 0,17 | 0,5 | 0 | 1 | 0 | 0,24 | 0 | 0,9812 | 330 | 0,009776 | 0,004512 | 0,003196 | **0,0094** |
| 0,52 | 0,24 | 0,17 | 0,5 | 0 | 1 | 1 | 0,41 | 0 | 0,948 | 400 | 0,02704 | 0,01248 | 0,00884 | **0,026** |
| 0,52 | 0,24 | 0,17 | 0,5 | 1 | 0 | 0 | 0,52 | 1 | 0,9312 | 720 | 0,035776 | 0,016512 | 0,011696 | **0,0344** |
| 0,52 | 0,24 | 0,17 | 0,5 | 1 | 0 | 1 | 0,69 | 1 | 0,9354 | 100 | 0,033592 | 0,015504 | 0,010982 | **0,0323** |
| 0,52 | 0,24 | 0,17 | 0,5 | 1 | 1 | 0 | 0,76 | 0 | 0,6432 | 330 | 0,185536 | 0,085632 | 0,060656 | **0,1784** |
| 0,52 | 0,24 | 0,17 | 0,5 | 1 | 1 | 1 | 0,93 | 1 | 0,915 | 850 | 0,0442 | 0,0204 | 0,01445 | **0,0425** |

In this case, the decision unit was trained on the weighting values corresponding to 52% of the trainee's stress state, 24% of anxiety and 17% of depressed state. The percentage values were chosen as the average results of psychological states characteristic of the individual. The values of associative items in the format of logical values 0 and 1 reflected positive and negative impressions of the test takers. The neural network learned at step 8 and was ready for use.

The system adapts to the personality each time it offers a level of questions in the test, as far as learning is concerned. Response time to questions and type of errors were taken into account.

Verification was conducted on representative groups of 1st year students of "Economic Cybernetics", "Hydrology and Meteorology" and "Information Systems and Technologies" of Taras Shevchenko National University of Kyiv while studying the course related to Python programming basics (Table 4).

**Table 4.** Table of input parameter values of representative groups

| Name of the speciality | Number of students enrolled | Relevance of the course to the speciality | Average percentage of psychological state per group | | | Time deadlines in hours per week | Indicator of interest in the course |
|---|---|---|---|---|---|---|---|
| | | | stress | anxiety | depression | | |
| Economic Cybernetics | 25/50 | no | 50% | 38% | 10% | 12 | 50% |
| Hydrology and Meteorology | 13/26 | no | 45% | 33% | 12% | 12 | 45% |
| Information Systems and Technologies | 25/50 | yes | 45% | 22% | 12% | 10 | 95% |

A mid-course debriefing was conducted and the following results were obtained (Tables 5, 6 and 7).

**Table 5.** Table of values of statistical indicators of representative groups trained with the smart block test question generation method system at the half of the course listening time

| Name of the speciality | Average percentage of psychological state per group | | | "Perception of information" indicators | | | The amount of training material broken down into subtopics | Learning pace | Indicator of interest in the course |
|---|---|---|---|---|---|---|---|---|---|
| | stress | anxiety | depress. | excel. | good | satisf. | | | |
| Economic Cybernetics | 35% | 30% | 3% | 5 | 10 | 10 | ½ | average | 60% |
| Hydrology and Meteorology | 30% | 35% | 2% | 3 | 5 | 5 | ½ | low | 40% |
| Information Systems and Technologies | 32% | 20% | 12% | 8 | 12 | 5 | ½ | accelerated | 80% |

The performance of the repetitive groups trained with the smart block test question generation method system at the stage of completion changed in relation to the training without the method system: interest in the subject increased and learning of the course moved to time-based deadlines. The percentage of students who could not overcome the course decreased to zero and those who did the work 'before the final formation of the discipline grade' decreased to 1–3% when the method system was used (Table 8).

**Table 6.** Table of values of statistical indicators of representative groups trained without the smart block test question generation method system at the half of the course listening time

| Name of the speciality | Average percentage of psychological state per group | | | "Perception of information" indicators | | | The amount of training material broken down into subtopics | Learning pace | Indicator of interest in the course |
|---|---|---|---|---|---|---|---|---|---|
| | stress | anxiety | depress. | excel. | good | satisf. | | | |
| Economic Cybernetics | 50% | 35% | 4% | 2 | 10 | 13 | ½ | low | 50% |
| Hydrology and Meteorology | 45% | 45% | 5% | 2 | 6 | 5 | ½ | low | 45% |
| Information Systems and Technologies | 54% | 34% | 6% | 6 | 14 | 5 | ½ | average | 80% |

**Table 7.** Table of values of statistical indicators of representative groups trained with the smart block test question generation method system at the completion of the course listening time

| Name of the speciality | Average percentage of psychological state per group | | | "Perception of information" indicators | | | The amount of training material broken down into subtopics | Learning pace | Indicator of interest in the course | Completion of the tests before the final course grade is generated |
|---|---|---|---|---|---|---|---|---|---|---|
| | stress | anxiety | depress. | excel. | good | satisf. | | | | |
| Economic Cybernetics | 37% | 30% | 0% | 5 | 10 | 10 | 9/10 | accel. | 100% | 2% |
| Hydrology and Meteorology | 35% | 35% | 0% | 3 | 5 | 5 | 9/10 | accel. | 100% | 3% |
| Information Systems and Technologies | 38% | 20% | 0% | 8 | 12 | 5 | 9/10 | accel. | 100% | 1% |

**Table 8.** Table of values of statistical indicators of representative groups trained without the smart block test question generation method system at the completion of the course listening time

| Name of the speciality | Average percentage of psychological state per group | | | “Perception of information” indicators | | | The amount of training material broken down into subtopics | Learning pace | Indicator of interest in the course | Completion of the tests before the final course grade is generated |
|---|---|---|---|---|---|---|---|---|---|---|
| | stress | anxiety | depress. | excel. | good | satisf. | | | | |
| Economic Cybernetics | 37% | 35% | 4% | 2 | 10 | 10 | 9/10 | accel. | 100% | 30% |
| Hydrology and Meteorology | 35% | 42% | 5% | 2 | 6 | 5 | 9/10 | average | 100% | 40% |
| Information Systems and Technologies | 44% | 32% | 6% | 6 | 14 | 5 | 9/10 | accel. | 100% | 45% |

### 3.3 Summary

A multidisciplinary study analyses the influence of basic knowledge and personality characteristics of learners on learning success and course satisfaction. The method of forming smart blocks of test questions in the learning process, adapted to the learning personality, using neural network technology was proposed. On the basis of this method a block of adaptive decision-making (using the obtained test results of basic knowledge and answers to questions determining personality characteristics) is developed. This block is integrated into the previously developed digital learning environment containing materials for learning “Python programming basics”. The research was conducted for three direct and non-direct IT-related majors. In the future, the digital learning environment can be supplemented with additional materials, and the method can be applied to the formation of tests for another 22 training modules – individual courses or their components on the platform https://dole.fit.knu.ua/. The platform was developed within the international project Erasmus plus dComFra. After russia’s full-scale invasion of Ukraine, the number and size of the target groups increased significantly. After the end of the project in 2022, the training is conducted under the auspices of the Ukrainian association of IT professionals, supported by 7 offices of digital competences of leading Ukrainian universities. The primary target groups today are: military and civilians in crisis situations caused by shelling and other war factors; temporarily displaced people; refugees; people with educational disabilities; etc. The method can also be applied in other systems and for other subject areas, i.e. it can be considered universal and one that ensures inclusion.

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# Designing Multi-disciplinary Interactive Collaborative Learning in Healthcare Engineering Education Through Academia-Industry Partnership

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**Abstract.** The healthcare industry faces complex challenges that require a multidisciplinary approach, yet traditional healthcare education may not adequately prepare students for real-world challenges. To address this gap, an academia-industry partnership was established between the Singapore University of Technology and Design (SUTD) and Singapore General Hospital (SGH). The partnership provides multi-disciplinary interactive collaborative learning experiences in healthcare engineering education, with a focus on medical 3D printing. Students work in teams comprising engineering, medical, and healthcare professionals to design and develop medical 3D-printed solutions for clinical practice and medical education. The approach provides students with practical experience and essential skills valued in the healthcare industry while promoting collaboration, co-creation, and knowledge exchange across institutions. The proposed approach can serve as a model for academia-industry collaborations and can be further enhanced by incorporating other emerging technologies.

**Keywords:** Academia-Industry Partnerships · Collaborative Learning · Medical 3D-printing · Healthcare Education

## 1 Introduction

Healthcare engineering (HCE) is a fast-growing field that requires a multidisciplinary approach to address complex and often evolving challenges in the healthcare industry. In this paper, we describe our approach to designing a healthcare engineering curriculum in partnership with academia, reflect on our experiences in implementing the course, and suggest how this can be adapted in other contexts. We start with a brief introduction to HCE, and explore the need for HCE, before describing our educational context, and our approach to forging industry-academia partnerships, curriculum design, and implementation. We end the paper with our reflections.

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### 1.1 Healthcare Engineering

Healthcare Engineering is the overlap of the two disciplines, health sciences, and engineering (Fig. 1a), and is defined as "engineering involved in all aspects of the prevention, diagnosis, treatment, and management of illness, as well as the preservation and improvement of physical and mental health and well-being, through the services offered to humans by the medical and allied health professions" [1]. HCE can be in the form of *engineering for healthcare intervention*, whereby engineering solutions are devised to test, prevent, or treat medical conditions or in the form of *engineering of healthcare systems* where engineering is applied in the setting of physical or organizational healthcare infrastructure.

The current healthcare landscape demands professionals who can work in multidisciplinary teams to solve complex problems. Thibault (2020) [2] identified six trends for the future of health professions education, and this includes:

i. Interprofessional education to better prepare for collaborative practice.
ii. Integrated education that is more patient, community, and chronic disease oriented.
iii. Humanistic education for health professions
iv. Continued life-long education for health professionals
v. A shift to competency-based education
vi. Technology-enhanced education to innovate education and practice

Thus, it is essential to consider these various facets of healthcare education and provide students with holistic educational opportunities to develop teamwork, communication, and critical thinking skills through interactive and collaborative learning.

Rambukwella *et. al.*, (2021) [3] point out that the medical field is still very much clinic-focused and that there is a need for more emphasis on integrating medicine with engineering and other disciplines. Traditionally, dual degree programs (MD/Ph.D.) allow medical students to pursue training in this area. An alternative route has been for engineering students to pursue interdisciplinary courses of engineering and health sciences such as biomedical engineering.

Even when there has been the successful integration of medical science and engineering principles into most healthcare engineering curricula, there is often still a lack of holistic and multi-dimensional learning opportunities to prepare students for real-world challenges that require the expertise of both medical and engineering fields. It is not only the curriculum that needs change but also the pedagogy, and this needs the partnership of expertise from both medical and engineering fields. With the developments in technologies such as 3D-printing, artificial intelligence, and machine learning, there is a growing need to integrate medical and engineering sciences. The question is how to go about this partnership and collaboration between healthcare and engineering to bring about interactive, collaborative, authentic, multi-disciplinary authentic healthcare engineering. In this paper, we present our approach at the Singapore University of Technology and Design (SUTD).

Over the past decade, SUTD has partnered with local public healthcare institutions to incorporate multi-disciplinary interactive collaborative learning experiences into its healthcare engineering curriculum. Here we describe one such collaboration with Singapore General Hospital (SGH) to jointly develop an engineering design project in a third-year module called "Topics in Biomedical and Healthcare Engineering". We partnered with a Radiologist and Occupational Therapist from SGH to develop a term-long project focused on the emerging field of clinical 3D printing to provide students with a unique and innovative collaborative learning experience and the necessary skills that will prepare them to tackle real-world healthcare challenges.

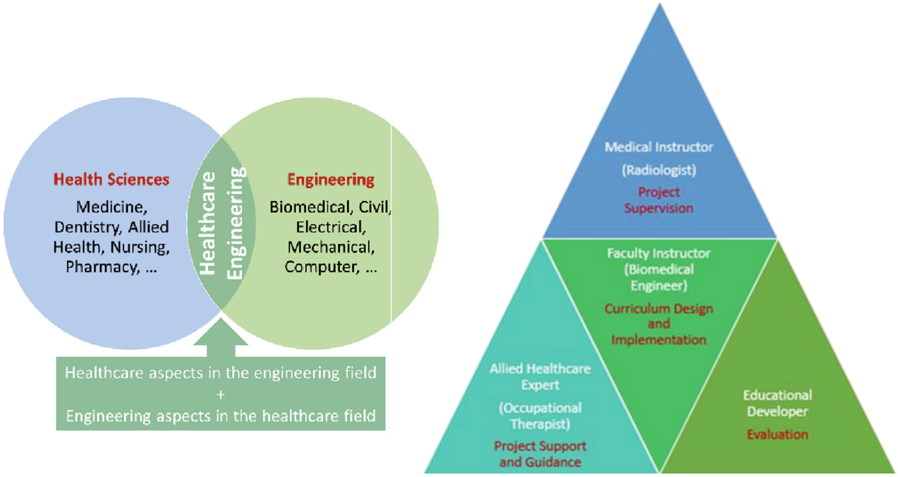


**Fig. 1.** a (Left). Healthcare Engineering at the intersection of health sciences and engineering, and b (Right) Academia-Industry collaboration model.

## 1.2 Our Educational Context

The Singapore University of Technology and Design (SUTD) was identified to be the top emerging engineering university in 2018 [4]. SUTD provides engineering and architecture education to 1500 undergraduate students annually and embraces learner-centric active, interactive cohort-based, and project-based learning pedagogies [5].

"Topics in Biomedical and Healthcare Engineering" (TBHE) is a 13-week healthcare module open to third year SUTD engineering undergraduates. This module is a core requirement for the Healthcare Engineering Design track in the Engineering Product Development (EPD) degree program. This course was launched in 2015 and developed and taught by the primary author of this paper. The case study we describe in this paper represents the version implemented in Spring 2023.

The objective of the TBHE module is to prepare engineering students with problem-solving and critical thinking skills to be able to apply their knowledge and skill sets to advance medical treatment and diagnosis. This module aims to equip students with a broad understanding of instrumentation for treatment and diagnosis, physiological sensors, biomechanics, biomedical imaging, and medical devices for various clinical applications. This module also includes a term-long design project where teams of 4–5 students work together to address a real-world healthcare problem.

The TBHE module chooses to adopt a project-based learning teaching methodology to provide authentic learning experiences whereby students can apply their theoretical knowledge and skills into real-life practice, under the mentorship and guidance of instructors and healthcare experts. In the Spring 2023 run of the course, 17 students were grouped into 4 project teams to design and develop 3D-printed wrist splints for patients with Triangular Fibrocartilage Complex (TFCC) injuries. Students were given access to a wide range of 3D printers in the SUTD Digital Manufacturing and Design and (DManD) Centre and SUTD-Dyson Innovation Studios (DSIS). Over 13 weeks, students used a design-thinking approach to Discover, Define, Develop, and Deliver a range of innovative 3D printed wrist splint prototypes.

Medical 3D printing has emerged as a promising field in healthcare, whereby the ability to produce patient-specific models, surgical guides, and implants has revolutionized patient care and medical education. However, traditional medical school education does not provide sufficient training to healthcare professionals to become proficient in 3D printing. Therefore, there is a need for a multidisciplinary collaborative approach which builds on the unique capabilities of each partner institution. The partnership brings together an interdisciplinary team of academic experts (faculty), industry professionals (clinicians), and students to co-design and develop 3D printed solutions for clinical practice and medical education. The learning experience integrates medical and engineering principles and emphasizes the importance of soft skills such as teamwork, communication, and critical thinking. The partnership also facilitates the exchange of knowledge and best practices between partner institutions. In the next section, we describe our approach to forging industry-academia partnerships, curriculum design, implementation, assessment, and feedback.

## 2 Our Approach to Academia-Industry Partnership

The Academia-Industry partnership in our case stems from the professional connection between the course lead, who is a biomedical engineer by training, and medical expert(s) from SGH, and is initiated by a shared passion to integrate engineering and medicine to inspire future leaders and innovators in this multi-disciplinary field and to build solutions that serve both fields.

The course lead designed the overall TBHE course curriculum and planned out the teaching methods, assessments, and rubrics. Design-centric, project-based learning was the choice of teaching methodology. A partnership with the medical experts was forged for two reasons. One reason is organizational goals in that there is a strong push in Singapore's higher education to develop university curriculums to prepare graduates to be work-ready innovative leaders. Hence universities undertake several strategies to achieve this, with industry partnerships being one such platform. Other strategies include Capstone projects, Internship opportunities, etc. The second reason is pedagogical. The benefits of authentic, multi-disciplinary learning are well supported in the educational literature.

However, such multi-disciplinary courses in partnership with industry are relatively new for most faculty instructors and hence the question is how to go about establishing these partnerships. In our case, already established joint research projects and connections lead to the development of a collaborative course project model. The course lead and the medical expert, a radiologist from SGH, discussed possibilities, brainstormed, and evaluated project ideas based on several criteria to finalise the design problem/project brief. Some considerations in deciding on the multidisciplinary project are the problem's complexity, feasibility, and required technical expertise.

Ultimately, the team decided on a student project to design a 3D-printed wrist splint to support patient recovery after TFCC injury. Traditionally, wrist splints are fabricated using a thermoplastic cast. However, there is a need for lighter, more breathable, and washable splints and 3D-printing offers a novel approach to achieving these properties. To provide a real-life clinical perspective, an occupational therapist from SGH was invited to join the teaching team. To inform and evaluate the pedagogical practices, an educational developer from SUTD participated in this process. Our objectives were to see what we can learn from the current implementation for continual improvement. The instructional team thus involved multiple stakeholders (Fig. 1b), who can provide their deep expertise and rich experiences/knowledge pertaining to their field. Such a partnership is critical because it is difficult to find a single expert in multiple fields. Our approach was to form a team of experts to leverage on this diversity.

Briefly, the 13-week module was structured as follows. In Week 1, the faculty instructor introduced students to the overall course structure and content. In Week 2, the design project brief (Fig. 3) was released to students and the medical experts (both the radiologist and occupational therapist) were present in class to provide insights on clinical 3D printing and the current practices of wrist splinting, respectively. An engineer from the SUTD Digital Manufacturing and Design (DManD) Centre was also on site to guide the students through the process of capturing a digital hand model using a handheld 3D scanner. Finally, students were asked to group themselves into teams of 4–5 and worked together to design and prototype the splints between Weeks 2 – 13. During this period, students continued to attend lectures and other activities on topics related to biomedical and healthcare engineering. In Week 7, student visited SGH to present an interim update of their project and received feedback from all three instructors: the faculty instructor, the medical instructor, and the allied health instructor. Students also toured the SGH wrist splinting facility to better understand the clinical context and patient needs. In the remaining weeks, students continued to refine their prototypes with continual feedback from the faculty instructor. In Week 13, teams delivered their final presentations and showcased the finalized wrist splint prototypes, again to all three instructors. Figure 2 shows some project-related activities and deliverables.

The design project contributed to a significant portion (35%) of the overall course grade. Students were required to submit regular team progress updates and were given feedback by both the faculty and medical instructors throughout the learning journey. The faculty instructor provided more content-oriented and general team-oriented feedback, whilst the medical experts provided project-based feedback. The team presentations were assessed by the instructors, and students were also given the opportunity to self and peer evaluate, and this looked at their meaningful contributions to group discussions and project planning, preparing of quality work on time, and demonstrating a cooperative and supportive attitude.

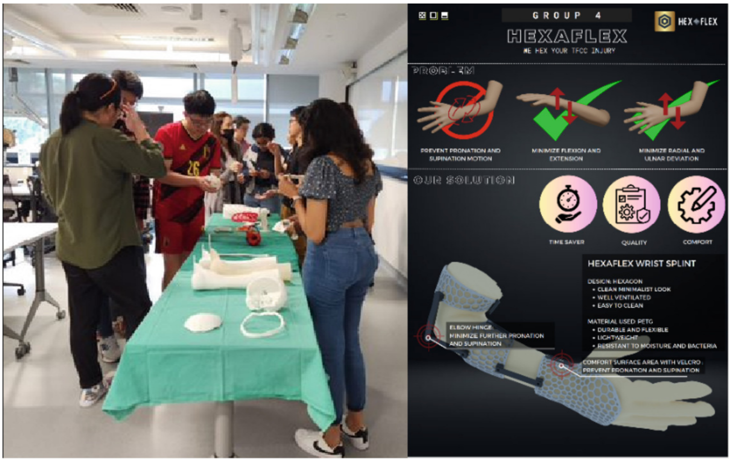


**Fig. 2.** a (Left). Students examining 3D printed artifacts and interacting with medical and allied health experts in Week 2, and b (Right). Students' final poster of splint prototype.

While there are several types of academia-industry partnership models, ours was based on functional expertise. The main collaboration was in the design and implementation of project-based learning.. Our hypothesis is that this approach will provide students with practical experience through interdisciplinary group-based projects, enabling them to apply their knowledge to real-world healthcare problems. The interactive and collaborative learning experiences will also help students develop essential skills that are highly valued in the healthcare industry. Moreover, the collaboration between academia and industry partners will provide students with exposure to the healthcare industry's needs and challenges, leading to a better understanding of the industry and its requirements. Through this non-traditional approach to healthcare engineering education, SUTD aims to nurture a new breed of healthcare engineers who are better equipped to harness technological advancements across disciplines to address current and emerging healthcare challenges. This can be seen as an incremental model of partnership than starting with the entire redesign of the curriculum.

## 3 Outcomes

Our objectives were to formulate an effective academia-industry partnership that builds effective curriculum, instructional design, pedagogy, facilitation, assessment, and feedback for healthcare engineering design. The main research question in our study was whether the implementation was engaging students in meaningful, authentic, and experiential learning. To this end, we look at the students' end-of-course evaluations, anecdotal and impromptu voluntary feedback, and the reflections of the academic and medical expert instructors. We present a summary of the findings here, which suggest that the course was found to be very interesting, engaging, and meaningful.

The end-term evaluations were very positive, with an overall course rating of 4.8 out of 5 (compared to the university average of 4.2). Students also gave excellent ratings of 4.7 and higher with regards to course content, organization, workload, and active learning experiences. We also examined the qualitative feedback of students to see if there were any pressing issues. Several students commented that the course was very interesting and that the project offered something unique given the real-world context and interaction with clinicians. They also enjoyed the hands-on learning experience with developing a 3D-printed wrist splint. The students also highlighted some challenges they faced with the project, such as the availability of 3D printers for full-sized prints and the need for extensive documentation.

Of the reflective feedback given by students, one of the suggestions was for future students to develop more electronic sensor-related technologies for healthcare engineering than a mechanical prototype such as a wrist splint. This can be seen as an individual preference. However, this also gave us ideas on new collaborative projects when moving forward. We anticipated that students may have challenges in learning and applying skills such as CAD, 3D scanning, managing time, and working with team members based on our teaching experiences and what is found in the literature. While students did express challenges in managing time, they seemed comfortable with learning and applying new skills, and their feedback suggested that group learning contributed to their learning. This suggests a need to manage cognitive load in view of the time needed. We quote one student's feedback, *"Working in groups helped me to learn from each other, and we took turns to try out scanning our wrists and helping each other. Learning this as an individual would have not been that fun or even possible. It also helped us to bond together as a team."*

Reflecting on the team-teaching experience, both the academia and industry partners felt satisfied with the progress of the course as having met the intended course learning outcomes. Students attained multi-disciplinary knowledge and skills in medical imaging, computer-aided design, 3D printing, and material selection, and developed other competencies such as clinical awareness, project planning and management, effective communication, and teamwork, etc. All students passed the course on the first attempt. Some suggestions for having a good working partnership are to identify suitable expert partners who share similar passion and ideology for teaching the specific content, being clear on everyone's roles, and co-creating a common project together while allowing the faculty instructor to take on the overall lead for the project and having clear communication. Working with different experts such as an allied health educator and an educational specialist also offered additional support and resources for the team. The challenge for the team is also in coming up with an interesting problem statement to drive their learning such that it is of the right complexity, difficulty, and feasibility. The team also agreed that it is important to scaffold the learning process with supplementary training workshops for additional skills such as CAD and 3D printing. Setting clear expectations and maintaining good communication to give feedback, or just to provide advice or encouragement is also important to support student learning. Building in formative and summative assessments that included feedback from instructors and students was also meaningful for learning.

Another set of outcomes of this project has been further collaboration between the faculty and medical experts on other educational initiatives, such as several projects offered under the Undergraduate Research Opportunities Program (UROP), etc. to design and develop other 3D-printed medical artifacts. In addition, the medical experts have established a new 3D Design and Printing Centre (3DPC) at SGH to further experiment with potential application of 3D printed designs in the clinical setting, and this leads to further refinement of the product and product development. The impact of the TBHE course delivery is beyond student learning, and it benefits both academia and industry partners in other ways.

Overall, a multi-disciplinary course such as this can be complex with many partners and learning components. When executed effectively, we find that it can lead to increased engagement, motivation, confidence, learning, and knowledge creation, for both students and instructors.

## 4 Conclusion

The proposed approach can serve as a model for academia-industry collaborations and be replicated across other healthcare engineering programs. Partnerships should be designed to promote collaboration, co-creation, and knowledge exchange across institutions. The interactive and collaborative learning experiences should be integrated across the four-year undergraduate engineering curriculum and evaluated regularly to ensure effectiveness. The approach can be further enhanced by incorporating other emerging technologies, such as virtual reality and artificial intelligence, to provide more realistic and immersive learning experiences.

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# Enhancing Vocational Training Institution's Curriculum Development in Lao PDR: Expert Recommendations for Industry Collaboration, Work-Based Learning, and Relevance to Labor Market

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**Abstract.** This paper explores the concept of cooperation between Vocational Training Institutions (VTIs) and the industry in the context of curriculum development in Laos. It analyzes the current state of VTI-industry partnerships and their challenges, aiming to identify best practices and recommendations for establishing effective collaboration between the two entities. Through a review of relevant literature on vocational education and training and VTI-industry partnerships in developing countries, as well as case studies of successful partnerships in Laos and the region, this research examines the factors contributing to successful collaboration. The research adopts a descriptive qualitative approach, utilizing expert interviews and employing Mayring's deductive categorization for content analysis. The sample for this research consists of three experts in the field of vocational education and training and skill development. To analyze the qualitative data collected from the expert interviews, Mayring's Structured Content Analysis (SCA) method is employed. Mayring's SCA is a systematic and structured approach to analyzing qualitative data. The findings reveal a consensus among experts regarding the inadequate level of collaboration between the industrial sector and VTIs in Laos, impacting the quality of graduates. Experts recommend actively engaging industry professionals in curriculum development and emphasize the need for government support through incentives and supportive policies. The paper's insights will benefit policymakers, VTI administrators, and industry stakeholders in Laos and other developing countries, fostering effective partnerships for curriculum development and supporting the growth of a skilled workforce to meet industry demands and promote sustainable economic development in Laos.

**Keywords:** Vocational Training · Work-Based Learning · Industry Collaboration · Labor Market Relevance · Cooperation of Learning Venues

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## 1 Introduction

In the rapidly evolving global economy, the importance of vocational training institutions cannot be overstated. These institutions play a vital role in equipping individuals with the skills and knowledge necessary to meet the demands of the labor market (Mouzakitis, 2010). The skilled workforce is crucial for sustained economic growth, the development of a robust and relevant curriculum within VTIs is of utmost importance (Misra, 2016).

Recognizing the need to strengthen the curriculum development process and align it with industry requirements, this publication presents a comprehensive set of expert recommendations tailored specifically for VTIs in Lao PDR. These recommendations focus on three key areas: industry collaboration, work-based learning, and relevance to the labor market.

The first area of emphasis is industry collaboration, which underscores the significance of fostering strong partnerships between VTIs and industries operating in Lao PDR. By actively involving industry professionals in the curriculum development process, VTIs can gain valuable insights into the current and future skill needs of the labor market (Kusuma and Napitupulu, 2022). Such collaboration ensures that the curriculum remains up to date, responsive to emerging industry trends, and aligned with the practical requirements of employers (GIZ, 2021).

The second area of focus is work-based learning, which advocates for a hands-on approach to education. Integrating practical training opportunities, such as internships, apprenticeships, and on-the-job experiences, enables students to acquire real-world skills and apply theoretical knowledge in practical settings (Gessler, 2017). This approach enhances their employability prospects and bridges the gap between education and industry needs, ultimately preparing them for successful careers in their chosen fields (Zeidan and Bishnoi, 2020).

Lastly, the publication highlights the critical aspect of relevance to the labor market. It stresses the importance of designing and delivering vocational training programs that address the specific needs of the local labor market. By conducting labor market assessments and engaging employers in the curriculum design process, VTIs can ensure that their graduates possess the skills and competencies that are in high demand, thereby increasing their chances of gainful employment upon completion of their training (Li, 2022).

Through the expert recommendations presented in this publication, VTIs in Lao PDR are provided with a roadmap for enhancing their curriculum development processes. By embracing industry collaboration, incorporating work-based learning opportunities, and ensuring relevance to the labor market, these institutions can empower their students with the skills and knowledge necessary to thrive in a competitive job market and contribute effectively to the economic development of Lao PDR.

## 2 Literature Review

Vocational training institutions (VTIs) play a vital role in providing students with the skills and knowledge needed to enter the workforce (Kargbo and Kanneh, 2018). These institutions focus on practical training and technical education, which are crucial for national development and reducing unemployment rates. However, VTIs face various challenges, including inadequate funding, insufficient infrastructure, and outdated equipment (Shehu and Alimi, 2016). To enhance the quality of VTIs, increased funding, modern equipment provision, and qualified instructor training are recommended.

VTIs also play a crucial role in addressing skills shortages and mismatches in the labor market (International Labour Organization, 2019). To ensure the relevance of skills provided by VTIs, close collaboration between these institutions and industries is necessary. However, effective cooperation between VTIs and industries in terms of curriculum development remains limited (Langat et al., 2018). This lack of collaboration stems from factors such as limited government support, industry's reluctance due to time and budget constraints, and hesitance among teachers to engage with the industry.

The involvement of industry in curriculum development is essential (Sampaio et al., 2021). Industry engagement ensures that the curriculum aligns with industry demands, leading to improved employability of graduates. Industry partnerships also provide valuable work-based learning opportunities, enhancing students' practical skills and employability (Kihn et al., 2019).

The dual training system, implemented in countries like Germany and Switzerland, combines classroom instruction with on-the-job training (Busemeyer and Trampusch, 2012). This system effectively develops practical skills and prepares learners for employment, benefiting both learners and employers (Grollmann and Wolter, 2014; Bahl and Sengupta, 2018). It also promotes social and economic mobility by reducing skills mismatches.

The best practices for the dual training system include strong partnerships between education providers and employers, flexible curriculum design, continuous evaluation and improvement, and high-quality training providers (Dearden et al., 2016; Kuczera and Wurzburg, 2012; European Training Foundation, 2018; Beicht et al., 2020).

Curriculum development principles guide the creation of effective and relevant curricula (Tyler, 1949; Wiggins and McTighe, 1998; Stufflebeam, 1971; Kelly, 2004; Schiro, 2013). These principles emphasize alignment with learning goals and objectives, incorporation of best practices in teaching and learning, assessment and evaluation, flexibility and adaptability, and collaboration and shared decision-making.

There is comprehensive research on possibilities of digitally supported, cross-institutional cooperation in teaching in German literature. Besides the well-known cooperation schemes in the so called dual system, mainly case studies from Saxony, a federal state in Germany, document how as well in the higher education such develops through digital media toward a new paradigm for education (Köhler and Neumann, 2013; Köhler et al., 2018; Paraskevopoulou et al., 2020).

In summary, VTIs are essential for developing a skilled workforce, reducing unemployment rates, and addressing skills shortages. Collaboration with industries, cooperation of learning venues, implementation of the dual training system, moments of digital transformation and adherence to curriculum development principles are vital for enhancing the quality and relevance of VTIs. These efforts contribute to improved employability and support sustainable economic growth.

## 3 Methodology

This research adopts a descriptive qualitative approach with a purposive sampling technique. The primary data collection method utilized in this study is expert interviews. Expert interviews involve individual interviews conducted with respondents who possess specialized knowledge and expertise in the research subject. These respondents provide valuable insights, authoritative opinions, and professional assessments related to the research topic (Libakova et al., 2015: 117).

The sample for this research consists of three experts in the field of vocational education and training and skill development. Expert A is the senior administrator of the Department of Technical and Vocational Education at the Ministry of Education and Sports of Laos. Expert B is the senior technical staff of the Vocational Education Development Institute, and Expert C is the senior staff of the Vientiane Capital Skill Development Center at the Ministry of Labor and Social Welfare.

The expert interviews follow a guided interview format with open-ended questions. The interview guideline serves as a reference to ensure comprehensive coverage of the research topic, but the interviewers have the flexibility to deviate from the guideline when necessary, allowing for in-depth exploration of specific issues raised by the interviewees (Mayer in Maruanaya and Koehler, 2022: 113).

To analyze the qualitative data collected from the expert interviews, Mayring's Structured Content Analysis (SCA) method is employed. Mayring's SCA is a systematic and structured approach to analyzing qualitative data. It involves a series of steps designed to identify and categorize key themes and concepts present in the data (Mayring, 2000).

The deductive categorization process in Mayring's SCA utilizes a set of question category indicators proposed by Mayring (2010: 65). These indicators are employed to define the categories and assign data points to specific categories. This systematic approach ensures rigorous and consistent analysis, grounding the categories in existing theory or research.

By employing Mayring's SCA and the expert interview method, this research aims to obtain rich and comprehensive insights from experts in vocational education and training and skill development, shedding light on the topic under investigation.

With these question category indicators, the researcher can systematically categorize the data into predefined categories. This method helps to ensure that the analysis is rigorous and consistent and that the categories used are grounded in existing theory or research (Table 1).

Furthermore, the data were analyzed using structured content analysis (Mayring in Kohlegger et al., 2009: 53).

Figure 1, from the study by Kohlegger et al. (2009), illustrates the coding process used in Mayring's Structured Content Analysis (SCA). The figure presents a flowchart that outlines the steps involved in coding the student-generated science reports analyzed in the study.

**Table 1.** Expert interview guideline questions according to the deductive categorization of Mayring (2010:65).

| Question | Category | Indicators |
|---|---|---|
| What does the concept of cooperation between VTI and Industry in terms of curriculum development in Laos? | 1. Guideline for designing the cooperation between VTI and Industry in terms of curriculum development | 1.1. Understanding the Dual-cooperative training programme<br>1.2. Understanding of dual-cooperative training in terms of curriculum development<br>1.3. Basis regulation for the implementation of the DCT |
| | 2. Curriculum development | 2.1. Understanding curriculum development in VTI<br>2.2. Existing model or concept of curriculum development in Lao PDR<br>2.3. Participation of industry in curriculum development at both the national and local level<br>2.4. Participation of other stakeholders in curriculum development in VTI |
| | 3. Component of the curriculum | 3.1. Strategy to determine the components of the curriculum (objectives, learning methods, learning media and materials)<br>3.2. Evaluation of curriculum |
| | 4. Current challenges of the development and implementation of the curriculum in Lao PDR | 4.1. Strategy<br>4.2. Policy<br>4.3. Stakeholders<br>4.4. Budget<br>4.5. Circumstance |
| | 5. Recommendation for improvement of VTI's curriculum development in Lao PDR | 5.1. Strategy<br>5.2. Policy<br>5.3. Concept of development<br>5.4. Components<br>5.5. Stakeholders<br>5.6. Budget<br>5.7. Quality Assurance |

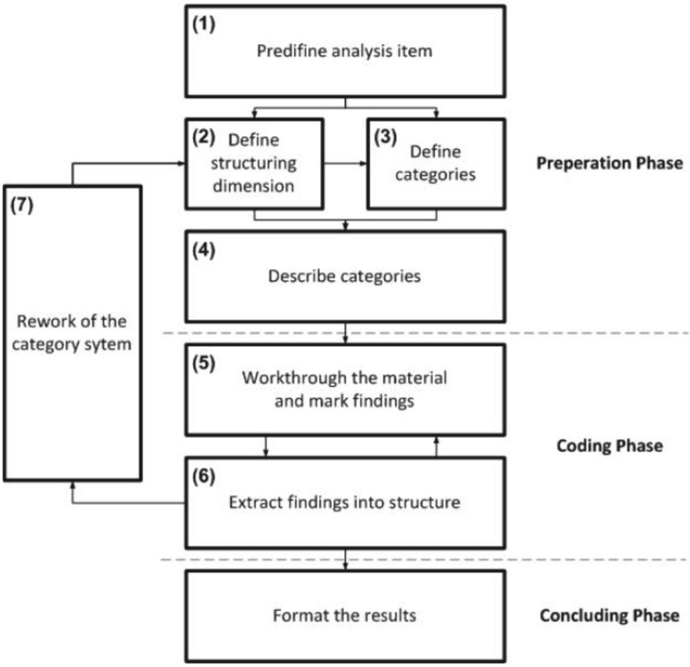


**Fig. 1.** Structured content analysis of Mayring (in Kohlegger et al., 2009: 53).

The coding process involves four main steps:

1) Definition of categories: In the first step, categories are defined based on the research question, and the content of the student reports. The categories are organized into a coding scheme that includes both main categories and subcategories.
2) Coding of the data: The student reports are then coded according to the categories and subcategories in the coding scheme. The coding process involves assigning each sentence or phrase in the report to one or more categories.
3) Checking for inter-coder reliability: To ensure the reliability of the coding process, two independent coders coded the student reports. The degree of agreement between the coders was measured using a kappa coefficient, and any disagreements were resolved through discussion.
4) Analysis of the data: Once the data has been coded, it is analyzed in terms of the frequency and distribution of the categories and subcategories. The results are then interpreted in light of the research question and the findings of the analysis.

Overall, Fig. 1. Provides a clear and concise overview of the coding process used in Mayring's SCA, illustrating how the method can be used to analyze qualitative data in a systematic and structured way.

# 4 Results

***Category. 1. Guideline for designing the cooperation between VTI and industry in terms of curriculum development***. The dual-cooperative Training (DCT) programme is a vocational education that combines classroom learning with practical experience in the workplace. It is a partnership between educational institutions and employers, with the goal of preparing students for the job market. The program consists of curriculum design, evaluation, and the integration of classroom learning with real-world experience. However, more specific examples and details are needed to understand the industries and fields that commonly use this type of training program and how it has been successful in preparing students for specific careers. Curriculum development is crucial for the DCT programme, with national-level collaboration and private sector requirements being essential. Experts emphasize the need for industry-school cooperation to ensure students acquire industry-relevant skills and enhance their employability. The Lao TVET Laws, amended in 2019, provide a legal framework for the DCT programme's implementation. The program received support from the german development agency GIZ and was included in the updated Lao TVET Law by the Ministry of Education and Sport. Overall, the DCT program in Laos benefits from a legal framework, government policies, and international support, demonstrating a commitment to its implementation and future development.

***Category. 2. Curriculum Development.*** The experts emphasize the importance of aligning vocational education curriculum with industry needs, involving skill analysis, and incorporating industry expertise. The DACUM model approach, used in Lao PDR, aims to ensure relevance to the work field. Industry participation in curriculum development is limited, with only a few schools in urban areas involving industry experts. The government should provide guidance and support for schools to collaborate with industry experts. Other stakeholders, such as civil society organizations, labor unions, and professional associations, should be involved in curriculum development processes to ensure relevance, effectiveness, and responsiveness to the needs of learners, employers, and society.

***Category. 3. Component of the curriculum.*** The experts emphasize the significance of a well-defined curriculum strategy for determining curriculum components. The experts stress the need for alignment with societal demands and the interrelatedness of objectives, processes, content, and evaluation. A clear strategy is crucial for effective vocational education programs that meet the needs of learners and society. The Ministry of Education shall conduct regular evaluations to monitor implementation, teacher activities, and teaching devices. These evaluations maintain quality, align with workforce needs, and promote effective teaching and learning. Various aspects, including objectives, materials, methods, and assessment, are examined to ensure curriculum effectiveness. In conclusion, a well-defined strategy for curriculum components and regular evaluation are vital in vocational education. The analysis highlights the importance of alignment with societal needs and the role of effective curriculum development and evaluation processes.

***Category 4. Current challenges of the development and implementation of the curriculum in Lao PDR.*** The Lao PDR faces significant challenges in developing and implementing a vocational education curriculum, particularly in involving industries. The strategy of involving industry in curriculum development is crucial, as it ensures that the curriculum is relevant to the labor market and prepares students with the necessary skills for employment. However, not all industries are interested in cooperating due to their prioritization of profits. This highlights the need for incentives for industries to participate in the curriculum development process, such as tax breaks or other forms of recognition. Time constraints are a major obstacle to coordinating with industries, resulting in incomplete information about work activities and skills. The lack of diversity in stakeholders involved in the development and implementation of the vocational education curriculum in Lao PDR is a concern, as only stakeholders from the industry are involved. This limited involvement of stakeholders from various backgrounds can lead to a narrow perspective in curriculum development and implementation. It is essential to have a diverse group of stakeholders to ensure that the curriculum meets the needs and expectations of all stakeholders. The government's budget is generally sufficient for the curriculum's planning, development, and implementation, but it only covers surface-level needs. Additional funding, particularly at the vocational institution level, is needed to support further development and address the specific requirements of each curriculum component. Budget constraints have led to obstacles in planning, developing, and implementing the curriculum, as training program duration needs to be restricted to accommodate budgetary constraints. The circumstances of the development and implementation of the curriculum in Lao PDR, particularly in rural areas, highlight the need for sustained financial support to overcome these challenges and ensure the effective implementation of the curriculum. Schools in rural areas face significant difficulties in developing and implementing the curriculum due to inadequate infrastructure, budget, and access to industry experts. The location of these schools is far from industry, making it difficult to coordinate and communicate with industry parties. Transportation costs and lack of funds also add to the challenges faced by these schools, as teachers in these areas often have to develop their own curricula without support from industry experts. In conclusion, addressing the circumstance-related challenges of the development and implementation of the curriculum in Lao PDR requires the government to invest in improving the infrastructure and budget of schools in rural areas, as well as developing programs to facilitate communication and coordination between schools and industry stakeholders, even in remote areas. By doing so, the Lao PDR can better prepare its students for the workforce and improve the quality of education provided in the country.

***Category. 5. Recommendation for improvement of VTI's curriculum development in Lao PDR.*** The experts recommend several recommendations for improving VTI's curriculum development in Lao PDR. They emphasize industry participation, policy, concept of development, components, stakeholders, budget, and quality assurance: industry involvement is crucial for maintaining current and relevant curricula, while industry partnership promotes efficiency and effectiveness. Internships help build hard and soft skills, and corporate involvement in Lao PDR curriculum development is also recommended; Policy should be strengthened through binding rules or laws to encourage industry participation in vocational education curriculum development. The government should establish regulations that compel industry to engage with schools, strengthen policies through legal frameworks, and consider incentives such as tax reductions; Components of curriculum development should include objective, subject matter, method, and evaluation aspects; Stakeholder involvement is essential for VTI's success, as it ensures an industry-aligned curriculum and equips students with essential skills; budget should be increased to support infrastructure and curriculum development; quality assurance is vital for assessing vocational education quality. Experts recommend timely, objective, and comprehensive evaluations, considering effectiveness, efficiency, relevance, and feasibility. Feedback and evaluation are essential while the curriculum is still valid. The CIPP evaluation model, focusing on Context, Input, Process, and Product, is suggested for correction. Periodic evaluations should be conducted to ensure curriculum alignment with objectives and market needs. Overall, the experts emphasize the importance of conducting thorough evaluations using suitable models to enhance the quality of vocational education curriculum development in Lao PDR.

## 5 Conclusion

In conclusion, during the expert interviews, several recommendations were made to improve the Vocational Training Institute's (VTI) curriculum development in Lao PDR in terms of various key measures as follows:

- Cooperation with Industry: The experts suggested that vocational schools need to involve stakeholders consisting of experts in the field of work related to the fields offered at the school. They recommended conducting regular meetings with stakeholders to get feedback on the curriculum, as well as providing internships for students in the industry.
- Work-based Learning: The experts recommended that VTI needs to increase work-based learning opportunities for students by collaborating with industries, cooperation of learning venues and offering apprenticeships and apprenticeships. They also suggested including practical experience as a mandatory part of the curriculum and providing training for teachers to supervise and guide students during work-based learning.
- Relevance to Labor Market Needs: The experts suggested that VTI should conduct regular labor market surveys to identify the skills needed by the industry and to adjust the curriculum accordingly. They also recommended involving the industry in curriculum development to ensure relevance and ensure that graduates meet the labor market's demands.
- Flexibility and Responsiveness: To increase flexibility and responsiveness, the experts recommended that VTI should revise and adjust the curriculum regularly based on industry needs and technological advancements. They also suggested providing a variety of courses and training programs to cater to different needs.
- Stakeholder Involvement: The experts recommended that all vocational schools in Laos should cooperate with the industry and involve experts from the field to benefit curriculum development. They suggested involving both industry experts and pedagogical staff who master methodical didactic knowledge.

- Budget: The experts suggested that the government should increase the budget for vocational schools in Laos, particularly in rural areas, where infrastructure is limited. They also recommended that schools seek additional funding from the industry and be proactive in obtaining external financial assistance.
- Quality Assurance: The experts suggested that VTI should regularly evaluate the curriculum using the CIPP evaluation model, which consists of Context, Input, Process, and Product. They recommended conducting periodic evaluations, at least twice a year, to check the overall performance of the curriculum and adapt to the development of science, technological progress, and market needs.

Overall, the experts emphasized the importance of involving the industry in curriculum development, providing practical experience through work-based learning opportunities, and regularly evaluating the curriculum to ensure relevance, flexibility, and responsiveness. They also suggested seeking additional funding to improve the quality of infrastructure and curriculum.

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# Teaching Best Practices

# Attention on the Academic Performance of Mathematics

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**Abstract.** Attention is a key in the learning process, so this study proposed to determine the influence of attention on academic performance in Mathematics. The Toulouse Piéron Attention and Perception Test was applied for evaluating the students' level of attention. The methodology used has a mixed approach, that is, both qualitative and quantitative, the levels of research implemented were descriptive, exploratory and correlational, with field, documentary and bibliographic modality. The population consisted of 51 students belonging to the fifth grade. For the analysis and discussion of results, SPSS was used, for the reliability of statistical data the Cronbach's alpha having a value of 0.917. In the results obtained after applying the Toulouse Test and after the analysis of the grades records of the mathematics subject, the level of significance $\alpha = 0.05$ was used, which in turn represents 95% confidence, obtaining a bilateral significance of 0.001 so it was concluded that there is a high correlation between the variables, since the value of $p = 0.001$ and this to be less than $\alpha = 0.05$ and according to the golden rule, the null hypothesis (H0) is rejected and the alternative hypothesis (H1) is accepted in which it is mentioned that attention influences the academic performance of the area of mathematics. It was concluded that most students have a high attention level, and the rest between the medium and low attention level, which are directly related to the grade scale.

**Keywords:** Attention · Attention factors · Academic performance

## 1 Introduction

Attention plays a fundamental role in the learning process, since it is the process by which our mind captures vividly and clearly one of several objects or ideas that occur simultaneously, that is, it is a process of concentration and selection of information from those most relevant stimuli, so perception, attention and memory are located within the cognitive processes that allow coding or processing information through stimuli in order to filter with basic or advanced processes. Moreover, attention being the basis of any learning directly affects learners´ academic performance, since through it one can obtain a high academic performance and acquire learning skills.

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Learning in a student is one of many manifestations of the results of their academic performance, which is influenced by multiple factors of different types, which have to do with the pedagogical attention that students receive from their teachers, and their performance in achieving effective and emotional learning.

## 2 State of the Art

The extrinsic factors present in attention are those captured by external stimuli, that is, those present in the environment and through which concentration is favored or hindered [10].

- The size: which makes it possible to capture stimuli with greater magnitude.
- The position: which allows greater uptake towards left and upper lateral areas.
- Color: since greater attention is paid to stimuli with color.
- Intensity: in the case of mostly striking stimuli.
- Movement: drawing your attention to moving stimuli.
- Complexity: to capture several stimuli at once.
- Relevance: to filter stimuli with a greater degree of importance.
- Novelty: which captures changes.

Likewise, it states that intrinsic factors are those specific or personal characteristics that allow to capture one's own mental stimuli, that is, they are present in each individual, so that it depends on each individual, being a component of voluntariness. Among them we have:

- The interests will depend largely on the interest of the individual.
- Expectations of results.
- Personality traits.

Attention is a process of concentration and selection of the most relevant information and selection of those important stimuli, leaving the other stimuli more distracted because they are not a central part of the process, so the concentration and focusing of consciousness are part of its essence [3].

In the same sense, attention is a cognitive function that allows attention either actively or passively, or voluntarily or involuntarily, to the interest of a person and awareness of stimuli or events, whether internal or external, chosen among all the perceptual stimuli present in each moment [3]. Therefore, in a classroom, attention is usually a determining factor since attention is the basis of any learning.

The functioning of the attentional process involves the participation of several brain structures [7]. Care comprises four sub-processes:

- Focused attention: consists of the initial activation through the ability to focus and efficiently execute actions, which is closely related to the perceptive motor speed capacity.
- Sustained attention or concentration: that involves remaining attentive for a long period of time despite frustration or boredom.
- Selective attention: which involves filtering and encoding information in the presence of distractors, so that the information remains in memory and can be stored for as long as necessary.

- Alternating attention: consists of changing attention adaptively and voluntarily according to the demands present in the environment, allowing to change the focus quickly.

Within the functioning of the attention consist of the following characteristics, which help to understand them better, in this sense, the reaction of the individual will depend mostly on the attentional process that is carried out, either in the filter, coding or analysis of the information [4].

- Orientation: emphasizes the ability to direct collective resources voluntarily towards relevant elements or events, that is, decide the actions to be carried out.
- Focusing: which refers to the ability to concentrate on one or several stimuli at the same time, discarding others that are not relevant in this process, so the relevance of the information will be decisive.
- Concentration: which emphasizes the ability of human beings to focus on a stimulus from among all those in the environment for a long time and ignore others.
- Cyclicality: which focuses on attentional capacity in terms of basic cycles, either in terms of activity or rest.
- Stability: which involves keeping your attention focused during a certain time parameter, whether short or prolonged, and at the same time staying focused and attentive to certain activity or information.
- Flexibility: which refers to the ability to respond to certain situations in various ways, managing to change the focus of thinking and its action.

In this sense, academic performance is the degree of achievement of the objectives of a student within the academic field, this involves the measurement of knowledge through qualifications, with this it is intended to generate basic competencies that facilitate students to fulfill their social and labor role pertinently. Therefore through academic performance the attitudes and aptitudes of students are measured as a response to the educational process and its application in everyday life. Thus, the evaluation of learning can and should be seen as a management system of a teaching process with specific characteristics, and its function should include the evaluation of learning produced in the classroom, where students demonstrate not only their knowledge but also their ability to apply them. [9].

Therefore, teachers should focus on proposing a time parameter and a continuous feedback process for students to achieve their learning goals, evaluation and teaching practice should be improved for the progress of student learning and, finally, evaluations should be realistic, relevant, constructive, communicative and flexible, to validate skills, knowledge and skill achievement [6].

There are several factors that directly affect academic performance. [1]:

- Biological factors: are those parts that make up the body structure of the student, such as sight, ears, hands, etc.
- Pedagogical factors: refer to learning problems that underlie various activities and tasks in schools, such as comprehension, reading speed, vocabulary richness, automatic calculation, and methodology.
- Social factors: what surrounds the student, such as family, friends, financial situation, health, among others.

- Family factors: they have a strong influence on the behavior patterns of students, and it is in the family environment where they acquire most of the factors that shape their personality.
- Economic factors: Children born into poor backgrounds experience different circumstances as they grow up.
- Psychological factors: go hand in hand with physical factors since a person must have a balance of mind and body to be at their best.
- Cultural factors: since there are still some parents who do not believe that it is worth studying since they think it is a waste of time.

## 3 Methodology

To thoroughly investigate the relationship of the variables, the survey technique was applied using the instrument of the Toulouse Piéron Test, which consists of measuring the degree of attention and concentration through a test with graphic figures distributed among 40 rows, classifying them by high, medium and low level according to the score of successes. The test was applied to 51 students belonging to the fifth grade of Basic General Education, 27 of the morning shift and 24 from the afternoon, who belong to “Nicolás Martínez” School. The test was also applied in order to know the level of attention they have and the relationship with their academic performance (Table 1).

**Table 1.** Reliability statistics

| Cronbach’s alpha | N° of elements |
|---|---|
| 0,914 | 51 |

*Note. Data obtained from the analysis in SPSS*

Taking into account Cronbach’s alpha based on the number of elements which allows to verify that the degree of reliability is excellent, so they are considered valid and acceptable results.

The research included a qualitative-quantitative approach, which focuses on knowing the educational reality. In this sense, their cognitive commitment to reach the truth is legitimate and common between the two. As for the qualitative approach, this is based on evidence that is oriented more towards the deep description of the phenomenon to understand and explain it through the application of methods and techniques. [5].

The modality used in this research was field, since this process allows to obtain data from reality and study them as they are presented, without manipulating the variables [11]. Likewise, documentary or bibliographic research is one that seeks to obtain, select, compile, organize, interpret and analyze information about an object of study from documentary sources, such as books, archive documents, audiovisual records, among others [2]. Therefore, the research data was obtained through the review of documents so that the information collected was organized in a coherent manner, taking into account the two variables attention and academic performance (Table 2).

The exploratory study "is applied in phenomena that have not been previously investigated and there is an interest in examining their characteristics" (p.2). This type of research helped to clearly interpret the topic and the relevant aspects around attention deficit and academic performance, so it was necessary to make direct observations in order to identify the problem and strengthen the knowledge of the variables. [8].

As for the descriptive level, it is mentioned that "the characteristics of the phenomenon are known and what is sought is to expose its presence in a certain human group" (p.2). For the quantitative process, the analysis of central tendency and dispersion data were applied. In the research with descriptive scope of qualitative type, phenomenological or narrative studies of constructivist were carried out, which seek to describe the subjective representations that emerge in a human group about a certain phenomenon [8].

As for the correlational study, it is said that "the need arises to raise a hypothesis in which a relationship between two or more variables is proposed" (p. 3). To this end, inferential statistical processes were applied to extrapolate the results of the research and thus benefit the entire population by inquiring in a pertinent way through the measurement of the relationship between the variables of attention and academic performance through the Toulouse Test. [8].

# 4 Results

**Table 2.** Results test of Toulouse Piéron applied to fifth grade students EGB

| Level of care (Toulouse test) | Range hits | Frequency | Percentage |
|---|---|---|---|
| High | 163 - 216 | 22 | 43,2% |
| Middle | 82 - 162 | 25 | 49% |
| Low | 28 - 81 | 4 | 7,8% |
| | Total | 51 | 100% |

*Note. Range established by scores described in the manual*

**Analysis and Interpretation**

Based on the results obtained through the Touluse Piéron test applied to 51 fifth-year EGB students of the "Nicolás Martínez" school both morning and afternoon shifts, it is evident that of the total population, 43.2% of students have a high attention level, 49% have a medium attention level and 7.8% have a low attention level. The relationship with the percentages that have been obtained through the application of the Toulouse Piéron Test can be considered that there is a considered number of the population that presents an average degree of attention since the score obtained varies between 82 and 162 correct answers, while there is a minority index of low attention that corresponds to students with less than 82 correct answers and on the other hand an average group is considered with average attention corresponding to students with correct answers greater than 162. In addition, the results are related to the academic performance presented by each student, evidencing the relationship between attention and academic performance (Table 3).

**Table 3.** Qualitative and quantitative scale of qualifications of the students of fifth EGB of the "Nicolás Martínez" School

| Quantitative scale | Qualitative scale | Frequency | Percentage |
|---|---|---|---|
| Master the required learnings | 9,01+ | 19 | 43,1% |
| Achieve the required learnings | 7,01 - 9,00 | 29 | 52,9% |
| It is close to achieving the required learning | 4,01 - 7,00 | 3 | 3,9% |
| Fails to meet required learning | $< = 4$ | - | - |
| | Total | 51 | 100% |

*Note. Qualitative and quantitative references taken from the General Regulations of the LOEI*

### Analysis and interpretation

Based on the records of qualifications that correspond to the first part of the subject of mathematics of the students of the "Nicolás Martínez" School, it is stated that 43.1% corresponds to students who master the required learning, 52.9% of students reach the required learning and 3.9% of students are close to achieving the required learning, and according to the record of grades, there is a considerable number of students who exceed the average necessary to pass the subject.

### Hypothesis Testing

Hypothesis formulation

$\mathbf{H_1}$: Attention influences the academic performance of Mathematics.

$\mathbf{H_0}$: Attention does not influence the academic performance of Mathematics.

### Statistician specification

For the hypothesis verification, Spearman's non-parametric Rho correlations statistic was used, it helps to obtain the statistical dependence of the ranking between two variables, agreeing whether there is a strong and positive correlation (+1) or strong and negative correlation (-1) (Table 4).

**Table 4.** Matrix of correlations between elements

| | Test | Mathematics subject grades |
|---|---|---|
| Test | 1,000 | 0,841 |
| Mathematics subject grades | 0,841 | 1,000 |

*Note. Data obtained from the analysis in SPSS*

**Significance level**
To verify the hypothesis, the significance level a = 0.05 was used, which in turn represents 95% confidence (Table 5).

$\mathbf{H_0}$: $P$value $\geq$ 0,05.

$\mathbf{H_1}$: $P$value $\leq$ 0,05.

**Table 5.** Correlations Rho de Spearman

| | | | Test | Mathematics subject grades |
|---|---|---|---|---|
| Rho de Spearman | Toulouse Piéron Test | correlation coefficient | 1,000 | 0,911** |
| | | Sig. (bilateral) | | 0,000 |
| | | N | 51 | 51 |
| | Mathematics subject grades | correlation coefficient | 0,911** | 1,000 |
| | | Sig. (bilateral) | 0,000 | |
| | | N | 51 | 51 |

*Note. **. The correlation is significant at the 0.001 level (two-sided)*

## 5 Conclusions

With the results obtained it is concluded that there is a close relationship entre the variables studied, given that the value of p = 0.001 is less than $\alpha$ = 0.05 and according to the golden rule, the null hypothesis (H0) is rejected and the alternative hypothesis (H1) is accepted in which it is mentioned that attention influences the academic performance of mathematics in the students of the fifth grade of the Nicolás Martínez School from City of Ambato.

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# Flipped Classroom in Pedagogical Practice

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**Abstract.** The flipped classroom method can be defined as an instructional method where students engage with teaching materials, such as videos or resources, prior to class. Subsequently, classroom time is dedicated to collaborative discussions, addressing challenging aspects of the curriculum, and applying knowledge through practical exercises under the guidance of the teacher. While we employed a similar teaching approach across various subjects, we encountered numerous shared experiences and findings. Notably, we observed that the application of the flipped classroom method can be influenced by the specific subject being taught, particularly in terms of content. We discovered that implementing identical teaching procedures within a flipped classroom framework does not consistently yield satisfactory outcomes in terms of students' knowledge gain, emphasizing the significance of subject-specific content. This prompts the question of whether the flipped classroom method is universally applicable across all subjects We sought the answer to this and other questions in the framework of a questionnaire survey, the results of which are reported in this article. Overall, we believe that when utilized and executed correctly, the flipped classroom can serve as a highly effective teaching method.

**Keywords:** Flipped Classroom · Educational Methods · Online Teaching

## 1 Introduction

We encounter different opinions on online teaching, which was forced on schools by the pandemic situation in March 2020. If we focus only on the field of higher education, the transition to such a form of teaching caused the least problems, as students had already encountered distance forms of teaching such as e-learning [1] and m-learning [2, 3].

During the closure of schools, but especially after the end of the pandemic situation, several publications, articles, and studies began to appear, which were related to the issue of various forms of distance education, in which individual teachers shared their experiences of how they dealt with the distance education of their specific subject. Diverse viewpoints were expressed. The results of the survey [4] showed a positive impact of distance education on students in the field of Teaching and Pedagogical Sciences. Students frequently cited various positive factors, including the convenience of studying from home, reduced commuting time and expenses, increased free time, enhanced

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time management, and improved information and communication skills. These aspects were commonly highlighted by students as valuable benefits associated with the flipped classroom method.

According to [5], the transfer of the educational process to the virtual online space resulted in a decrease in the level of attention, the possibility of control, and an overall decrease in the quality of education for teachers and students alike. One of the reasons cited by the author is the reduction in communication components that are fully utilized in face-to-face teaching. According to the author, this change in teaching format is especially prominent in subjects that require physical interaction with teaching materials or engage multiple senses (such as sight and hearing). Additionally, subjects that prioritize problem understanding over memorization of encyclopaedic knowledge are also affected by the shift in teaching methods.

In the article [6], the authors also point out that changing teaching methods from face-to-face teaching to distance learning methods and replacing face-to-face teaching with e-learning activities does not automatically mean a decrease in the level of student knowledge. The use of modern information and communication technologies leads to the development of digital competencies for both teachers and students.

The stated opinions document both the positive and negative aspects of distance education, and we identify with both of them.

From our perspective, the age of the students is a significant factor that greatly impacts the effectiveness of distance learning. Teaching primary school pupils, secondary school students, or university students differs significantly, whether in traditional classroom settings or in remote education.

The content of the subject taught is another crucial factor to consider. Some subjects are extremely challenging to teach solely through online means. These subjects often require specialized laboratory equipment or dedicated laboratory workstations, such as in chemistry or physics. Additionally, there are subjects were acquiring theoretical knowledge alone is not sufficient, as students also need to develop practical skills, such as serving guests in a restaurant, driving a car, piloting an airplane, or performing surgical operations on patients.

As with face-to-face teaching, there are different methods of education that teachers can use depending on the age of the students, the content of the subject, the range of lessons and other factors. Choosing the right teaching method is only up to the teacher. The teaching method they choose for their subject depends on their pedagogical abilities and skills. It is evident that only with the help of an appropriately chosen and properly implemented teaching method, it is possible to achieve a high-quality educational result.

## 2 Flipped Classroom

Flipped Learning is a "pedagogical approach in which direct instruction moves from the group learning space to the individual learning space, and the resulting group space is transformed into a dynamic, interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter" [7].

The Flipped Learning Network (FLN) emphasizes the distinction between a Flipped Classroom and Flipped Learning, as recognized by the governing board and key leaders. It's important to note that these terms are not interchangeable. Flipping a class can potentially result in Flipped Learning, but it is not an automatic outcome. Many teachers may already employ a form of flipped learning by assigning readings, supplementary videos, or extra problems for students to complete outside of class. However, to truly embrace Flipped Learning, teachers must incorporate the following four base pillars into their practice: Flexible environment, Learning culture, Intentional content, and Professional educators [7].

In addition to the pillars, they also established checklist of eleven indicators that educators must incorporate into their practice [7].

Flipped Learning is an instructional approach that aims to align pedagogy with the demands of our modern world and its ever-evolving circumstances. It is important to note that Flipped Learning does not signify a complete overhaul of pedagogy. Instead, it allows for the implementation of certain conditions within the learning process. For instance, if students fail to complete the initial lesson, they may not be granted access to subsequent lessons. This approach promotes individualized education, recognizing that each student has their own unique pace of learning and assimilating information. Additionally, incorporating video content can be an effective tool within Flipped Learning [8].

A flipped classroom revolutionizes the traditional learning experience by inverting its structure. Instead of delivering lectures during class time, they are recorded beforehand and shared with students as their "homework." This approach allows for classroom time to be utilized for interactive discussions and engaging activities.

The primary objective of flipping the classroom encompasses the creation of a more interactive and dynamic learning environment within the classroom, the facilitation of individualized learning by allowing students to progress at their own pace and the empowerment of instructors to customize the course content to meet the specific needs of each student. In other words, flipped classroom aims to address the inherent limitations of the conventional lecture format, which has been in practice since the mid-fourteenth century [9].

The flipped classroom emphasizes the use of blended learning approaches that involve different cognitive and affective responses on the part of learners [10].

Having students watch assigned short instructional videos on their own before a face-to-face or online class can play a positive role in reorienting students' attention to learning [11].

Providing lecture materials in an on-demand format allows students the flexibility to access them at their convenience and in a location that suits their preferences. Moreover, students can review crucial or ambiguous information repeatedly until they have a thorough understanding. Consequently, students arrive in class equipped with a solid comprehension of the subject matter, enabling them to actively engage in discussions and practical activities that put their knowledge into practice.

Within the classroom setting, various activities such as group work, comprehension tests, presentations, and practical applications of the subject matter can take place. As students engage in these activities, they may have individual questions that arise. In such instances, both the teacher and fellow students are available to offer responses and support, thus facilitating a more personalized learning experience for each student. [9].

Flipped classroom represents a more efficient use of class time, as it focuses on the practical application of knowledge during class.

A Flipped Classroom is „when you give out materials before class. However, Flipped Learning only happens if the above-mentioned pillars are also in place. "[12].

In our perspective, the flipped classroom can serve as a highly effective teaching method when implemented correctly. However, it is crucial to assess whether this approach aligns with the specific needs and circumstances of both students and teachers. Additionally, careful consideration should be given to the potential impact on students' learning and performance.

## 3 Course of Teaching

We applied the flipped classroom in the teaching of various subjects and for students of various fields and grades (Table 1).

**Table 1.** List of subjects taught using the flipped classroom method.

| University/Faculty | Subject | Year/degree | Study programme |
|---|---|---|---|
| Trnava UniversityFaculty of Education | ICT in education | 1/bachelor | Preschool and elementary pedagogy |
| | Information education in primary school | 1/master | Teacher for primary education |
| | Management of ICT assets | 1/bachelor | Teacher of informatics |
| Comenius University Bratislava<br>Faculty of management | Managerial statistics | 4/master | Management |
| | Modelling of economic processes | 4/master | Management |
| | Introduction to computer statistics | 3/bachelor | Data analytics |

The content of all the subjects that we taught in the flipped classroom method requires work on personal computers. Within these subjects, students were supposed to learn to work with special software and then solve assignments and tasks with that software. These assignments differ depending on the specific subjects, for example in Managerial Statistics they utilized the R software for statistical computations, or in the Introduction to Computer Statistics they utilized the programming language Python for statistical model creation.

During the implementation of the flipped classroom, we provided the students with video recordings that contained an explanation of the teaching material in a similar way as if we were explaining the curriculum during face-to-face teaching. The video recordings were created in the MS Teams environment and, if necessary, were edited with the appropriate software.

We gradually made the videos accessible to students via MS Teams, ensuring they were available no later than the Friday preceding the week of online or face-to-face instruction. Students had the option to either watch the video recordings online or download them onto their computers. Depending on the curriculum content covered in the videos, students could learn the presented procedures and test the functions of various programs on their own computers. In the event of any difficulties, they had the opportunity to revisit the videos multiple times. Such flexibility is not always feasible during in-person instruction, as time constraints prevent teachers from repeating specific steps multiple times, particularly when other students have already grasped the concept.

Traditional face-to-face instruction involved synchronous teaching in physical classrooms, whereas distance learning occurred online via MS Teams, following a schedule that mirrored the class timetable. Through online teaching, students had the opportunity to join sessions initiated by the teacher. The number of students in a lesson was not limited, allowing students to participate in multiple sessions if they so desired. These sessions primarily served as consultation periods, during which the teacher addressed any questions raised by students regarding the video recordings' content.

The MS Teams program offered a highly valuable feature during online synchronous classes, namely the capability of screen sharing. This function served various purposes: the teacher could share their screen to present procedures and solutions, while more frequently, students shared their screens to seek assistance. If a student encountered a challenge, they shared their screen with all participants in the meeting, enabling the teacher to identify the mistake and provide verbal guidance on rectifying it. This process allowed other students to observe and learn from the entire problem-solving procedure. If they encountered a similar error, they could address it simultaneously. We considered this aspect the most practical advantage of synchronous online teaching compared to face-to-face instruction. In face-to-face teaching, if multiple students faced the same error, the teacher would have to address each occurrence individually at their respective workstations, consuming significantly more time.

As the semester progressed, we observed during online consultations that students assigned varying levels of importance to the provided video recordings for self-study. Surprisingly, some students would attend the online class without having watched any of the provided videos beforehand. This behavior was even noticed by their peers, who became quite exasperated with their questions, responding with remarks such as, "You were given a thorough explanation in the video, watch it instead of wasting time with unnecessary questions!" In these instances, the students themselves would acknowledge that they had not yet viewed the specific video lecture being referred to.

Conversely, there were instances where questions arose in class that pertained to video content scheduled for the sixth or seventh week of instruction, merely three weeks into the teaching process. Interestingly, these students expressed a keen interest in the topic, demonstrating their curiosity regarding its progression. As a result, they gradually accessed and watched all the provided videos in chronological order.

During the online lessons, we observed an interesting phenomenon. Each study group had a designated teaching time according to the schedule. Because all students were assigned to one team within MS Teams, they could participate in any meeting as it was accessible to everyone. The teacher had the convenience of an automatically generated “attendance list” that could be downloaded for monitoring student participation. It turned out that during the semester, but especially towards its end, some students were connected for several hours and followed the events in different study groups.

## 3.1 Education Results

As part of one of the taught subjects (ICT in education), we compared the academic results of students who completed teaching using the flipped classroom method and the results of face-to-face teaching students.

In both teaching formats, students independently solved assignments at home and submitted their work electronically. Evaluation of the students’ performance was conducted based on uniform criteria.

Table 2 shows the achieved results of the students and the number of participants in the lessons.

**Table 2.** Table of input values

| Grade | A | B | C | D | | E | FX | Observations | Sum |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 1,5 | 2 | 2,5 | | 3 | 4 | | |
| Face-to-face teaching 2018 | 46 | 47 | 28 | 7 | | 1 | 9 | 138 | 227 |
| Face-to-face teaching 2019 | 33 | 37 | 14 | 2 | | 0 | 3 | 89 | |
| Flipped classroom (online) 2020 | 64 | 36 | 11 | 0 | | 0 | 0 | 111 | 231 |
| Flipped classroom (online) 2021 | 84 | 25 | 11 | 0 | | 0 | 0 | 120 | |

The results of descriptive statistics (Table 3) show that the average and median grades in face-to-face teaching were worse than in the online classrooms.

**Table 3.** Descriptive statistics of face-to-face and online teaching

| Form | Amount | Average | Standard deviation | Median | Min | Max | Range | Skewness | Kurtosis | Standard error |
|---|---|---|---|---|---|---|---|---|---|---|
| *Face-to-face* | 227 | 2.14 | 1.25 | 2 | 1 | 6 | 5 | 1.53 | 2.39 | 0.08 |
| *Online* | 231 | 1.45 | 0.66 | 1 | 1 | 3 | 2 | 1.14 | 0.06 | 0.0 |

The statistical findings indicate that, in the specific subject under consideration, students attained superior academic outcomes through the implementation of the flipped classroom approach compared to traditional face-to-face method.

### 3.2 Statistical Processing of Results

As part of processing the results, we hypothesized that the acquired level of students' knowledge is higher in flipped classroom teaching than in face-to-face teaching. We proved the hypothesis using appropriate statistical methods.

We determined the normality of the probability distribution of the samples using the Shapiro-Wilk normality test. The Shapiro-Wilk test gives the expected result (Table 4) as both data sets have a p-value less than 0.05. Thus, in both cases, the data differ from the normal distribution, so in further research, we worked with the non-parametric Wilcoxon test.

**Table 4.** Results of Shapiro-Wilk normality test

| Method | W | p-value |
|---|---|---|
| Face-to-face | 0.72557 | $< 2.2e-16$ |
| Online | 0.67278 | $< 2.2e-16$ |

To ensure the validity of the Wilcoxon test, it was imperative to examine the assumption of homogeneous dispersion within the two analyzed samples. To assess the homogeneity of variance, Levene's test, utilizing the median of the data, was employed. The outcomes of this test are presented in Table 5.

**Table 5.** Results of Levene's Test for homogeneity of variance

| Degrees of freedom | F value | p-value |
|---|---|---|
| 5 | 0.6846 | 0.6356 |

The obtained p-value, exceeding the threshold of 0.05, indicates that there is no statistically significant difference in variances between the two samples. Consequently, the assumptions of the Wilcoxon test are satisfied.

A one-sided variant of the test was employed to assess the data. With a predetermined significance level of 0.05, as indicated by the lower p-value (Table 6), it is confirmed that the academic performance of students significantly improved under the flipped classroom educational method.

**Table 6.** Results of Wilcoxon test of mean values

| | |
|---|---|
| W | 34575 |
| p-value | 3.448e-12 |

The hypothesis is supported by the evidence, confirming a significant disparity in the proficiency level of students in the subject "ICT in education." Specifically, students who underwent the flipped classroom format demonstrated superior academic achievements compared to their counterparts who followed the traditional face-to-face teaching approach.

As early as 2014, case studies conducted in Spain, Hungary, and the Czech Republic [12] unveiled a notable distinction in the outcomes of students taught through the conventional face-to-face method versus those taught using the flipped classroom approach. Our own research findings align consistently with these previous studies.

## 4 Assessment of Flipped Classroom by Students

Based on the experience gained during education using the flipped classroom method, we decided to find out what opinion the students formed about this form of teaching.

To find out the students' opinion on the implementation of teaching using the flipped classroom method, we created a questionnaire that we distributed electronically. The questionnaire was distributed to 185 respondents who completed the subjects listed in Table 1 during the past school year using the flipped classroom method, it was anonymous, and its completion was not mandatory. It was filled in by 134 respondents, i.e., the return rate of the questionnaire was 72.4%.

The questionnaire comprised a concise set of four closed questions, with predetermined answer options. While one question could be considered as scaled, as it entailed rating on a scale from one to five, the ultimate selection was like grading from excellent to insufficient or from pass to fail, requiring respondents to choose a single value.

To evaluate the questionnaire, we used the methods of exploratory analysis, with the help of which we examined and visualized the data, and thus obtained a better overview of the answers to the questions asked. We evaluated the answers to each question separately. We used a percentage evaluation, with the help of which the importance of each item was determined, i.e., we found out what importance the respondents attribute to individual values. However, it is important to note that this evaluation method does not facilitate direct comparison between different values, meaning that it cannot determine the relative importance of one value over another [13].

In the first question, we asked the respondents: "How would you rate the flipped classroom teaching method?" The respondents' answers to the first question are shown graphically in Fig. 1.

The responses indicate that 90% of the respondents rated the flipped classroom method of teaching as above average (excellent - 68%; very good - 22%), providing confirmation that students are highly satisfied with this educational approach. However, it would be intriguing to explore the reasons behind the negative feedback from the remaining 10% of students. This could serve as an incentive for a future research project, delving into the factors influencing their perspective.

The subsequent two questions focused on the feasibility of employing the flipped classroom method in distance and face-to-face teaching. The responses of the participants are depicted in Fig. 2 and 3, revealing that students can envision the implementation of the flipped classroom approach in both present as well as distance educational formats.

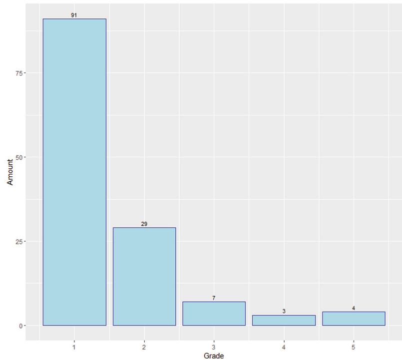


**Fig. 1.** Distribution of the answers to question 1.

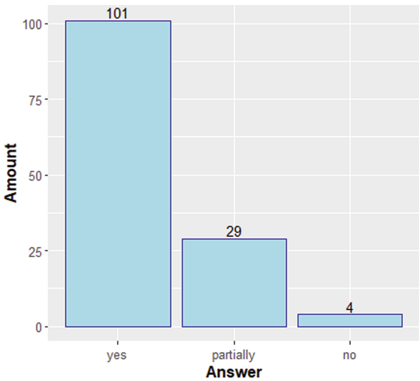


**Fig. 2.** Distribution of the answers to question 2.

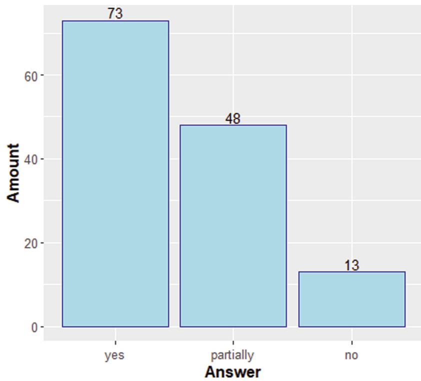


**Fig. 3.** Distribution of the answers to question 3

Figures 2 and 3 illustrate the contrasting viewpoints of students regarding the utilization of flipped classrooms in distance and face-to-face education. While there is a prevalent positive opinion toward distance education, the perception of the flipped classroom method in face-to-face education is less definitive. Notably, the number of respondents (10%) who do not endorse this method for traditional education has also increased. Despite the diverse range of subjects and universities among the respondents, the findings indicate that the flipped classroom approach is well-received among students in the context of distance education.

The final question aimed to gauge students' perceptions of interactions with the teacher during face-to-face or online lessons, which are crucial components of the flipped classroom method. Figure 4 displays the responses of the participants to the question: "Do consultations with the teacher during the lesson provide students with adequate feedback on their understanding and mastery of the subject matter?".

A significant majority of respondents (73%) indicated that the consultations provided satisfactory feedback from teachers, while an additional 25% expressed partial satisfaction. When combined, these percentages reach 98%. This indicates that the communication between teachers and students during face-to-face or online lessons is deemed adequate for clarifying or expanding upon the content covered in video recordings, ensuring a comprehensive understanding of the subject matter.

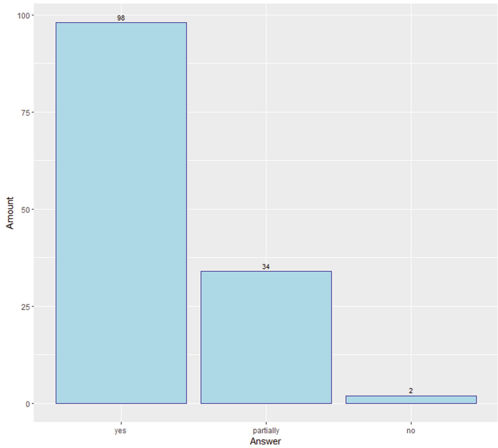


**Fig. 4.** Distribution of the answers to question 4.

## 5 Conclusion

The findings of our research, along with the responses gathered through the questionnaire, clearly indicate, and substantiate the efficacy of employing the flipped classroom approach for certain subjects. It is evident that this method can yield comparable success rates to both face-to-face instruction and distance learning. However, the degree of achievement largely hinges on the teacher's creativity and expertise. The teacher's responsibility extends to preparing and delivering high-quality electronic learning materials while simultaneously guiding and motivating students towards increased autonomy in their studies. Modern technologies present teachers with the chance to harness their didactic and pedagogical creativity, thereby enhancing the effectiveness, quality, motivation, interest, and creativity of their teaching endeavours [14].

Implementing the flipped classroom approach, whether in distance learning or face-to-face education, can prove highly beneficial for students. It enables individualized learning and fosters interaction among peers and teachers, regardless of geographical distances. Nevertheless, teachers must ensure that the learning materials are meticulously prepared, ensuring clarity, accessibility, and comprehensibility for all students. Additionally, resources should be readily accessible to support students who may require assistance in grasping the content.

In general, the flipped classroom approach offers students enhanced flexibility in their learning journey and facilitates accelerated progress towards their goals. This teaching method exhibits remarkable adaptability across various educational settings, encompassing both face-to-face and distance learning. Teachers should embrace a mindset open to novel instructional approaches and be prepared to customize their teaching methods to suit the unique needs and abilities of their students.

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# Fostering Emotional Intelligence on Challenge-Based Learning Principles

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**Abstract.** The aim of the present research is to investigate the effectiveness developing Emotional intelligence in entrepreneurship, based on the principles of Challenge Based Learning. Suggested Emotional Intelligence training tools developed on the basis of a synthesis of the latest theoretical data and application software. The methodological basis of the proposed tools is the 4-component instrumental model for the development of emotional intelligence (4El Model). Training based on the application of innovative training tools was conducted within the elective course "Emotional intelligence in youth and senior entrepreneurship" at Comenius University Bratislava. The construction of student profiles of 15 Erasmus+ students before and after course confirmed the effectiveness of implementing Challenge-Based Learning principles. The data was collected through chatbot testing. It was found that students used different approaches when working in teams: task-based or relationship-based. The practical value of this study lies in the simplicity, clarity and effectiveness of Emotional Intelligence training tools. The Emotional Intelligence training tools all four components of 4El Model: Self-awareness, Self-management, Social-awareness and Relationship management. They can provide a deeper understanding for university teachers who want to develop soft skills in students as part of problem-based/oriented education.

**Keywords:** Emotional intelligence · Model of Emotional Intelligence · Education · Tools

## 1 Problem Statement

Sustainable development poses new challenges to university education. The development of soft skills is becoming an essential and relevant prerequisite for the professional success of graduates. One such critical skill is Emotional Intelligence (EI). EI contributes to effective communication, collaboration and success in an environment of constant change. The disciplines of EI development are increasingly being integrated into the higher education process. At the same time, it is important to use methodological approaches that maximise the development of students' EI within the allotted time.

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Launching EI training courses at Universities embodies two crucial Sustainable Development Goals: 3) good health and well-being, and 4) quality education (United Nations, 2015). EI leads to social and economic effects. Firstly, EI helps to cope with stress and stay healthy in the workplace. Secondly, EI leads to active knowledge-sharing behaviour, cooperation and effective communication, which creates additional value in companies. In the information flow of Industry 4.0, these soft skills play a vital role in the professional success of future graduates. Implementing innovative resources to foster the development of emotional intelligence, which aligns with the 17 Sustainable Development Goals (SDGs) established by the United Nations. These SDGs, available, not only generate worldwide interest but also necessitate interdisciplinary cooperation to address pressing global needs. Therefore, incorporating these goals into educational tasks recognizes their significance and urgency.

Employees involves utilizing emotional intelligence to effectively communicate, negotiate, lead projects, inspire, and manage a team. People who possess a high level of emotional intelligence have a clear understanding of the company's future, improve the company's financial results, establish positive relationships with business partners, outperform competitors, and leverage their emotions to achieve favourable outcomes.

Entrepreneurship education through mindfulness, which requires reflection on oneself, development of one's ideas, successful communication and team collaboration is based on challenges. The training course "Emotional intelligence in youth and senior entrepreneurship" at Comenius University Bratislava uses the principles of Challenge-Based Learning (CBL) as an opportunity to enhance the quality of learning. Successful Entrepreneurial Learning occurs when students actively perceive a situation as a challenge and effectively overcome it [1–3]. It implies to involve the conscious development of self-evaluation and metacognition skills.

CBL has attracted the attention of scientists because of its significant achievements in the field of education [4]. CBL is an instructional methodology that traces its origins back to experiential learning. It revolves around initiating the learning process with an open-ended, real-life challenge as the focal point [5]. CBL represents an interactive and interdisciplinary approach to both teaching and learning. CBL is a captivating and cross-disciplinary methodology for education that motivates students to leverage modern technology in tackling authentic, real-world challenges. Research results demonstrate a positive impact CBL on the development of entrepreneurial skills, thinking and the number of entrepreneurial ideas [6]. CBL fostering research objectives and the students' basic needs, intrinsic motivation and communication skills [7]. We believe that the use of EI training tools on CBL principles will improve the quality of training graduates and equip them with essential 21st century competences.

## 2 Analysis of Recent Research and Publications

In 2008, a paper was published that presented the initial framework of CBL [8]. Challenge-based learning (CBL) originated from the pioneering efforts of technology company Apple and has since been adopted globally by universities, schools, and various institutions [9]. Subsequent research has demonstrated the effectiveness of student-centered learning methods [10]. Challenge-Based Learning is a method of experiential learning where students acquire knowledge and skills by actively engaging with genuine challenges. Throughout this process, students receive guidance and support from professors and external stakeholders. What sets this approach apart from other methodologies like Problem-Based Learning or Project-Based Learning is that students have the opportunity to apply the knowledge and competencies they have acquired during their university education in real-life situations [11].

In entrepreneurship, CBE is about going beyond the traditional 'narrowly focused' notion of entrepreneurship, to allow students to act creatively and independently. Key competencies supported in the module will be opportunity recognition and exploitation; building and initiating; creativity and innovation and the confidence to propose ideas [2]. Emotional intelligence contributes to process emphasis. It fixes attention on particular stages of cooperation. It makes the process of building entrepreneurial teams conscious. The focus is not on the result, but on process awareness. CBL is presented in three phases: engage, investigate and act [8].

Students are tasked with generating, developing, and executing solutions that pertain to environmental, social, and/or economic aspects. These solutions are derived either from existing information or through the acquisition of fresh knowledge from various disciplines [12]. Engaging in CBL experiences brings forth numerous potential advantages. These experiences align with several crucial aspects outlined by Graham disciplines [13] as essential for future engineering programs to excel on a global scale. These include the incorporation of authentic and active learning approaches, providing students with choices in problem-solving and learning methods, facilitating training in multidisciplinary teamwork and decision-making, and satisfying students' desire for meaningful education experiences. By embracing CBL, educational institutions can effectively address these key features and deliver comprehensive learning opportunities to students.

However, despite a considerable amount of foreign scientific papers dealing with issues of application of CBL for entrepreneurship development, we found a lack of tools for development of emotional intelligence in entrepreneurship based on CBL principles. We consider the development of emotional intelligence in entrepreneurship with elements of CBL to be a very promising research area in the field of higher education.

The aim of the present research is to investigate the effectiveness of training tools for developing EI designed with CBL principles. This article presents a practical set of training tools for developing the EI of future entrepreneurs. Training tools aimed at developing Self-awareness, Self-management, Social-awareness and Relationship management are based on solving real-world problems with collaboration and technology. Training based on the application of new training tools was conducted within the elective course "Emotional intelligence in youth and senior entrepreneurship" at Comenius University Bratislava. The empirical analysis is based on an original dataset of questionnaires filled by students who took part in the elective course "Emotional intelligence in youth and senior entrepreneurship". Voluntary testing was conducted at the beginning and end of the training course.

The novelty of the article lies in the introduction of new and effective training tools for the development of emotional intelligence in entrepreneurship.

## 3 Results and Discussion

According to CBL principles, students look for business ideas, they ask questions, search for relevant information, do market research and try to find answers to practical problems. As they search, they go from simple to complex solutions. They learn the tools to build their own business in the process of solving a practical problem. At the same time, students work in teams and prepare joint reports. A special feature of the course is that each stage of the training takes place consciously. The training is accompanied by the habit of questioning oneself, observation, self-monitoring, empathy and teamwork skills. The main characteristics of the learning process are presented in the Table1.

**Table 1.** Characteristics of an EI development process based on CBL principals

| Characteristics Challenge Based Learning [14] | EI on CBL principals |
|---|---|
| Learning/Students work with teacher and experts in their | Students develop a deep knowledge of the subjects they are studying. Completing a creative task is a challenge, it triggers new knowledge generation and necessary resources. Students ask themselves questions to find a solution. The development of self-awareness |
| Focus/Students are confronted with an open, relevant, problematic situation that requires a practical solution | Students need to solve situation in business that form a practical skills in real team environment. The development of self-management |
| Product/Students need to create a solution resulting in concrete action | Students create their own business project, which they consider interesting and relevant. They learn to make decisions and take responsibility. The development of self-management and relationship management |
| Process/Students analyse, design, develop, and perform the best solution to deal with the challenge for them and other people to evaluate | Students work in teams, evaluate the ideas and contributions of each team member. The development of social-awareness and relationship management |
| Teachers role/Coach, co-researcher, and designer | The teacher asks leading questions and creates an atmosphere for discussion. Students ask questions to the reporting team. The development of relationship management |

The 4-component instrumental model for developing EI (4EI Model) [15] is the basis for teaching EI. The 4EI Model is adapted to a business environment and includes four parts: Self-Awareness, Self-Management, Social-Awareness and Relationship Management. Methodological approaches with elements of Challenge Based Learning have been developed for the improvement of each component of EI. We offer EI training tools, based on contemporary theoretical research and uses applied software. The tools are designed for each comoponent of the 4EI Model: Self-awareness, Self-management, Social-awareness and Relationship management. The tools bases on the latest theoretical research (scientific results from Scopus and Web of Science databases and information Coursera, Udemy, Prometheus platforms), modern software (chat bot "Alarm Clocks" in the Smart Sender program), and visualisation elements (EI profiles [15]).

In this approach, they devote more time and effort to developing innovative but realistic solutions to the problem, outlining the resources and activities to implement the business idea. In this approach, students study "big ideas" in detail and consistently. If initially the business idea seems difficult to implement, by the end of the course students have a clear understanding of their customers, marketing activities, have a strategy and understand how to divide roles in the team. Applying the tools to solve a practical problem in which the team is interested allows the basic principles of CBL to be implemented.

The tasks are creative and require an individual approach. In this way students' ability to innovate and find solutions is developed. They generate new ideas and share their ideas with the group.

During the preparation of the report, the students work together as a team to find solutions to creative problems. The teacher corrects the direction of the search. During the report, they learn to cooperate and present their point of view. The Table 2 describes.

the basic CBL principles and main tools for developing Emotional Intelligence in entrepreneurship on the basic CBL principles. *The study proposes innovative tools that allow consistent development of each part of* 4EI Model. *The systematic approach is based on contemporary theoretical research and uses applied software.*

A unique aspect of teaching the subject is the use of podcasts, videos, case studies and discussion forums. After studying each theoretical material students were asked to prepare a presentation. The presentations suggested discussions. As a rule, students focused on a social or environmental goals. As a result, students' level of emotional intelligence increases during the training.

The training tools' effectiveness is measured using the "Emotional Intelligence in Business" questionnaire. Testing is convenient to carry out in the Smart Sender program (the link to the chatbot: https://t.me/SEID_balanceEI_bot?start=ZGw6MzM5Njk). Testing is voluntary and confidential. The proposed methodological approaches have been implemented and validated in the elective course "Emotional intelligence in youth and senior entrepreneurship" at Comenius University Bratislava. We see a positive dynamics in the development of all components of 4EI Model (Table 3).

**Table 2.** CBL principles of for developing Emotional Intelligence

| CBL principles [14] | Emotional Intelligence training tools |
|---|---|
| 1) A flexible and customizable framework that can be applied as a guiding pedagogy or integrated with other progressive methods of learning; | At the core is 4EI Model, the components of which are developed through innovative tools |
| 2) A walkable model with multiple points of entry and the capability to start small and create big; | The 4EI Model assumes the development of each component and uses quantitative measurement |
| 3) An open framework without any proprietary concept, product, or subscription; | Open access and scientific publications about 4EI Model |
| 4) A process that puts all students in charge and manages learning; | Self-aware approach of studentsto the proposed tasks |
| 5) An authentic environment to meet academic standards and establish a deep connection with the content; | Training takes place in a university environment |
| 6) A focus on global ideas, meaningful challenges, and the development of local and age-appropriate solutions; | Sustainable Development Goals Compliance |
| 7) An authentic relationship between academic disciplines and real-world experience; | Solving business problems in real conditions using innovative tools |
| 8) A framework for developing twenty-first-century skills; | EI is essential 21st century competence |
| 9) The purposeful use of technology for researching, analysing, organizing, collaborating, networking, communicating, publishing, and reflecting; | The tools are designed for each component of the 4EI Model: Self-awareness, Self-management, Social-awareness and Relationship management |
| 10) The opportunity for students to make a difference; | Creative problem-solving |
| 11) A way to document and assess both the learning process and products; | Building EI profiles at the beginning and end of the course |
| 12) An environment for deep reflection on teaching and learning | Opportunity for self-evaluation and further self-education |

**Table 3.** A fragment of the test "Emotional Intelligence in Business".

| Students of Erasmus+ program | Self-Awareness (tools: Alarm Clocks) | Self-Management (tools: Alarm Clocks) | Social-Awareness (tools: presentations) | Relationship Management (tools: Argumentation Algorithm) |
|---|---|---|---|---|
| 1 | 1,143 | 1,000 | 0,971 | 1,036 |
| 2 | 1,161 | 1,571 | 1,619 | 1,458 |
| 3 | 1,000 | 1,450 | 1,156 | 1,107 |
| 4 | 1,000 | 1,000 | 0,914 | 0,906 |
| 5 | 1,053 | 1,091 | 1,000 | 1,059 |
| 6 | 1,194 | 1,103 | 0,900 | 1,037 |
| 7 | 0,926 | 1,083 | 0,870 | 1,158 |
| 8 | 1,000 | 1,067 | 1,000 | 1,067 |
| 9 | 1,259 | 1,214 | 0,946 | 0,967 |
| 10 | 1,240 | 1,438 | 1,053 | 1,190 |
| 11 | 1,292 | 1,160 | 1,267 | 1,037 |
| 12 | 1,083 | 1,053 | 0,897 | 1,063 |
| 13 | 1,115 | 1,000 | 0,912 | 1,000 |
| 14 | 1,033 | 1,083 | 1,000 | 1,120 |
| 15 | 1,000 | 1,037 | 0,846 | 1,320 |
| **Average** | **1,100** | **1,157** | **1,023** | **1,102** |
| Positive dynamics in responses | 66,67% | 86,67% | 66,67% | 80,00% |
| Lack of momentum | 26,67% | 13,33% | 6,67% | 6,67% |
| Negative dynamics in responses | 6,67% | 0,00% | 26,67% | 13,33% |

The results of the launch elective course "Emotional intelligence in youth and senior entrepreneurship" demonstrates an **Average** increase EI of students in all components of the 4EI Model Self-awareness, Self-management, Social-awareness and Relationship management. The absence of dynamics in the Self-Awareness assessment indicated a fairly high initial level of students' self-awareness. A significant negative dynamic in Social Awareness was due to the students' more careful self-assessment of their own level of empathy after the course. It may also indicate the need for more effective tools to develop Social Awareness. The feedback indicated that, in general, students felt stressed before the start of the session, which may have slightly increased the negative dynamics of the responses. Overall, positive feedback was received. The students' interest and readiness to work independently on EI development increased.

## 4 Conclusions

The results of the "Emotional Intelligence in Business" questionnaire proved the effectiveness of the tools described in the article. Teaching EI in Universities is a promising area for training successful professionals. EI enables the development of effective communication skills, which is a prerequisite for success in the fast-changing landscape. Effective training tools based on contemporary theoretical research and modern computer software are essential for successfully teaching EI. EI training has practical social and economic implications. EI prevents emotional burnout, increases stress resistance, the ability to prevent conflict situations, and contributes to the preservation of health and well-being. At the same time, EI forms openness, assertive behaviour, and the ability to communicate and use the potential of collaboration participants, which increases productivity and creates additional opportunities and assets. CBL is an effective interdisciplinary learning experience for identifying and solving real business problems. It can be applied in the training of future managers, economists, pre-entrepreneurs. CBL allows you to create a pathway from simple to complex issues and find logical solutions for them. CBL allows students to combine expertise from different backgrounds and create effective teams to implement business ideas. CBL supports the development of emotional intelligence and allows students to solve real business problems.

This work contributes providers evidence of the effectiveness of экспериментальных entrepreneurial courses Martin, D. A., Conlon, E., & Bowe, B. (2019). The role of role-play in student awareness of the social dimension of the engineering profession. European Journal of Engineering Education, 44(6), 882–905. (Colombelli et al. 2021c). This work enriches practical approaches to implementing the principles….. We complement qualitative methodologies (Martinez and Crusat 2020) with the quantitative assessment of the effectiveness of challenge-based programs through pre-program and post-program testing. Empirically, these data show that the impact of training tools on Challenge Based Learning' principles is extremely relevant and they contribute significantly to the development of Emotional Intelligence in Entrepreneurship. This paper has limitations. The study only looked at the attitudes and intentions of Erasmus+ students before and after the course, but not their actual behavior during periods after their participation in the course. In future research on entrepreneurship education, the effect of challenge-based learning programs can be tested in two ways: 1) to expand testing by increasing the number of participants in the educational course, 2) longitudinally, by researching and analyzing the possible creation of enterprises.

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# Hands-on Experiments on Atomic Structure and Particle Physics for Primary Teachers at CERN

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**Abstract.** The "Atomic Structure and Particle Physics" training lab was a part of CERN's "Playing with Protons" program designed for Greek primary school teachers who specialize in physics and IT education. The lab's main goal was to integrate particle physics, cutting-edge scientific research, and scientific methodology into primary school physics education through simple hands-on experiments on modern physics and engineering. This paper focuses on the Particle Physics lab at CERN, which was then transferred to a K-5 and K-6 physics class. Simple physics experiments were chosen to enable science teachers and their students to easily reproduce and examine some core ideas of particle physics in the school lab. According to results, the lab had a significant positive impact on the students' performance, while also inspiring educators to foster a research culture among their pupils by exposing them to cutting-edge science and technology. Active participation in hands-on experiments allowed students to gain a deeper understanding of scientific principles. The lab was evaluated by 95 students, and their feedback indicated a high level of satisfaction with the program.

**Keywords:** Hands-on Experiments · Physics Education · STEAM

## 1 Introduction

This work aims to explore and analyze issues that arise through the introduction of modern Physics and aspects of technological innovation from CERN (European Organization for Nuclear Research) into physics education of the primary level. Specifically, the study highlights the importance and general role of hands-on experimentation in physics education, focusing on experiments utilizing simple materials that are related to particle physics (Nantsou 2023). Our hypotheses and research questions concern the effectiveness of proposed teaching methods for modern physics laboratories, such as Learning-by-Doing (LBD) (Dewey 2009; Roberts 2009) and Learning-by-Research (LBR) (Costa & Las Casas 1999; Nantsou 2023). The study investigates whether these

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teaching methods not only enhance the development of students' and teachers' experimental skills but also promote a deeper understanding of physical laws and principles related to particle physics, fostering familiarity with scientific thinking, and conveying what one may refer to as the essence of physics (Hewitt 1983).

### 1.1 Physics Education in Greece

The Greek educational system has faced criticism due to its outdated and exam-focused approach, which often hinders students' long-term learning outcomes and practical skill development (Nantsou 2023). In the field of physics education, there has been limited emphasis on systematic, hands-on experimentation and practical activities within Greek schools, despite the Physics Curriculum including provisions for real and demonstrative experimentation at the primary school level (Elliniadou & Sofianopoulou 2022, 2023). Consequently, primary and middle school teachers predominantly rely on traditional lecture-style teaching methods, neglecting recommended experimental teaching materials found in textbooks (Nantsou et al. 2021a, b; Nantsou & Tombras 2022b). It is worth noting that primary school physics is typically taught by educators who lack recent experience in physics labs or have not received hands-on physics training. Such deficiencies in teacher training and pedagogical practices may contribute to a lack of student engagement and interest in physics, as well as limit the depth and breadth of their knowledge and understanding of physics laws and principles. Therefore, there is a pressing need for a more student-centered approach to teaching physics that prioritizes hands-on experimentation and active learning. This can be accomplished through the implementation of modern teaching methods, such as Learning-by-Doing and Learning-by-Research, which have proven effective in enhancing students' experimental skills, deepening their understanding of physical laws and principles, and fostering scientific thinking (Nantsou et al. 2020).

### 1.2 Physics Education at CERN

Since 1998, CERN's Teacher Program has been providing high-quality scientific training to secondary school physics teachers (Nantsou et al. 2021a, b). Moreover, CERN has expanded its educational initiatives to include selected groups of students, such as high school students from various countries and primary school teachers (Brice 2019). CERN's High-School Teacher Programs have gained international recognition, attracting participation from over 40 countries and equipping thousands of educators with updated knowledge and skills in particle physics. The scholarly literature widely acknowledges CERN's commitment to providing high-quality scientific training and education to both educators and students. An important exhibition simplifying complex physical phenomena of modern physics through experimental activities is scheduled to take place at CERN in the course of 2023. The expansion of these initiatives to include primary school teachers and students represents a promising development that has the potential to significantly impact physics education at an early stage of learning (Brice, 2019).

The educational program of modern physics, entitled "Playing with Protons" (PwP), was established at CERN with the objective of investigating the potential impact of modern physics and cutting-edge research on physics education (Alexopoulos 2014, 2016; Nantsou et al. 2021a, b; Nantsou & Tombras 2022a). This program was piloted for two years in the Hill Memorial School's physical science laboratory in Athens, Greece, with K-5 and K-6 students. Tina Nantsou, who attended the CERN Greek Teacher Program in 2013, developed the program's educational materials and proposed hands-on experiments using simple materials, which were later presented at CERN (Alexopoulos 2016; Nantsou 2023). The CMS Experiment recognized the value of the researcher's pilot program and decided to evolve it into a teacher training program for primary education in 2016, with a pilot implementation in Greece (Alexopoulos 2014, 2016). As part of the continuous professional development (CPD) for primary school physics teachers, targeted educational activities were developed based on the PwP program agenda, which aligns with the National Physics Curriculum. Together with the CMS Experiment, the ATLAS Experiment, Universities (UoB, NKUA), Research Institutes (Perimeter, STFC), and international organizations (ISN, OT) participated in the teacher training program. The continuous professional development program (CPD) PwP aims for excellence in primary education and physics education. Since its establishment, six PwP CPD programs have been organized at CERN, with the participation of 40 primary teachers and IT educators and 20 science educators from UK. Upon their return to their home countries, the 60 trained educators implemented similar experiments and activities for modern physics to their schools, while also informing and training colleagues from other schools in Greece and UK. On average, the multiplicative factor per participant in the PwP CPD is as follows: one educator trained 180 students and seven teachers in three different schools. Until 2020, 346 teachers in 155 schools in Greece and UK educated 9,000 students in modern physics through the PwP program (Nantsou & Tombras 2022a; Nantsou 2023).

## 2 Exploring the Structure of Matter and Fundamental Particles

The modern physics lab was designed to develop and enhance students' experimental skills in the school physics lab. The program's teaching method placed great emphasis on fostering students' creativity, critical thinking, and collaboration skills. This research paper provides a brief overview of the experimental activities related to particle physics conducted in the PwP "Atomic Structure and Particle Physics" program. The materials used in this program were low-cost and easily accessible for teachers, including clay, dental picks, candies, lollipops, and flour.

The decision to use everyday materials is particularly beneficial for educators with limited financial resources or those working in schools with limited support in scientific equipment. It provides them with an opportunity to offer high-quality scientific education to their students at a low cost. The strategic use of simple materials in physics education promotes scientific literacy by actively engaging students with materials they encounter in their daily lives. Additionally, it enables them to repeat the experiments at home and explore variations on their own. In the PwP "Atomic Structure and Particle Physics" lab, hands-on experiments and activities were implemented to enhance the understanding of the fundamentals of Particle Physics. The lab addressed various research questions related to the atom's structure, properties of elementary particles, historical experiments in discovering the atom's structure, the discovery of the Higgs boson, and the Standard Model of particle physics. The lab curriculum also aimed to develop the analytical and technical skills necessary for conducting research in the field of PER and Engineering Education. Below are some of the research questions addressed in the "Atomic Structure and Particle Physics" lab:

- What is the structure of an atom?
- Which particles make up the atom and what are their properties?
- What are the historical experiments that led to the discovery of the atom's structure?
- What is the Standard Model of elementary particles?
- What is the significance of the Higgs boson's discovery by CERN for particle physics?
- What is the connection between particle physics and cosmology?
- How does CERN contribute to our understanding of the creation of the Universe?

These questions served as a stimulus for the second part of the lab, which involved Learning-by-Doing experimentation by the students and educators using all materials available at their disposal.

### 2.1 The Structure of the "Atomic Structure and Particle Physics" Laboratory at CERN: A Comprehensive Overview

The primary objective of the modern physics lab was to offer a glimpse into the forefront of research conducted at CERN, the world's largest particle physics research center. Another aim of the lab was to inspire teachers to engage in independent study and exploration of modern physics, enabling them to develop their own original teaching materials upon their return to the classroom. Additionally, the lab's structure allowed participants to delve into the methodology of doing science. The researchers initially familiarized themselves with international advancements in the examined field and then conducted independent experiments to contribute to the advancement of scientific inquiry by putting their personal ideas into practice. Finally, they communicated the results of their research to their colleagues and actively engaged in discussions and an exchange of opinions and ideas. The experimental lab at CERN followed the structure below (Table 3):

- A 60-min session comprising experiments and simple hands-on activities focused on particle physics, with simultaneous reference to its fundamental principles and the history of science.
- A 60-min session dedicated to the practical application of the basic principles of particle physics, during which the teachers constructed models of atoms, protons and neutrons, quarks, as well as the Standard Model.

The lab involved conducting experiments under the guidance of the coordinator while also engaging in Learning-by-Doing activities. Following the conclusion of the lab, physics teachers shared their insights and participated in open discussions. We list some examples of experiments and activities (Figs. 1 and 2) that took place in the "Atomic Structure and Particle Physics" lab below:

**Table 1.** The PwP "Atomic Structure and Particle Physics" Lab timeline.

| Activity | Method | Time |
|---|---|---|
| Experiments+ Theory | Guided | 30 |
| Demonstrations | LBD | 30 |
| Making models | LBD | 20 |
| Whole group sharing | LBD | 10 |

- Hands-on activities involving the creation of atomic models using plasticine, macaroni, candy, and toothpicks. In these activities, the structure of matter was explored using materials such as clay, straws, dental tools, and candy. Participants were provided with images of atomic models and attempted to recreate them in three dimensions using their own imagination and creative impulse, while following natural laws.

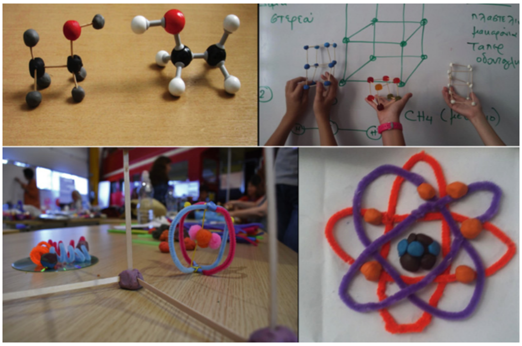


**Fig. 1.** Creating atomic models with plasticine, macaroni and toothpicks.

- Exploration of Particle Physics subjects using a black box constructed from simple materials: boxes of different sizes (transparent, semi-transparent) were used, and small objects such as metal balls and food items were placed inside. The participant had to guess the contents of the box without opening it; they could shine a flashlight or laser on it, hit it, or use magnets. The goal of this activity was to help participants understand that scientists discovered the structure of matter without physically "opening" it, if one is to follow the metaphor of matter as a black box. The methodology followed in this activity mirrored the one used in particle physics labs, including hypothesis formation, selection of experimental methods, experimentation, drawing conclusions, formulating theories, and announcing results to the scientific community.
- Experimental methods for demonstrating subatomic particle collisions: to study the collision of proton beams, we used laser beams and created a model of the Large Hadron Collider (LHC), as well as models of the collision. The detector for capturing

the collision of the two beams was a mobile phone camera that recorded the collision of the photons.

- Development and implementation of a charged particle detector for educational purposes: The particle detector consisted of (a) an electroscope and (b) a cloud chamber, which served as a detector of cosmic radiation (muons, alpha particles, electrons, positrons). The particle and charge detectors were constructed using simple materials and tools such as glass jars, aquarium vessels, aluminum foil, dry ice (frozen carbon dioxide), isopropyl alcohol, etc. These materials allowed for the observation of natural phenomena and the detection of particle trajectories.
- Integrating Particle physics and creative arts or a theater-based approach in the classroom: The participants represented the particles (protons, neutrons, electrons, quarks, Higgs boson) through movement, dancing, and enacting the collision of proton beams in the Large Hadron Collider, as shown in Fig. 2. The first image illustrates the collision of beams and the emergence of the Higgs boson. The second image demonstrates how particles acquire mass, the third image portrays an atom in the schoolyard, while the fourth image illustrates the interactions of particles. This embodied representation of particles and the microcosm through playful theatrical performance enabled the participation of all participants in the modern physics lab.

**Fig. 2.** A theater-based approach of particle physics.

The lab had the primary goal of bridging the gap between the basic atomic structure taught in schools and the research carried out at CERN. The program aimed to empower teachers with a deep understanding of modern particle physics theories and equip them with effective tools to convey these complex concepts to their students through interactive and hands-on activities. By incorporating playful and captivating learning approaches that built upon the students' existing knowledge of atomic structure, the ultimate objective was to foster a genuine passion for physics among the students.

## 3 Research Questions

This work primarily investigates the possibility of teaching particle physics to young students without emphasizing mathematical equations. To guide our research and evaluate our educational proposal, we have formulated the following research questions:

- What are the key concepts of particle physics that can be effectively taught to primary school students without relying on mathematical equations?
- What is the impact of the lab on the knowledge levels of primary school students regarding particle physics and atomic structure?
- How does the Learning-by-Doing methodology contribute to the understanding of particle physics in a primary school setting?
- What are the perceived advantages and limitations of using non-mathematical methods to teach particle physics?

This research paper primarily focuses on the learning outcomes observed during the implementation of the proposed modern physics lab in a school environment.

## 4 Methodology

### 4.1 Objectives

The Playing with Protons workshop had the following main objectives (Nantsou & Tombras 2022a):

- Familiarizing K-6 science teachers with the distinctive culture of particle physics, as well as the cutting-edge technology, applied physics, and innovation taking place at CERN, the world's largest particle physics lab.
- Testing new teaching approaches in the field of particle physics, with a particular emphasis on hands-on experimental activities using simple materials and resources. This approach aims to enhance the confidence of both teachers and students in the subject matter.
- Creating educational scenarios and lesson plans in modern physics that build upon existing curricula. These scenarios aim to enrich the educational experience, intensify student interest, and stimulate motivation in the field of particle physics.
- Providing new resources and modern, innovative educational materials in the field of particle physics, while also promoting the ability to critically evaluate these sources.

These objectives collectively aim to enhance the understanding and appreciation of particle physics among primary school teachers and students, fostering a positive and engaging learning environment.

### 4.2 Participants

The results of the lab evaluation conducted by educators, as well as the pre- and post-tests administered to the students, will be presented in detail. The lab was evaluated by the following:

- 30 primary science teachers
- 96 primary students (K-5, K-6)

The teachers participated in the Playing with Protons lab during the years 2016–2018. These educators were science and IT teachers in primary public schools throughout Greece. The selection process was carried out by the PwP CERN committee. Each year, hundreds of science educators applied, and 20 were chosen. After an interview process, the final selection included 10 educators per year. The evaluation of the Playing with Protons school lab took place during the academic years 2021–22 and 2022–23 as part of the physics lab course.

### 4.3 Research Methodology

The research employs both quantitative and qualitative methodologies. Data collection was carried out using material such as questionnaires, tests, field notes, worksheets, and homework assignments. Analysis of the questionnaires and tests given to the students was conducted to study the level of understanding of basic physical laws and principles in particle physics. The statistical analysis was conducted using the IBM SPSS Statistics 26.0 software.

## 5 Results

### 5.1 Results for Teachers

During the first year of the laboratory evaluation in 2016, we encountered the following issues with the hands-on labs:

- Limited availability of time for conducting experiments
- Absence of accompanying worksheets to provide guidance during the experimentation process.

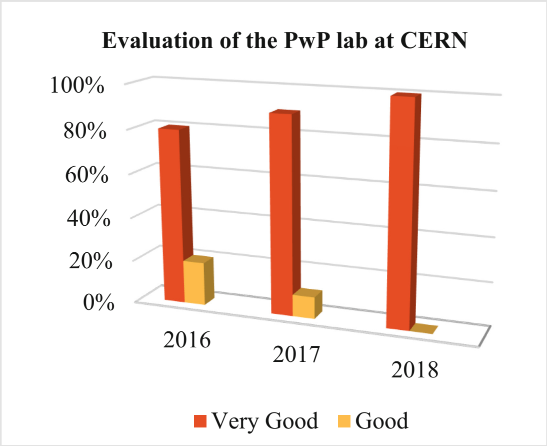
In the second and third years of the lab evaluation, the following improvements were implemented:

- Educators were provided with supplementary worksheets to assist them during experimentation. These worksheets could be used as desired or to facilitate parallel theoretical study
- The lab structure was modified to allow for increased time dedicated to experimentation.

The laboratory received positive evaluations (Table 2) from the teachers due to the following reasons:

- It familiarized them with conducting hands-on experiments in particle physics, which they could reperform with their own students.
- It enhanced their comprehension of the research conducted at CERN and equipped them with the knowledge and ability to teach related subjects in their classrooms.

**Table 2.** *"How satisfied are you with the lab?" PwP lab at CERN.*




## 5.2 Results for Students

The results of anonymous questionnaires, as well as the pre- and post- tests for students are presented in this section. The majority of students understood the key concepts of the lab: Model of the Atom, Collisions of Beams, Higgs Boson (Table 3).

**Table 3.** What were the difficulties you encountered in the PwP lab?

| Modern Physics Topic | Correct % | Incorrect % |
|---|---|---|
| Model of the Atom | 100 | 0 |
| Standard Model | 60 | 40 |
| Collisions of Beams | 90 | 10 |
| Particle Detectors | 80 | 20 |
| Black Box | 70 | 30 |
| Higgs Boson | 90 | 10 |
| Chemical Compounds | 60 | 40 |

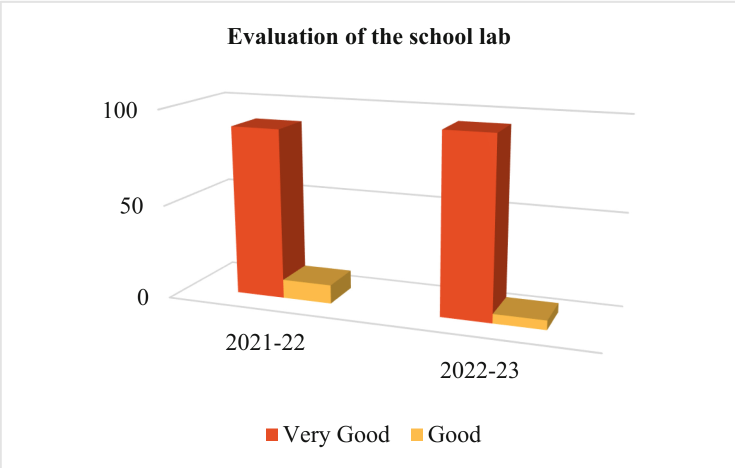
The grading was done using a scale ranging from 0 to 10. All students from grades K-5 and K-6 who attended the laboratory completed both pre- and post- tests that included experimental questions. Additionally, the tests encompassed simple theoretical questions that had been covered during the students' Learning-by-Doing experimentation as well as in the physics course.

**Table 4.** The statistical results of the laboratory in modern physics

| Test | N | Mean | St. Dev |
|---|---|---|---|
| Pre- test K-5 | 45 | 7.4800 | 1.67517 |
| Post- test K-5 | 45 | 9.5911 | 1.63427 |
| Pre- test K-6 | 50 | 7.4860 | 1.51483 |
| Post- test K-6 | 50 | 9.1960 | 0.98684 |

The results from the pre- test (M1 = 7.4800, SD1 = 1.67517, M2 = 7.4860, SD2 = 1.51483) and the post- test (M1 = 9.5911, SD1 = 1.63427, M2 = 9.1960, SD2 = 0.98684) showed that the experimental method for the particle physics laboratory had a positive effect, improving the performance and understanding of cognitive subjects under consideration (Table 4): t (44) = -7.836, $p < 0.001$ and t (49) = -11.318, $p < 0.001$.

**Table 5.** The PwP "Atomic Structure and Particle Physics" students' results.




Students also positively evaluated the laboratory (Table 5) because:

- it provided them with a first glimpse of particle physics (Table 3)
- it led them to understand the fundamental experimental research that is being conducted in the field (Table 3).

Statistical data extracted from our research demonstrates the fact that the lab significantly enhanced the students' knowledge levels in experimental techniques, fostering a profound comprehension of the large-scale experiments conducted at CERN.

## 6 Discussion and Conclusion

Greece is currently facing a shortage of science laboratories that promote active student participation and hands-on exploration of complex concepts in modern physics and technology (Nantsou & Tombras 2022a; Elliniadou & Sofianopoulou 2022, 2023). Moreover, there is a lack of physics laboratories where students can practice scientific methodology and develop scientific thinking skills (Godfrey and Walwema 2016). Many educators in the field of natural sciences believe that a solid foundation in classical physics is necessary before introducing modern physics, considering it conceptually challenging for compulsory education. In this study, we aimed to bridge this gap by integrating modern physics and its practical applications into students' daily lives. Specifically, we explored the potential of incorporating new teaching techniques, particularly hands-on experimental activities using simple materials, into the mandatory curriculum. The Playing with Protons "Atomic Structure and Particle Physics" lab successfully enhanced students' knowledge levels in experimental practices. These hands-on activities not only motivated educators to impart the research culture to their students but also exposed them to cutting-edge science and technology. Active participation in hands-on experiments facilitated a deeper understanding of scientific principles and provided a more interactive and dynamic learning environment, thus fostering students' engagement and interest in particle physics.

Through our study, we demonstrated that teaching modern physics through simple experiments using everyday materials is crucial for building students' self-confidence in exploring physics in their daily lives (Elliniadou & Sofianopoulou 2022, 2023). Promoting innovative physics projects in primary education and employing interactive learning strategies to teach particle physics should be widely adopted as the standard practice in school physics. To successfully implement hands-on physics education within compulsory education, it is essential to develop the relevant skills and capabilities of educators through systematic and high-level training. Based on our findings, the LBD (Learning-by-Doing) educational method emerges as the most suitable teaching approach for all educational levels, including educators. The educators who participated in the Playing with Protons program at CERN were highly receptive to the proposed learning-by-doing teaching method of modern physics through experiments and activities using simple materials and resources. K-5 and K-6 students who took part in the Playing with Protons particle physics labs demonstrated a grasp of the fundamental concepts presented. Forthcoming research will investigate whether these modern physics labs positively impact students' understanding in their middle school chemistry lessons, where atomic structure and basic elements are taught using different educational methodologies.

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# Digital Collaboration Practices in Engineering Education

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**Abstract.** Applying team projects is widely recognized as an effective way to develop engineering students' collaboration and project management skills, while there are serious challenges in the organization and supporting digital communication, collaboration, and teamwork. The purpose of this study is to present the ongoing experience in adaptation of the course "Project Work Technology" to online/blended learning settings by using a combination of a variety of instructional methods and digital technologies. The changes that address the need for the development of communication and collaboration skills were introduced into all curriculum elements, including learning outcomes, course content, types, and duration of students' projects, assessments, etc. The main attention was paid to the effective use of collaborative learning activities and related digital tools. The research question was to evaluate the impact of the course on communication and collaboration students' skills and readiness for teamwork.

**Keywords:** Engineering Education · Online/blended Learning Setting · Teaching Methods

## 1 Introduction

Communication and collaboration are among the key skills in today's engineering practice. Many modern engineering curricula include team projects, whose benefits were actively reported in the literature [1]. Despite the rapid switch at first to distance and/or blended learning was rather difficult because of the wide range of technical and pedagogical issues, it led to the rethinking and enhancement of the traditional face-to-face teaching and learning methods related to the organization and support of the students' team projects.

It should be noted, that for first-year students, the challenges related to participating in remote team projects have been complicated by weak ties with classmates, lack of self-confidence, and the growing role of self-directed learning skills. Also, they must adapt to the demands of higher education in general, improve digital skills, and master professional content. This presents a challenge of how to encourage productive communication and collaboration between students and prepare them for future activities in blended learning settings.

This paper reports on the ongoing experience in adapting the course "Project Work Technology" to online/blended learning settings using various teaching and learning

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methods and digital technologies. The research question was to evaluate the impact of the course on the communication and collaboration skills of engineering students and their readiness for future teamwork.

## 2 Background

Project-based learning (PBL) is considered to be an effective pedagogical approach that has been widely adopted in engineering education. Many publications have focused on the application of PBL with learning emphasis on the development of communication, teamwork, and project management skills of engineering students and fostering their self-confidence, problem-solving, and self-directed learning skills [1]. Meanwhile, an analysis of the students' perception of online learning during the COVID-19 pandemic shows such issues as a lack of academic contact with peers and engagement during online classes, and a lack of guidance/communication with instructors [2, 3]. According to the research on the team dynamic of undergraduate engineering teams during lockdowns, the following difficulties were mentioned by the significant number of participants: delayed communication, decrease in productivity, procrastination, lack of motivation, and low satisfaction with project results [4, 5]. In addition, the authors admit that the efficiency of team performance depends on positive peer relationships, assigning roles among team members, and the level of engagement in shared regulation of planning, collaboration, and monitoring [4, 6].

Some studies have tried to identify the best practices to overcome problems related to digital collaboration practices, which include leveraging the convenient LMS to manage the course, providing students with a clear syllabus and instructions for all types of activities, encouraging group discussion and small-scale problem-solving activities, breaking down a long lecture into shorter segments with more frequent breaks, the flexibility of instructional methods [2]. Such observations correlate with the studies about designing face-to-face and/or online courses. For the course to be effective, the course content and approaches to assessment, as well as teaching methods, should align closely with one another. In addition, for the online course, the main attention must be paid to the pedagogy – the mechanics of transmitting information, communicating with students, and actively engaging the students in learning [7].

Since the 2017–2018 academic year, an integrated course "Project Work Technology" was introduced to the engineering degree program in Automation and Computer-Integrated Technologies (ACIT) at the Bohdan Khmelnytsky National University of Cherkasy, Ukraine. The course begins in the second semester of the first year of studies and lasts 6 semesters, completing a bachelor's diploma project in the eighth semester. In each semester, 3 ECTS credits are allocated to work on the course "Project Work Technology", which is equivalent to 30 classroom hours. The course encouraged students to work on real-world projects whose complexity is increasing, supporting the hierarchical nature of engineering education. Moreover, according to the multidisciplinary approach, a special focus is on the coordination of the learning outcomes and content of the course with other disciplines of the current and previous semesters (see [8]). The lectures, individual laboratory work, and team projects were held according to the traditional classroom-based approach.

The Spring 2020 experience, when the first-year students had to work remotely in teams, confirmed the significant challenges caused by the rapid transition to online learning. Only two projects (of the four groups of three-four students each) were completed by teams and the quality of projects was significantly lower than in the previous years. Among the reasons that made it difficult for them to work together, the students pointed out the inability to constantly communicate with other team members, problems with organization virtual meetings, role assignments, technical difficulties, difficulties with the software, etc. Productive connections with classmates who joined the same team and constant interaction with the teacher, when the material was discussed in small portions, helped in the successful project completion.

# 3 Methodology

## 3.1 Digital Tools and Course Organization

The contradictory experience of implementing remote team projects in Spring 2020 led to the necessity of the course “Project Work Technology” modification by introducing changes into all elements of the curriculum: learning outcomes, content, assessment, and, first, pedagogy. According to the modified structure, the course starts with the basics of project management to provide students with first-hand knowledge about project management and also help them to gain some experience in communication and collaboration in online/blended learning settings. Then, in the next semesters, students study UML and directly work on the practical development of the information system using the Scrum methodology. In Semester 1, the learning material was divided into five topics (Fig. 1).


**Fig. 1.** "Project Work Technology” course design.

The list of learning outcomes includes the following general competencies: the ability to identify the purpose of the project and work consistently and methodologically correctly to achieve these goals; to be able to present the results in written, oral, and graphic form, to be able to communicate with other team members using different digital tools, to be able to work effectively within project teams.

While working on the course modification we have taken into account that active student engagement in online classes and different types of learning activities require the use of a wide range of digital tools. Therefore, we defined the main types of student activities during the classes and ways to provide these activities in an online environment and digital tools, respectively. Some examples are presented in Table 1.

**Table 1.** Examples of learning activities, methods, and related digital tools

| Activity | Method | Digital Tools |
|---|---|---|
| Collaboration | In-class small group activity<br>Peer Instruction<br>Peer Feedback<br>Think-pair-share<br>Cooperative Learning | Office suite/file-sharing platform<br>Messaging apps (Telegram, Viber)<br>Project/team tool (Trello, Slack)<br>Video meeting platforms (Google Meet, Zoom breakout rooms, Wonder)<br>Online whiteboards (Jamboard, Padlet)<br>Online forms/survey tools<br>Mind mapping tools (Coggle, Genially) |
| Discussion | Problem analysis (brainstorming, "World Café", "Disney's Three Chairs" etc.) | Live engagement tools (Mentimeter, Slido)<br>Google Meet Chat<br>Online whiteboards (Jamboard, Padlet) |
| Practice | Thematical practical tasks<br>Producing digital resources (infographics, videos, models) | Office suite/file-sharing platforms<br>Graphics tool (Canva, Prezi, Genially)<br>Project/team tool (Trello, Slack, Discord) |
| Production | | |

It should be noted that the full list includes acquisition, investigation, and formative and summative assessments used in the course. Choosing the digital tools, we preferred the Google apps or tools integrated with Google Workspace, because the course is entirely organized via the university's Google Classroom. Also, the tools that are commonly used in engineering and design were used.

Before the start of classes, the invitations to join the class on Google Classroom were sent to students. Such a step is part of establishing of teaching presence and supports students' engagement with an online course. They can read welcome messages, and find information about the course structure, policies, assessments, useful links, etc. We also ask students to join the survey that contains questions about their expectations for course learning activities and assessments. In order to evaluate the previous students' experience related to using LMS and other digital tools, in 2021 we added to a survey a few questions about the digital tools, that we have planned to use. It helped us to identify tools and activities that needed additional attention.

### 3.2 Digital Tools and Course Organization

During the class, we used a mix of synchronous and asynchronous modes, supporting communication and collaboration between students both during the classes and in between. Such an approach ensures active student engagement promoting both direct and indirect development of subject-specific and general competencies.

The contact hours, that were reserved in the weekly schedule, were mainly conducted via Google Meet, so students can easily join the class using a unique Google Meet link. To provide a well-structured and easy-handling learning environment the materials in different digital formats (presentations, lecture notes, short videos, useful links, examples etc.), quiz assignments, and individual and group tasks were grouped under Google Classroom topics according to the course structure. Also, students were informed that they can use the public and private comments, which are available on each Google Classroom assignment or question, to contact teachers.

At the beginning of the course, students were asked to present themselves describing their course expectations, interests, preferences, digital and other skills, temperament, etc. which is useful for the group composition. Considering the influence of positive emotions and communication with peers on the students' motivation, we reserved some amount of contact hours for icebreakers (up to 5 min at the beginning of the lesson), "low-stake" polls (up to 5–7 min polls using live engagement tools), reflections etc. The typical online class consists of small amounts of theoretical material (15–20 min) presented by the teacher with shared slides and/or a whiteboard (using a tablet with a pen) and a group work session (35–40 min) following the concepts of microteaching and cooperative learning. For example, after considering the concept of Problem Tree and Solution Tree Analysis, groups, randomly formed by using a free online service, had to build such trees on Jamboard communicating freely in breakout rooms.

During the new learning material presentation, the main attention was paid to threshold concepts of project management. We encouraged students to share thoughts and ideas orally or via Google Meet chat. The chat waterfall technique was also used when all students must type "answer" into the chatbox without sending it. Then, they must hit "send" at once. Therefore, all students could join without being afraid to repeat the answer that has already been published. It also is possible to organize chat discussions asking students to type pro- and contra-arguments in turn.

Among other cooperative learning strategies, the jigsaw technique was also used where students divided into groups of 3 to 5 worked on one aspect of the general topic. After that, new groups were formed which included students from all groups to share information. For example, the material about Project Breakdown Structures can be divided into three subtopics – WBS, OBS, and CBS. To encourage students to self-directed learning the flipped instruction approach was also used for the "good-to-know" topics when students should do some pre-class activity, e.g., watch a video or read an article and leave comments or answer multiple-choice questions.

It should be noted that while preparing students for collaboration we mixed them between groups. The permanent teams were formed since Week 6 for the rest of the semester. Students' teams had to choose a real-world problem and develop the conception of the web-based application. Each team worked with the Trello board to organize the project data and tasks. Then, it was necessary to develop a project plan, define roles and responsibilities, and create the project documentation (WBS, OBS, Gantt chart, network diagram, etc.). The main attention was paid to the importance of shared regulation of planning, collaboration, and monitoring.

The change in teaching and learning activities led to the modification of the procedure for the assessment. A combination of formative and summative assessments was used. The performance tasks and quiz assignments completed by students during the semester are worth 50% of total marks, group assessment tasks - 30%, and team projects - 20%. During the last class, the so-called Projects Fair was organized. The teams should present their ideas and project documentation using shared slides or videos. The teacher evaluates the different aspects of projects using the guide with criteria and rubrics. Other students were asked to take part in the peer evaluation and rate the presentation via an anonymous Google form. Also, each member of the team was asked to evaluate team members' performance using a peer evaluation form that consists of questions about participation, responsibility, efforts etc.

## 4 Results and Discussion

The study is conducted using the action research approach based on action, evaluation, and improvement of pedagogy and practice. In total, a cohort of 40 first-year engineering students took part in the research: 14 (Spring 2021) and 26 (Spring 2022). Participants included 80% male (n = 32) and 20% female students (n = 8).

At the beginning of the semester, the students were asked to fill out an anonymous online survey. The entry survey contained questions about students' expectations for course learning activities and assessments. It should be noted that the rate of students who got acquainted with the course curriculum before the beginning of the semester was 64,29% in 2021 and 84,6% in 2022 which is significantly higher than in 2020 with 28,56%, respectively. Also, we asked students to evaluate their proficiency in the use of different software (a five-point scale was used). The highest average values were for messaging apps, video hosting platforms, and presentation software (between 4.7 and 4.1), while proficiency in using Office suite apps, LMS, and video meeting platforms were rated significantly lower (between 3.8 and 3.3). All students reported that they never used teem tools (Trello, Slack) and only 3 students worked with online whiteboards before. So, the additional instructions and useful links about these programs were added to Google Classroom.

We collected the students' expectations related to collaboration with peers and project work. Most students stated that they would like to learn how to work in a team including the ability to critically evaluate their own ideas and express them within the teamwork, understand and accept different opinions, play different roles in a team, plan the work of a team and be able to use digital tools to enhance teamwork.

During the semester students' feedback was collected to evaluate their perception of group tasks and identify how they organized the teamwork. The anonymous survey after the first group task showed that the students were rather satisfied with their results (92,8% and 88,4% in 2021 and 2022, respectively) and team performance (78% and 69,2%), but over the quarter of students mentioned the lack of effort of some group members. The survey repeated after the third group task showed an increase in perception of team performance – 85,7% and 74,4%. Students stated that they used Discord (3 groups) or Telegram (1 group) as team communication tools.

Also, students were asked to answer a series of questions concerning their perception of the current course experience, namely, what aspects and activities helped them to complete the course successfully. The results shown in Fig. 2 demonstrate that students have a positive attitude toward the applied tasks and tools. Students highly rated team projects, group, and individual tasks, stating that individual tasks support a better understanding of theoretical concepts, while group tasks and team projects were seen as opportunities to apply them in practice. A few students noted that it was a bit challenging and time-consuming to transform their own ideas into project concepts.

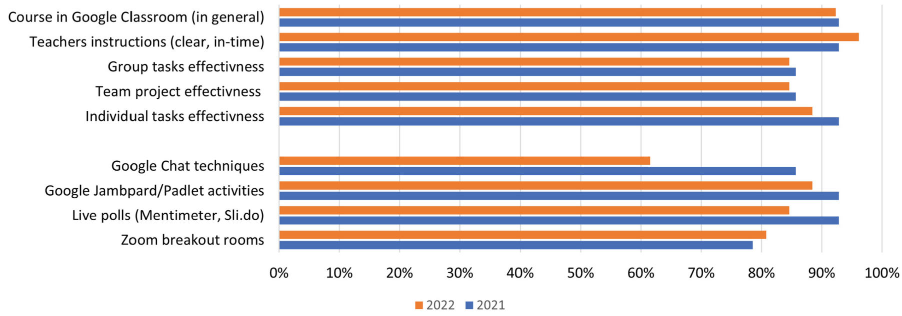


**Fig. 2.** Summary of students' responses

In addition, the students were requested to evaluate how much their abilities have changed after the course completion. The results are presented in Fig. 3.

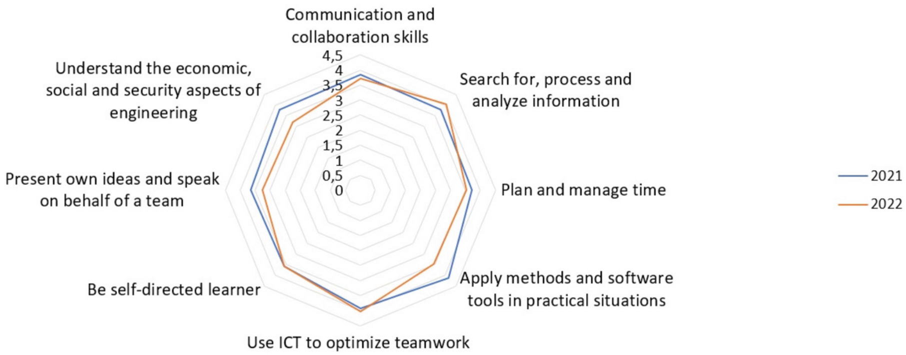


**Fig. 3.** Summary of students' responses to their abilities change

87,5% (35 students out of 40) reported an improvement in their abilities to work in a team and use ICT for remote collaboration. 77,5% (31 students) stated that they have learned much about project management and its role in the professional context.

## 5 Summary and Acknowledgements

Our findings enable us to draw the following conclusions. First, it should be noted that we understand that our findings are tentative. The sample size is small; therefore, additional iterations of research are needed. In addition, this study concentrates only on the students' perception of the course while the teachers' implications are crucial to the creation of the complex framework of implementing strategies for fostering students' communication and collaboration skills during online/blended learning.

The research findings indicated the effectiveness of adaptation of the traditional face-to-face learning activities to the online/blended learning settings by using such tools as Google Meet, Chat, shared online boards, live engagement tools, etc. It is important to support balance between the various learning activities by taking into account students' feedback and providing simple and clear instructions and assessment rules. The proposed approach, which flexibly combines individual and group tasks and team projects, helps to adapt students to online/blended learning. At the same time, performance tasks and sequences of quiz assignments with the opportunity to improve results, group tasks, and team projects work on the different levels of Bloom's taxonomy, contribute to the formation of knowledge, skills, and general competencies, including problem-solving, critical thinking, creativity, etc. The team project is a way to extrapolate theoretical and practical skills to real-world problems.

The study takes the issue of fostering students' communication and collaboration beyond one of the educational activities allowing us to interpret them as a way to overcome the lack of academic contact with peers in the online course. The learning materials can be allocated to a separate discipline for students from other programmes.

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# First-Year and Graduate Teacher Training Students' Views on the Teaching Career

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**Abstract.** In our study, we present a research that examined the correlation between first-year and graduate teacher training students' career image, teaching intention and pedagogical potential. Our goal was to assess the changes that occurred over the three years, from the beginning of the studies to the graduation, in the attitudes and intentions of engineering students, who, at the beginning of their higher education enrolled in teacher training in addition to their undergraduate studies. We examined whether, according to their judgment, there are any changes in their views regarding the teaching career and in the evaluation of their own teaching skills.

The survey was conducted in two academic years: in the 2020/2021 academic year first-year students, while in the 2022/2023 academic year graduate students participated in the survey. The comparison was made on a sample of students from the Sapientia Hungarian University of Transylvania Teacher Training Institute. The components of the self-edited questionnaire are: socio-demographic questions, characteristics of the teaching career, qualities of an effective teacher, assessment of the importance of teaching, the teacher's self-image. Students filled out the questionnaire on Google Forms.

**Keywords:** Teaching career image · Teaching intention · Engineer - Teacher training

## 1 Introduction

The Romanian Sapientia Hungarian University of Transylvania Teacher Training Institute was created with the intention that engineering students studying in Hungarian would have the opportunity to participate in psycho-pedagogical training in their mother tongue, as well as to prepare them for the challenges of practical teaching [1]. In national minority education, besides the educational function, its identity-forming function is also of outstanding importance, which can prevail if young people participate in Hungarian-language education [2]. For the minority communities, the key to preserve identity lies in mother tongue education, the foundation of mother tongue literacy and transmission of national culture values [3]. For years, in the public education in Romania, there has been a great need for teachers with technical training. Most engineering undergraduate

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students of Sapientia Hungarian University of Transylvania study at the Târgu Mureș Faculty of Technical and Human Sciences. At the Teacher Training Institute in Târgu Mureș approximately half of engineering and half of human sciences students complete the first-level pedagogy module in addition to their bachelor's degree. The teaching certificate will entitle them to work as a teacher in the compulsory stage of public education after completing the training: the four years of primary school (grades 5–8); the lower stage of secondary education (grades 9–10). The Ministry of Education publishes[1] an overview of the teachable subjects assigned to the degree, which is updated annually.

After obtaining their diplomas, young people can take a job in public education through a competitive exam. The competitive exam is prerequisite for obtaining a teaching position that is organized uniformly at the national level by the Ministry of National Education based on a methodology, subjects and literature developed by the same Ministry. Candidates take the exam comprised of subjects announced in the field of expertise corresponding to their certificates: one third of the final score can be awarded for their professional knowledge, one third for the teaching methodology and one third for the general psycho-pedagogical issues of teaching and education. Candidates who obtain at least a grade seven (the highest grade is ten) can occupy a teaching position as a full-time qualified teacher[2]. Those who do not achieve this grade can only become a part-time/substitute teacher, which is valid for one academic year, and they can retake the exam in the following academic year [4].

The professional advancement of teachers takes place in three stages: final exam/tenure exam, didactic degree II and didactic degree I exams. The highest professional degree is teacher of excellence.[3] Anyone who succeeded in getting a job in public education must take another exam after two years of teaching. Teachers who have at least two years of teaching experience as a full-time teacher or at least three years as a substitute/part-time teacher can apply for the so called tenure exam/final exam. In order for someone to apply for this exam, the candidates must receive at least a "good" rating in the annual evaluation and the qualification given by the specialist inspectors. According to the current law and methodology, the final exam is a requirement to obtain the right to practice the teaching profession.

The next steps of professional advancement consist of obtaining didactic degrees II and I. These exams are organized by further education centers operating alongside universities. Obtaining these degrees is considered further education, with these teachers' job opportunities increase, they can apply for higher positions, like leadership positions. Teachers, who kept teaching without interruption for four years after their final exam, are entitled to apply for the didactic degree II. Between obtaining didactic degrees I and II, the applicant teacher must gain another four years of teaching experience. In order to obtain the didactic degree I, just like in the case of didactic degree II, applications take place at the education inspectorate, after which the applicants' files are sent to the universities.

[1] Centralizatorul disciplinelor/ The centralizer of disciplines.

[2] Profesor titular.

[3] Profesor excelent.

Career development is the result of a long process of professional development, therefor it cannot be narrowed down to a single decision, but requires a series of decisions. At all stages of their lives and careers, individuals need to make decisions regarding their career development. These decisions are also influenced by peer pressure and social expectations [5]. There are also many challenges for beginner teachers, as they have to take up a new role and cope with many new situations that are initially not familiar to them [6]. In terms of staying in the profession and career socialization, the starting quality of a career will be crucial for them [7].

The surveyed students made their first major decision when they applied for teacher training alongside their undergraduate studies. Graduates who completed their teacher training and are about to take their final exams, have to make another decision: whether or not they want to teach in the public sector. Based on what they learned and their practice teaching experience, they can better assess whether they would be able to succeed in the teaching profession. The question is how desirable this profession is for them.

## 2 Presentation of Survey

In our study, we present a research that examined the correlation between first-year and graduate teacher training students' career image, teaching intention and pedagogical potential. The survey was conducted in two academic years: the same class participated in the survey, in the 2020/2021 academic year as first-year students, while in the 2022–2023 academic year as graduate students. The comparison was made on a sample of students from the Sapientia Faculty of Technical and Human Sciences Teacher Training Institute in Târgu Mureș.

Our goal was to assess the changes that occurred over the three years, from the beginning of the studies to the graduation, in the attitudes and intentions of engineering students, who, at the beginning of their higher education enrolled in teacher training in addition to their undergraduate studies. At the beginning of their studies half of the surveyed students (45.1%) stated that they would like to teach after completing their studies, while 49% considered teacher training to be just an option. We assessed the extent to which their intention to practice the teaching profession after graduation changed, and how attractive the teaching career was to them after completing the training. We examined whether, according to their judgment, there are any changes in their views regarding the teaching career and in the evaluation of their own teaching skills. Our question was, to what extent they consider the knowledge gained during the psycho-pedagogical training to be useful.

The components of the self-edited questionnaire: socio-demographic questions, characteristics of the teaching career, assessment of the importance of teaching, the teacher's self-image. Students filled out the questionnaire on Google Forms. Data processing and analysis was done with the SPSS 22.0 program.

# 3 Results

## 3.1 Presentation of the Sample

In the academic year 2020/2021, a total of 102 first-year students whereas, in the academic year 2022/2023, 64 third-year teacher training students completed the questionnaire. 97% of the first-year students and 87.6% of the third-year students took part in the survey, while 30.47% dropped out (opted out of the training). Distribution of first-year students by the field of study: 47.1% technology, 52.9% human sciences. Distribution of third-year students by their field of study: 42.2% engineering/technology, 57.8% human sciences. The gender distribution of the surveyed students is almost the same: in the 2020/2021 academic year 52.9% girls, 47.1% boys, and in the 2022/2023 academic year 54.7% girls, 45.3% boys. The dropout rate is similar in both fields of study.

## 3.2 Students' Teaching Intentions

Questions which we used to examine students' intention to teach was presented in [8]: i.e. how do they feel about a teaching career at the beginning and as well in the end of their studies. "From the following five answers they had to choose the one that suits them the best: very important to me, I definitely want to teach; important to me, if I would have the opportunity, I would want to teach; it is a good opportunity, but it is not my main career aspiration; not important, it is only a backup plan; not at all important, I would only teach if I could not find another job".

We combined the answers and created three further groups: teaching is important, it is an option, and it is not important. Students' responses at the beginning of their teacher training and as graduates are significantly different ($chi^2 = 9.546$, $p = .008$): 45.1% of first-year students consider teaching important, compared to the 39.1% of third-year students; 49% of first-year students think of teaching as an option, compared to the 39.1% of third-year students; while 5.9% of first-year students and 21.9% of graduates do not consider teaching important. Comparing human sciences and technology graduate students, the difference is significant ($chi^2 = 7.020$, $p = .030$): nearly half of human sciences students (48.6%) and a quarter of technology students (25.95%) consider teaching important; 10.8% of human sciences students and 37% of technology students do not consider it important; similar percentage of the students think teaching is an option: human sciences 40.5%, technology 37%.

The percentage of technology graduates who want to teach decreased and the percentage of those who prefer to work in the professional sector increased. This is supported by further findings, as their views on teaching reveal that they think teachers are disrespected and underpaid.

## 3.3 Students' Teaching Career Image

Students' opinion on the teaching career was examined with 13 statements (Table 1), using a 5-point Likert scale (1 - not at all true, 5 - completely true) [8]. Students' responses from both classes show that the highest values were given to professional aspects, such as outstanding communication skills (rank 1) and educators serve society (rank 2). Both first-year students and graduates consider teaching to require a high level of professional knowledge (rank 3), meaning that vocational calling is the central element of their career image. Regarding the work of a teacher, they are aware that it involves a lot of work (rank 4) and it leaves little free time (rank 13), also it is an emotionally stressful (rank 7) activity. These results are in accordance with the results of previous studies [9].

The prestige of the teaching profession declined in recent years in Romania [10]. This is also reflected in our previous [8] and present survey results. Comparing the results of the two groups, we see that the mean of graduate students is significantly lower for three factors: teachers are socially valued (Mean 2 = 3.20, rank = 10), teachers are respected (Mean 2 = 3.00, rank = 11) and teachers are well paid (Mean 2 = 2.64, rank 13). Graduates' ratings are higher for the compatibility of teaching with family life (Mean 2 = 4.38, rank 3). Overall, students' perceptions of teaching changed over the three years of study, i.e. they believe that teachers are not held in high regard, they are not respected well enough by society and that teaching is not a well-paid profession.

### 3.4 Self-reflection: Resources for the Teaching Profession

Alongside teaching intention and teaching career image, we also looked at how students think about themselves in terms of their abilities, qualities and aspirations. Eight statements (Table 2) were rated on a Likert scale from 1 to 5 (1 strongly disagree, 5 strongly agree). Teacher potential is the collective name we gave to the factors of teaching skills, characteristics and attraction to the profession, because we believe that the inner resources, the person's inner reserves and the knowledge about these are essential requirements for being able to teach effectively [8].

In our previous research, where we compared the responses of two different group of first-year students, regarding their teacher potential, we found a significant difference when comparing by gender: girls were significantly more likely to say that they want to teach and educate, that they are interested in a teaching career and want to work with young people and children. At the same time, both boys and girls believed that they have the characteristics and skills needed for teaching and would like to do work in the future that will help them learn and develop. The environment also encourages and supports girls to pursue this career [8].

In the present study, no significant difference was found between the responses of first-year and graduate students, i.e. over the three years no changes occurred in the way they think about their own abilities and characteristics (Table 2). Gender differences emerged once again: girls are more encouraged to become teachers (Mean = 3.97) than boys (Mean = 3.17); girls are more interested in jobs where they can work with children and young people (Mean = 3.89), while boys are less interested (Mean = 2.86).

There are significant differences in results when comparing graduates' by their field of study. Human sciences students are more encouraged to become teachers (Mean = 3.92) than technology students (Mean = 3.15) ($F = 5.979$, $p = 0.17$); human sciences students would prefer a job working with children and young people (Mean = 3.84) whereas technology students are less interested (Mean = 2.85) ($F = 14.602$, $p = .000$); technology students are significantly less interested in teaching ($F = 4.111$, $p = .047$): technology (Mean = 3.33), non-technology (Mean = 3.81).

**Table 1.** Characteristics of the students' teaching career image

| Characteristics of the teaching profession 2020/2021 | | Statements | Characteristics of the teaching profession 2022/2023 | | T-test |
|---|---|---|---|---|---|
| Rank | Mean 1 | | Mean 2 | Rank | |
| **1** | 4.67 | Teaching requires outstanding communication skills | 4.48 | **2** | N.S |
| **2** | 4.59 | Teachers serve society | 4.55 | **1** | N.S |
| **3** | 4.52 | Teaching requires a high level of professional knowledge | 4.33 | 4 | N.S |
| 4 | 4.24 | Teachers work a lot | 4.05 | 5 | N.S |
| 5 | 3.97 | Teaching is emotionally demanding | 4.38 | **3** | ** |
| 6 | 3.86 | School holidays fit in well with family life | 3.91 | 6 | N.S |
| 7 | 3.69 | Educational qualifications are accepted everywhere | 3.83 | 7 | N.S |
| 8 | 3.64 | Teaching is socially valued | 3.20 | 10 | ** |
| 9 | 3.58 | The work of teachers is respected | 3.00 | 11 | *** |
| 10 | 3.58 | Teaching is a secure job | 3.52 | 8 | N.S |
| 11 | 3.25 | Teaching provides a predictable career | 3.47 | 9 | N.S |
| 12 | 3.07 | Teaching is a well-paid profession | 2.64 | 13 | ** |
| 13 | 2.62 | Teachers have a lot of free time | 2.95 | 12 | * |

### 3.5 Assessment of the Benefits of Teacher Training

As we observed, the intention to teach decreased among the graduate students, but the question was raised regarding how they perceived the usefulness of the three-year teacher training. On a scale from one to five, students rated how beneficial they thought the training was (1 - not at all, 5 - very much). In a response to an open question, they were allowed to justify their answers as desired.

**Table 2.** Teacher potential-compared means of first-year and graduate students

| Statements | 2020/2021 | | 2022/2023 | | Independ. t-test | Sig. |
|---|---|---|---|---|---|---|
| | Mean | Std. Deviation | Mean | Std. Deviation | t | |
| I possess the qualities of a good teacher | 3.74 | .703 | 3.92 | .803 | −1.575 | N.S. |
| Teaching matches with my skills | 3.77 | .795 | 3.77 | .792 | .070 | N.S. |
| I like to teach and educate | 4.18 | .895 | 3.98 | .951 | 1.314 | N.S. |
| I am interested in teaching | 3.87 | .919 | 3.61 | .953 | 1.770 | N.S. |
| Others think I would be a good teacher | 3.97 | .842 | 4.09 | .894 | −.915 | N.S. |
| I am encouraged to become a teacher | 3.40 | 1.119 | 3.59 | 1.294 | −1.011 | N.S. |
| I want a job where I can work with children and young people | 3.56 | 1.034 | 3.42 | 1.124 | .834 | N.S. |
| I want a job with the possibility of constant learning and self-development | 4.50 | .702 | 4.55 | .733 | −.454 | N.S. |

The mean value of 4.23 indicates that the training was considered to be useful. No significant difference was found when comparing by gender and by field of study. In their explanations, some students mentioned teaching methods as being useful, such as frontal work, small group activities, and work in pairs. Many referred to the teaching practice, their own teaching experience, as being useful. In addition, they valued the discussions on teaching careers and the fact that they received up-to-date and realistic information on the specific characteristics of Hungarian public education in Romania. Many of them admitted that the positive and committed attitude of their teachers towards their students and teaching was exemplary, i.e. in their words "You have to love what you do!".

## 4 Summary

According to both first-year and graduate students' views on teaching, teaching requires excellent communication skills, benefits society and is a lot of work, but it is unpredictable and does not pay well. Almost half (45.1%) of the first-year students stated that they would like to teach, while the proportion of those who would like to teach decreased among graduate students. 5.9% of the first-year students said that they considered teaching as an option and that teaching was not important to them, while the percentage was significantly higher among graduates (21.9%). In comparison to human sciences students, engineering students are significantly less likely to consider the teaching profession important at the beginning and at the end of their teacher training. According to the graduates, teacher training significantly changed their views on teaching and the teaching profession.

First-year engineering students considered participation in teacher training to be a development opportunity. After completing the training, they said that their views on teaching changed significantly, they have a more realistic perception of the challenges and a better appreciation of their responsibilities. We are aware that higher education in engineering is a very intensive phase of professional development for students, which in the given circumstances is complemented by teacher training. Few people wish to become teachers because their profession is more profitable. Teacher training didn't succeed in strengthening the teaching intentions of engineering students who participated in our survey, but it led to the acquisition of psycho-pedagogical knowledge and attitude formation.

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# Self-Regulated Learning Strategies: Zimmerman's Cyclical Phases Model and Writing Skill

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**Abstract.** English is the most widely spoken language with more than 1,400 million speakers around the world. In Ecuador, English is taught as a foreign language in which the writing skill has been identified as a problematic one to be developed successfully. According to several studies, strategies and methodologies applied in class are responsible for having good or bad results in the development of a language skill. The present study aimed to investigate the influence of self-regulated learning strategies in the development of writing skills in EFL postgraduate students. Investigating the impact of SRL on EFL postgraduate students' writing skill and the aspects that significantly improved based on Zimmerman's Cyclical Model contribute to the teaching and learning process in language learning. This research employed a pre-experimental design; the sample was a group of 26 EFL postgraduate students in a teaching training program at an Ecuadorian public university. The instrument used to collect the required data was a standardized Cambridge exam (PET) applied as a pre-test and post-test. The approach of this research was quantitative since it allowed collecting, analyzing, and presenting the data obtained from the results of the pre-test and post-test. The data was analyzed using statistics analysis. This research presented some findings: self-regulated learning strategies allowed students to improve their writing skill and turned them into autonomous and lifelong learners. Therefore, self-regulated learning strategies not only helped students to improve and develop writing skill but also helped them to develop positive attitudes needed to support their writing performance.

**Keywords:** Writing skill · self-regulated learning strategies · EFL university students

## 1 Introduction

Globally, English is one of the most widely spoken language with more than 1.4 billion speakers, most of whom learn English as a second language. However, writing is one of the problematic skills to develop in the English as a Foreign Language (EFL) process. Due to this identified issue, researchers, and practitioners has adopted the use of Self-Regulated Learning Strategies (SRL) formulated by Graham and Harris three

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decades ago to improve writing and self-regulation [1]. These strategies were created with three main objectives: to help students in the writing process, to support students in the use of strategies to develop writing skills, and to develop a positive attitude and confidence [2]. Similarly, Zimmerman developed SRL (goal setting, reflecting, planning, and organizing) strategies to increase motivation and improve academic performance [3].

Writing is a complex task and one of the most difficult skills to learn. Also, it takes a long time to master the writing process and develop a standardized written form. Writing is a cognitive task that requires students to regulate both external (learning environment) and internal factors (writing factors and specific skills) [4]. Therefore, students need to develop self-regulation strategies for their subject matter skills to write well. A self-regulated learning perspective on writing helps students monitor, review, and edit their writing products and become self-directed [5]. For example, the use of discrete processes of self-regulation of writing, including goal setting, self-monitoring, and self-assessment, teaching self-monitoring, and self-reinforcement can be applied to broader and more diverse writing activities [6]. Moreover, self-regulated learning promoted positive attitudes in the writing process, which was influenced by self-regulated behavior. Self-regulated learning may enable EFL students to better understand and produce high-quality writing products through self-regulated learning strategies [7]. The self-regulated learning of writing is a complex system through which students build a sense of self-efficacy [9]. Students' effectiveness is developed through self-regulated learning strategies that allow them to control and manage their behavior and internal thoughts [10]. Therefore, the motivation to write is created for the control of the learner in the writing process [11].

This study aims to analyze whether Self-Regulated Learning Strategies (SRL) develops the writing skills in EFL undergraduate students.

## 2 Literature Review

Self-regulated learning (SRL) emerged as a new learning theory and model that facilitates the transfer of knowledge and skills to real situations and makes students independent of teachers [12]. These strategies allow students to gain more experience in the learning process and the teacher acts as a guide in the classroom. Self-regulated learning is a key concept to understand the cognitive, motivational, and affective aspects of learning. In fact, SRL is related to students' thoughts, feelings, and actions to achieve personal goals [13]. These strategies help students understand and control the learning environment in which learning occurs [14].

In addition, it is important to understand the main components of self-study. First, the cognitive component includes the encoding, memory, and storage of information, as well as the skills and habits necessary for critical thinking [15]. Another important component is metacognition which includes self-monitoring and adjusting the learning process [16]. The motivational component is another characteristic which provides understanding about students believes and attitudes, and how they influence the use and development of cognitive and metacognitive skills [17]. Additionally, autonomous learning strategies emphasize how students choose, organize, and shape the learning environment [18].

### 2.1 Self-regulated Learning Strategies: Zimmerman's Cyclical Phases Model

Zimmerman's Cyclical Phases Model is organized into three phases: forethought, performance, and self-reflection [19]. In the first phase, the students analyzed the task, set goals, and reach several motivational beliefs. In the second phase, the students perform the task while monitoring their progress, and use several strategies to keep engaging students. In the last phase self-reflection, students assess how they performed the task and make an evaluation of the success or failure of the task. Self-regulatory learning is divided in three phases: forethought phase (task analysis and Self-motivation beliefs), performance phase (self-control and self – observation), and self-reflection phase (self –judgment and self-reaction) [20] (Fig. 1).

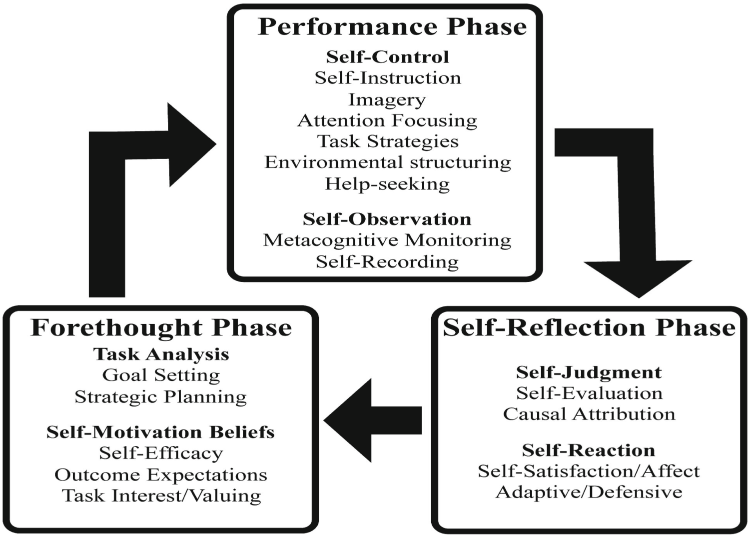


**Fig. 1.** Zimmerman's Cyclical Phases model and its phases.

## 3 Methodology

### 3.1 Participants

This research was carried out at an Ecuadorian public university. The participants were twenty-six EFL undergraduate students (17 females and 9 males) whose age was between 19–22 years old. The participants were students of a pre-intermediate level of English according to the Common European Framework. The population was selected randomly from two courses of third semester for the purpose of this study.

### 3.2 Research Design

The methodological approach of this research project was quantitative as it allows researchers to collect information using pre-test and post-test. The research design was pre-experimental. It was carried out in a controlled environment which facilitates the verification of how effective the application was. Additionally, the instruments applied in the research were a pre-test and a post-test in to evaluate the writing level of the students before and after the application of the treatment (self-regulated learning strategies). The instrument was selected from the standardized test called Cambridge Preliminary English Test (PET). The test was divided into four sections (listening, reading, writing, and speaking). In fact, the writing section chosen was divided into three parts. The first part consisted of writing an email, meanwhile, in the second part the students had to write an article, and the last question asked them to write a story. This section was selected because students could write about familiar topics. The rubric to evaluate the texts was taken from the PET (Preliminary English Test) that evaluated the four criteria (organization, communicative achievement, language, and organization) on a scale of 0 to 5 for each one.

## 4 Results and Discussion

To obtain the results an see the influence of Self-Regulated Learning Strategies in the development of the writing skills in EFL learners, it was needed to apply a pre-test and a post-test. Statistical analysis was used to compare the range of differences between them which are described in Table 1.

**Table 1.** Comparative results pre-test and post-test.

| Results | Criterion | Pre-test | Post-test | Difference |
|---|---|---|---|---|
| Part 1 Email | Content | 2,5 | 3,8 | **1,3** |
| | Communicative | 2,6 | 3,5 | 0,9 |
| | Organization | 2,6 | 2,9 | **0,3** |
| | Language | 2,8 | 3,4 | 0,6 |
| Total | | **5,6** | **6,8** | **1,2** |
| Part 2 Article | Content | 2,8 | 3,4 | **1,2** |
| | Communicative | 2,3 | 3,4 | 1,1 |
| | Organization | 2,2 | 3,1 | **1,2** |
| | Language | 2,8 | 3,5 | **0,7** |
| Total | | **5,1** | **6,7** | **1,4** |
| Part 3 Story | Content | 2,2 | 3,5 | **1,3** |
| | Communicative | 2,8 | 3,2 | **0,4** |
| | Organization | 2,8 | 3,3 | 0,5 |
| | Language | 2,8 | 3,3 | 0.5 |
| Total | | **5,3** | **6,7** | **1,4** |
| Average total | | 5,6 | 6,8 | 1,4 |

Based on Table 1, it is observable the results obtained in the pre-test and post-test of the three sections of the PET exam. For the first section, the students had to write an e-mail. The average of the post-test was 5,6 meanwhile the result in the post-test was 6,8 points, which means that there was a difference of improvement 1,2 points. Therefore, there was a good improvement in the students after using the treatment of "Self-regulated learning strategies". Moreover, the most significant change was in content criteria because there was a difference of 1,3 points, which means that students had better management of the content. However, the lowest score obtained was in the organization criteria because students didn't use linking words and cohesive devices to create a good organization.

In the same way, in Sect. 2 the learners had to write an article. As we can see the difference between the pre-test and post-test was significant. In the pre-test, the average was 5,1 points and the post-test graded 6,7 points so the difference was 1,6 points. Indeed, the major improvement was in organization and content. There was a difference of 1,2 points, which means that students made good use of some linking works or cohesive devices and wrote good content. Meanwhile, there was not a significant improvement in language criteria since the difference was a minimum of 0,7 points, which means that students had some grammatical mistakes and spelling errors.

Lastly, Sect. 3 in which the learners had to write a story had a similar level of difference in relation to Sect. 2. The average of the pre-test was 5,3 and the post-test graded 6,7 points thus the difference was 1,4 points. Finally, the total average of the pre-test was 5,2 and the total average of the post-test was 6,7 as a result the difference was 1,4 points. It means that the treatment and the interventions were useful and helped students to improve their writing. Further, there were good results in the content criteria as the difference was 1,3 points which means students followed instructions and the content was relevant. However, there was not an improvement in the communicative achievement criteria because there was a difference of 0,4 points, which means that story did not have a good structure.

### 4.1 Discussion

After the analysis and interpretation of the data collected, there were key findings that support the hypothesis theory that self-regulated learning strategies influence the development of writing skill.

During the interventions it was possible to observe that the students gradually developed these positive attitudes due to the use of self-regulated learning strategies. Therefore, the students when developing these attitudes had a positive change and improved in writing performance. Self-regulation strategies develop a high interest and motivation to learn because they believe that they can achieve their own personal development which allows students to have a better performance of writing [12]. SRL strategies improve the writing skill of the students with the use of motivational variables [13]. Likewise, the students were able to improve because the SRL strategies focus on both the development of attitudes and the improvement of writing.

Self-regulated learning strategies are essential for lifelong learning, and it is a process in which the student controls, monitors and influences his/her own thinking process that requires knowledge and skills [13]. During the application of the self-regulated learning strategies, it was possible to observe how the students, when carrying out work independently, acquired more autonomy and efficiency on how they would complete their work. In the same way, this was projected in the results of the post-test because the students improved in each section and evaluation criterion. In other words, the students could monitor and control their writing because they previously acquired knowledge through autonomous work. Additionally, it is related to the motivational process where students feel more encouraged with learning. Therefore, through self-regulated learning strategies, students developed critical thinking that allows them to become autonomous and complete any assigned task or work effectively [14].

## 5 Conclusion

The present research was conducted to analyze the influence of the self-regulated learning strategies in writing skill. After an extensive study were obtained some results from where conclude that the main strategies that were identified were goal setting strategy, planning strategy, homework strategy, self-efficacy, homework strategy, self-instruction strategy, self-monitoring, and self-assessment. All these strategies allowed students to improve their writing skills on different assessment criteria (content, communicative achievement, organization, and language) of three different types of writing (email, article, and story). During the application of the self-regulated learning strategies the students worked by themselves to achieve their goals and at the same time worked with their classmates to share information. Also, the students completed tasks to reinforce their learning and writing skills, and at the end, they received feedback from the teacher. Therefore, self-regulated learning strategies improve writing skills in many aspects they can write competent writing which contains good content, communicative achievement, and organization and make good use of vocabulary and grammar. The use of self-regulated learning strategies was effective in the learning and development of writing. The students had an evident improvement in each one of the evaluation criteria during the performance of the writing. Most of the students produced outstanding writings because there was a better organization, a clear communication objective, and content, unlike the performance they developed prior to the application of the treatment.

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# The Relevance of Language Register When Writing in English as a Foreign Language Contexts

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**Abstract.** Writing proficiency is one of the key abilities that students of English as a foreign language must possess. In a variety of social contexts, people frequently make conscious or unconscious linguistic decisions to communicate. This study sought to understand how language registers affect how well writing skills develop in students enrolled in a Language Teaching Training program. This study used a quantitative approach and a pre-experimental design. The study involved applying two pre-test writings, and two post-test writings and eight-session intervention. The templates used to create the written pieces were modified from the Longman Preparation Course for the TOEFL iBT Test (2015). Using the Cambridge University B2 level scoring criteria, the writing samples received scores over 10 points. In this way, 30 students in a program for language teachers created various pieces of writing that showed their knowledge of the subject. The T-test statistical instrument was used to demonstrate the degree of efficacy of language registers in the development of writing skills. It was found out there is a bond between language registers and the development of writing skills. Main findings revealed learners used informal English registers more confidently than formal registers.

**Keywords:** Register · writing skill

## 1 Introduction

People regularly make conscious or unconscious language choices in order to communicate in a range of social circumstances. When writing, it is vital to use proper grammar, semantics, and syntax, and it's also crucial to write effectively in accordance with various social contexts.

It is essential to control the characteristics of speech situation and linguistic variety in order to be appropriate in a communicative act. The majority of social interactions, in particular in the field of sociolinguistics, are dependent on situational considerations; as a result, various speech settings influence the writer's or speaker's choice of a language variety [1].

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The core of any speech situation and the selection in language variation is “register”, which is a linguistic variety that is deemed appropriate for use in a particular 2 type of speech situation [2].

Certainly, there are many spoken and written registers, however they are allocated between formal and informal registers. The speaker or writer could differentiate the level of formality in a text studying the linguistic features that belong to a specific register. For example, a person may be able to distinguish a spontaneous speech, a personal letter or an academic journal, analyzing linguistic features like lexical, phonological, grammatical, or semantic elements [1] in a text. As register influences manner of expressions, a speaker or writer usually switches between formal and informal speech forms in order to adapt to different linguistic contexts basically for the purpose of linguistic appropriateness of the situation [3].

Nevertheless, writing involves several subskills, some of these related to accuracy; that is to say, using correct forms of language [4]. With written skills there is another aspect that supports the production of written texts, that there is plenty of time to examine the sort of register that ruled such text. Therefore, every writer is expected to consider the relationship between themselves and their readers. Also, the understanding of the situation in which they find themselves before selecting the most suitable lexical items according to register that is required.

In Ecuador, learning the English language has been a specific requirement for thousands of people either for studies or work. Furthermore, the learning of this language, as in others, implies achieving an acceptable proficiency level in areas like grammar, discourse, and sociolinguistic competence [5]. All of these, are part of the communicative competence which are important in order to interact with others in a community. When learning English as a Foreign Language (EFL), it is seen that several learners can use complex vocabulary and sentences in writing but struggle to change their register and stance to suit the requirements of various communicative contexts [6]. They not only need to learn vocabulary or grammar; but also, they should learn how to use all the language devices in the right moment, circumstance, or communicative situation. They ought to learn the importance of formality and informality in language through the role of register in speech situations. The application of register is part of understanding the situational setting in which language is used.

In the present study, it is considered register in writing a required but not sufficient methodology to determine English proficiency. It has been explored learners’ writing ability to use register in different contexts.

Accordingly, this study sought to understand how language registers affect how well writing skills are developed in students enrolled in a Language Teaching Training program.

The present study is driven by the following research question:

1. How do language registers influence writing skills development?

### 1.1 Literature Review

Most people speak or write in a different way with family members, friends, and work colleagues or in class. All of these contexts create situational variation that is called register [7]. A language register is a variety of a language or a level of usage, as determined by a degree of formality and choice of vocabulary, pronunciation, and syntax, according to the communicative purpose, social context, and standing of the user [8]. Therefore, language registers act as functional varieties in different types of speech situations and regarding the appropriate use of language, its level of formality in a particular speech situation or social setting. Language register is the standard in sociohistorical language. In this way registers are sociohistorical formations that constantly change in shape and significance as a result of the behaviors they are used in; all registers include social exchange to some extent [9]. Language register occurs when both social situation and degrees of everyday situations are linked [10]. The configuration of semantic resources that a person of a culture normally identifies with a scenario type is known as a language register. It is the meaning potential that can be understood in a certain social setting However, early stages of learning a language can be difficult for speakers or writers because of the difficulty in recognizing the semantic options in a social exchange [11].

In Academic contexts, the language commonly used for writing research articles, essays, and others, as well as the language used in casual social interactions in face-to-face informal conversations, or when writing personal emails, serve as illustrative examples of registers that, despite obvious linguistic overlap, present distinct subsets of co-occurring prevalent linguistic features that cater to the pragmatic needs of each context [12].

It is possible not to notice the shift of language registers with long discourses, however, Fig. 1 shows the differences ranging from very formal to casual register in salutations.

| Very formal | Formal | Neutral | Informal | Very informal, casual |
|---|---|---|---|---|
| How do you do | Hello | Hello | Hi | What's up! / Hey! |

**Fig. 1.** Language Registers in salutations, Lund (2018)

The register-based method helped students write more effectively at both the intermediate and advanced levels, in Iranian contexts.

**Types of Register**

**Informal**

Informal writing is more casual and spontaneous [7]. It is used when communicating with friends or family either in writing or in conversation. It is used when writing personal emails, text messages and in some business correspondence. The tone of informal language also known as casual register, is more personal than formal language.

Academic writing (n.d.) [13] points out that this type of register is occasionally used in journalism. On the other hand, to use an informal register, there is a close relationship between the writer, audience, and topic with a degree of casualness. The informal register is not the same as familiar register and is more careful with grammar. However, the tone of this is conversational, using colloquial language, contractions and some slangs.

**Formal**

Formal register is neither colloquial nor personal and is the register that is mostly used in academic writing [14]. This register distance from Informal registers since it is less personal. It is used to express professional or academic thoughts. In formal register, strong opinions can be expressed objectively, it does not break any of the rules of written grammar and often has a set of rules of what not to do when using this register [15].

## 2 Methodology

### 2.1 Participants

The population involved in this research study were thirty EFL undergraduate students from ninth semester in a program for language teachers at Universidad Técnica de Ambato. Tweny female and ten male students were part of this sample who ranged from 21 to 23 years old.

### 2.2 Research Design

This study used a quantitative approach and a pre-experimental design. The research involved; applying two pre-test writings, an eight-session intervention, and two post-test writings. The templates used to create the written pieces were modified from the Longman Preparation Course for the TOEFL iBT Test (2015). Using the Cambridge University B2 level scoring criteria, the writing samples received scores over 10 points. In this way, 30 students in a program for language teachers created various pieces of writing that showed their knowledge of the subject. A Wilcoxon signed- rank test statistical instrument was used to verify the hypothesis and demonstrate the degree of efficacy of language registers in the development of writing skills.

### 2.3 Data Collection Strategies

A procedure of three stages was followed to collect the quantitative data. Firstly, students were tested with two 200-word pieces of writing as a pre-test, one for informal register and another for the formal register. For the informal register students were asked to create a personal e-mail. For the formal register, students had to write down a letter to the Dean of a school complaining about the closing of the library. Secondly, the intervention comprehended eight sessions where students reviewed meaning and types of registers and its connection with the Sociolinguistics field as well as its importance and role in the development of appropriateness when writing. Some practice on formal and informal writings were carried out where they were instructed about colloquial language, idioms, slang and punctuation to make their writings more casual. At the same time, they reviewed and practiced appropriateness in language writing letters of inquiry, complaint, job offer and application. Thirdly, two topics of writing were given as a post-test. For the informal register, students were riquired to write an email to a friend or family member. For the formal register, students had to write a letter of application for an English teacher position. The guidelines that students had to follow when creating their writings for the pretest and posttest are shown in Fig. 2.

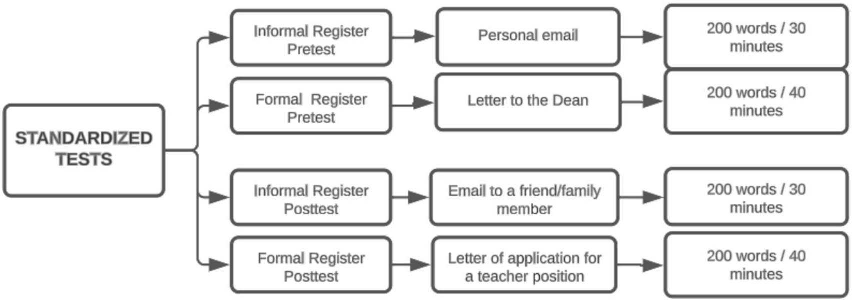


**Fig. 2.** Pre- test and Post- test writings instructions

# 3 Results and Discussion

## 3.1 Pretest- Posttest Contrastive Results Analysis

In the stage of experimentation, students developed four pieces of writing, two in the pre-test and two in the post-test. These were graded out of 10 points using a rubric from Cambridge University.

The comparative writing results analysis of learners who completed their writing assessments is shown in Fig. 3. The scores of the students in the Informal register writing increased from 7.9 on the pretest to 9.1 on the posttest, gaining 1.2 point, and in the Formal register writing they increased from 7.2 on the pretest to 7.5 on the posttest, gaining 0.3 point. It is clear that after the intervention, learners' test results improved. Interestingly, the use of informal register enhanced more than the formal register.

The SPSS software demonstrated that this reseach had a non-normal distribution in accordance with the two currect significance degrees: sig 0.05 (Non-normal distribution and sig $>$ 0.05 (Normal distribution), with sig. 0.000 and 0.029 being lower than sig. 0.05 (necessary value). In addition, Wilcoxon test, which is shown in Table 1, was used to determine whether the hypothesis was accepted or rejected.

Table 2 lists the outcomes of the post-test total minus the pretest total ranks, with $0^a$ negative ranks, $29^b$ positive ranks, and 1c ties adding up to a total of 30 in the informal register pre and posttest. On the other hand, the formal register pre and posttest has $0^d$ negative ranks, $17^e$ positive ranks, and $13^f$ ties, addin up to a total of 30. The mean ranks were 15,00 and 9,00, while the sum ranks were 435,00 and 153,00.

The asymptotic significance of the pre and posttest is shown (Table 2). Given that the hypothesis is rejected if sig $<$ 0.05, but accepted if sig $>$ 0.05, and that the results

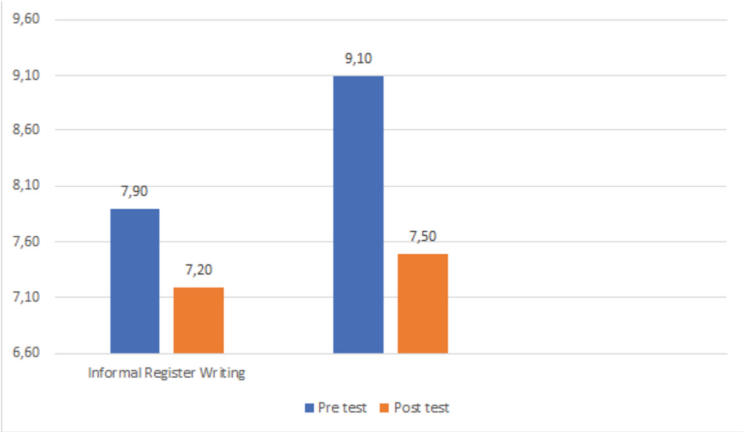


**Fig. 3.** Pretest- posttest comparative writing results analysis

**Table 1.** Wilcoxon Signed Ranks Test

| | | N | Mean Rank | Sum of ranks |
|---|---|---|---|---|
| Posttest informal- | Negative ranks | $0^a$ | ,00 | ,00 |
| Pretest informal | Positive ranks | $29^b$ | 15,00 | 435,00 |
| | Ties | $1^c$ | | |
| | Total | 30 | | |
| Posttest formal- | Negative ranks | $0^d$ | ,00 | ,00 |
| Pretest formal | Positive ranks | $17^e$ | 9,00 | 153,00 |
| | Ties | $13^f$ | | |
| | Total | 30 | | |

*Note.* [a]. Posttest informal Total < Pre- test informal Total. [b]Post- test informal Total > Pre- test informal Total. [c]Posttest informal Total = Pre- test informal Total. [d]Posttest formal Total < Pretest formal Total. [e]Posttest formal Total > Pretest formal Total. [f]Posttest formal Total = Pretest formal Total.

**Table 2.** Test Statistics[a]

| | Pretest informal -Posttest informal | Pretest formal -Posttest formal |
|---|---|---|
| Z | -4.738[b] | -4.025[b] |
| Asymp. Sig. (2-tailed) | .000 | .000 |

*Note.* [a]Wilcoxon Signed Ranks Test. [b]Based on negative ranks produced a reliability range of 0.000 < 0.05, it can be concluded that language registers have an impact on the development of English writing skills.

In this investigation it was possible to demonstrate that registers have a close relationship with writing development, since learners developed informal and formal pieces of writing effectively. This fact matches a previous study which indicate that register-based approach had a positive influence on learners' writing skill enhancement [16]. Furthermore, it was possible to determine students improved the way they write informally, more than formally.

## 4 Conclusions

It was possible to assess the degree to which language registers contributed to the growth of writing abilities while taking into account the outcomes of the pre- and post-test writings. According to the statistical results, there was a significant improvement in students' pieces of writing. This allowed a number of students to produce well-written pieces that showed how they could utilize the formal and informal registers thoughtfully, as well as how they related to the participants in the encounter and how familiar they were with them.

Learners were able to create formal and informal well-written texts demonstrating appropriate use of these registers and by adapting their language to suit the purpose and their audience. It was identified that learners used informal English registers more confidently than formal registers.

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# Upside-Down Creativity! Reversing Science Concepts Learning for Tertiary Level Students

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**Abstract.** Natural sciences are important for humanity and our knowledge of the world. A key factor for effective teaching that can lead to knowledge and improvement of learning outcomes is the promotion of students' active participation, the activation of their creativity and their encouragement to implement their own ideas in the educational process, based on their own experiences and individual learning styles. Teachers are suggested to adapt their teaching practices based on their teaching subjects, the profile and learning styles of their students, and the teaching goals they have set for any particular subject. The flipped classroom approach and the creation/visualization of students' mental representations/models in natural sciences were applied as an alternative form of teaching in order to strengthen students' creativity, positive attitude towards science and their cognitive level. Students of a University Pedagogical Department, as being prospective primary education teachers, participated in the research. For the purposes of the study, a mixed method research approach (qualitative and quantitative) was used. The results of the focus group discussion and personal interviews as well as students' final exams revealed a number of interesting findings arising from the application of the specific technique and tools (flipped classroom, self-made models/constructions/visualization of scientific concepts). According to the results, students' creativity was highlighted and enhanced, their active participation in the educational procedure increased significantly and their attitude towards science was positively modified, followed by improved cognitive results.

**Keywords:** Physics concepts · flipped classroom · activity theory · multiple intelligences · multiple representations · creativity

## 1 Introduction

Natural sciences are considered an important part of human culture reflected both on the daily routine of the world and its need to provide a better understanding of the phenomena surrounding it. They are also regarded significant for the field of education as being a dominant and essential pillar of knowledge and learning. It is argued that a mistake teachers should avoid making is to assume that all students learn in the same way [1]. This is because, according to the theory of multiple intelligences [2], every learner learns differently than other learners. A necessary condition for successful teaching and learning to take place is teachers' awareness of students' different learning styles

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which tutors should be able to elicit for effective learning to take place [3]. Teachers should exploit this knowledge and, using appropriate teaching methods and strategies, should help their learners reach the best possible learning outcomes [4]. Additionally, teachers should be able to create a learning environment that is attractive, creative and flexible for learners and their different learning modes, to help them develop internal learning motivations, to connect their teaching with students' everyday life, needs and interests and to promote interdisciplinary and collaborative instructive exchanges in their educational processes [5]. Creativity is defined as the individuals' ability to face various problems in life in an original and methodical way. Creativity is intertwined with imagination, while its development often depends on people's the personal experiences but also on the opportunities that will be given to them to manifest this uniqueness [6].

As each learner develops different types of multiple intelligences, learning, remembering, performing and/or understanding the cognitive content is accomplished in different ways [7]. To this end, it is necessary for teachers to offer multiple representations of the same subject during their teaching course of action, as this fact assists learning. The term "multiple representations" refers to the introduction of the same concepts in different ways, for example verbally, visually, mathematically, graphically etc. [8]. Specifically, there are various ways of representations such as: text, photos, diagrams, tables, equations, experiments – activities, simulations, animations, and more [9]. Representations can be classified into two broad categories: external and internal representations [10]. The use of multiple representations for the introduction of scientific concepts or phenomena aims to help learners develop their own understanding. It is emphasized that multiple representations can improve the understanding of scientific conceptual knowledge, strengthen problem solving skills, limit the difficulties of understanding the connections between different representations, enhance the enjoyment of learning science and lead to deeper and more coherent science concepts comprehension [11].

Activity theory [12] allows the realization of communication and interaction between students, using a variety of tools and works of art to enhance learning in an interdisciplinary way. According to the activity theory, learning, knowledge and expertise are distributed through the cooperation of individuals in the community [13]. More specifically, individuals or groups of people can collaborate in order to take actions to find a solution to a problem or achieve certain aims using a number of tools or strategies for this purpose. Based on the above, an alternative and interactive teaching method or strategy is flipped classroom [14]. Flipped classroom can be used to support individual or group actions taken to facilitate science concepts learning, through a framework that promotes active participation, collaboration, hands on activities, and emphasizes communication and creativity in the didactic process. Jon Bergmann and Aaron Sams [15] were the two educators who first introduced flipped classroom. According to their method, the teaching content is pre-introduced or suggested to the learners by the teacher and processed and expanded by the learners at home before actual teaching takes place. More particularly, the process is, in a way, reversed or else "flipped", as students prepare the material outside school and homework activities can in fact be implemented at school. In other words, in this technique, the study of the material to be taught precedes teaching and is done by students outside the classroom, with material students themselves mainly find and use, with the help and guidance of the teacher, when needed. The teaching time in the classroom follows and is devoted more to interactive activities, in which students actively engage with the teaching content [14].

The method is based on the constructivist theory, as students engage actively in the learning process, being responsible for their own learning and understanding. It is a student-centered approach with teachers being facilitators and guides in the instructive procedure [15]. A major benefit is the possibility for further exploitation of the learning content in the classroom, given that students are already familiar with the new concepts before the actual teaching, thus, saving valuable time for expanding knowledge and clarifying vague points during the actual teaching time [16].

Research argues that today's learners' profile demands the use of different teaching methods than traditional ones [18]. According to literature, flipped classroom is an innovative educational method, which displays a lot of advantages in the educational practice [17]. According to research the flipped classroom approach brings benefits to language teaching and learning practice [19] and replaces traditional lectures displaying positive learning outcomes [20–22], cognitive benefits [23, 24] and student satisfaction [25, 26]. Flipped classroom can increase the quality of period of teaching time for the benefit of learners [27] and involves learners in the learning activities in an interesting and fun way [28]. It also enhances learners' engagement and other skills needed today [29], as it is a technique that learners like and enjoy [30] and has a major impact on students' learning processes as well as their mind-set [31]. Generally, and as research demonstrates, flipped classroom helps learners become autonomous and responsible for their learning and offers them the possibility to take action for their own knowledge [32]. Characteristics such as self-efficacy, in-class social interaction, and high levels of satisfaction have been reported [33]. Research also argues that the use of flipped classroom will provide an entirely new impetus to teaching as an instruction methodology in the future [34]. The use of flipped classroom, as an interactive instructive technique, led students to more successful performance, helped them enhance their participation in class and enjoy their lessons [35]. Research results also revealed that the exploitation of the flipped classroom technique has had a positive impact on students' attitudes towards learning, homework completion, comprehension of the cognitive content, preparedness of the material, interest, motivation and engagement in the teaching process [36].

However, some concerns have been reported about flipped classroom [37]. For instance, research claims that although flipped classroom is an effective alternative method for teaching and learning, it is not clear whether it can be implemented for all subjects [38]. Nevertheless, the method is found to have positive results in learning as flipped classroom displays certain characteristics, (positive and negative) [39] and its success depends on a variety of factors [24].

## 2 Rationale for the Present Study

Classrooms of today are becoming increasingly demanding as students have a plethora of representations and sources of information, where knowledge is concerned, that make them become more selective in what they choose to do or study. This multimodal and multifaceted aspect of learning sources leads teachers to strive in order to find ways to accomplish students' presence in the lesson and attract their attention span and participation in the courses in order to increase their interest, cognitive level and efficiency.

Based on this need, tutors seek ways to motivate their learners on the one hand, and on the other to address their learning gaps, facilitate their understanding in new concepts, increase class participation and help them gain new knowledge. Mainly however, they put a lot of effort to guiding their learners' way into 'learning how to learn', a fact which constitutes a significant skill both for academic and life purposes.

Keeping the above in mind, we decided to conduct the target research in order to detect whether the use of the flipped classroom technique and students' self-made science representations/models/creations can augment University students' participation in science courses, creativity, interest in the lessons and cognitive level. In particular, flipped classroom was applied as an alternative instructive technique in order to enhance students' positive attitude towards science, boost student creativity, foster initiative taking and promote engagement in the classroom. Above all however, we aimed at offering learners the opportunity to undertake responsibility for their own learning, promote student autonomy, critical thinking and learning motives for science concepts. All in all, the use of the flipped classroom approach and the visualization of the students' mental representations/models for science concepts aimed to enhance creative skills, to activate their engagement and interaction in the educational process, to positively change their stance towards science and improve their learning outcomes.

## 3 The Research

### 3.1 Purpose and Research Questions

The purpose of the research was to investigate the extent to which the use of flipped classroom technique and students' visualization of self-made science concepts mental representations/models can enhance disposition towards science, creativity, class participation, communication as well as students' cognitive level in a variety of science concepts. The research questions are as follows: 1. What is students' opinion on flipped classroom? 2. To what extent can flipped classroom enhance learners' science disposition, creativity, participation and interaction in the teaching sessions? 3. To what extent can flipped classroom enhance learners' cognitive level in science concepts?

### 3.2 Research Sample

The population we aimed at was University students from Greece. Our sample was 71 University learners who participated in the present research. The participant learners attended science courses taught at a Pedagogical University Department, the aim of which is to train and educate them accordingly in order to become primary education level teachers in the future.

### 3.3 Research Method ad Tools

The study was carried out using a mixed method approach (qualitative and quantitative). In particular, semi-structured personal interviews with ten randomly selected learners were conducted for the research issues. For triangulation purposes, reliability and validity of the research [42], a focus group discussion with 14 also randomly selected learners was conducted to provide us possible answers to our research questions. Note-taking was also employed throughout the research period to offer us a better insight to the research issues. The effectiveness of the process was assessed through students' final semester exams in the relevant courses. Data was also received observing and taking notes from students' peer evaluation exchanges for students' models.

The semi-structured items of the personal interviews and focus group discussion questions were similar and were formed basically based on key areas: attitude towards science, interest in the sessions, active participation and creativity enhancement, cognitive performance and overall impression of the method. Of course, students' answers expanded further, providing us with valuable material and information for our research issues. For the validity of the research tools, the interviews and focus group questions were piloted before their actual use with three students (for the interview questions) and another three (for the focus group questions). All respondents in the piloting of the tools were not participants of the actual research. The piloting of the tools aimed to test the items for wording, accuracy, coherence, understanding and in case of inaccuracies or vague points to redesign them based on the respondents' comments.

### 3.4 Ethical Concerns

Before the implementation of the main study interviews and focus group discussion, and in order to ensure the validity and reliability of the research, the necessary clarifications and explanations were provided to all interviewees, so that the topics of discussion would be fully understood [41]. All participants were reassured that the discussions would be anonymous, and that the data would be used only for the purposes of this research. It was also explained to the interviewees that they could withdraw any time they felt uncomfortable or uneasy. The place and time of the interviews and focus group conversation were arranged based on the participants' decisions. All respondents gave their voluntary consent for their participation in this research. Finally, for ethical reasons, in the discussion of the results section, all participants are referred to as P1 (participant 1), P2 (participant 2) and so on.

### 3.5 Research Process

The study was conducted within the academic year 2022–2023. The students attended the courses of astronomy and earth sciences, taught during the Fall semester of 2022–2023. Before the actual teaching of a series of science concepts, and at least two weeks in advance, students were assigned certain topics (i.e. the water cycle, earth rotation, earth atmosphere and other related phenomena). Throughout the semester they were assigned the visualization of two topics – one obligatory and one not obligatory. Every topic was assigned to a number of eight to ten students (the same topic) to study and prepare in order to create/visualize a model of how it works and how to integrate it in a micro-teaching process to present and explain to their classmates. The reason we assigned the same topic to a number of eight to ten learners every time was in order to see the diversity in creativity and any variation in the visualization of their model/creations depending on the individual profile of each student. In due time, each student presented his/her work to the rest of the class, where productive discussion and interaction (in the form of peer evaluation and student interaction) took place between the students and between the students and the professor. Each student's presentation and explanation of his/her model to the rest of the students ranged between 10 to 15 min. After each presentation, the interaction that followed and, in a way, peer evaluation did not aim to critique the final output but rather for the audience to ask questions, clarify vague issues and express their thoughts about the concept/model presented.

What is more, and upon the completion of all the presentations of each topic by the eight or ten students each time (surprisingly every model/creation being so much differently depicted from the others, despite the same topic), students-presenters went through the process of feedback themselves, recapitulating essentially the content of their model/phenomenon (as their topic was the same for the eight or ten of them). At this time, the teacher had a supportive and facilitating role and intervened only when and if necessary, for any filling in of any further information asked. More specifically, throughout the presentations, the posing of the questions by the audience and the answering by the students-presenters, the teacher had the role of the observant while the presenters were the ones who undertook the responsibility of the revision of the phenomenon that was presented through their models. This was a fact that enhanced a lot groupwork and communication in class.

### 3.6 Data Analysis

For the analysis of the interviews and focus group discussion the conventional type "content analysis" method was employed [42]. After the transcription, the repeated listening and reading of the discussion statements content, the most significant parts that linked to the research questions were isolated and recorded and the data analysis units/key words were determined. The key words were "attendance", "active", "interest", "participation", "understanding", "science", "model", "initiative", "learning", "flipped", "performance", "disposition", "engagement", "autonomy", "critical thinking", "creativity", "communication" that were included in the participants' answers, in relation to the aims of the research and research questions.

Regarding the quantitative aspect of the research, the students did not undergo a pre or post testing process. Rather their performance was compared to that of the students of the previous semester who were tested on the material of identical, topics, level of difficulty and test structure by the same teacher/researcher. The only thing that differed was that the students of the previous year were not taught through the flipped approach but through traditional lectures. What is more, one of the reasons the teacher decided to apply this approach in his classes was due to students' low performance and dropouts of the year before, a fact that led him to think of exploiting the alternative technique of the flipped classroom to detect any changes or variations with the learners during the next semester.

# 4 Results

## 4.1 Content Analysis Findings

The findings in this study will be discussed herein in relation to each of the research questions:

Research question one: What is students' opinion on flipped classroom?

Based on the interviews and focus group discussion answers flipped classroom was considered as an interesting teaching method which "*turned class inside out*" P2, gave learners a different perspective of science concepts introduction and learning and a good motive to study at home. "*I didn't expect I would get so happy to work at home!*" P6, "*We [students] really got down to it and in a way competed with others to prepare something interesting for our topic with our models*", P4, "*I am mainly quiet in class and I am bored hearing teachers talk all the time. This didn't happen now and I am pleased because things changed, we [the students] did most of the talking"* P7. "*I liked this technique a lot, I worked a lot to prepare the material we were assigned and I felt good to do it for a good purpose, to explain it and present it to class, to my fellow students*" P9. When asked what exactly it is they liked most about the flipped classroom their answers varied. Others emphasized the taking of initiatives and others the opportunity to exploit their creative side when implementing their own science models. They also reported the possibility of interacting with others during the post-presentation phase and explanation of their models, which offered them both joy and the opportunity to expand their knowledge. Students claimed that working beforehand (before the actual introduction of the concepts by the teacher) strengthened their self-appreciation about their performance and facilitated their understanding of the science concepts. As they explained, they had plenty of time to investigate, comprehend, question, or reach a decision about the new science concepts identification and description of how their models worked or were depicted by them, presenting them and integrating them in a microteaching process (given that they are prospective elementary school teachers and are being trained how to teach).*"I really enjoyed having to take my own decisions of how to study and prepare for the material of my model which I would have to present. I kept thinking of how I would like this to be in real class, with young learners I would have to teach in the future and that I would try to do my best for them to understand"* P9, *"This method [flipped classroom] was, is very nice, it is very different than what other teachers do in class and I like it because I have to use my imagination and creative skills a lot about how to create the model I had to do, and then show them in class. I did both them [the obligatory and the non-obligatory models-tasks], I liked the water cycle very much*" P8.

Research question two: To what extent can flipped classroom enhance learners' positive attitude towards science, creativity, participation in the lesson, and interaction in the teaching sessions?

According to the participants the use of flipped classroom was seen as an 'interesting idea', a 'nice change', an 'unexpected method', an 'attractive process', an 'innovative suggestion', and more. Students explained that the use of flipped classroom namely augmented their anticipation and participation in the sessions: "*Lessons with flipped classroom were a nice change"* P5, *"Working for my models and trying to make them* *understandable and how to explain them helped me become more open, and it was nice that I could see all of us [all the students who did their own models] wanted to do something good, prepare something nice, we used videos, others painted the model, I used simple every day materials, we all gave our personal touch at our work*" P5, *"Lectures are almost always very boring, and tiring. Having to prepare the material before the teacher and present it in class to explain it was a great idea … I kept busy and excited"* P6, "*Such tools [flipped classroom] work well I think because they get you involved, they make you more active, more responsible to find the right way to do your work and show to others how you think your model works and answer questions later or explain what they don't understand. I liked this part also a lot"* P2. Students argued that flipped classroom is an innovative method to teach, as opposed to traditional lectures where teachers convey the material and learners simply take notes to study later. As they admitted, this method allowed them to search deeper into their topic in advance, investigate it more analytically, and therefore, learn better and be prepared to answer questions or respond to clarification of vague observations during the sessions. This process allowed a high level of interaction among all, a fact that had a positive impact on the way they considered science courses. According to them, suddenly, science became interesting, self-made models aroused their curiosity, brought up and enhanced their creativity (something that some of them were not aware they had to this extent) and boosted their self-esteem about their learning skills. "*I was very motivated to create my models and present them to class… it was a nice feeling being like a teacher! I think I did a decent job… [laughters]*" P10, "*Flipped classroom made me work harder I think which is surprising for me!! [smiles] but also I had a lot of fun*" P6, *"For every model I had to create I gave it a lot of thought and effort to learn as much as possible. Because of that I also felt a bit proud of myself and more confident of myself of what I can or cannot do. A smart method! [flipped classroom]"* P4. *"Other classes in the University are so much different than what we did with this approach [flipped classroom] in these science courses [concepts of astronomy and earth sciences]. I like this difference because I like to take action, I want to be involved, I don't like to be passive, it bores me a lot. All I did before was mainly attend but with this [flipped classroom] I took control of my work, I answered the questions others asked, I gave explanations, I felt important and this is amazing I think"* P8. *"Perhaps the most interesting subjects [astronomy, earth sciences] for me! I always looked forward to class!*" P7, "*I was so surprised to see that I could actually create my models well enough and I was so creative and with good imagination! I thought they [his models] would be terrible but it was not like that, the others [his classmates] liked them, I know they were very simple, because I just painted them but they were very creative they [the other students] said and that made me feel proud and artistic as well!"* P3.

Research question three: To what extent can flipped classroom enhance learners' cognitive level in science concepts?

As aforementioned, the results of the final exams – where the flipped classroom approach was used - were compared to the previous year students' mean scores in the final exams. The final exams of the research had the same format as those of the previous years. In particular, the testing items were not exactly the same but their content was of exactly the same philosophy and of the same gravity. All items derived from a bank of questions that the tutor had created for the students' assessment in the final exams throughout the semesters. The exams comprised open ended questions, multiple choice, or problem-solving items. They were prepared by the researcher who was also the tutor. Regarding the students, their cognitive level was not differentiated over the semesters as they all come with the same cognitive background when they enter the university. More specifically, the characteristics of the participants of this intervention were the same as of those learners of the previous year who had not been taught with the flipped classroom method.

Thus, based on the results of the final semester exams it can be said that students' performance improved from $6.4 \pm 1.13$ (mean score) (of the previous semester) to $8.3 \pm 1.03$ (this semester) (an increase of a percentage of 29,7%) on the grading scale from 1 to 10. This result implies that there was an increase in their performance as opposed to that of the previous year. In particular, it seems that students' engagement with the visualization of their mental representations of their topic led to their active engagement, positive attitude towards the science courses, which consequently led to their better preparation and concepts understanding and finally to a better cognitive performance.

### 4.2 Discussion of the Results

The present research aimed to investigate the extent to which the use of flipped classroom technique and the visualization of students' self-made science concepts models can enhance disposition, class participation, creativity, communication as well as students' cognitive level in science concepts. The results derived from the analysis of the personal interviews, the focus-group discussion, the note taking and the semester exams results data revealed that the use of flipped classroom had a positive impact on the learning process, student creativity, engagement and concepts understanding. Students described the integration of flipped classroom as useful, innovative, necessary and interesting. The findings agree with other findings about the positive effect flipped classroom presents in the learning process [19, 23, 27, 35].

Students stressed the fact that the use of flipped classroom transformed in a way the boring lectures, turning them into interesting procedures. As they argued, the integration of flipped classroom mainly allowed them interact constructively after each presentation, become more creative and enhance their curiosity. Based on learners' remarks, the whole process facilitated science concepts understanding, offering them joyful and creative moments. The students stressed how impressive was the fact than none of the students had created a model similar to other students and that each creation was unique. According to the results of this research it can be said that learners' involvement in the flipped classroom approach motivated them to want to attend classes, and helped them have a better understanding of the material introduced. It is also noteworthy that students' performance was higher with a considerable number of A marks in the final exams as opposed to the previous year. Students expressed their wish this process to be used in other courses as well. Based on the note-taking data, the interviews and focus group discussion answers, and peer evaluation/views exchanging comments it can be said that flipped classroom "made a difference" for students and changed their attitude towards science courses. As they said, flipped classroom was a 'necessary change' for 'frequently boring lectures" where "teachers go on and on and students have to endure it". Students explained that lessons became more interesting, pleasant and "time to have fun" and be very creative. As they explained, flipped classroom gave them a good reason to remain in class "out of their own choice", "because they learned" because "they wanted to share their self-made models", because "they enjoyed the sessions more" and because the process "facilitated understanding".

What is more, the change of their role from student to teacher gave them an impetus to engage with the subject matter in depth in terms of understanding it and in terms of presenting it to other people who did not really know the subject matter as their topic was different than the others. Students had to visualize the information, the concept, the model, to draw, to create in any form and produce a final output. This made them more actively involved as they did not only have to create their model but also to present it. This was a big responsibility for them as they had to search, study, prepare, visualize, present, interpret and explain their representation. It can be said that this change of roles and aforementioned skills is mainly the real aim of the flipped classroom process. Furthermore, the questions posed after the presentations did not only promote productive discussion but also allowed clarifications, exchange of views and further knowledge about the topic presented through a variety of perspectives from every learner.

Considering the importance of the effectiveness of students' achievement in academic teaching contexts it can be argued that, as Freeman [8] claims "We need to stop 'killing' students' performance and interest in science by constantly lecturing, instead of helping them think like scientists". After all, being tutors, we should always remember that "Good teachers do not merely 'deliver content' to students, but wake them up, throw them on their feet, and pull the chair away." [29]. Only then, education could perhaps display better results and we could perhaps be proud to claim that we live in a democratic society, that not only has meaning and conveys knowledge but also turns learning into a joyful experience for those who wish and make a hard effort to learn.

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# The Impact of Hybrid Spaces in Higher Education Experiential Learning

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**Abstract.** The recent Covid-19 pandemic has accelerated the creation of hybrid learning spaces in which students connect and interact through a mix of physical and technology-mediated encounters. However, these changes were often abrupt and didn't develop in parallel to appropriate pedagogical approaches. This paper focusses on the spatial dimension of the learning process and in its role in fostering innovative pedagogical approaches. Based on a case study framed in a course being offered at Utrecht University in the Netherlands, and the changes in spatial context triggered by the pandemic, we show that hybrid spaces can give rise to a more flexible and personalized learning experience in higher education. By exploring new ways to integrate the physical and digital dimensions, it is possible to create hybrid spaces that facilitate community creation able to enhance the learning experience through collaborative experiential learning.

**Keywords:** Hybrid spaces · Experiential learning · Higher education · Hyflex learning

## 1 Introduction

The recent Covid-19 pandemic has accelerated the creation of hybrid spaces in which students connect and interact through a mix of physical and technology-mediated encounters. These changes forced by the pandemic were abrupt and didn't develop in parallel with appropriate pedagogical approaches. As argued by Trentin (2015), to exploit the potential of hybrid spaces fully, it is necessary to associate them to an appropriate pedagogical scheme. Only in this way, innovation will be not only technological but didactic.

The emergency related to the pandemic in conjunction with lack of an adequate online learning strategy at most institutions offered the possibility to explore new ways to integrate the physical and digital dimensions. It has been possible to experiment with the creation of innovative hybrid spaces that facilitate community creation in connection with valuable learning paths. Hybrid spaces can provide a learning experience beneficial for the well-being and empowerment of students that takes their needs and learning style into account.

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The goal of this paper is to focus on the spatial dimension of the learning process and its impact in fostering innovative pedagogical approaches. As case study, we consider the experience developed in the context of a bachelor course being offered at Utrecht University in The Netherlands, during the Covid-19 pandemic. The course takes an experiential learning approach and comprises plenary lectures and working groups. The pandemic offered the possibility to experiment with the creation of innovative hybrid spaces able to account for the learning needs of the students and their well-being in this new context. These spaces have given rise to didactic innovation able to improve the teaching and learning processes, while setting the basis for a more flexible and personalized learning experience in higher education.

## 2 Background

The point of departure of the spatial experiment carried out in the context of our case study, is that of space as a social product. Space plays a crucial role in the creation of a community which is an important aspect of the learning experience. It structures co-presence and interaction patterns of people that create the conditions to give rise to communities (Hillier 1996). As argued by Hillier and Hanson (1984), social relationships are fostered by two mechanisms: spatial solidarity, that is through sharing the same local world and getting together in physical space and by transpatial solidarity through sharing the same interests that can extend across physical space boundaries.

It has been argued that there is an inevitable relation between spatial and social phenomena that influence each other given that human beings live in a spatial dimension in addition to a social and temporal one (Castells 1996; Hillier 1996; Massey 2005; Soja 2010). Therefore, space is essential in giving rise to communities, but at the same time, communities can operate to create space.

An additional element that plays an important role in the creation of space, which has been crucial during the pandemic is media. This is not only the case in urban contexts in which (mobile) media contribute to the creation of public space giving rise to the fusion of the digital and physical dimension (de Souza e Silva, Firth 2010; Farman 2012), but also in the case of learning environments.

Digital spaces favor transpatial solidarity since people can come together based on their interests and goals, as is the case of digital platforms such as Teams, Zoom or even Blackboard. These platforms become a space of encounter where information, knowledge and values are shared, leading to interaction. These digital platforms create meeting places for shared (learning) experiences giving rise to a contact zone (Pratt 1991). This is a space for encounters and thus a space for potentiality, as in the case of unexpected use of media, such as the stratagematic actions discussed in Monachesi and Turco (2017). Stratagematic actions are characterized by an unexpected use of the hybrid spaces created by (mobile and social) media: physical and digital, local, and global. They produce side effects that could be exploited by communities to refine, define, and eventually reach their goals, if they become aware of their potential.

As argued by Cook et al., (2016), connections and interactions occur through a hybrid network of physical and technology mediated encounters that are fundamental in the co-construction of knowledge.

More specifically, the emergency due to the Covid pandemic has paved the way for innovation and experiments as in the case of the hyflex model (Abdelmalak and Parra 2016). In this approach, synchronous online and F2F components are combined in a single course and students can choose when and how they attend. There are similarities with blended learning approaches but hyflex incorporates them into a more flexible framework. The hyflex model implies that campus-based students and online students interact but are physically separated. The approach grants high flexibility to students in the way they attend a course considering their different learning needs and preferences. In this setting, students have equal opportunities to interact with the instructor and classmates according to individual preferences and needs (Miller et al. 2013). Furthermore, this approach takes into consideration the differences in backgrounds, learning styles, motivation, needs, interests and goals in adult education (Knowles et al. 2005) and the fact that acknowledging these differences improves the learning process (Holton et al. 2001).

## 3 Course Description

The case study presented in this paper focusses on a bachelor course being offered at the faculty of Humanities at Utrecht University, in the Netherlands. The course had been offered for several years before the pandemic started and it usually attracts between 70–90 Dutch and international students. The course lasts seven weeks with four contact hours per week.

More specifically, the course is structured in a plenary lecture of one hour attended by all students and 3 hours of working groups of about 20–25 students in which they work at an assignment in small groups of 3 people. The assignments constitute the basis for an analytical and theoretical report submitted after 3 weeks and a project, that comprises an implementation component, which is carried out in the remaining weeks. Results are summarized in a report based on the assignments and it is submitted at the end of the course. The lecturer provides individual feedback during class work, as well as to each assignment's results which are summarized in a short blog. Students get both an individual and a group grade in these reports to ensure that in case collaboration in a subgroup doesn't work properly, students that perform well don't get penalized. However, groups that manage to carry out good collaborative work can opt to get a common grade.

The course takes an experiential learning approach in which students acquire not only theoretical and practical knowledge, but also develop creativity as well as the capacity to carry out collaborative work. Students take an active role in the learning process and the role of the lecturer is mainly that of a facilitator.

## 4 Experiments in Hybrid Space Development

The course analyzed in the case study was attended in presence when the first lockdown occurred in March 2020, since it was in its final weeks, it was decided to complete it online. The three remaining weeks until the end of the course relied on an approach in which use was made of the Blackboard learning management system (LMS) that was used for communication about the tasks to be carried out, written feedback from the lecturer while the plenary lectures were recorded and could be listened at leisure. Questions about the lectures were answered in written format while students continued to work together through their favorite communication software, mainly WhatsApp since Utrecht University didn't have a strategy or an infrastructure in place to carry out online activities.

The course was successfully completed mainly thanks to its experiential learning approach that proved to be very flexible also in the new emergency context since students were already used to carry out tasks independently with the lecturer only acting as facilitator. Furthermore, since the course was close to the end, students were already familiar with the task, the approach, and the requirements which made the online transition easier. The LMS functioned as an important digital collaboration space in which not only instructions were provided but also comfort and support in a very difficult time, with international students trying to get back home and completing the course even in a different continent.

The structure of the course was not affected by the pandemic emergency, except for the disappearance of the plenary lecture, unlike other courses not based on experiential learning in which instruction and testing went through an abrupt change. However, the spatial dimension of the course was affected since it changed from encounters in a physical classroom space to a digital LMS setting. Interactions between the students and the lecturer, were mainly in written form, while those among students continued in their preferred form.

In the second year of the pandemic, that is 2021, the whole digital infrastructure of Utrecht University was in place and relied mainly on Microsoft software, that is Teams and the Blackboard LMS. The course was carried out entirely online, this new space of interaction triggered some changes in the organization of the course format from having working groups and one plenary lecture to working groups only. F2F lectures had become problematic in the last years since it is difficult for students to maintain attention for hours and they were a source of frustration both for students and the lecturer. Therefore, the plenary lectures were entirely replaced by recorded lectures that students could listen offline. Given that the experiential learning approach worked very well in the first emergency period of the pandemic, it was reinforced with a strong focus on communication, interaction, exchange, and community building in the context of the two working groups. Each session was structured into:

- thirty minutes with all group students present featuring a Q&A about the recorded lecture on the papers to be read, as well as discussion on the relation between the theoretical literature and the (practical) assignments;
- one hour work in subgroups of three students to carry out assignments to which individual feedback was provided by the lecturer;
- 15–20 min of final discussion in which students reported their own findings, allowing students to learn from each other. Alternatively, break out rooms were used so that students could get to know other students beyond their own subgroup.

The experiential learning approach was reinforced by the new spatial dimension characterized by the shift from physical classroom space to digital online space. The configuration provided by the Teams platform with the various groups and subgroups reflected nicely the physical space of the classroom and didn't require adjustments in the lecturer's approach. The interaction among students and between students and lecturer was seamlessly transferred from a physical to a digital modality and facilitated by the Teams functionalities.

Teams was only used as online classroom space while the use of the Blackboard LMS remained the same, that is as archiving platform of course content and to send announcements to the whole class and/or to groups and subgroups.

An advantage of this new setting triggered by the online configuration (even though it could have been implemented also in a physical classroom environment) is that discussions could be adapted to the needs of each working group and to their level while this is more difficult in the case of plenary lectures that do not account for the differences among student's level and interests. In addition, theoretical aspects can be better connected to the (practical) assignment. Students always mentioned this as an issue since there was a separation between the plenary theoretical lecture and the more practical working groups. The Q&A discussion at the beginning of the working group allowed for a better connection between theory and practice.

In the third year of the pandemic, that is 2022, with restrictions being relaxed a new experiment was carried out in hybrid space development to consider the changed needs of students and lecturer. More specifically, students could choose to attend classes either online or in presence while the lecturer was teaching online.

The motivation for this choice relied on the fact that while the university decision makers enforced courses in presence under the assumption that students missed physical interaction, the situation attested through surveys in my course was more complex. Most students appreciated the advantages offered by online attendance in a period in which contagion was very high and would mean missing several classes. In addition, the university narrative neglected the diversity of the student population and oversimplified their needs and those of the lecturers. Similarly, it didn't consider the learning approach adopted by the various lecturers.

A more classical learning approach based on plenary class lectures and standard testing had more problems in transferring to an online or hybrid modality both for lecturers and for students, however, this was not necessarily the case for an experiential learning approach. In addition, such an approach is based on collaboration and interaction supporting community forming.

Based on this more complex picture, it was opted for a new experiment with a hybrid learning space based on an interaction of the physical and the digital dimensions, giving rise to a flexible and personalised learning experience. Students could integrate individual learning with collaborative group work in various modalities according to their own needs and learning style. Lecturer could account for her caregiver role and the necessity of giving lecture in a more protected environment.

## 5 Evaluation

The Covid-19 pandemic has triggered changes that have affected both the spatial dimension and the structure of the course under consideration reinforcing its experiential learning approach. Students have been positive about the new set-up developed in the third year of the pandemic, as a qualitative evaluation has revealed.

More specifically, when students submit their (final) report, they are asked to carry out a self-reflection on the skills acquired as well as on the course organization and on the specific hybrid approach adopted in the course. The course was completed by 69 students and 55 of them submitted a reflection, this is 80% of them, which is a very high percentage compared to the formal evaluations enforced by the university with a response rate ranging between 10–15%.

About 14% of the respondents, that is 8 students, declared that they prefer attending classes in presence and among the reasons presented they mention that they are more motivated and thus more productive when they are in a physical classroom, this is also due to a better contact with the lecturer, the possibility to ask questions in real time and thus better discussions. One of the respondents mentioned that she didn't like to have to collect questions to be asked during the Q&A. Students reported that even though they attended the course in presence, they missed the presence of other students since the majority attended the course online.

In fact, 53% of the respondents, that is 28 students mentioned that they prefer to attend the course online, for similar reasons to those that attend it in presence: they feel that they are more productive, and they can concentrate better online. They say that at home they have a quieter environment, and they can focus better since they don't have the background noise created by people working together at the assignments.

These students also acknowledge the possibility to follow their own pace and be able to reflect more on the information acquired. This is especially the case with respect to the recorded lectures since they can listen to them when they want and they can play them over if they miss something or if they get distracted. In addition, they find a big advantage the possibility to listen to the recording if they are ill. This was a situation quite common in the period that the course was offered since there was still quite high Covid contagion. On the contrary, courses being offered in presence didn't offer recorded lectures to the students that could not attend classes, anymore.

Students were very positive about the possibility they had to choose the modality of attendance that better suited their situation and especially the fact that they could decide it on a daily basis. The word 'freedom' occurs quite frequently in these responses. This flexibility and personalization of the learning path was highly valued.

An additional group of respondents emerged from the evaluation, that is those that could see both the positive as well as the negative sides of this form of hybrid teaching: they were 34% (i.e., 19 students). This group also appreciated the possibility to choose the modality of attendance, however, they mentioned that since most people attended online, they were not really motivated to attend in presence. They also reported that even though they would prefer to be in presence, traveling to class was not worth the effort since the lecturer would teach online. All students acknowledge that online attendance requires less traveling, and this fact is experienced as positive since they gain time that they can use for leisure activities or to study more. They also recognize that this form of hybrid teaching allows people to attend class even if they are ill, which is a great advantage. They also mention that the class where they worked at the assignments is quite noisy since people can be loud when they discuss issues. They also acknowledge that they find more stimulating to have the teacher teaching in class and answering questions in real time.

It is interesting to note that when given the choice, very few students attended the course in presence. While at the first meeting, 30% of the students attended in presence, at the second meeting only 10% were in class and the number got lower by each session. During the last two weeks everybody attended the course online. This was especially the case for the Friday session.

## 6 Discussion

The changes in course setting in the third year of the pandemic due to hybrid space development have been appreciated by most students, as the qualitative evaluation previously discussed has revealed.

Most students are positive with respect to the replacement of plenary lectures with recorded ones since they are shorter and they can be listened offline, at own pace. On the other hand, there are few students that miss the real time answers to questions that arise when the lecturer explains theoretical literature in a class setting. They do not like the fact that they must collect them and submit them at Q&A time. As lecturer that has taught this course in presence for years before Covid, I find that the time saved through recorded lectures can be spent in discussing relevant issues and in providing personalized feedback, which is more useful and interactive. Furthermore, students had serious difficulties in listening to a lecturer for more than one hour since students' attention span has considerably lowered during the years. In fact, plenary sessions provided in presence were characterized by a decrease in attendance towards the end of the course, while attendance level remained constant in the new setting in which students had a choice.

Similarly for the hybrid learning space created. All students appreciated the possibility to choose the mode of attendance. However, it is not the case that all students prefer to attend classes in presence, as the university narrative promoted by decision makers tend to stress and new guidelines have now enforced. Students are different, in the setting investigated, the majority appreciates online classes because they focus better within a home environment than in class. They can concentrate better, and they are thus more productive, this is the case especially for hyperactive students. On the other hand, there is a small percentage of students that do prefer to attend physical classes because they feel more motivated by the presence of other students, by the teacher and because some of them cannot properly focus behind a screen.

All students though appreciate the possibility of choice that was granted in the course and they suggest that it should be retained in the future. Therefore, the university decision makers should be more open to hyflex learning environments.

However, even students that do not favor online class attendance, acknowledge that the noise created by people discussing the assignments in small groups is quite disturbing and makes it difficult to focus. As lecturer, providing feedback to the different small groups of students carrying out the assignments in the computer room is very tiring, due to the noisy environment one is exposed for several hours. More generally, lecturing online doesn't require a high tone of voice, often needed to teach to big groups. An interesting side effect of online teaching is that as lecturer one gets access to a very intimate environment, often it is the students' own bedroom that is visible. This is especially the case when personal feedback on the assignments is provided, it becomes easier to establish a connection with the students and assess his/her well-being because of the inclusion offered by the screen.

A small group of students mentioned that it was not enough to have fellow students in class, they missed the physical presence of the lecturer. This outcome was unexpected in a course that heavily relies on group work and collaborative projects. One would imagine that physical presence of group members is more essential than physical presence of the lecturer that has only a facilitator role.

It is for this reason that a new spatial configuration has been explored this year in which students can choose to attend the course online or in presence while the lecturer is in presence but teaching through Teams.

It should be mentioned that in the spatial experimental settings described in this paper, the hybrid learning option supported by Utrecht University has not been adopted. The setting suggested by the university envisaged hybrid classrooms in which online interaction through a digital platform coexists with physical class interaction. However, hybrid classrooms tend to exclude online students with priority given to those in the physical setting, making community creation difficult. Despite technological progress, sounds quality is still low in hybrid classrooms and students attending online are cut off. It is for this reason, that the hybrid spaces, developed in this case study, have always relied on the digital platform as spatial configuration for communication, interaction and community creation.

The new special configuration proposed this year allows for an interesting learning environment since the online teaching remains dominant, but it is embedded in the physical classroom space. As previously discussed, Hillier (1996) claims that physical space is crucial because it structures co-presence and interaction patterns of people that ultimately will give rise to communities. Therefore, even if interaction is mediated by the digital platform to provide both online and in presence students equal participatory conditions, physical co-presence of both students and teacher in a physical class environment should be beneficial to those students that attend in presence because they need the motivation provided by a learning community. In other words, the effect should be similar to that one gets when studies in a library.

The hybrid space in which students and lecturer come together physically but teaching occurs online might include both spatial and transpatial solidarity (Hillier and Hanson 1984) and thus foster the creation of a strong learning community in which individual needs are considered and valued. While spatial solidarity triggers social relationships and coming together in physical space, transpatial solidarity fosters social relationships beyond the physical space. The latter might not be sufficient for those that are less motivated by strong interests in the topic and in the learning goals, making thus necessary to establish social relationship in the physical space (i.e. spatial solidarity). However, online teaching through the Teams platform will bring together these two communities mediated by the physical and online presence of the lecturer.

The course is not finished and evaluation results are not available for this new setting, however, students prefer to attend the class online, really few people attend it in class, about 10–15%. In general, students that have personal issues that want to discuss or that need special attention attend classes in presence, as well as students that prefer working at assignments together in a physical environment. This was especially the case for the session before submitting the final report in which students and lecturer discuss the organization of the paper. It was suggested by some students that it might be a good idea to make the first class meeting with compulsory physical presence in order to get to know fellow students.

## 7 Conclusions

Hybrid spaces offer flexibility to both students and lecturers as well as a personalized learning environment that takes individual needs into account. The case study considered reveals that students appreciate the flexibility offered by the hybrid space that facilitates students' participation and interaction at the basis of the experiential learning approach.

Academic institutions support a narrative that enforces the return of students to compulsory physical class attendance and they tend to neglect that both students and lecturer have experienced and experimented different teaching and learning approaches in the past years. The case study presented shows a complexity in students' needs and learning approaches that cannot be neglected. It should be considered by supporting an hyflex model that gives students a choice in learning path and especially in attendance mode, compatible with their busy schedule now that the pandemic emergency is over.

The fact that most students prefer to attend classes online might have an impact on sustainability and the environment. However, as claimed in Batmunkh (2022), we underestimate the environmental impact of our daily internet usage mainly due to the data centers and the servers necessary to support it. Online activity comes with a cost since it triggers carbon footprint emission, even simple emails have an impact, thus also online education. Even though the best way to calculate carbon footprint is still a topic of debate, it would be relevant to calculate in more detail the emission of online teaching compared to students traveling to attend physical classes, especially in a small country like the Netherlands with a good transportation system that stimulates commuting. It would be interesting to assess whether online education has a beneficial effect on the environment or in fact contributes even more to increase the carbon footprint.

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# The Effectiveness of Gamification to Enhance Writing Skills in English as a Foreign Language Contexts

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**Abstract.** Writing is a skill that can be challenging for EFL (English as a Foreign Language) learners to master; as a result, it requires a lot of instruction and practice with written assignments in order to become a satisfying activity for English language learners. In order to obtain the desired learning outcomes, it is vital to develop ways to make this practice more pleasant and beneficial. One such choice is to gamify activities for learners. The purpose of this study was to examine how gamification influences the growth of writing abilities. This study used a pre-experimental design and a quantitative methodology. Thirty-three Ecuadorian students took part in this study as participants. Additionally, eight sessions were used to gather the data during three stages: pre-test, interventions, and post-test. The Pre-test and Post-test were taken from the Cambridge A2 Flyers exam, and the written performance of the students was graded using a rubric. The researcher mostly used worksheets and writing exercises using a variety of tools during the intervention. The researcher also included gamified elements including extra points, badges, time limits, leaderboards, tasks, and incentives. Main findings revealed that employing gamified exercises, students' English writing skills enhanced in areas of organization, mechanics, syntax, grammar, content, and writing process.

**Keywords:** Gamification · Writing Skill · EFL contexts

## 1 Introduction

English has become a key for professional and academic success. This makes it crucial to master it. Unfortunately, Ecuador is located in one of the lowest levels of English communicative competence development in South America, according to the English Proficiency Index [1]. The employment of conventional teaching methods may be a major factor in this.

On the other hand, when learning a foreign language, learners need to develop their productive and receptive skills, however, they struggle with productive skills, especially writing [2], which is a challenging skill to teach [3]. Accordingly, researchers have

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devoted a lot of thought to how to make the learning process engaging and motivating for learners. As a result, researchers have shed light on this problem by examining several efficient ways that have aided practitioners. Gamification, which involves using game design elements in non-game contexts [4], has thus emerged as a cutting-edge and trending topic to boost learners' engagement at any age. Previous research suggest gamification is a successful strategy since it enhances learning, depending on the context in which it is being implemented and the qualities of the users [5].

Consequently, this study aimed to examine how gamification influences the growth of writing abilities. To find out the effectiveness of gamification, the researchers carried out a series of interventions where the strategy was applied. The researcher question that guided this study was:

1. What are the effects of gamification on the development of writing skills?

## 2 Literature Review

Gamification is a learning strategy that incorporates game dynamics into educational and professional settings with the goals of boosting knowledge retention, developing one or more abilities, or rewarding particular behaviors [6]. Gamification is the use of game review strategy to provide an expressive and meaningful experience for scholars [7]. It traces the progress of participants by displaying game information in each activity. It breaks the most crucial goals into achievable grades and seeks to motivate users to perform better on each applied activity. Given that it results in an increase in learners' attention and motivation, it is advantageous [8]. In addition, gamification is an innovative approach that has grown in significance in education since it aids in the development of students' diverse skills and enables them to achieve a better degree of knowledge through the fusion of gaming [9], and learning. This strategy has been applied in several educational institutions to raise student engagement and performance, helping them to meet their academic goals [10]. Therefore, this enables students to foster soft skills including problem-solving and social relationships [11].

Gamification offers benefits including the development of greater commitment, improvement encouragement and management of learners' motivation [12]. Characteristics of this strategy highlight the progress bars that indicate the score results to the students throughout the class, gifts or badges to award students' recognition of accomplishments and time limit with which learners feel the need to concentrate to successfully complete the activity [13].

Furthermore, it has been demonstrated that gamification is associated with improvement in academic writing skills [14], and the growth of writing in a different and funny way, establishing a path which encourages learners to keep going [15, 16].

## 3 Methodology

### 3.1 Participants

The population involved in this research study were thirty three 7th grade Ecuadorian students (14 male and 19 female) ranged from 11 to 12 years old.

### 3.2 Research Design

The methodology applied in this research was quantitative with a pre-experimental design. Additionally, eight sessions were carried out to gather the data in three stages: pre-test, interventions, and post-test. Each session lasted 40 min. The Pre-test and Post-test (Part 7) were taken from the Cambridge A2 Flyers exam, and the written performance of the students was evaluated using an A2 rubric, which measured: content, organization and language. Scores were transformed to 10 points by using the rule of 3. All the data were computed through SPSS statistical program. A Wilcoxon signed- rank test was used to verify the hypothesis and interpret the findings of the pre-test and post-test averages with a 5% ($\alpha = 0.05$) level of error of significance.

### 3.3 Data Collection Strategies

The interpretation of the pre- test scores and post-test scores allowed to verify the hypothesis through the treatment application. The first day the learners took the pre test, then eight interventions were carried out in which students were given worksheets and writing tasks with a range of tools. The interventions mainly regarded the presentation of writing strategies, followed by practical activities which were designed using gamified components including extra points, badges, time limits, leaderboards, tasks, and incentives. A variety of platforms such as Nearpod, Wordwall and Padlet were used in the interventions. In every session students developed a piece of writing as a final activity. All of those were carried out using gamified components. Finally, the posttest was applied, data was tabulated and interpreted.

## 4 Results and Discussion

### 4.1 Pretest- Posttest Contrastive Results Analysis

After the application of the pretest and posttest, the data from the two tests were compared.

**Table 1.** Comparative Results Pretest and Posttest.

| Criteria | Pre-Test Results | Post-Test Result | Difference | Expected Average |
|---|---|---|---|---|
| Content and Communication | 1,50 | 2,30 | 0,8 | 3,33 |
| Organization | 1,10 | 2,10 | 1 | 3,33 |
| Language | 1,48 | 1,80 | 0,32 | 3,33 |
| Test Scores | 4,08 | 6,2 | 2,12 | 10 |

**Table 2.** Shapiro-Wilk normality test.

| | Kolmogorov-Smirnov[a] | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Stadístic | Gl | Sig. | Stadístic | gl | Sig. |
| Pre-Test | ,155 | 33 | ,042 | ,915 | 33 | ,014 |
| Post-Test | ,233 | 33 | ,000 | ,879 | 33 | ,002 |

a. Lilliefors Significance Correction

Table 1 shows the writing results of pretest and posttest on the use of gamification. Learners' writing development over 3,33 raised from 1,50 to 2,30 (0,80 point difference) in Content and Communication. Regarding Organization, they had a rise from 1,10 to 2,10 (1 point difference), and in Language knowledge they increased from 1,48 to 1,80 points (0,32 difference). As it can be evidenced, the use of gamification in EFL learning is benefitial for developing writing skills.

The Shapiro Wilk statistical test was used. It can be observed that the significance level of the pretest is 0.014, while in the Posttest it is 0.002. Thus, it was required to apply the Wilcoxon non-parametric test to verify the hypothesis.

In Table 3, it is shown the Wilcoxon test results, which indicate 1[a] negative ranks, 31[b] positive ranks, 1[c] ties, getting as total 33. Furthermore, 2.00 and 16. 97 were the mean ranks, and the sum ranks 2.00 and 526,00.

**Table 3.** Wilcoxon Signed Ranks Test.

| | | N | Mean Rank | Sum of Ranks |
|---|---|---|---|---|
| Post-Test - Pre-Test | Negative Ranks | 1[a] | 2,00 | 2,00 |
| | Positive Ranks | 31[b] | 16,97 | 526,00 |
| | Ties | 1[c] | | |
| | Total | 33 | | |

*Note.* [a.] Post test < Pre- test. [b] Post- test > Pre- test. [c] Post- test = Pre- test

The asymptotic significance of the pre and posttest total is shown in Table 4. The hypothesis is rejected if sig $< 0.05$, but it is accepted if sig $> 0.05$, hence, the results obtained $0.000 < 0.05$ (range of reliability) accept the alternative hypothesis and reject the null hypothesis, concluding that gamification affects learners' writing development positively.

In this research work, it has been demonstrated that gamification has had a positive effect on English as a foreign language learning. It was possible for learners to develop

**Table 4.** Test Statistics[a]

| | Post- test Total - Pre- test Total |
|---|---|
| Z | $-4{,}914^{b}$ |
| Asymp. Sig. (2-tailed) | ,000 |
| *Note.* [a] Wilcoxon Signed Ranks Test. [b] Based on negative ranks | |

their writing skills, for instance, when organizing their ideas; implementing vocabulary, linking words, and conjunctions. Students learned English more effectively and in a different and funny way. These findings match previous studies where gamification has been demonstrated to be motivating [17–20].

## 5 Conclusions

The use of gamification had a positive influence on the development of the writing skill since in each intervention the students developed different pieces of writing with the use of different gamified activities in English. There was a significant improvement on learners. Gamified activities helped hold the attention and motivation of learners with the use of rewards, extra points, prizes and gadgets, allowing learners enhance their writing skill. Main findings revealed that employing gamified activities, students' English writing skills increased in areas of organization, mechanics, syntax, grammar, content, and writing process.

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# Real-World Experiences

# Surface Monitoring at Dams Using Drones and AI-Based Analysis for Advanced Anomaly Assessment

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**Abstract.** The growing request of renewable energies, in particular hydro power plants, in the last century led to a large number of built dams, which are used to store water in order to generate renewable energy. Due to their age of about 50 to 100 years many dams demand an extensive monitoring of the structures to ensure a safe operation as well as to identify potential problems as early as possible in order to minimize maintenance costs. Therefore, new strategies need to be explored to bring the surface analysis and documentation of large concrete dams to a "next level". One approach that has emerged is to use drones for visual inspection by capturing high-resolution images of the dam and using artificial intelligence to analyse the huge amount of data. The aim of the master thesis is to examine and develop a suitable method in particular a process that supports dam operators by a drone-based surface documentation and inspection with a suitable evaluating algorithm reducing the manual effort. High quality images of the recorded dams are necessary to identify abnormalities such as cracks, sintering, corrosion, bursting on the dam by automated image analysis using artificial intelligence. To provide a further processable 3D visualization of the dam as well as an overlay with the findings, a 3D model of the dam is generated by a photogrammetric image analysis.

**Keywords:** Surface Monitoring · Dam safety · Unmanned aerial vehicle · Artificial intelligence · Photogrammetry

## 1 Introduction

With the development of power plants in recent centuries, a large number of dams [1] have been built, which are used to impound water and thus optimize and increase the efficiency of hydropower plants, bringing economic, environmental and social benefits. Nevertheless, they represent a potential of threat to people living in areas below these constructions. The risk of a failure increases with age, as dams are exposed to various impacts such as gravity, water pressure, and changing weather conditions [2]. For this reason, the structures are intensively and continuously monitored and also visually inspected regularly to identify potential hazards early enough being able to take actions.

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Digitization may contribute to improve the current monitoring of structures, as it can be performed more transparently and accurately [3]. New technologies offer opportunities to improve the surface monitoring of dams using new surveying technologies. One approach that has emerged is to use drones for visual inspection by capturing high-resolution images of the dam and using artificial intelligence (AI) for further analysis.

The current method for visualization and anomaly assessment of dams involves visual inspection of the structure to document abnormalities in order to initiate corrective measures at an early stage [4]. The primary goal is to identify changes of the dam surfaces and the surrounding areas. The focus here is to inspect recognizable deficiencies in the concrete surface such as cracking, bursting, sintering and erosion [2].

The currently adequate method for assessing the surface includes inspection by means of drawings and photos taken by high quality cameras from different locations at the dam [2]. In this process, the entire dam is recorded by overview photographs, divided into blocks for orientation. Particularly important or conspicuous areas are photographed again in more detail [5]. Figure 1 shows an example of such a surface documentation of the dam Margaritze, which is located in Carinthia, Austria. The orange squares visualize the concreting sections, and the red area highlights one part of the dam that requires special attention.

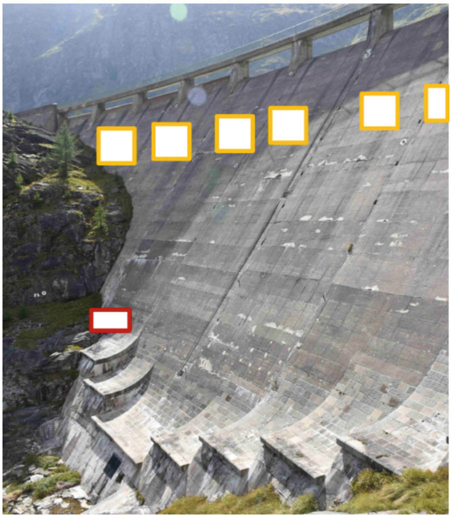

**Fig. 1.** Example of the surface documentation of the Margaritze dam [6]

Depending on the dimension of the construction, such a documentation consists of 10 to 200 photos. These have to be evaluated manually afterwards. The detected abnormalities on the concrete surface are usually drawn in a 2D computer aided design (CAD) plan of the entire dam that is only approximately geo-referenced (see Fig. 2).

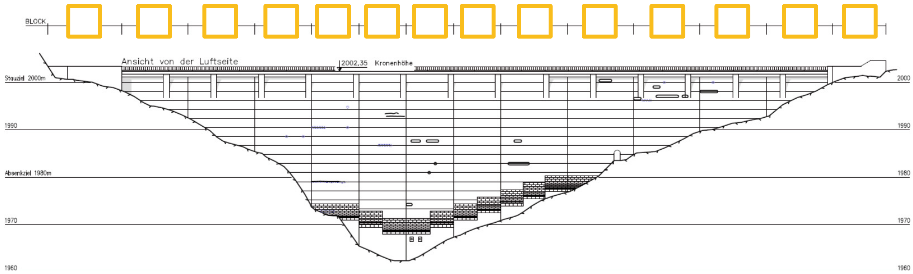


**Fig. 2.** 2D plan of the dam air side of Margaritze with marked anomalies [6]

Each documented finding is described and commented in detail in the plan and assigned to categories. Due to the limited image quality when considering details in an overview photo, minor changes over time are hardly recognizable. Statements on the exact dimension of a potential visual change in the cm or mm range are not possible and therefore a significant limiting factor of a performed surface analysis.

## 2 Problem Statement and Research Overview

A more detailed method to document the dam surfaces is gaining in importance as several dams have reached an age of 50 years and some even 100 years [7]. This highlights the necessity to regularly monitor the condition and behaviour of the dam in order to be able to react to anomalies at an early stage and to take appropriate measures [2] to increase the lifespan and reduce potential danger [4].This means that a detailed and qualitative [3] assessment and documentation must proceed in order to keep the probability of failure as low as possible and to be able to guarantee human safety and the functionality of the dam [2, 7]. However, the current method only partially offers these possibilities, which means that further research is required in this field.

The aim is to create a suitable method or process that supports dam operators in the inspection by using drones and a suitable evaluating algorithm for the detection of anomalies on the concrete surface. It is important that the images taken with the drones record the anomalies such as cracks, sintering, corrosion and bursting in detail and provide a basis for the detection with artificial intelligence. In order to obtain a visual representation, photogrammetry can generate a 3D model on the basis of the photos. These topics are elaborated in detail in relation to the following research questions.

Research question 1: How can the conventional method of assessing dam surfaces be improved by using unmanned aerial vehicles for image acquisition and artificial intelligence for image analysis?

Research question 2: What level of automation can be achieved in the recording and analysis of the dam surface?

Research question 3: Is an approximation of over 90% possible for the detection rate of abnormalities using AI-based image analysis?

## 3 Methodology

The research questions are to be answered by analysing the data empirically. Based on practical investigations at a selected dam, the necessary processes and data will be collected and analysed. The dam Margaritze operated by Verbund Hydro Power GmbH in Austria was chosen for a case study in order to be able to collect this data in detail. The dimension, a simple geometry of the dam and a few obstructions in the surrounding area were the main reasons for choosing this dam as test area. The M300 RTK drone combined with the Zenmuse P1 camera, from the manufacturer DJI, were used.

One main goal of the field investigation was the evaluation of a fully automated acquisition of images to document the surface condition of dams by drone flights. In particular due to the promising conditions on site and furthermore to assess the quality of the recorded images, if they deliver improved quality of the surface inspection in the expected level. To find this information, images were recorded by drone at the Margaritze dam, and the resolution was analysed. In addition to the photographs of the dam, an important aspect of the aerial survey is to identify the possible level of automation and the extent of the potential of fully automated aerial surveys in this area.

To get a more precise overview of the level of detail, a 3D model (see Fig. 3) was created of the images using photogrammetry in the Agisoft Metashape software. Photogrammetry enables the creation of 3D reproductions by overlapping images from different angles and perspectives by constructing a 3D model from a 2D representation using hints in the photos [8]. In order to be able to assign a dam to a location in the 3D model, it needs to be geo-referenced, which means that individual coordinates are allocated to the dam. This is accomplished in the surveying area by measuring control points that are placed on the dam wall and the crown. These are fixed points on the dam, which were recorded using a total station and then assigned to the images in the model.

Subsequently, the recorded images are fed into an artificial intelligence that analyses the image data for abnormalities. In order to achieve the highest possible recognition rate, the AI will be trained in advance and during the field test using predefined objective irregularities.

## 4 Results of the Researched Method

### 4.1 Drone-Supported Recordings at Margaritze Barrier

The field study at dam Magaritze has shown that it is possible to collect high-quality images using a drone. But it requires a quite high amount of time at the beginning for unexperienced pilots to configure all relevant parameters like camera parameters, distance settings of the drone and gimbal orientation for a successful survey. As many of these parameters have to be changed during the flight, the pilot has to be highly concentrated all the time to achieve high quality images but also to prevent collisions with obstacles in the surrounding environment. For this reason, even experienced pilots need a couple of days to capture larger dams.

It also has shown, that only minor areas of the dam could be captured by an automated flight of the drone. Most of the time, the pilot had to take over manual control of the drone. The reasons of this are the surrounding area next to the structure and/or the dam itself, which reduce the number of Global Navigation Satellite System (GNSS) satellites. So, the signal cannot reach the unmanned aerial vehicle (UAV), which results in unknown coordinates. The GNSS is a system in which position and navigation are determined by receiving signals from navigation satellites [9]. Nevertheless, it is possible to automatically map the crown of the dam using the drone's controller, as there is an available signal here. This results in a partially automated flight of the dam.

Due to the manual flight, the distance to the dam could not be kept correctly all the time and was slightly varying in a range of 10 m $\pm$ 2 m. The installed camera offers an image resolution of 8192 $\times$ 5460 pixels per picture resulting in a ground sampling distance (GSD) of approximately 1.25 mm per pixel using the 35 mm objective. In total 3,837 images were recorded covering the complete air side, crown and partly the water side of dam Margaritze using an overlap rate of about 70% (horizontal and vertical) that is necessary for a highly accurate 3D model.

### 4.2 Generation of a Georeferenced 3D Model

The captured images produce a high amount of data which is processed in the next step to create a 3D model of the dam. To transform the high amount of images a sophisticated hardware and an enormous amount of storage space is required. Due to the small size of the Margaritze dam, measuring 39 m in height, the processing of a complete 3D model with an average ground sampling distance (GSD) of 1.5 mm/pixel was possible within one week. This means that one pixel on the photo represents 1.5 mm on the dam. This low ground resolution results in a high level of detail and is only possible because of the short recording distance between the drone and the dam.

The photogrammetric approach produces a point cloud of 1,845,881 mesh points generated from the photos, which means that Agisoft Metashape extracts individual points from the images to create a complete model. The point cloud allows to calculate the geometry between the points [10] and connects them with several triangles. Therefore, a 3D-Modell can be generated which consists out of 5,225,450 high quality surface areas. These parameters and the developed model are displayed in Agisoft Metashape after finalisation and is approximately illustrated in Fig. 3. The orange points represent the attached and measured control points that were included in the model, which enables the georeferencing of the dam.

The generation of the 3D model is an important part of the entire method, as it can be used to visualize anomalies. It enables a total impression of the abnormalities on the dam, which allows the assessment to be performed with a higher level of detail, in contrast to the images recorded only by high quality cameras.

### 4.3 Utilization of the Image Recordings for Surface Analysis Using Artificial Intelligence

Beside using the images to create 3D models, they can be loaded in a predefined algorithm. In this case, predefined algorithm means training and adapting an existing detection algorithm that was developed for the detection of abnormalities on bridges. Due to the coarser structures of the dam surfaces, it has been shown that training through structure images is required to provide acceptable results.

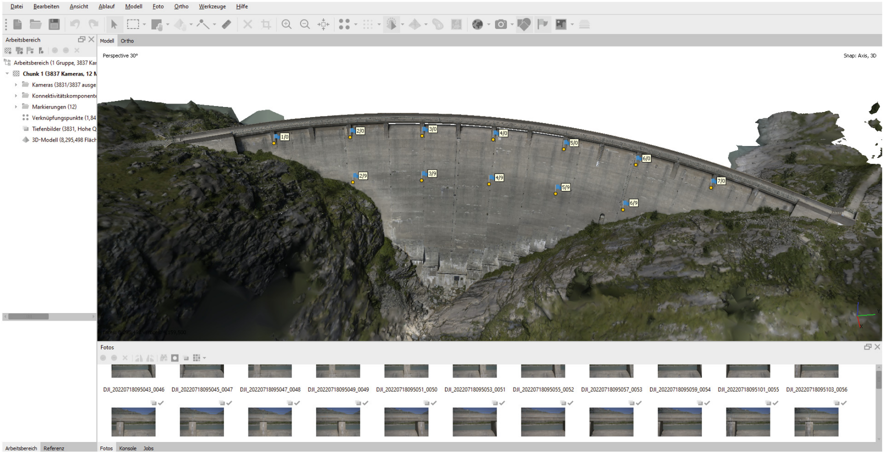


**Fig. 3.** 3D model of the airside of the dam Margaritz

The training was conducted with 113 images. The trained algorithm was evaluated with a predefined dataset. It was found that the accuracy and detail of crack detection has greatly increased. An example of the detected anomalies is shown in Fig. 5. A number of cracks (traced in red) and sintering (blue areas) are recognised in the original image of the dam surface marked by the AI automatically.

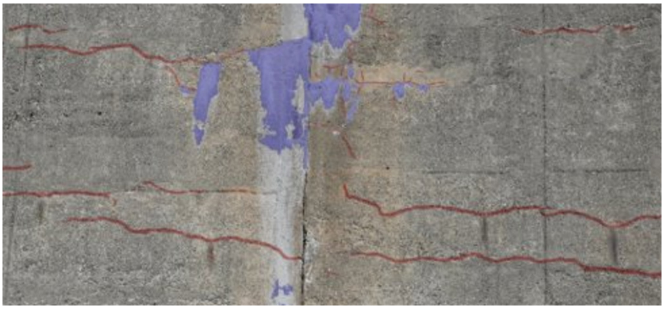

**Fig. 4.** Example of an image with detected cracks and sintering [5]

As a result, there is an improvement in the detection of anomalies which resulted in a significant increase in the accuracy rate. In addition, there is a considerable improvement in the detection of cracks and a reduction in false detections of concrete sections and other errors. This results in an increase in the accuracy rate of about 60% compared to the untrained algorithm. Also, the anomaly sinter showed a significant improvement. In contrast to the untrained algorithm, there was an increase of 76% in the detection rate. This shows that 91% of the anomalies are detected by the algorithm. Table 1 demonstrates the impact of training on the algorithm and reveals an increase in accuracy rate.

**Table 1.** Results of the anomaly detection algorithm (adapted and non-adapted)

| Anomaly | Accuracy before the training [%] | Accuracy after the training [%] |
|---|---|---|
| Cracks | 33 | 92 |
| Sintering | 11 | 87 |
| Spalling | 65 | 67 |
| Total | | **91** |

## 5 Conclusion and Outlook

Overall, this process proves to be a beneficial method, as compared to the current practices, because of the high-quality improvement of the documentation of the dam surface. The 3D models can propose a more accurate documentation of the current state and abnormalities can be examined in more detail by experts. The new method offers the possibility to support visual inspection and damage assessment.

Furthermore, the analysis by artificial intelligence could offer significant advantages in the recording of anomalies, as these are more clearly traced in the images and therefore a higher number of abnormalities are detected. Training the algorithm has resulted a huge improvement in detection, leading to an accuracy rate of 91%.

Nevertheless, this innovative method has also disadvantages that should not be disregarded. The processing of the data sets requires increased effort and computing time, and suitable hardware and software is necessary. In addition, the largely manually controlled drone flight results in an increased workload for the drone pilot.

However, further development concerning hardware, software and also automated drone flying is foreseeable. A different technique for overcoming the GNSS problem, will be further investigated. There are already companies working on the issue of the unavailability of the GNSS signal.

A feasible approach in this case would be to utilize a total station, which tracks the drone via a prism and therefore constantly sends the position of the UAV to the controller, which in return continuously communicates with the drone. This setup is generally illustrated in Fig. 5. In the future, this could lead to the possibility of completely automated flights over dams, which in turn could reduce or simplify the time and effort required for flights.

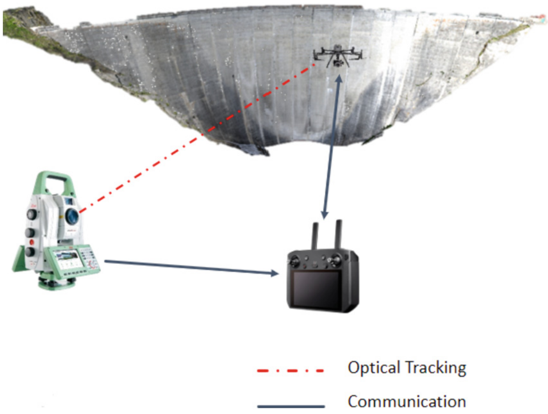


**Fig. 5.** Possible approach to bridge missing GNSS coverage

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# Investigation of Digital Product Services for B2B Products

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**Abstract.** For companies, it became quite common to offer their customers the whole package of product-service systems instead of just a product by itself. Those systems consist of the product and some additional kind of digital feature or service that supports the product throughout its lifecycle. This paper aims to investigate digital product services for the case of a B2B company. After determining what lies behind such terms as servitization or product-service system, the possibilities that can arise from those services, both for the company and for their customer, are shown. To investigate those possibilities, a benchmark study was conducted, determining the services of companies that are within the branch, cross-industrial, and also in the B2C field. Later on, holding workshops with company employees resulted in personas and user stories to ensure a good fit of the selected services to the specific company. Overall, this paper's goal is to present a definition for the relevant terms, possibilities of such services, and a research structure to help companies achieve such outcomes.

**Keywords:** B2B Platforms · Digital Product Services

## 1 Introduction

In today's industry, the role of physical products has changed from what it used to be and just offering good products and regular after-sales services is no longer sufficient [1, 2]. Also, digitalization is acting as a key enabler for servitization [3]. Being part of a product service system (PPS), digital product services can be considered an additional part of a physical product, which is supporting this product throughout its lifecycle [1]. As information and communication technologies (ICT) have evolved so quickly over the last few years, the connection between physical and digital products can appear to be almost seamless [4].

But starting with additional services is not something companies should do rashly. It will require changes in the organizational structure and possibly even in the business model [3]. In addition to this, resources might have to be allocated or increased as there will be a higher need for staff, facilities, finances, and more. Those efforts and the high risk of a negative financial return at the beginning of such a process, therefore have led to some companies abandoning their new services after just a couple of years [5, 2].

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To ensure that it is worth the effort, a perfect fit of those services for the company and its customers is to be ensured. For this, well-thought-through planning of such services is crucial. In the case of this paper, the services that are then put together should be fitting for an Austrian B2B company.

This paper aims to take a closer look at the different kinds of digital product services and service systems that a company could potentially choose from and how those can be categorized. This shall help create an understanding of the possibilities and the differing scope of needed resources. Taking a look at possible opportunities and risks may also help with reasonable decision-making.

Another step that is taken to ensure a well-fitting service package is the execution of workshops with employees of the concerned company. The creation of personas and user stories shall give a clear view of existing but also of potential future touchpoints of the company and the customer. Knowing the issues and needs of the customer as well as knowing the touchpoints enables a better understanding of where those services can benefit the customer the most.

## 2 Digital Product Service

Digitalization is an ongoing process that hardly any company can escape from. Just offering their physical products might no longer be enough to generate the right competitive advantage [6]. For companies offering physical products, this can result in the switch to a product-service system, enabled by digitalization. Maybe it even leads to changes in business model, but it can certainly result in increased customer satisfaction [3].

### 2.1 Servitization

Servitization can certainly be seen as a strategic alternative to product innovation, making the products a better fit for the customer's needs [5]. So instead of just offering their customer a product or a service, companies will offer the product and service in combination. Those services can include offering support, knowledge, and the option of self-service [7]. But it can also mean a process, where companies transform their business into the direction of providing services to their customers [8].

*Coreynen et al.* [5] provide a way of categorizing different characteristics and possibilities of servitization (see Fig. 1). This can also be useful for companies when starting off with such services.

For this approach, servitization is divided into services that are focused on products and those that are focused on the customer's process. It also differentiates between different levels of value propositions, where customer involvement is higher, as shown in the bottom level of the pyramid, and relatively low at the top. Those value proposition levels are differentiated by offering more basic services in terms of input, more advanced services like some kind of performance, and complex services that provide full-on results [5]. And while those services may immensely differ in the resulting effort and complexity for the provider, they all fall under the heading term of servitization.

Now, some samples of categories of the servitization pyramid will be given. The bottom tiers are input-based: the supplier gives the promise of performing a deed. For the bottom left category, the product life cycle services, such a service helps ensure the proper functioning of a machine during its life cycle. This can be done by providing services such as inspections of the machine. For the bottom right tier, the process support services, the customer is supported in his doing. Here a service in terms of consulting for certain processes could be done [9].

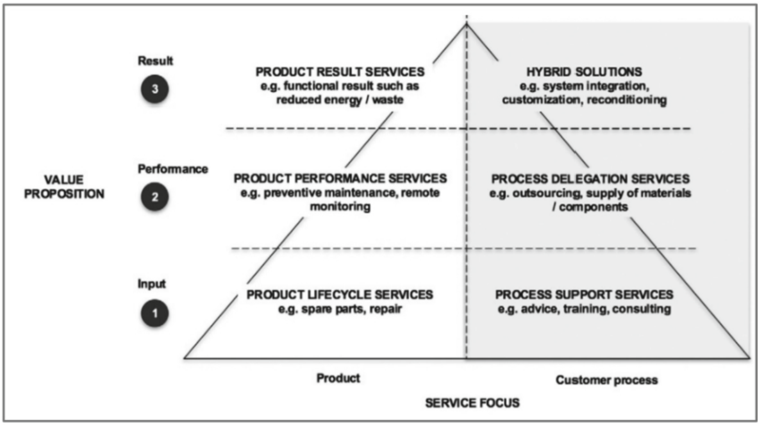


**Fig. 1.** Servitization pyramid – an approach for defining servitization devised by Coreynen et. al. [5]

## 2.2 Product-Service System

Closely related to servitization are the product-service systems (PSS), describing things such as different ways of offering products but also different ways of adding a digitalized layer to the product. But again, a tangible product is combined with the intangible layer of service [4, 10].

One way of looking at product-service systems would be by differentiating them into different categories. Here, the services are divided into systems that have their value mainly in the product content or mainly in the service content. The higher the service value in the product content, the more product-oriented the service will be. The higher the service value in the service content, the more result-oriented the service will be. If a product has value both in product and service content, it is use-oriented. For product-oriented services, in addition to selling a product, a company will deliver services that are related to the product itself. Those could include maintenance contracts or advice on the best way of using a product. With the use-oriented services, a customer does not purchase a product, instead, the product is rented or leased. Offering result-oriented services means that instead of offering a specific product or service, the company agrees on providing a certain result [10, 11].

Taking a look at digitalized versions of those services, one can differentiate between internet-based, IoT-enabled, and smart PSS. The internet-based PSS is the oldest version and mostly just makes use of internet-enabled services. IoT-enabled PSS followed the internet-based services and added an industrialized layer. By making use of technologies like RFID, with this service the products get more connected with each other. The newest version here is the smart PSS, allowing services in the fields of smart connectivity, analytics, and more [4].

### 2.3 Chances and Risks When Implementing Digital Product Services

Now that the definitions and varieties of digital product services are clear, there is still the question of why companies would want to use such services and what the underlying risks and difficulties are. To start off with the positive, in a time where offering a product by itself runs a high risk of not cutting the mark, adding fitting product services can help reach a new level of differentiation. This can higher the competitive advantage and help the financial performance [6]. Also, it can help build loyal customer relationships and can help meet a customer's needs better [5].

But, implementing such services also comes with risks. Especially if not well executed, there is a high risk of a negative financial impact. For smaller companies, there is the added difficulty of coming up with the needed resources. In order to be able to provide such services there may be more competencies, human resources, or finances needed than some companies can provide [2, 5]. In addition to this, there are also barriers from the customers' side. There can be difficulties with their willingness to share certain information with somebody outside of the company or their lack of willingness to switch to a payment system that affords more than a one-time payment in the purchasing process [5, 8].

### 2.4 Examples of Digital Product Service Systems

As the previous chapters have shown, offering the customer added services to their products can be carried out in quite different ways. But there are some kinds of services that appear noticeably more often in the B2B environment. Those services often contain different kinds of maintenance contracts or other support in those terms. By using technologies like RFID tags, companies can offer their customers a quite convenient way of doing repairs and services at their machines. After scanning the tag, different solutions to the potential problem may be provided directly on the screen of the user's scanning device. Here, for example, the user can be provided with video tutorials on how to fix the issue. In case that spare parts are needed, a customer may be able to order the right part directly on their phone. This can be especially helpful, if there are multiple parts that look alike, as scanning the tag of the product prevents mix-ups and potential human error. If the user on-site is not able to solve the problem, it can be possible to contact a service technician the same way the user retrieved the previous information. And as the only tool needed to scan an RFID tag is the user's phone, this is very convenient for the end user. For those service performances, the company can offer its customers different kinds of contracts. Depending on the contract type, different service offerings are provided to the customer. For example, by paying a monthly fee, the customer has unlimited access to video tutorials to fix the issues without having to wait for help from the company. If they do not pay the fee, they may have to pay a certain amount every time they want to access those videos.

The full scope of possibilities that are available to companies is currently under heavy investigation. The results will be published in the course of the next paper.

## 3 Making the Service Fit for the Company

To make the services a good fit for the company, one should be fully aware of the user. With this, a better understanding of how the services can benefit the customer can be developed. For the Austrian B2B company this is done by conducting a workshop with employees of the company. In this workshop, personas and individual user stories for those personas are created. As further explained later in this chapter, this shall help get a better feeling for the actual user of the end product, in this case, the user of the digital product service.

### 3.1 Personas

While first proposed by *Alan Cooper* in 1999, personas represent the targeted user, put together through the usage of collected data [12]. Using the existing knowledge, the target group is described in detail in the form of one or more fictional persons. It acts as the archetype of the end user. A persona can show different aspects of the person's lifestyle and may include both their private and professional goals [13, 14]. It also shows the motivations, frustrations, goals, and other fictional details of this imaginary person. Basically, they represent the requirements for the product or system to be developed. Personas have become an important aid to keep a user at the center of almost any development process and help to keep the developed solution user-friendly [12, 15]. As shown in Fig. 2, usually those personas also get a name and a picture. Then a fictional biography is created for them. It may also be helpful to come up with a phrase or quote that is a good fit for this person [12].

In the case of the Austrian B2B company, this user persona may be a technician of the customer's company, working in the field, being directly responsible for installing the devices and checking on them.

### 3.2 User Story

Now, user stories will be examined further. Widely used throughout different agile methods like SCRUM, the user story describes how the user interacts with a system and what their needs for such a system are. This can be done both in business language and in everyday language. Mostly it is only a couple of sentences long. In addition to the personas, this tool is another aid for the developers to really understand the customer's needs and empathize with them [16].

It is possible to actually include existing users in the process of creating the user story. But it is also possible to create them during a workshop. The user story will then be included over the whole duration of the development process. While within the development process, the user story should not be neglected. Also, active participation of the user in the development is strictly not desired [17].


**Fig. 2.** Example of a Persona [12]

### 3.3 Combining the Knowledge

After gathering information about the customer and their interaction with the product, this knowledge has to be combined with the overall topic of the digital product service. Knowing where and how exactly the customer interacts with the product helps to define service packages and offerings for the customer that they would truly benefit from. In this step, it can be questioned how the customer is using the product and what is expected from it. Here, thinking outside the box may be necessary. Maybe a customer could benefit from the flexibility and pricing difference that comes with leasing a product. They would not need the whole amount of money at once, right at the beginning of the purchase but have fixed, plannable costs for the whole duration of usage. Additional costs for maintenance would already be covered this way and if the product is no longer needed, the customer can give it back. The providing company on the other hand could benefit from an ongoing income. Keeping ongoing costs for maintenance low would be a goal here and the company would have increased motivation to provide exceeding products that keep up to their promises and have a high life span. Thinking outside of the box may be necessary here because possibilities such as leasing the product to the customer would break with existing strategies and may even require a redefinition of the company's business model.

## 4 Conclusion and Outlook

So far, the research results have shown a broad spectrum of services, in this case, more precisely digital product services.

Seeing the scope of the services provided by big companies gives a good overview of the possibilities out there. At the same time, it always has to be kept in mind, that a lot of companies simply do have access to a higher amount of resources and therefore are able to realize such services at a bigger scope. This has to be taken into consideration, as the scalability of added services can tend to be low and the company would maybe have to start the service off almost at the full scope. Providing services to the customers requires constant efforts and the work is not done with the first implementation. Further human and financial resources must be deployed over the course of the product's and the service's life cycle. In addition to this, the chances of starting with a negative financial outcome are high and companies might need to push over this phase, staying optimistic of a change and then seeing a financial benefit of the services.

For the Austrian B2B company this means, that the decisions on which digital product services are then implemented in the end has to be well thought through. The possibilities a sheer endless and plenty of options can be a good fit for the customer. In order to offer a service that will also provide good service to the company, not just the customer, it must be ensured that the services can be maintained in the long term. The effort for developing such services is one thing, but the long-term efforts are not to be underestimated.

A possibility for the company could be to focus on services that require little to almost no manpower once fully rolled out. The development itself could possibly be outsourced, reducing the needed manpower for this project to a bare minimum, potentially increasing the initial costs though. If the manpower, as well as the needed know-how, are available in-house, this would for sure be the solution to strive for. This way, the costs could be kept comparatively low, and dependencies on external partners for support, later on, could be avoided.

Such a service could for example be some type of product configurator, where the user can configure a product that fits their needs best. A user would enter their requirements for a product and the most suitable product would be presented to them, ready to order.

Offering a service where a user is directly connected to a service technician that can help in the event of acute malfunctions or damage would result in the need for an increased workforce on the team. Especially in times when the labor market is difficult for employers, this may not lead to the desired outcome. Here, the benefit for the user would be, that it provides a stress-free option for them to figure out which products they could need as well as providing data on which products or application areas are most commonly looked for.

Overall, this topic is still under heavy investigation and the final results will be published in the course of the next paper.

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# A Study on Reasons for Student Dropouts in a Computer Science Bachelor's Degree Program

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**Abstract.** High dropout rates are a common challenge in higher education, particularly in computer science degree programs. These dropouts impede our ability to produce a greater number of graduates in this highly demanded field due to the limitation of the capacity of students enrolled in the first semester. Identifying the reasons behind dropout is a complex task, as the individuals involved are often inaccessible or unwilling to reflect on their lack of success. This paper aims to investigate the factors contributing to dropout rates in computer science degree programs. Through a comprehensive literature survey and qualitative interviews, we have identified the underlying causes of dropout in our computer science bachelor's degree program. Our findings reveal a range of reasons, with time constraints and misaligned expectations of the degree program emerging as the most frequently mentioned factors in our interviews. Based on these insights, we present several recommendations aimed at reducing the dropout rate.

**Keywords:** Computer Science Education · Dropout · Dropout in Higher Education

## 1 Introduction

Higher education dropouts are a worldwide phenomenon, but different dropout patterns can be observed in different countries. For example, the dropout rate in countries such as the United States, Spain, France, and Austria ranges from 30 to 50%, while in Switzerland it is between 7 and 30% and in Finland it is the lowest at 10% [3]. Dropping out means leaving a particular program, regardless of the motivation. Dropout rates in higher education, particularly in computer science degree programs, present a significant problem. The high demand for skilled professionals in the field of computer science makes it crucial to educate and retain as many students as possible. However, when students drop out of these programs, the potential number of graduates decreases, hindering the supply of qualified individuals in an increasingly technology-driven world.

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This issue is compounded by the fact that computer science programs often have limited enrollment capacities, further limiting the opportunity to produce a sufficient number of graduates. Consequently, dropout in computer science degree programs not only undermines the educational aspirations of individuals but also creates a shortage of qualified professionals to meet industry demands.

Although dropping out is most common in the first semester of a study, the first three semesters are considered particularly critical in terms of precautions that should be taken to avoid dropping out.

The causes for student dropout are multifaceted, including academic and pedagogical factors, university management, and the student's personal and individual problems. Breaking down and understanding the different motivations for leaving is essential to taking effective measures to reduce the dropout rate. [4].

This work aimed to identify reasons for early dropout from computer science degree programs from the existing literature and to record any countermeasures that have already been implemented. As a result, we filtered out various categories of factors for the early dropout from a technical degree program. Based on this research, we conducted qualitative interviews at our university to investigate the specific reasons that led to dropouts in our computer science study program. Similar to the literature survey, we categorized the reasons for dropping out before graduation based on our interviews.

The remainder of the paper is structured as follows. Section 2 presents the results of our literature survey, including the most frequent reasons for the dropout. In Sect. 3 we describe the results of our qualitative interviews. Section 4 discusses and compares the results of literature survey and interviews. Here we also give some recommendations for mitigating dropout risks. Finally, in Sect. 5 we conclude the paper.

## 2 Dropout Factors Based on Literature Survey

In order to identify relevant insights on dropout factors in computer science related degree programs, we have carried out a literature review based on the guidelines presented in [1, 2]. We have searched four databases and digital libraries that index scientific articles in the field of computer science. In particular, our search included the following libraries: IEEE Xplore, SpringerLink, ACM Digital Library, and Science Direct. The databases were searched for articles containing at least one of our selected search terms in their full-text. Based on our previous knowledge of the research area as well as on screening searches, we have picked the following search terms: "dropout IT studies", "dropout STEM studies", "dropout computer science [studies]", "higher education dropout", "study dropout", "university dropout". The search was conducted at each database with the keyword combination that delivered the most results. This filtering yielded the following results:

- **ACM**: 644,901 results for: "dropout computer science studies"
- **IEEE Xplore:** 399 results for "dropout IT studies"
- **Science Direct**: 88,071 results for: "dropout IT studies"
- **SpringerLink**: 5,952 results for dropout "STEM studies"; content type: article

After screening all the results, we noted that many of them turned out to be irrelevant to the topic. For example, a broad selection of articles related to machine learning applications that try to predict dropout rather than examining the different reasons that can lead to a dropout. Nevertheless, nine papers stood out that provided essential insights on the subject of dropout in computer science studies, three of which are detailed below.

Based on this literature, different factors for the premature termination of a technical degree could be filtered out, which were divided into the categories: previous knowledge, lack of knowledge about what to expect from the chosen study, feeling of not belonging in the IT field, tutoring, studying habits, the student's employment situation, lack of social integration, poor teaching and advice. Country-specific dropout reasons were ruled out for this work.

**Previous Knowledge**

A common reason for poor academic performance during the early years of college is a lack of prior education in the technical field. A four-year study was conducted in an electrical engineering program at a university in Durango, Mexico, which shows that 50% of the students who dropped out did not receive any prior technical training from an appropriate middle school [3].

To develop methods to reduce the dropout rate, [5] asked 301 Estonian information and communication technology students to fill out a questionnaire before starting their studies and after the first semester. In addition, the electronically stored data of the approval process were included for the evaluation. Poor knowledge of mathematics and unfulfilled expectations of the studies were highlighted as important factors for dropping out of the course.

**Lack of Knowledge About What to Expect from the Chosen Study**

False expectations of the intended course of study emerged as another reason for prematurely dropping out of a technical course. For example, [3] states that students with advanced knowledge or professional experience in the technical field had a concrete picture of what to expect during their studies. While the expectations of students with no previous experience in the technical field were sometimes not met, students with previous experience had a clear idea of what knowledge they would acquire in the coming semesters. So that those interested in studying can form realistic expectations concerning the technical degree they are aiming for, [6] recommends holding careers orientation days with the opportunity to attend specific lectures. These days should be held before the enrollment phase, ensuring that interested prospective students can compare their expectations to those the selected field of study offers. Since the loss of interest in the field of computer science turned out to be an important factor for dropping out of studies, an attempt was made to use Massive Open Online Courses (MOOCs) to get potential future students interested in the field of IT and inform them about the contents of the studies [7].

**Feeling of not Belonging in the IT Field**

The authors in [8] investigated uncertainty about belonging as a relevant predictor for intentions to drop out by computer science students. Female students, in particular, are often less sure that they belong in the computer science environment than their male fellow students. This self-image affects academic performance and their perception of the future benefits of the chosen field of study. The desired degree also impacts the probability of a degree dropout. The dropout rate of students who did not choose this profession as their first option is around 15% [3].

**Tutoring**

Tutoring is understood as a strategy that offers students timely support from qualified teachers in the event of study and learning problems and is thus intended to prevent the student from falling behind academically. Tutoring can also strengthen the student's emotional stability and thus contribute to his or her academic, personal and professional development. In order to research the effect of tutoring programs on the number of students dropping out of electrical engineering, [3] followed 122 students who took part in a tutoring program over four years. Of these students, only 15 dropped out, mostly in the first four semesters.

The study conducted by Mussida and Lanzi [9] also attributes tremendous importance to tutoring and proposes a tool that sends automatic messages with tutoring offers to students with a high probability of dropping out. This tutoring offer is intended to be an optional activity and help to close the student's knowledge gaps. The study by [3] examined the academic success of students who received tutoring during their studies, and it was found that among the dropouts, only a tiny percentage of students received tutoring. Nevertheless, some students stated that tutoring is useless and that some tutoring units are held only as counseling units. Therefore, more effective communication between tutor and student is of great importance to achieve the desired learning success and thus reduce dropouts, especially in the first semesters.

**Studying Habits**

Other predictors of intentions to drop out among computer science students are a lack of time management and poor study habits such as procrastination [7]. Reasons computer science students drop out include that the students generally do not spend enough time on their studies, pay too much attention to specific subjects and thus neglect others, or particular subjects are more complex than the students expected and they, therefore, did not have enough time for them [5]. If students suffer from these learning problems, [3] suggests discussing them as part of a tutoring program and helping students in this area.

**The Student's Employment Situation**

Students who have a full-time job alongside their studies or who are affected by increasing overtime pressure or work commitments in their part-time job are exposed to an increased risk of dropping out of their studies [10]. Studies show that the dropout rate for working students is around 34% [3]. Loans and scholarships can reduce the risk of dropping out, as the financial necessity of working alongside their schooling is reduced. Students can therefore devote more time to their studies. For working students, their employer's endorsement of their education is an advantage, as this can also impact academic success [5].

## 3 Qualitative Interviews with Dropouts

Based on the findings of the literature survey, we further investigated the factors that lead to a dropout in the bachelor's degree of Computer Science and Digital Communications (CSDC) at the University of Applied Sciences FH Campus Vienna via qualitative interviews.

For this purpose, an official e-mail was sent to approximately 100 former students who did not complete their studies. The e-mail provided information about the purpose of the study, the procedure and duration along with the offer of a compensation of 20 euros.

Ultimately, after a 6-month period (September 2022 to February 2023), 14 former students replied to the e-mail and agreed to participate by answering questions about their demographics, their motivation, preparation, and general experience relating to the CSDC study program, their reason(s) for terminating their studies and what could have prohibited them from dropping out in a 20- to 30-min online interview. Answers were written down during the interview and no recording took place, which was made clear to participants. A guideline was followed throughout the interview though depending on participants' answers, additional questions may have been asked or others excluded as necessary.

The 14 former students (3 females, 11 males) were between 22 and 38 years old (mean $\approx$ 28 years) at the time of the interview, with 4 of them having studied full-time and 10 having studied part-time. The educational background of the former students varied greatly, with 3 having graduated from an academic secondary school (AHS in Austria), 1 from a vocational school with higher education entrance qualification (BHS in Austria), 2 from a commercial high school (HAK in Austria), 4 from a secondary school with a technical/engineering focus (HTL in Austria) and 4 who passed the university entrance exam. Additionally, 2 participants had obtained a bachelor's degree before their CSDC studies, 2 participants had obtained a master's degree and 1 person obtained an associate degree.

**Categorizations**

Although a common trend relating to the dropout rates could not be established due to the limited number of participants, an early attempt was made to categorize their reasons for terminating their studies before graduation. Therefore, what follows is a summary of the most common responses along with a more detailed discussion of the categories. Note that participants may have named more than one reason, which is why the number of participants across all categories may be greater than the number of study participants.

Table 1 shows the distribution of participants mentioning one or more of the 7 established reasons for dropping out of the CSDC bachelor's study program.

**Lack of Time**

The most common reason for participants' study termination prior to graduation that was particularly prevalent in former students who worked alongside their studies was the lack of time. Participants mentioned not being able to find enough time to catch up with their studies while also working full- or part-time. Some stated having tried to reduce working hours to increase study time, but to no avail, while others could not afford to earn less

**Table 1.** Established dropout categories mentioned by the respective number of participants[1]

| Category | Number of participants |
|---|---|
| Lack of Time | 5 |
| Social Isolation | 4 |
| Psychological Strain (i.e., stress, lack of motivation, depression etc.) | 4 |
| Discontentment/Different Expectations | 3 |
| Psychological/Cognitive Impairment (i.e., autism, reduced memory retention etc.) | 2 |
| Loss of Relevance | 1 |
| Particular Course | 1 |

income. Further, one participant mentioned to have studied in another program while at the same time also working part-time, while another stated to find it impossible to make up lost time after being sick for two weeks, especially during the most demanding time of the semesters, i.e., when most exams and project hand-ins occurred.

**Social Isolation**
Several participants mentioned issues relating to loneliness and difficulties connecting with other people in their peer group. Part of the reason for this may have been the start of the pandemic situation forcing participants to stay at home and study via distance learning, thus limiting social contact to the computer screen, which some may have had difficulties adjusting to. Participants mentioned having wished for more/better ways to connect to colleagues or a more cooperative experience altogether. One participant stated to have tried to communicate their need for help to colleagues on multiple occasions but was met with silence or rejection each time.

**Psychological Strain**
An issue partially related to social isolation is the psychological distress participants felt during their studies. This involves stress, lack of motivation, depression, anxiety, and burnout – all of those can be associated with dealing with the demands and deadlines of the courses. One participant mentioned having experienced psychosomatic issues related to the stress that accompanied their studies, such as hair loss.

**Discontentment/Different Expectations**
Some participants mentioned a general discontentment with the study program. The specific reasons ranged from expectations of more support in programming courses,

[1] One person/category was not considered for this listing as they dropped out before the semester started and therefore never attended a single class. The reason for this early termination was discouragement through friends along with a preference for a different city/country altogether.

better arrangements for students who worked part- or full-time, better support by teachers/advisors, up to wishes for a better organization and communication or the possibility of a bigger challenge for more advanced students.

**Psychological/Cognitive Impairment**

Two particular cases terminated their studies mostly for their lack of support by colleagues and/or teachers in dealing with their specific challenges: One participant experienced difficulties in their studies due to their autism disorder, while another participant had suffered from a stroke and not fully recovered, especially their memory retention. However, in both cases, the former students were not aware of any support that the university could have offered, like a talk with the gender & diversity department or the possibility of distributing one semester across two.

**Loss of Relevance**

One participant started this program due to an increase in interest for IT that was motivated by their working environment. However, their new position did not require or motivate any IT related knowledge, which rendered the participant with a sense of lack of relevance.

**Particular Course**

One participant mentioned dropping out of the study program for not being able to pass a certain course.

## 4 Discussion

The first part of this paper reviewed existing literature on reasons for study dropouts in an IT-related field, which yielded results that correlated to some extent with the findings from our own study. This chapter aims to combine both parts of this research and provide recommendations for improving the situation to reduce future dropout.

First, the most prevalent reason found in the qualitative interviews conducted (Lack of Time) can be attributed to two categories from the literature, namely “Studying Habits” and “Students’ Employment Situation”. Working while studying and the resulting lack of time emerges as a dropout factor, both in the literature survey and in the qualitative interviews.

In addition to increased stress, reduced study time, and resulting fatigue during classes [12], students have less time to socialize with their peers, which may further lead to a diminished connection between college and students [13]. However, this work-to-study conflict can also be used to boost personal resources by transferring and adapting skills and knowledge acquired in one role (work or studying) to the respective counterpart. For example, improving one’s interpersonal skills in the workplace can result in improved academic performance [14]. Yet, the interviews revealed that not only students who were working alongside their studies had difficulties managing their time to catch up with the learning material, but also some full-time students who were overwhelmed with the demands of the study schedule. A way of mitigation could be to promote and facilitate studying as a team more, since students from different backgrounds may be able to help each other out in various subjects. Additionally, more information about scholarships and financial aid programs may help students who are forced to drop out because of financial reasons.

Second, the category "Discontentment/Different Expectations" from the interviews highly overlaps with the category "Lack of Knowledge about what to Expect from the Chosen Study" from the literature, since the answers suggest that students with any level of prior experience with IT would benefit from more information about the study curriculum and its contents, what to expect from professors and colleagues, the procedures and communication channels of the university and so on. Therefore, an introductory session before or at the start of the semester could be set up to inform students more about the topics that they can expect to study, how they are taught, why they are relevant and in what ways this knowledge can be applied.

Third, while other categories mentioned in the literature, such as "Lack of Previous Knowledge in the Field" or "Feeling of not Belonging in the IT Field" might have influenced our study participants to some degree, they were not stated as main reasons for dropping out. Instead, two reasons were mentioned with equal frequency, which may have emerged out of the necessity of the pandemic situation to limit contact with teachers and students to an online form, namely "Social Isolation" and "Psychological Strain". Both of these reasons may have influenced each other, since feelings of loneliness have been known to increase stress levels [11]. Several students mentioned in the interviews to have imagined their studies differently in terms of the social aspect, i.e., with more on-campus classes and therefore more possibilities of connecting with colleagues. This new situation may have further increased the psychological strain that students experienced throughout their studies, beside the stress that the challenging courses may have already evoked. Again, one way of avoiding particularly the feeling of social isolation some students experienced, but also the impact of psychological strain is to elicit more interconnected studying opportunities, as suggested in the first paragraph of this chapter.

Fourth, the three reasons with the fewest mentions ("Psychological Impairment", "Loss of Relevance" and "Particular Course") are also not represented in the literature reviewed but may be representative of a larger population. Especially students who deal with psychological impairment would benefit from more information regarding support for their special needs, which may be communicated more both on the university website and in an introductory session, such as suggested in the second paragraph of this chapter. Additionally, collecting and processing feedback throughout a course may help to reduce dropout rates, since teachers may be able to identify problematic areas during the current semester and react and adjust their classes accordingly.

Although the category tutoring or lack thereof was not stated as a specific dropout reason by the participants in this study, it may still be helpful to make tutoring offers more widely known and provide information about how tutoring sessions may be helpful to students.

## 5 Conclusion

Numerous prior studies in the field of computer science have explored a wide range of factors related to student dropout in higher education, including reasons for selecting a computer science degree program and reasons for dropping out. The primary objective of this research was to provide an overview of relevant studies on student dropout and empirically investigate the specific reasons within our own degree program. By leveraging this overview, we derived recommendations aimed at reducing the likelihood of high dropout rates.

Based on our interviews, the primary reason for dropout is time constraints, particularly among our part-time students. To address this issue, fostering collaborative student groups can enhance the efficient utilization of learning time through mutual assistance and support. The second significant reason for dropout is mismatched expectations regarding the degree program. To tackle this challenge, it is essential to offer potential students a more transparent depiction of the degree program. As a tangible step in this direction, we have introduced a podcast that provides information about the program and individual course contents to both current and prospective students.

In our future work, we plan to implement concrete measures to address the primary reasons for dropout, such as enhanced support for student groups. Additionally, we will continue evaluating the dropout rate and investigating the underlying reasons contributing to it.

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# A Case Study on the Readiness of Rajamangala University of Technology Lanna in Entering Times Higher Education University Impact Rankings

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**Abstract.** When referring to the Roles of Higher Education for Sustainable Development Goals (SDGs), with awareness of the importance and a desire to contribute to the achievement of the goals in concert with all organizations by 2030 as endorsed by the 193 United Nations member states at the end of 2022, the Rajamangala University of Technology Lanna (RMUTL) management team has made an effort to drive the organization to engage in this role through the establishment of a high-potential working group for preparing and applying to participate in the World University Ranking "Times Higher Education University Impact Rankings", a platform focusing on selecting and ranking universities according to their proportion of creating positive impact on society and the environment. To ensure the validity of our results, the research team has adopted a qualitative paradigm aimed at addressing the research question, in the matter of understanding and readiness of RMUTL in bringing organization into the university ranking process that is both for an engagement with an international drive and an increase in competitiveness to strive for excellence, through the perspectives of selected executive representatives and working team representatives; and eventually; it brought to the conclusion based on the approval of the working group that RMUTL is ready to bring the organization to participate in the assessment of 6 goals out of 17 goals of the SDGs.

**Keywords:** SDGs · Impact Rankings · Higher Education

## 1 Introduction

The 2030 Agenda for Sustainable Development initiated and driven through the United Nations Summit on Sustainable Development, with the Declaration reads: *"We, the Heads of State and Government and High Representatives, meeting at United Nations Headquarters in New York from 25 to 27 September, 2015 as the Organization celebrates*

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*its seventieth anniversary, have decided today on new global Sustainable Development Goals"* [1]. The Sustainable Development Goals consist of 17 goals which are expected to result in implementation in bringing about changes to the world both at the level of thinking and developing through three key dimensions, known as the "Three Pillars of Sustainability", consisting of social dimensions (People), economy (Prosperity), environment (Planet), and combined with two additional dimensions, namely Peace and Institutions (Peace) and Balanced Development Partnership (Partnership). These five elements are known as the 5Ps of the Sustainable Development Goals (The 5Ps of the SDGs) and aim to fulfill their achievements by 2030 in accordance with the 193 UN member states' endorsement, including Thailand. For the research team, images and experiences about the United Nations policy-driven movement through this initiative are considered very successful in terms of raising awareness and participation at all levels of the organization and all sectors of the country, even Higher education institutions (HEIs), where the issue has further fueled the eruption of new challenges. When the world university ranking stage under the name Times Higher Education Impact Rankings (THE Impact Rankings or Impact Rankings) was established in 2019, Impact Rankings was both the first and only stage of the *"…global performance tables that assess universities against the United Nations' Sustainable Development Goals (SDGs)"* [2]. Impact Rankings ranks and contributes to reports on progress towards the implementation of each goal of the SDGs as proposed or notified by the applicant university for assessment, and are not required to participate in all 17 goals. Currently, *"the 2022 Impact Rankings is the fourth edition and the overall ranking includes 1,406 universities from 106 countries/regions"* [2]. For Rajamangala University of Technology Lanna (RMUTL), the university administrators have greatly recognized the importance of this agenda. This is why efforts have been made to bring the university into the rankings of THE Impact Rankings, which will not only participatively express a sense of responsibility as a member of society, but will also drive the organization in a direction that includes strategies, tactics, goals and action plans that are in line with the drive both nationally and globally to achieve the aim at the same time. The result in other areas that will be directly obtained is to recognize and acknowledge the status of the university in the matter of excellence, competitiveness or competitive conditions, etc. It is important that before entering the university rankings, the management team and specialized working groups have been established as an ad hoc task force of RMUTL: 1) have an idea whether RMUTL is ready to enter the rankings of THE Impact Rankings or not, and if ready, which SDGs goals (Goals) and/or which Targets it is ready for, and 2) be able to see how RMUTL will benefit from such interventions. These are research questions that the research team will seek to answer through both qualitative and quantitative perspectives, by utilizing research processes and tools for obtaining information from the group that the research team expects to be able to represent the executives and the ad hoc working group established for this purpose of RMUTL. Research results are beneficial to the process and development of the work of the ad hoc working group for bringing RMUTL into the process of World University Rankings, as well as expanding the results to build understanding at the community level of RMUTL and society at large.

## 2 Purpose

1) To study processes, preparation strategies as well as conditions that could be useful to enhance a university or higher education institution in progressing towards the THE Impact Rankings.
2) To explore the perspectives of representatives of the executives and the ad hoc task force established concerning the readiness of RMUTL in entering the THE Impact Rankings and focusing on challenges faced by the representatives in gathering evidence to support each SDGs.
3) To analyze, synthesize and interpret the data to find out suggestions and recommendations from a practical point of view to enhance RMUTL in successfully making progress towards the assessment criteria of the THE Impact Rankings and become a competent university in a global higher educational platform.

## 3 Approach

This study is informed by an interpretive qualitative research perspective. It is developed from an analysis and synthesis of literature relevant to the current research focus. An interview is adopted as the data collection method because it can be useful to help the researcher in gathering in-depth data from the participants, i.e., experience is described by words rather than presenting it in terms of statistical numbers. Furthermore, the participants are purposely selected from a group of RMUTL representatives who were involved in the process of data gathering and data submission of the application in the Times Higher Education Impact Rankings 2019 (Fig. 1).

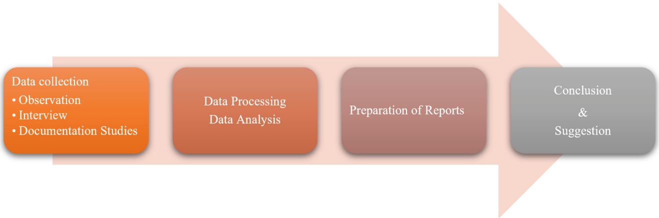


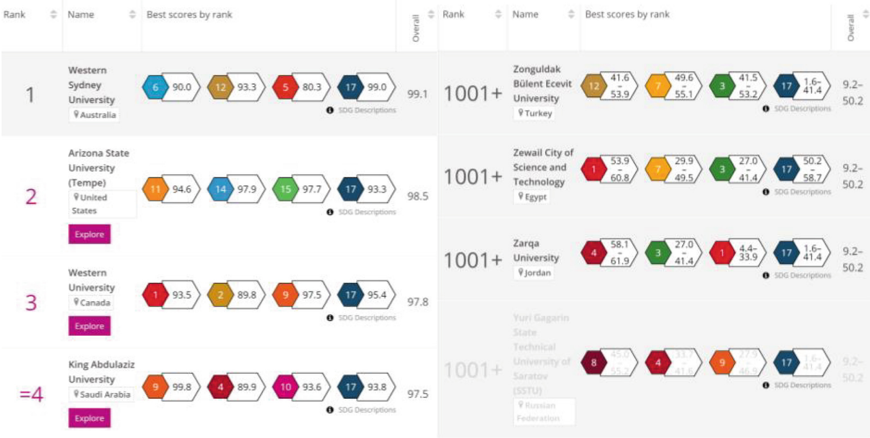

**Fig. 1.** Summary of research stages

Concerning data analysis, the present study intends to focus on four aspects: strength; opportunity; weakness; and challenges. This means the data analysis will be based on the organization's internal and external factors to help identify goals and working procedures in obtaining a desirable result accredited by the THE Impact Rankings.

## 4 SDGs and Participation of Higher Education Institutions (HEIs) Through THE Impact Rankings Platform

*"Although the SDGs aren't focused on higher education, the achievement of the Sustainable Development Goals by 2030 will require all hands on deck. It will require different sectors and actors working together in an integrated manner by pooling financial resources, knowledge and expertise. This must include the resources of universities*

*and higher education"* [3]. The above is one of the key motives for the Times Higher Education (THE), usually known in world university circles as an organization providing services similar to being a provider of World University Rankings that was previously used to organize rankings which in the big picture covered only the two main areas of university activity, namely research (Global rankings) and teaching (Teaching rankings), and later expand to cover one more issue, the impact (Impact ranking). Elsevier (2022) cited the World Economic Forum who stated that "*… the Times Higher Education (THE) University Impact Rankings are the World's first global attempt to document evidence of universities' impact on society, rather than just research and teaching performance. To do this, THE uses carefully calibrated indicators to provide comprehensive and balanced comparisons across four broad areas: research, outreach, stewardship and teaching"* [4].




**Remarks:** SDG 1: No poverty, SDG 2: Zero hunger, SDG 3: Good health and well-being, SDG 4: Quality education, SDG 5: Gender equality, SDG 6: Clean water and sanitation, SDG 7: Affordable and clean energy, SDG 8: Decent work and economic growth, SDG 9: Industry, Innovation and Infrastructure, SDG 10: Reduced inequality, SDG 11: Sustainable cities and communities, SDG 12: Responsible consumption and production, SDG 13: Climate action, SDG 14: Life below water, SDG 15: Life on land, SDG 16: Peace, justice and strong institutions, SDG 17: Partnership for the goals

**Fig. 2.** Impact Rankings 2022: Example of an overview ranking results announcement [7]

This point can be considered that THE Impact Rankings are another forum that allows universities around the world to participate in exhibiting the progress and achievements of the operations in various dimensions as if they are traveling companions for achieving the United Nations' Sustainable Development Goals (SDGs) in areas of one's own readiness or upstandingness, even standing on the path of the competition, but it is like a concerted effort of the higher education sector to aim for creating mutual benefits for mankind. Losing or winning through the rankings is therefore both an impetus and a reward, not only for the organization or the people in that university, but also for the benefit of both the current and the next generations. This practice is inevitably tied to the direction of sustainable development according to the definition: *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs"* [5]. Although in the above point of view, THE indicates that

HEIs are not specified by the SDGs as leaders in leading society towards the achievement of its goals, but that does not mean that among the 17 goals comprising sub-goals, the so-called Targets, another 169 targets and 232 unique indicators (244 in total but 12 duplicates), there is no mention linking to HEIs, such as SDG 4: Quality Education with the goal "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all." This goal covers 4 targets and in target 4.3, it is labeled: **"***By 2030, ensure equal access for all women and men to affordable and quality technical, vocational and tertiary education, including university"* [6]. In addition, in the view of scholars from Centre for Environmental Policy, Imperial College London has commented that *"Higher Education also forms an important part of other goals related to poverty (SDG1), health and wellbeing (SDG3), gender equality (SDG5) governance, decent work and economic growth (SDG8), responsible consumption and production (SDG12), climate change (SDG13), and peace, justice, and strong institutions (SDG16)"* [8]. The above opinion given is only an overall view because if considering it briefly according to Fig. 2, it will be found that each HEIs may have differences in readiness, potential, and prominence in driving to achieve SDGs goals. It is further reaffirmed that, for the research team, the highest implication of having over 1,406 HEIs from 106 countries/regions enrolled in the THE Impact Rankings is not only a ranking of who can do better, not just a competition to be No.1 in marketing and management, but also a demonstration of the great role and consciousness that HEIs should play in developing for a sustainable balance of the planet together for the next phase from the 5$^{th}$ or 6$^{th}$ edition of the THE Impact Rankings 2024 or 2025 onwards. It is expected that further efforts will be made to the issue of providing more opportunities for young refugee women and men around the world to enter higher education more, which is a major request from The UN Refugee Agency (UNHCR) for the next movement of HEIs that are members of THE Impact Rankings.

## 5 RMUTL: Self-reflection Before Taking on New Challenges

### 5.1 From "College" to "University" [9, 10]

Under the supervision of the Office of the Higher Education Commission, the Ministry of Higher Education, Science, Research and Innovation (MHESI), RMUTL is a Thai government higher education institution, located in the Upper Northern Region of Thailand, formerly known as "Phayap Technical College", a vocational institute established on August 8, 1957. On February 27, 1975, Payap Regional Technical College was transferred to be under the College of Technology and Vocational Education under the name "College of Technology and Vocational Education, Payap Technical Campus". This change is for the purpose of accelerating the production of manpower in teaching or vocational education teachers with bachelor's degree programs, including other fields, but still providing vocational education at the level lower than bachelor's degree simultaneously. After His Majesty King Bhumibol Adulyadej granted a new name to the group of technological and vocational colleges nationwide as "Rajamangala Institute of Technology", the name has been changed to "Rajamangala Institute of Technology, Payap Campus" on September 15, 1988, along with the mission of development, educational management in accordance with national policies and labor market demands in creating hands–on graduates of science and technology. The elevation of academic status to "Rajamangala University of Technology Lanna" has taken place on January 18, 2005 according to the Rajamangala University of Technology Act. Currently, RMUTL provides education at both vocational certificate and bachelor's degree levels, comprising six campus areas: Chiang Mai (central area), Nan, Tak, Phitsanulok, Lampang and Chiang Rai. Teaching and learning are divided into four faculties and one college, namely 1. Faculty of Business Administration and Liberal Arts 2. Faculty of Science and Agricultural Technology 3. Faculty of Engineering 4. Faculty of Fine Arts and Architecture and 5. College of Integrated Science and Technology. In the first semester of the academic year of 2022, according to the information of the Office of the Permanent Secretary for MHESI, RMUTL has a total number of 14,988 students [11] and the Personnel Administration Division of RMUTL has revealed the total number of personnel of all types to be 1,940 persons in total, [12] updated as of November 7, 2022. Besides, RMUTL is also classified as one of the higher education institutions in the Technology Development and Innovation group from a total of 18 institutions across Thailand, according to the MHESI classification, there is a task that must be accelerated to achieve a variety of indicators including the development of students and graduate entrepreneurs, seeking funding from external sources to support the creation of new entrepreneurs or businesses, exchanging of knowledge between institutional personnel and business or industry sectors, and the building of cooperation to develop entrepreneurs, create innovation with the business sector, and between higher education institutions.

### 5.2 Identity Prominence Associated with the SDGs

With spatial diversity, the division of administrative and educational management areas are divided into 6 areas in 6 major provinces of the North of Thailand. Besides prospering with the charm of wisdom roots, memorable legends and history, RMUTL is also located in a predominant strategic economic position nationally and regionally in Southeast Asia. The current Acting Rector of RMUTL has established a policy on the issue of being "University of Learning", which is one out of nine policies served as the key guideline for development of the university through efforts to actively and continually promote the development of learning resources within the university, with the expectation to involve all sectors in the development based on the needs and appropriate to context of the area on the basis of creation of live and creative learning resources under the concept *"Appropriate learning resources based on identity, one area, one model"*, which can be briefly identified as follows: *"1) Chiang Rai: Business management, 2) Chiang Mai: Innovation, technology, invention, and modern community development model, 3) Lampang: Agriculture, agro-industry, smart farm, a learning center for healthy diet research, plant genetics and agricultural management under the concept of His Majesty's Science, 4) Tak: Technology and support for expansion of the Special Economic Zone, 5) Nan: Biodiversity, and 6) Phitsanulok: Development of safe agriculture"* [13]. In addition to being fully equipped with environmental elements accompanied by diverse identity and spatial strengths, in the past, RMUTL had been able to develop the organization to have multi-dimensional potential based on widely accepted expertise, such as: *"1) Agricultural technology 2) Engineering technology 3) Entrepreneurship 4) Creative Lanna and 5) Technology Education"* [14]. From self-reflection in the aforementioned dimensions, it illustrates the values of the organization in terms of being a university that has high potential, have a direction to drive the organization, have operational results and strong ties to the SDGs, which, if having a good management related to project management and information management, it is believed to be able to report the results of the implementation to THE Impact Rankings with competitive significance for at least ranking at the level of Upper Middle Class ranking.

## 6 Readiness of RMUTL in the Administration and Subcommittee's Perspectives

### 6.1 Upstream Information, Motives, and Leaps to New Challenges

From the meeting on "the driving policies of RMUTL World ranking" by the administration and subcommittee, the goal of bringing RMUTL into the ranking process of THE Impact Ranking and other ranking systems has been prioritized and motivated. The rationale for joining the ranking was convincingly described in the meeting by referring to the key message in the speech given during the anniversary celebration of the establishment of the Ministry of Higher Education, Science, Research and Innovation (MHESI) that stated at one point that *"MHESI is ready to drive Thai higher education, science, research and innovation to international standards and sustainably increase international competitiveness ranking by 2037"* [15]. The meeting presentation proceeded with the sharing of information from the symposium entitled "Thailand and South East Asia Masterclass"; which presented the criteria, assessment indicators, and methods for importing data into the quality assessment system of the World University Rankings with the help of Times Higher Education (THE) in providing advice through training. The presentation then transitioned to the Excellence Development Plan of RMUTL, for the fiscal year of 2023–2027, which consists of a strategic plan that provides the guideline for driving RMUTL towards the university's development goals under the vision of *"A leading university for professions and technology in producing hands-on graduates for sustainably enhancing the quality of life of society, communities, and locality"* [16]. Considering all information presented, it becomes clear about the need to push RMUTL into the ranking of THE Impact Ranking as soon as possible, along with three main reasons: 1) it will reflect the quality of the university; 2) it will provide a means to compare RMUTL with other universities; and finally, 3) it will lead RMUTL to the goal described in the university development plan. In the past, UniRank published the report of 2023 for Thai University Ranking of a total of 123 Thai higher-education institutions. According to the report, RMUTL was ranked: "*49$^{th}$ for country rank, and 5,562$^{th}$ for world rank"* [17]. For the 2023 Best Universities in the World, organized by EduRank.org Rankings, rankings of a total of 14,131 universities in 183 countries worldwide, RMUTL was ranked: *"5,706$^{th}$ in the world; 2,098$^{th}$ out of 5,830 universities in Asia; 39$^{th}$ out of 125 universities in Thailand; and 3$^{rd}$ out of 7 universities in Chiang Mai*" [18]. However, in the case of the announcement of the world university ranking results of UniRank and EduRank.org Rankings, the research team consider the results as "open system ranking"; a non-voluntary ranking assessment in which the rating organization may rely on extracting data from information sources within its reach, such as the websites of institutions, ministries, or other ranking platforms for consideration; different from "closed system rankings" such as QS World University Rankings, Times Higher Education or Quacquarelli Symonds, which are based on the mutual perception of both parties, the rating organization and candidates, as well as having a process in the direction that leads to credibility (e.g., recruitment, objective indicators, opportunities to present information). In some cases, institutions can also clarify and supply further information to the representatives or committees of rating organizations, etc. In addition, in terms of excellence in professional hands-on skills, academics, research, art, culture, and social service, RMUTL's faculty and students are also genuinely unique because over the 18 years of becoming a university, combined with the strong foundation before then, RMUTL has produced numerous phenomenal contributions on national, regional, and international stages such as being the national skilled labor champion for at least 5consecutive years, representing Thailand in the WorldSkills Competition 2022 Special Edition and being able to win the medal of excellence. In 2021, seven RMUTL researchers were listed in the AD Scientific Index 2021: World Scientist and University Rankings 2021. In summary, these were the source of speech at the steering committee meeting to lead the organization into the world university rankings that said, "RMUTL has made a lot of contributions," but has not yet been consolidated in the direction of utilization for the purpose of increasing competitiveness or in the way to compete for market space as many top universities have already begun. This is therefore the motives and drive for RMUTL to decide to step into THE Impact Ranking arena.

## 6.2 Piloting and Participating by Selecting Six Goals Ready for Ranking Out of 17 in Total

An additional subcommittee consisting of operating working groups of 27 members in total was appointed with the appointment order signed by the Rector of RMUTL dated October 19, 2022. Then the working group meeting was held in which the Chairman of the Steering Committee presented the results of an inquiry on the views of individuals towards the work context of RMUTL and the SDGs of 16 Goals, because SDG17 is a requirement of THE Impact Ranking that information for assessment must be submitted, under the question *"Select 3 SDGs that are consistent with the work context of RMUTL and 3 that have empirical accomplishment as an evidence, except item 17, do not have to choose"* [19]. The survey was conducted on September 13–19, 2022. A total of 66 participants participated in expressing opinions (N = 66) and had 16 Goals of SDGs as 16 statistical factors. Out of the total 16 factors considered, the SDG4 factor was the most important factor in the sample group, at 69.7%, followed by the SDG9 factor at 53%, which was quite a distance away from other factors, indicating the great significance of these two factors. The next factors ranked 3$^{rd}$, 4$^{th}$ and 5$^{th}$ are SDG12, SDG8 and SDG3 respectively, which indicate similar significance, 30–36%. The other is 6$^{th}$ and 7$^{th}$ are SDG15 and SDG2, with the importance of 21.2% and 16.7%, the rest of the factors account for less than 10% in their importance distributed among the remaining factors. The representatives of the steering committee and the subcommittee leverage these results to help make informed decisions regarding the SDGs goals to prioritize and focus on (Fig. 3).

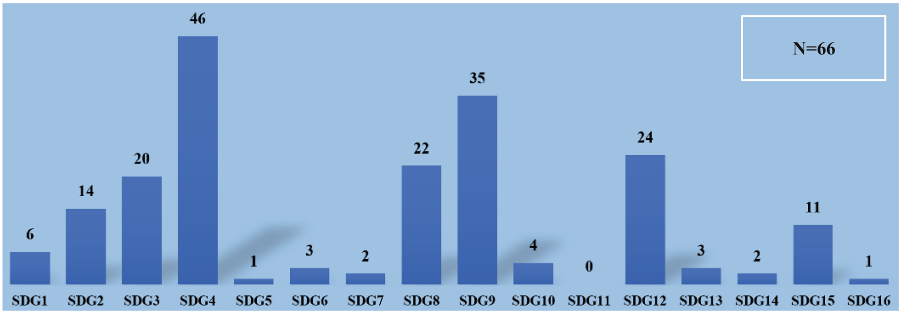



**Fig. 3.** Views on the accomplishment of RMUTL that are in line with the SDGs [19]

Therefore, it came to a conclusion of an execution of piloting participation in the assessment and ranking of a total of 6 goals as shown in Table 1.

**Table 1.** 6 SDGs goals that RMUTL will pilot for ranking by THE Impact Ranking.

| Goals | Definition [20] |
|---|---|
| SDG2: Zero hunger | *End hunger, achieve food security and improved nutrition, and promote sustainable agriculture* |
| SDG4: Good health and well-being | *Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all* |
| SDG8: Decent work and economic growth | *Promote inclusive and sustainable economic growth, full and productive employment and decent work for all* |
| SDG9: Industry, innovation and infrastructure | *Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation* |
| SDG11: Sustainable cities and communities | *Make cities and human settlements inclusive, safe, resilient, and sustainable* |
| SDG17: Peace, justice and strong institutions | *Strengthen the means of implementation and revitalize the global partnership for sustainable development* |

The pilot herein refers to participation in THE Impact Ranking. This hands-on effort in a sense is similar to an experiment. The working group has done its best in hopes of achieving a good ranking level, being competitive with other universities around the world, yet open to accept the results to be announced together in this challenging pace on the global stage. Furthermore, one of the goals is to connect the potential database to be available for further contests on other ranking arenas.

### 6.3 SWOC ANALYSIS: In the View of the Administration and Subcommittee

In order to exhibit the view on the readiness to enter the process of applying for the assessment and ranking of world universities by THE Impact Ranking of the representatives of RMUTL executives and a working group that was established in an ad hoc fashion, the research team has therefore selected four individuals, consisting of two representatives from the management team and another two from the working group to answer analytical questions regarding strengths, opportunities, weaknesses, and challenges on the issue of the readiness to drive RMUTL into the world university rankings and how it will affect Stakeholders, the results are shown in Table 2. Overall, from the representatives of both groups, the views are quite consistent with the dimension of the readiness of RMUTL in the aspect of potentiality of personnel, areas, as well as promoting a priority given by executive members and, more importantly, the readiness in terms of performance or empirical evidence that will be used to answer the questions of the SDGs for each goal, target, and indicator.

**Table 2.** SWOC Analysis results

| Representatives | Strengths | Weaknesses | Opportunities | Challenges |
|---|---|---|---|---|
| Executive 1 | RMUTL is ready to change | Lack of understanding | Already working towards the goal | Towards sustainability |
| Executive 2 | RMUTL Demonstrated performance and talented personnel | Lack of data storage and management | Build credibility, reputation, and can expand the customer base, such as students, to the organization | Building understanding and policy initiatives for understanding |
| Working group 1 | Executives are alert and focused | Budgets are limited | Is a small organization, easy to manage | It is something new that needs to be done for survival and competitiveness |
| Working group 2 | RMUTL is ready for technology and innovation | Lack of understanding of Impact Ranking system | Be in the right region | Increasing understanding of personnel |

The biggest obstacle to the matter of readiness is the understanding of the SDGs system itself, which in this round the working group is still considered new to the system, including the distribution of information that will be used to answer questions or provide evidence, it will also be necessary to develop a system to store information into categories for the next time. In terms of understanding management for the working group, RMUTL executives have provided training conducted by experts to overcome these barriers.

# 7 Recommendations and Conclusions

## 7.1 Recommendations

1) *Organize a database on the website to be easily accessible,* such as a dedicated page or section for storing and disseminating information in all dimensions that ranking organizations are interested in and in what direction we would like them to reach us, look at us in whatever image or potential level that is factual, it should be fully presented.
2) *Leverage diverse channels to disseminate information for audiences at a national and international level. The university should not rely solely on public relations on the university website and should not forget to disseminate information in international languages as well as other widely used languages.* Information dissemination is the role of RMUTL's Public Relations Department directly because distributing news from sources on the Internet as much as possible is an important factor in how the world sees or encounters more corporate information. As it is known, a competition in the world education arena and most ranking organizations use English as a medium, hence the presentation materials should be prepared for conveying information in all functional purposes to maximize public relations effectiveness to be competitive. In addition, the presentation of information is more linguistically diverse, especially languages in new trends such as Chinese, Russian, Indian, which are an undeniably advanced advantage.
3) *Foster understanding and engagement at the corporate level is essential for achieving sustainability goals.* Delegating tasks among working members require decision makers to understand staff and students as well as stakeholders at the community or society level to effectively lead the organization as a whole to achieve its sustainability goals. Therefore, developing the understanding of every element of this initiative and raising communal awareness across the organization are of great importance in achieving the goals together.

## 7.2 Conclusions

From the perspective of the World University Rankings research panel, if looking at it ingeniously, it is one of the contexts for taking internal and external assessment of quality assurance that RMUTL has the right to review itself before diving into the ranking assessment from THE Impact Ranking. When it comes to educational quality assurance, in principle, there are two main functions: 1) to assure that educational institutions have courses, personnel, and teaching tools, facilities, services, or any other responsibilities of high standards, and 2) to continuously improve as the results from the assessment or recommendations for change will guide the university to become better. This will inevitably enhance the efficiency of educational institutions. Both of these are the responsibility of the educational institution to safeguard the institution's standards and to protect the interests of learners, parents, communities, society, and stakeholders as a whole. Therefore, by putting the emphasis on quality, the university can reap the positive, long-term impact, that will lead to more profound and multi-faceted effects than one would expect. For example, if educational institutions can develop learners to be aware of the environment, community, and possessing good engineering skills. Learners may take advantage of their skills to develop communities and mitigate environmental degradation, and may pass on their awareness and consciousness to the next generation. This is one aspect of sustainable development as it is a phenomenon at the impact level. The fact that RMUTL by university administrators attaches importance to stepping into THE Impact Ranking arena is not only advantageous for its publicity, or competitiveness, as these may be only a by-product, but also for the noble aspiration of joining this global movement and collective responsibilities. More importantly, instead of competing for academic excellence which may not be fairly judged when great differences exist when it comes to technologies, budgets of universities, when comparing the third world, developing countries, and developed countries, it is therefore best that RMUTL strives and focuses on this balanced goal of social, economic and environmental aspects; which is the ultimate goal of defining these global initiatives or SDGs.

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# Teaching Nonlinear Control by Means of a Ball on the Wheel System

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**Abstract.** A comprehensive education in control engineering naturally includes nonlinear control theory. Understanding the associated methods is a great challenge for many students due to the required theoretical background and the often-missing applicability of the methods to real-world problems. The proposed paper deals with how this problem can be addressed using a specially developed practical experiment, a so-called Ball on Wheel (BOW) system.

An EC motor exerts the necessary torque on a vertical wheel to control the trajectory of a ball lying loosely on it's contour. Different controllers were developed using the nonlinear control theory of full state linearisation. In addition, the BOW system offers various operating modes by applying individual reference trajectories to the linearised state space. Using the BOW laboratory model, both the challenges and the advantages of the mechanical design and the implemented controls are examined. This approach provides students with the practical and understandable meaning and necessity of nonlinear control theory.

**Keywords:** nonlinear control · control systems education · rapid control prototyping · system commissioning

## 1 Introduction

A modern education in the field of control engineering requires a comprehensive understanding of various theoretical and practical aspects. Students are expected to develop a strong foundation in mathematical modeling, system analysis, and of course control design. They must also possess skills in programming, simulation, and implementation of control algorithms using modern software tools (e.g. Matlab/Simulink).

On the other hand, understanding the associated control design methods is a great challenge for many students due to the required theoretical background and the often-missing easy applicability of the nonlinear methods to real-world problems. We basically observe through hands-on projects and lab-experiments, students are encouraged to apply their theoretical knowledge to real-world scenarios and to develop innovative solutions [6–8].

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### 1.1 Main Purpose

The Systems Design study program covers nonlinear control engineering courses including nonlinear control methods, such as feedback linearization or backstepping. They usually involves complex theories and difficult mathematical concepts. Despite the many textbooks or literature available on the subject, a hands-on approach is still the better teaching approach and increases motivation for many students to grasp even complex theories.

Of course, a variety of laboratory exercises are already implemented in our study program Systems Design concerning the field of linear control engineering (e.g. Position control of a DC motor) [9]. On the other hand, there are currently no available lab experiments that require nonlinear control for a sufficient performance. Our classical inverse pendulum experiment, for example, can be successfully controlled with linear controllers, e.g. state space controllers.

The main objective of this work is to present a control experiment, a so-called Ball on Wheel (BOW) system. It investigates how the motivation and subsequently the learning outcomes of students in the System Design's field of control engineering can be increased through processing a practical nonlinear experiment. Several other BOW systems designed for research purposes have been characterized by their bulky construction [3] or the absence of 3D printing and industrial standard components in their construction [4]. An essential characteristic of our experiment is that it has been realized through modern techniques such as 3D printing. This enables it to be designed as a portable laboratory experiment. Additionally, it incorporates a novel sensor concept.

## 2 Ball on Wheel System

The considered Ball on Wheel system consists of a circular wheel placed in a horizontal position, as seen in Fig. 1.

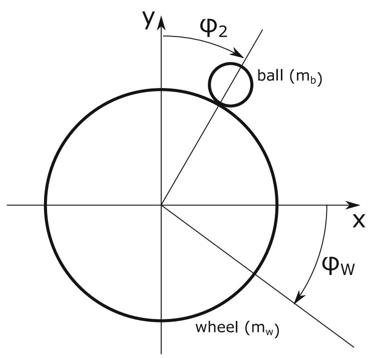


**Fig. 1.** Illustration of the Mechanical Principle: Ball on the Wheel System

The wheel is perpendicular to the ground and can rotate freely around its axis. It serves as the main platform for the ball and provides the necessary rotational motion. A spherical ball is positioned on the outer edge of the wheel, in contact with its surface. The ball is not rigidly attached to the wheel and can move independently. Its position and movement are influenced by the rotation of the wheel (and external control inputs). The wheel's acceleration and deceleration induce forces on the loosely coupled ball, enabling the balls stabilization in an unstable equilibrium state.

A change in speed is required to apply force to the ball, counteracting the gravitational force. The wheel is powered by an EC-motor which receives an input current. A real-worlds realization of our BOW experiment is given in Fig. 2, depicted below.

**Fig. 2.** Real-world system for the Ball on Wheel configuration

## 2.1 Mathematical Model

The Lagrange method is employed to derive an appropriate mathematical description of the system. Thereby, the angle $\varphi_W$ describes the rotational wheel angle, whereas $\varphi_2$ describes the angle between the centre of the ball and the centre of the wheel and the input current is denoted as $i$ (see also Fig. 1). Then the equations of motion can be expressed as:

$$\ddot{\varphi}_2 = \frac{\alpha \cdot sin(\varphi_2) - K_{fw}\rho \cdot \dot{\varphi}_w + K_g\rho \cdot i}{r_{ges} \cdot N} \tag{1}$$

$$\ddot{\varphi}_w = \frac{\gamma \cdot sin(\varphi_2) - K_{fw}\beta \cdot \dot{\varphi}_w + K_g\beta \cdot i}{N} \tag{2}$$

A detailed description of the derivation process for the mathematical model and the abbreviations and parameters used can be found in [1,3]. It is immediately apparent that the BOW system is a non-linear system.

The BOW system can be effectively described using a non-linear state-space model. The state vector is denoted as $\mathbf{x} = [x_1\ x_2\ x_3\ x_4]^T = [\varphi_W\ \varphi_2\ \dot{\varphi}_W\ \dot{\varphi}_2]^T$. The input of the system is specified as $u = i$. The non-linear state-space model for the BOW system can be written as an affine input system of the form

$$\dot{\mathbf{x}} = \mathbf{f}(\mathbf{x}) + \mathbf{g}(\mathbf{x})u \tag{3}$$

with

$$\begin{pmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \\ \dot{x}_4 \end{pmatrix} = \underbrace{\begin{pmatrix} x_3 \\ x_4 \\ \frac{\gamma \cdot sin(x_2) - K_{fw}\beta \cdot x_3}{N} \\ \frac{\alpha \cdot sin(x_2) - K_{fw}\rho \cdot x_3}{r_{ges} \cdot N} \end{pmatrix}}_{\mathbf{f}(\mathbf{x})} + \underbrace{\begin{pmatrix} 0 \\ 0 \\ \frac{K_g \beta}{N} \\ \frac{K_g \rho}{r_{ges} \cdot N} \end{pmatrix}}_{\mathbf{g}(\mathbf{x})} u \tag{4}$$

The mathematical model serves as a fundamental tool for both simulation and control design purposes. These processes are performed within the MATLAB/Simulink environment.

### 2.2 Controller Design

The BOW system can be appropriately controlled using the method of feedback linearization [5]. For a full state feedback linearization the flat output function $y = h(\mathbf{x}) = \frac{\rho}{r_{ges}\beta} x_1 - x_2$ has been chosen [5].

The control law for a feedback linearized system with a flat output (order $n = 4$) using Lie derivatives [10] is provided as follows

$$u = \frac{1}{L_g L_f^3 h(\mathbf{x})} \cdot \left(-L_f^4 h(\mathbf{x}) + v\right) \tag{5}$$

The control law for the given state-space model is given by [2]

$$u = \frac{N r_{ges} sin(x_2) x_4^2}{K_g \rho cos(x_2)} - \frac{\alpha sin(x_2)}{K_g \rho} + \frac{K_{fw} x_3}{K_g} + \frac{N^2 r_{ges}^2 \beta}{(\gamma\rho - \alpha\beta) K_g \rho cos(x_2)} \cdot v \tag{6}$$

The feedback linearized system is then controlled by a state space controller

$$v = \mathbf{k}^T \mathbf{z} \tag{7}$$

The utilization of Lie derivatives is necessary for both the control law and the state transformation matrix, represented as $\mathbf{z} = \mathbf{T}(\mathbf{x})$[1].

The main control task is now to stabilize the ball in the so called upper equilibrium state $\mathbf{x}_e = [\varphi_{w_e}\ 0\ 0\ 0]^T$ by the proposed controller.

[1] $z_i = \mathbf{t}_i = L_f^{i-1} h(\mathbf{x})$.

### 2.3 Practical Use of the BOW System in NCS Course

The system was developed to provide students in the nonlinear control engineering course with practical and understandable concepts. The process of deriving the mathematical model and learning mathematical methods (such as Lie Algebra, etc.) was perceived by the students as more engaging and motivating when applied to the real-world model compared to textbook examples.

The calculated model and control algorithms need to be initially tested in the MATLAB/Simulink environment. This was achieved through a guided exercise and a homework project.

In order to illustrate the control behaviour of the system, two test procedures were closely examined. Therefore, the control task can be executed in an intuitive and physically understandable way.

### 2.4 Dead Lock Operation

In the so-called deadlock mode, the ball is stabilized in an upright position (refer to the Fig. 3). During this mode, the wheel speed is maintained at zero. The investigation of the real-world system reveals that the maximum achievable start-up ball angle is measured to be 72.765°. The results shown in Fig. 4 are obtained using feedback-linearizing controller with a controller gain vector of $\mathbf{k}^T = [0\ 100\ 100\ 10]^T$. A comparison between simulation and real-world behavior is depicted in Fig. 4.

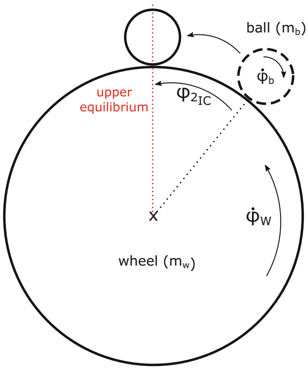


**Fig. 3.** Sketch of the deadlock operating mode [2]

### 2.5 Constant Speed Operation

Acceleration and deceleration exert a force on the ball and rendering constant speed operation ineffective in influencing the ball's behavior. This circumstance gives rise to the second operating mode of the BOW system.

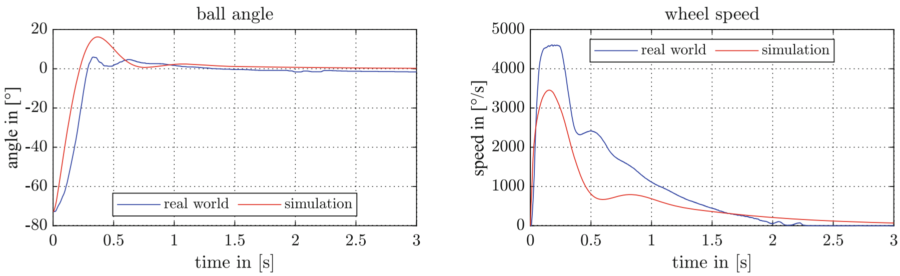


**Fig. 4.** System states for maximum start-up angle of 72.765°

Again, the goal is to stabilize the ball back to its unstable equilibrium position. Furthermore, the test setup can be expanded by incorporating a reference signal. The investigations have revealed that the maximum rate of change of the reference signal is highly dependent on the physical parameters of the system, including the ball, motor, and moment of inertia of the wheel. A reference signal of $r(t) = \varphi_2(t) = 35sin(\frac{1.5}{2\pi}t)$ was employed as a meaningful testing signal. The results, comparing the simulation and real-world behavior, are presented in Fig. 5. All investigations regarding the BOW system have been conducted using the MATLAB/Simulink environment. The Simulink real-time add-on enables operation with Speedgoat, which is a high-speed control prototyping hardware platform.

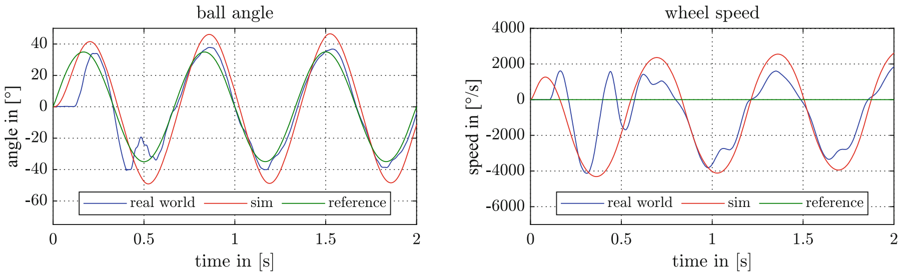


**Fig. 5.** Show mode with 1.5 Hz frequency and ±35° ball angle amplitude

## 3 An Accompanying Laboratory Exercise

The practical component of the course, together with the theoretical aspect, is a crucial component of technical education. Although complex nonlinear systems can be adequately described by sets of equations, it is essential to include a practical laboratory course to motivate students to learn and directly apply these concepts. The lab session for the BOW system is split into different exercises.

**Exercise Part 1** serve as preparation for the actual practical lab experiment. In addition to the lecture, the students are required to develop a nonlinear state space model. As a useful output, the students create a MATLAB *function* to simulate the system model

```
function x_dot = Plant(x1, x2, x3 ,x4, u)
```

**Exercise Part 2** focuses on the practical application of the linearization method and aims to demonstrate its relevance and limitations. Students are required to derive a linearization model around the upper equilibrium to derive a linear (state space) controller.

The linearized system equations of the form

$$\Delta\dot{\mathbf{x}} = \mathbf{A}\Delta\mathbf{x} + \mathbf{b}\Delta u \tag{8}$$

leads to a defined and linearized system equation around the upper unstable equilibrium point which is given by:

$$\Delta\dot{\mathbf{x}} = \begin{pmatrix} 0 & 0 & 1.0000 & 0 \\ 0 & 0 & 0 & 1.0000 \\ 0 & 27.7606 & -1.1240 & 0 \\ 0 & 82.1827 & -0.2604 & 0 \end{pmatrix} \Delta\mathbf{x} + \begin{pmatrix} 0 \\ 0 \\ 177.4462 \\ 41.1078 \end{pmatrix} \Delta u \tag{9}$$

The designed controller is validated using the non-linear model. The controller is used to evaluate both the described *dead lock mode* and the *constant speed mode* are evaluated.

The reference signal is given by

$$\begin{aligned} r &= [x_{w_{ref}} \ x_{2_{ref}} \ \dot{x}_{w_{ref}} \ \dot{x}_{2_{ref}}] \\ &= [\phi_{w_{ref}} \ \phi_{2_{ref}} \ \dot{\phi}_{w_{ref}} \ \dot{\phi}_{2_{ref}}] = [0 \ 0 \ 34.9066 \ 0] \end{aligned} \tag{10}$$

It should be noted that stabilisation using this method is only possible in deadlock mode and not in constant speed mode.

**Exercise Part 3** focuses on finding a non-linear controller using *feedback linearization*. The Eq. 6 shows the final control law. Following Chapter 2.2, the students are expected to practically implement and test the theoretical controller design using MATLAB, on a real system.

Moreover, students can explore the concept of *flat output* directly. While the choice $y = h(x) = \frac{\rho}{r_{ges}\beta} \cdot x_1 - x_2$ for the feedback linearization leads to a suitable result, the output $y = h(x) = x_1$ would not do so. Again, with the help of the controller, both the described dead lock mode and the constant speed mode are evaluated on the real-world system. It is now observed that the stabilization of the ball in the upper unstable equilibrium is achievable with this control law.

The implementation of the laboratory project was crucial in supporting the students' understanding in number of ways, including:

- Limitations of the linearization method
- The need of to use mathematical methods, including Lie Algebra or Diffeomorphism
- Importance of implementing feedback linearization for complex systems

## 4 Conclusion

This approach, i.e., the integration of theory and application on the designed real-world model, teaches students the practical and understandable importance and necessity of nonlinear control theory in our study program Systems Theory. The practical realisation of the experiment but also the implementation within the framework of the associated course is described in this paper. Overall, it was found that a practical implementation of a control theory increases the students' forgetting curve (Ebbinghaus theory).

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# Competencies in Higher Education Standards of Ukraine: Definition, Content and Requirements for the Formation Level

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**Abstract.** The Ukrainian higher education system is in a state of reform, the vectors of which correspond to the Bologna process, sectoral European integration, and the competence paradigm. One of the areas of change is the creation of higher education standards (HES), which are approved by the Ministry of Education and Science of Ukraine. HES contain lists of general and professional competencies that must be developed by graduates of higher education institutions (HEI), as well as expected program learning outcomes. HEI's teachers are mostly dissatisfied with the quality of HES, but do not try to change them, but treat the requirements of these standards formally. This is confirmed by the results of an anonymous survey of 50 teachers of engineering specialties and 50 teachers of medical specialties of Ukrainian HEI. The study is devoted to the reasons for the creation of low-quality HES and ways to improve them. For this purpose, it is proposed to shorten the list and names of competencies with fixation in the Law of Ukraine "On Higher Education"; establish requirements for the necessary levels of formation of all competencies for the bachelor's, master's and doctor of philosophy educational levels; carry out assessment of the formation of competences in parallel with the assessment of students' academic progress according to ECTS; to change the approach to creating and making changes into HES.

**Keywords:** Key Medical Competencies · Key Engineering Competencies · Program Learning Outcomes

## 1 Problem Statement

Since 2018, the Ministry of Education and Science of Ukraine has been actively creating new national higher education standards (HES) for the bachelor's, master's, and doctor of philosophy educational levels [1], which are mandatory during study. HES contain lists of competencies that must be developed in a graduate. The list of both general and

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special (professional) competences provokes criticism from teachers of many specialties regarding their titles and composition [2, 3]. In terms of content, the same competencies have a different composition in different HES and differ from those developed by scientists [4]. There are no requirements at which level these competencies should be formed in graduates of different educational levels [5]. Complete lists of competencies are generally unattainable for each individual graduate, that is, they cannot be formed within the framework of educational programs under the relevant HES.

There are rules governing the formation of HES, but there are no public plans for the sequence and timing of their development. Formally, there is a procedure for public discussion of HES before their approval, but most teachers learn about the HES content already after their approval. At the same time, there are no clear mechanisms for making changes to the HES, if after testing them in practice it turns out that they are difficult or impossible to implement [2, 5].

The analysis of scientific publications on this topic shows that, to a large extent, the problem is related to the Ukrainian society's misunderstanding of the essence of higher education reform, which is inconsistent and long-term, leading to the implementation of the Bologna process and European integration in a long, winding way [6]. Against the background of the approval of HES, there is a gradual decline in the quality of higher education [3, 7], therefore, the rules by which this process takes place are perceived negatively. We drew attention to the fact that every researcher on this issue who publishes articles to defend his thesis avoids criticizing the HES content and the mechanisms of their creation. However, in the professional pedagogical environment of both engineering and medical fields of education, the inconsistency of the created HES with the teachers' needs and expectations is constantly discussed at the practical level. This leads to a formal attitude towards drawing up work programs and syllabi with lists of competencies. These documents for the educational process are often simply copied from similar ones without the necessary understanding.

HES are focused on building competencies. However, in pedagogical practice, there is no evaluation of students' success in the formation of competencies. Instead, students' academic progress is evaluated according to the European Credit Transfer and Accumulation System (ECTS), which allows to evaluate only the formation of such components of competence as knowledge, skills and abilities [2, 5]. There are no criteria for evaluating competencies in the HES and any other regulatory acts. These facts, in our opinion, are a problem that negatively affects both the ability to fulfill the requirements of HES and the quality of higher education in general. However, without conducting an objective study, these opinions remain only the shared beliefs of the participants of the research group.

## 2 The Purpose and Hypothesis of the Study

### 2.1 Purpose of the Study

The purpose of the study is to determine the reasons for the creation of low-quality standards of higher education and to find opportunities for their correction, taking into account the competence approach in modern education.

### 2.2 Hypothesis of the Study

The hypothesis of our research is the possibility of correcting the existing situation by: 1) setting the requirement to reduce the list of competencies from several hundred to several dozen; 2) requirements for clear titles of competences in the Law of Ukraine "On Higher Education", consisting of one word (for example, "digital", "valeological", "linguistic", "communicative" and the like); 3) determination of requirements for the necessary levels of all competencies formation for each level of higher education; 4) the introduction of the mandatory practice of assessing of competences formation (in %) in parallel with the assessment of students' academic success according to ECTS scale; 5) changes in the principle of working groups formation for creation HES; 6) creation of a flexible legislative mechanism for introducing changes into HES.

## 3 Research Material and Methods

### 3.1 Research Reference Framework

As part of the study, we propose to consider HES as high-quality if it meets the following criteria:

1. Realistic (all program learning outcomes can be achieved, competences are formed at the minimum to maximum levels set for the relevant educational level);
2. Clear (contains clear, unambiguous and unblurred wording of all program learning outcomes and competencies, general and professional);
3. In demand (subjectively perceived by teachers and students as a guide to actions during education, and does not exist formally);
4. Flexible (can be adjusted according to the established procedure in case of errors, ambiguous and unclear wording or unattainable goals).

### 3.2 Stages of Research

System analysis and bibliosemantic methods were used in the study. At the first stage of the research, the sociological method (anonymous survey and in-depth interview) was additionally used.

**At the first stage,** we studied the attitude of medical and engineering disciplines teachers to the existing Ukrainian HES by anonymously surveying in two relevant groups with 50 respondents each (100 respondents in total) and with the processing of the results in Google Sheets. A total of 134 teachers of Ukrainian higher education institutions (HEI) were interviewed. 6 questionnaires were rejected for the reasons of reporting incomplete information about themselves, non-compliance with the criteria for inclusion in the group of respondents and contradictory answers to control questions. From 128 qualitative questionnaires, 100 were randomly selected (Table 1).

Random selection was applied with a twofold purpose: 1) to increase the reliability of the statistical result of the sample within the 95% confidence interval according to the rules of factor analysis in pedagogy [8]; 2) to simplify the perception of the results of the study under the condition of 1 respondent ~ 1%, 1 the respondent of the medical teaching profile ~ 1 the respondent of the engineering teaching profile.

**Table 1.** Forming a sample of questionnaires to which answers were received from teachers of engineering and medical specialties in higher education institutions of Ukraine.

| Teaching profile | Quantity of questionnaires | | |
|---|---|---|---|
| | General | Cull | Selected at random |
| Engineering | 61 | 2 | 50 |
| Medical | 73 | 4 | 50 |
| In total | 134 | 6 | 100 |

The criteria for inclusion into the respondent groups were: 1) experience of teaching medical or engineering disciplines in universities of Ukraine for at least 5 recent years; 2) lack of higher pedagogical education, which involves the study of HES creating methods and the competencies essence.

The questionnaire questions were follows:

1. *Are you satisfied with the standards of higher education that you use in your work, in particular with the list of competencies that should be developed in graduates?* Answer options: a) yes; b) no;
2. *To what extent do you understand the content and criteria for the of all competency's formation from the standards by which you work?* Answer options: a) don't understand; b) partially understand; c) understand well; (when evaluating the result, we considered that a) and b) = do not understand; c) = understand);
3. *Do you think it is necessary to evaluate the formation of competencies in students in parallel with their evaluation according to the ECTS system in order to adhere to the competency approach of modern education?* It was possible to choose several answers, and among them are the following: a) no, ECTS is enough; b) no, you don't need to spend time on it; c) yes, if it is required by law; d) yes, it will help to improve the educational process;
4. *If you consider the existing higher education standards to be of high quality (according to the criteria of "realistic", "understandable", "demanded", "flexible") – skip this question. If you consider the existing higher education standards to be of poor quality, what is the reason?* It was possible to choose several answers, and among them are the following: a) standards are created by ministry officials who are not interested in the convenience of using them in practice; b) approved standards do not take into account or insufficiently take into account scientific research in the discipline; c) write your version.

Additionally, three medical and three engineering teachers, without a pedagogical education, who participated in the HES creation, were interviewed by the confidential in-depth interview method. They were asked questions about their participation in the work of standards-making groups: participation in the work was real or formal, whether comments and suggestions were taken into account in the HES final version, whether there was a lack of special knowledge about the competences and principles of HES creating?

**At the second stage of the research,** we studied Ukrainian HES [1], approved on May 22, 2023 (Table 2), for the purpose of teaching students a healthy lifestyle (i.e. for the purpose of forming valeological or health-saving competence). The competence chosen for research is one that is often found in HES, and its importance cannot be doubted considering the value of health both for each person and for the whole society. Using the example of valeological competence, we studied the issues of brevity in formulating the titles of competences, their demarcation/combination with other competences. All possible formulations of the requirement to teach students to lead a healthy lifestyle, maintain and strengthen their health, and prevent diseases were taken into account.

**Table 2.** The number of studied standards of higher education at the bachelor's, master's, and doctor of philosophy levels.

| Educational level | Bachelor | Master | Doctor of philosophy |
|---|---|---|---|
| Number of standards | 109 | 100 | 46 |
| In total | 255 | | |

We have more carefully studied HES that correspond to the specialty of the research group members: 222 (Medicine; masters); 141 (Electric power engineering, electrical engineering and electromechanics; bachelors); 142 (Energy engineering; bachelors, masters); 143 (Atomic energetics; bachelors).

In these HES, the lists of general and professional competences and the expected program learning outcomes have been analyzed. The research question concerned the theoretical possibility of forming the listed competencies in HEI graduates in full.

## 4 Research Results and Their Discussion

### 4.1 Results of the 1st Stage of the Study and Their Discussion

Based on the results of an anonymous survey of 100 HEI teachers of Ukraine, we found that 92% of respondents are not satisfied with HES, in particular with the list of competencies that they should develop in graduates. 73% of respondents do not understand the content and criteria for evaluating the competencies formation listed in the HES of their teaching profile. 84% have a formal attitude to the need to form the specified competencies in accordance with their content in the HES: only 34% of respondents consider it necessary to spend time on additional assessment of competence formation in parallel with ECTS assessment.

91% of respondents consider the approved HES to be of poor quality (according to the criteria of "realistic", "understandable", "demanded", "flexible"). 86% of respondents believe that HES are created by ministry officials who are not interested in the convenience of using them in practice. 39% of respondents believe that HES approvals do not take into account or insufficiently take into account scientific research in the discipline. 31% of respondents say that HES tasks are not concise or vague. 25% speaks of too high requirements that cannot be fulfilled within the framework of HES. 2% indicate the presence of content errors in HES. Although 5% answered the question, which showed that they consider the existing HES to be of poor quality, but did not determine the reasons (their answers were approximately as follows: “it is difficult to say”). This stage of the ascertainment experiment confirmed our own attitude towards the existing HES. We also received confirmation of the need for changes proposed in points 1–4 of the research hypothesis.

It should also be noted that the assessment of academic success of students on the ECTS scale, which allows for the assessment of only knowledge, skills and abilities, leaves the motivational, value and personal components of competencies unassessed [5; 7]. At the same time, the most popular distance education platforms in Ukraine (in particular, Moodle) have all the necessary tools for assessing the formation of all components of competences. But these functions are not used by teachers due to the lack of requirements in the HES or other normative acts of Ukraine that regulate the educational process [9; 10]. At the same time, it is impossible to replace assessment of competence formation with ECTS assessment, because assessment of personal and motivational-value components of competence requires not tests, but questionnaires of psychological and pedagogical content, for which it is generally difficult to give grades (often it is only possible to assess progress in %) [11].

An in-depth interview showed that specialists without special knowledge about the competences and principles of HES formation are involved in the creation of HES. Their participation in the work groups is often formal, and their suggestions and comments are often not taken into account in the final version of the HES. Two out of 6 interviewees even said that they regret their agreement to participate in the creation of HES, because they are not satisfied with the final result.

### 4.2 Results of the 2nd Stage of the Study and Their Discussion

It has been established that the requirement to form a healthy lifestyle among HEI graduates of Ukraine is present in the vast majority of approved HES of all fields of education and all levels of education (bachelor, master and doctor of philosophy). It was found that the title and content of valeological (health-saving) competence differ significantly in different educational standards. There are a total of 6 options for the competence title and the composition of the task of teaching a student to lead a healthy lifestyle with other HES tasks: 1) direct training to lead a healthy lifestyle; 2) formation of health-saving or valeological culture (a broader concept than health-saving competence [4, 12]); 3) formation of health-saving competence with an emphasis on environmental issues; 4) “use various types and forms of physical activity for active recreation and leading a healthy lifestyle”, or “strengthening health through physical exercises and physical activity”; 5) “to organize an educational space in compliance with the principles of safety of vital activity, sanitation and hygiene, psychological comfort”; 6) physical and mental health-saving, life rescue, provision of premedical assistance.

Therefore, in the absence of a clear definition of valeological competence in the Law of Ukraine “On Higher Education”, in different HES not only are its different definitions provided, but the authors of HES also consider this competence as part of various educational tasks. We did not find requirements for the level of formation of this competence in any HES. The conducted analysis confirms the need for a clear definition of this competence, like many others, in the law in order to avoid verbosity, blurred wording, which should simplify the understanding and practical use of HES by teachers.

In our opinion, changes to the HES can be made at the initiative of any national university that has relevant disciplines and has concluded that the quality of the HES is insufficient and has applied to the Ministry of Education and Science of Ukraine in accordance with the established procedure. The Ministry should start the procedure for making changes to the HES in a short term (within a month), and in the matter of changing the definition or competence title, contact the Committee on Education, Science and Innovation of the Verkhovna Rada (Parliament) of Ukraine. In our opinion, the working groups for the creation of HES must necessarily include only specialists who have two degrees: one in the HES specialty, the other in pedagogy. Regarding competences, before being included in the group, they must pass a test on knowledge of the theory of competences.

Analyzed approved HESs for 141–143 and 222 specialties have common weaknesses: the titles of the vast majority of both professional and general competencies in them consist of whole sentences; similar standards have different titles in different standards; requirements for the levels of competence formation are not defined; there are too many competencies that need to be developed. Thus, the medical HES contains a list of 25 professional competencies, which can be reduced to 3 key ones (diagnostic, therapeutic and prophylactic).

Existing requirements to form competencies in each graduate for HES 141–143 and 222 cannot be fulfilled, because they cover all future engineering (in the areas chosen for research) and, accordingly, medical specialties. That is, one standard is written for doctors and engineers of all future specialties. For a representative of each individual specialty, the level of familiarization with most competencies is sufficient, which corresponds to the initial levels of their formation according to B. Bloom's taxonomy [13].

The fact that for many academic years in a row there are no HES in some specialties in which students are taught and diplomas of higher education are issued draws attention. For example, from the specialty 141 (Electric power engineering, electrical engineering and electromechanics; masters) and 143 (Nuclear energetics; masters).

## 5 Conclusions

According to the results of the conducted research, we consider the hypothesis to be confirmed. To improve the quality of HES, we propose to reduce the list of competencies from several hundred to several dozen (with the definition of key competencies); give clear one-word titles to all competencies; write down the definition of competences in the Law of Ukraine "On Higher Education"; establish requirements for the necessary levels of formation of all competencies for the bachelor's, master's and doctor of philosophy educational levels; to evaluate the formation of competencies (in %) in parallel with the evaluation of students' academic progress according to the ECTS scale; change the approach to creating and modifying HES.

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# Collaborative Experiential Learning for the Study of Noise Pollution and Improvement in Soundscape Design

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**Abstract.** By exposing students to activities that include listening and being aware of the noises and sounds of the environment, they can develop an environmental and social awareness that enables empathetic attitudes towards the users of the space of the specific place. The objective of this work is that, from a collaborative and experiential experience, students can generate awareness of how important it is to consider a good urban design of the soundscape for the welfare of the population and users of it; another objective is that students develop critical thinking skills for decision making. The methodology proposed here presents an interactive approach and educational innovation in the teaching-learning process around engineering. To achieve the immersion of students in experiential learning, an activity was designed to be carried out in an intense week of work, during which students must perform sound walks in an urban area to obtain measurements of sound levels (noise in dB) generated by daily activities, the decibels measured had an average of 65 dB, from these results, they make proposals for improvement of urban design to reduce noise pollution. A survey carried out among the students shows averages above 9.0 in the students' approval of the activity. In the presentation of the analysis of the results by the higher education students, it was possible to observe the development of critical thinking skills, while expressing how the activity helped them to become aware of the importance of knowing about noise pollution.

**Keywords:** Experiential learning · Educational Innovation · Higher Education · Soundscape · Urban design · Noise Pollution

## 1 Introduction

In 2020 Howard presents a review and comparison of Experiential Learning (EL) among different authors; this work defines experiential learning as learning where students are actively involved and committed in the process of developing skills, knowledge and

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competencies. They specify that experiential learning takes place in a specific place and time, i.e., the place where the learning activity takes place has both a geographical and conceptual significance, and additionally argue that interactions and contact with people are key in the development of this type of learning. They conclude that embodied cognition is a central consequence of physically immersing learners in the learning space [1].

Sound has been present in human life since the beginning of civilization. Over the years, sound has experiment transformations in its source. The original source was nature, but as time passed by, men have been able to generate sounds. Nevertheless, they have suffered transformations into what we now identify as noise. To understand differences, between noise and sound, noise will be defined as those sounds that are no longer pleasant for the ear. Currently, in large cities, people are highly exposed to sounds classified as noise, which can have both, physical and mental health effects [2].

Environmental sounds or soundscapes are not a simple physical element, they are considered a strategic part in the study of environmental acoustics. These studies belong to a system of relations between humans and the environment. According to Rehan, "the qualitative perspective of sound, which includes sonic diversity and acoustic ecology, is a neglected area of urban design" [3] and it is a key part to define the identity of a place. In recent years, studies have been carried out on how different noises can affect the perception of public spaces and their soundscape [4–7]. Although studies into sensory expectations of consumer products, retail and entertainment environments have emerged.

Literature suggests an opportunity field for learning in areas of engineering and industry 4.0 from empathy, which is presented as one of the great challenges of the 21st century [8]. As review shows, by exposing students to activities that include listening and being aware of the noises and sounds in the environment, they can develop environmental and social awareness that enable empathy attitudes toward the space users of the specific place [9]. In the work of Han and Varan [10], is shown that there is a correlation between empathy and interactivity, whenever interactivity increases, empathy increases too.

The objective of this work is to share with the readers that, from a collaborative and experiential experience, students can generate awareness of how important it is to consider a good design of acoustic spaces for the welfare of the population and the users of the same, while students develop critical thinking skills for decision making. The methodology proposed here presents an interactive and innovative approach to the teaching-learning process in engineering that can be easily replicated in other environments.

## 2 Methodology

To achieve the immersion of students in experiential learning, an activity was designed to be carried out in an intense week of work, during which students must go out into the streets of an urban area to take measurements of sound pressure levels (noise in dB) generated by the daily activities carried out by users of the spaces. Based on these results, they make proposals for improvements in urban design to reduce noise pollution.

Mainly students of architecture, civil engineering, music production engineering, sustainable development engineering and physical engineering participate in it. Students are divided into teams of 4 members.

The activities that the students carried out in urban areas were organized in 3 stages:

1. Urban diagnosis of the study area and definition of the monitoring points.
   a. Define the study site: A place with a highly perceived identity.
   b. Map the schools on the site to settle the monitoring points.
   c. Define the local regulations.
2. Sound and noise analysis of each monitoring point.
   a. Record the decibels of each point in 3 different lapses of time (morning, evening, night).
3. Analysis and interpretation of results.
   a. Noise analysis
   b. Mapping the results.

### 2.1 Urban Diagnosis of the Study Area and Definition of the Monitoring Points

For the first stage, the site San Pedro Cholula was select in the metropolitan area of Puebla-Tlaxcala in Mexico. On the area of 4.3 km$^2$ 17 points were settled, the site has 9 schools that were taken in consideration with other eight points of general interest, they include: a church, a park, a restaurant-bar, a market, a cemetery, a gymnasium, a monument at the intersection of streets and the house of municipal culture.

The Official Mexican STANDARD NOM-081-SEMARNAT-1994 [11]. "Which establishes the maximum permissible limits of noise emission from fixed sources and its measurement method", The maximum permissible limits of the sound level in weighting "A" emitted by fixed sources are: from 6:00 am to 22:00 pm are 68 dBA and from 22:00 pm to 6:00 am are 65 dBA.

In the study, a multidisciplinary group of students and 3 professors in charge of the investigation participated in soundwalks. San Pedro Cholula area was divided into 4 regions, the students worked in teams of 4 and each team worked at 4 or 5 points within the assigned region, for each zone, an educational center was taken as a reference point, from which the measurements of the 5 points were made, all within a maximum distance of 500 m.

### 2.2 Measurement of Noise Levels

For the second stage, measurements of noise levels were registered with three sonometers of 2270 B&K. The sonometers were previously calibrated with a calibrator 4232 of B&K. The measurements were taken along three-week days in three different hours in every settled point. Using sonometers use sound level meters to measure sound pressure level (SPL dBA) at three different times 9–10 h, 14–15 h and 17–18 h for three days. Measurements are taken in one-minute series, and three to five measurements should be taken at each assigned time. At the end of the day, we have at least 9 measurements of 1 min per reference point.

### 2.3 Analysis and Interpretation of Results

The following procedure was carried out, in order to analyze the information collected in soundscapes of the site: *Determine insights out of the information gained*. Carry out the analysis of the data obtained using simple descriptive statistics. *Design soundscape proposals for the site according to the insight*s. Based on the results obtained, it is expected to be able to make a proposal to improve the public space. *Information map for further studies.* Record the results obtained on a map, so that the experiments can be reproduced, and urban spaces can continue to be improved.

### 2.4 Evaluation of Participating Students

On the other hand, to monitor the development of the students, they are evaluated based on a table of criteria (see Table 1) if the objective of the activity carried out is met. Where 1 is the minimum achieved and 5 the objective is met.

**Table 1.** Evaluation instrument

| Critical thinking | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| 1. Diagnose situations based on strategic thinking appropriate to the context | Does not identify problem, does not contextualize | Identifies the problem but does not contextualize | Identifies the problem but contextualizes poorly, does not reach the strategic diagnosis | Contextualize, diagnose the problem, and apply strategic thinking | Contextualizes, diagnoses the problem and applies strategic thinking to generate a solution proposal |
| 2. Develop arguments consistent with the context of the problem | It generates ideas with weak relation to the context that are poorly organized and poorly written | It generates ideas with weak relation to the context, with little organization and order, with deficiencies in the writing | It generates arguments with weak relation to the context but well organized and written | Craft consistent and context-related arguments | Craft arguments that are consistent, concrete, and strongly related to the context |

At the end of the activity, the students answer a survey about the immersion activity carried out during a week, with questions such as the following:

- I developed the skills that the teacher said we would address through the activity.
- Through the activity I managed to realize the contribution of value that I can make to the community, organization, or society in general.
- I believe that I can apply what I have learned in other situations.
- The activity represented a different challenge than my classes.
- In the activity in which I participated there were spaces for reflection on the learning acquired.

This survey is designed on a scale of 1 to 10, where one is totally disagree and ten is totally agree. This survey is applied by the institution ate the end of the academic courses; it is called "Student Opinion Survey" (ECOA for its acronym in Spanish).

Additionally, each student writes a reflection on the activity carried out and whose objective is to involve them in the collaborative learning experience, this reflection reflects whether the idea that an activity that involves an approach to reality positively impacts students is fulfilled.

# 3 Results and Discussion

## 3.1 Analysis of Students' Data

Table 2 show the averages of the SPL registered at the three times proposed for the study at the 17 points corresponding to study zone, it can be note that there is a variation in the SPL records, this is due to the different economic and mobility activities that are carried out in each area at different times, however it can be seen that the recorded sound levels are between 50 dBA to 80 dBA, maintaining an overall average of around 65 dBA SPL. Due to the results shown on the table, the national regulations on NOM-081-Semarnat the maximum decibels allowed near schools is 55 dBA. Nevertheless, is just one of the schools (marked on black) that accomplish the regulations.

**Table 2.** Sound pressure level (dBA SPL)

| Point | Place | dBA SPLavg | var coeff | dBA SPLmin | dBA SPLmax |
|---|---|---|---|---|---|
| P1 | School "La Piramide Cholula" | 55.4 | 4.3 | 48.0 | 62.0 |
| P2 | Church" San Gabriel Arcángel" | 55.7 | 6.4 | 50.0 | 70.0 |
| P3 | School "Juan Carlos Bonilla" | 56.2 | 5.0 | 50.0 | 67.0 |
| P4 | Institute Idia | 58.9 | 6.1 | 50.0 | 69.0 |
| P5 | School "Jose María Lafragua" | 59.3 | 3.7 | 53.0 | 66.0 |
| P6 | School "Lázaro Cárdenas" | 61.1 | 3.7 | 55.0 | 68.0 |
| P7 | Park "Plaza Concordia" | 57.0 | 3.6 | 50.0 | 64.0 |
| P8 | Institute "García de Cisneros" | 61.1 | 2.9 | 56.0 | 67.0 |
| P9 | School "Yoliztli De Cholula Ac" | 64.1 | 3.6 | 58.0 | 72.0 |
| P10 | School "Intercanadiense" | 63.8 | 2.6 | 59.0 | 68.0 |
| P11 | Municipal Market | 64.6 | 4.8 | 58.0 | 72.0 |
| P12 | Cultural House | 64.8 | 2.0 | 60.0 | 67.0 |
| P13 | Xelhua Monument | 64.9 | 5.3 | 56.0 | 75.0 |
| P14 | School "Narciso Mendoza" | 67.1 | 4.0 | 61.0 | 74.0 |
| P15 | Cimera Gym | 66.8 | 3.5 | 59.0 | 72.0 |
| P16 | Municipal Pantheon | 68.1 | 3.6 | 62.0 | 75.0 |
| P17 | Enamorada Restaurant-Bar | 78.9 | 3.1 | 75.0 | 86.0 |

In Fig. 1, a bubble chart is presented in the plan of the areas where the study was conducted, the diameter of the bubbles represents the perceived loudness and the number corresponds to the point where the recordings were made. The knowledge gained from the measurements allowed us to identify links and patterns in noise that can be applied to the design of soundscapes in the big city.

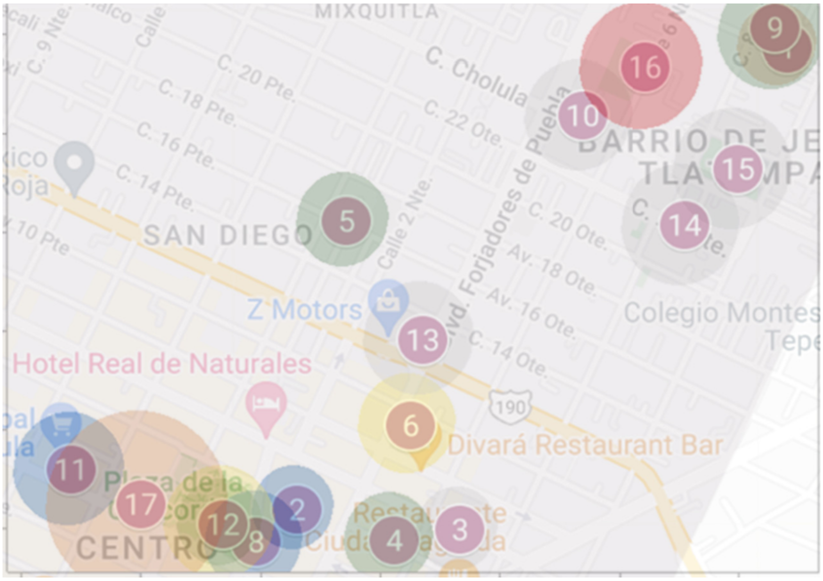


**Fig. 1.** Bubble graph perceived loudness

Another factor that it must take into account is that the perception of sound that can be registered with a measuring device does not necessarily correspond to that perceived by the human ear, due to this it is important to use psychoacoustics, with which they can be related the physical characteristics of a physical stimulus and the psychological response it elicits in a subject; Since the volume is only a subjective of how strong a sound is, it will differentiate what is perceived measured in dBA and what is registered with the sound level meters.

Figure 2 shows (logarithmic scale) the relationship between measurements made using the sound level meters and the perceived volume calculated using Eq. 1,

$$\psi = 2^{L/10} \tag{1}$$

where L is the sound level measured in dB and $\psi$ is perceived sound volume of pure tones, therefore, the sound level is an indicator of the perceived volume [12].

It is observed that at a measurement of 55 dBA the sensation is only 48 dB, while for the maximum register of 68 dBA SPL up to 110 dB can be perceived, thus generating an idea of silent or bustling spaces, so even if it is not found by above the norm allowed for public spaces (65 dBA) if a sensation of noise is generated, which makes it easier for people to identify it as a more or less beautiful space, among other characteristics. As a complementary part of the work, a catalog of sounds by area was made; some of the most frequent identified sounds at all points were: cars, birds, the sound of the wind

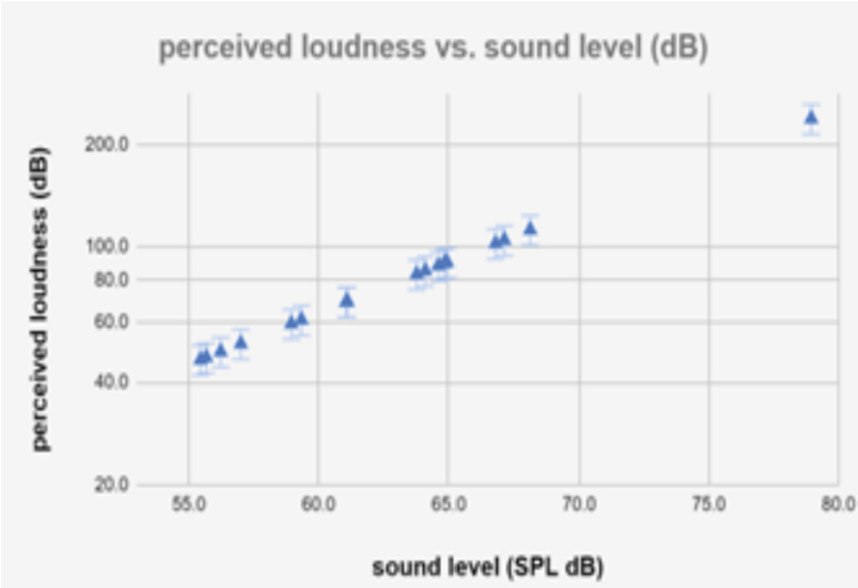


**Fig. 2.** Perceived sound based on decibel records.

in the trees or bushes or the murmur of people, and also more localized sounds such as: running water, cuts on the board, music, children playing; which will be very useful for registering a sound map for future studies, Fig. 3 shows an example of a sound map of the 5 points studied in one of the areas of San Pedro Cholula.

Once the sources of the sounds were identified and a difference was made with the sources that produce hearing pollution, students participating in the study were asked to brainstorm how an improvement could be made in the soundscape, among the proposals that students made to improve the acoustic quality and at the same time maintain a pleasant view, is the use of a natural barrier (shrubs and/or trees) that serves to absorb or reflect the sounds and at the same time causes the increase of pleasant natural sounds such as birds or the sound of the wind. All teams agreed to propose an improvement of the streets and signals to reduce the noise caused by traffic and passers-by.

A similar study was carried out by Engel et al. [5] in Aachen, a German medium-sized city, the 30 participants in their study answered a questionnaire divided into two parts, the first part referring to the comfort of the area and the other to acoustic perception, while they recorded the sounds of the area. They found a correlation between the soundscape and the perception of well-being. Radicchi [13] proposes a method called "open-source soundscapes" for the study of soundscapes, but his study is aimed at quiet spaces. This study focuses on areas with no high noise levels. However, they mention the importance that a space with less noise provides a better feeling of well-being within our experiment the data acquisition was carried out in the study spaces, values of around 65 dBA were found, according to Maristany [14] and these values are appropriate for the study of soundscapes. Lu, et al. [15] carried out a study of the noise produced by traffic and how it affects the perception of transients, just as we returned values between 50 and 70 dBA,

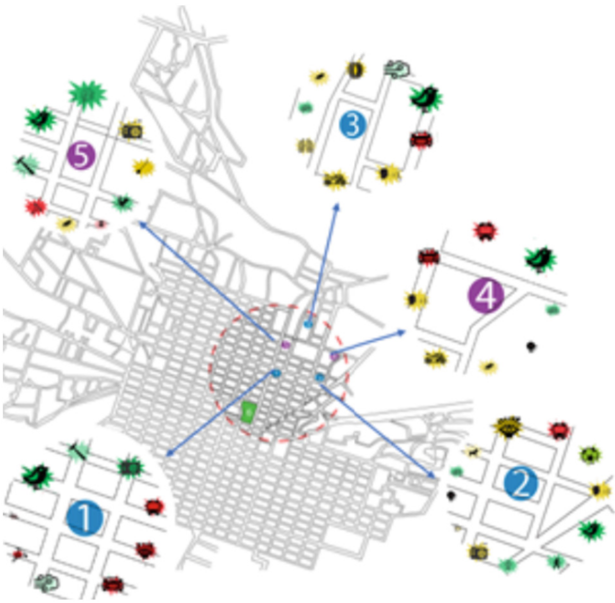


**Fig. 3.** Sound mapping

they concluded that deliberately increasing natural sound could be an effective method to improve the quality of the soundscape in the high noise area. Like us, they mention that these findings can provide a reference that helps to know, value and at the same time design urban spaces with better quality in both visual and sound spaces. Finally, we can return to the proposal of Kang, et al. to implement sound maps, which is based on three points: 1) Recognition and profile of sound sources. 2) Prediction of the perceptual attributes of the soundscape and 3) Implementation of soundscape maps [16].

### 3.2 Collaborative Learning Experience

An important part of the activity was the presentation of results by the students, who made a presentation of the analysis of their data, as well as the sound maps made and proposals for improvement of the urban acoustic landscape. Among his proposals are to build green walls, check the state of the roads, smart cruises (coordinated traffic lights) and well-defined pedestrian areas.

During the week that the activity was carried out and considering the presentation of results, the three teachers involved in the experiential activity evaluated the students participating from the evaluation instrument presented in Table 1. In general, it was agreed that on average, the students reached level 5 in the development of skills. That is, the students showed:

> *"Contextualizes, diagnoses the problem and applies strategic thinking to generate a solution proposal." And "Craft arguments that are consistent, concrete, and strongly related to the context".*

At the end of the activity, it was possible to register that the students satisfactorily completed the experiential learning activity, through the evaluation rubrics it was possible to monitor the development of their competences, on the other hand the student survey shows averages above 9.0, this is show in the Table 3.

**Table 3.** Students' perception of activity

| Questioning | Average | Dev |
|---|---|---|
| I developed the skills that the teacher said we would address through the activity. | 10 | 0.0 |
| Through the activity I managed to realize the contribution of value that I can make to the community, organization, or society in general. | 9.63 | 0.7 |
| I believe that I can apply what I have learned in other situations. | 9.75 | 0.66 |
| The activity represented a different challenge than my classes. | 9.12 | 0.93 |
| In the activity in which I participated there were spaces for reflection on the learning acquired. | 9.75 | 0.43 |

As mentioned above, students were asked to write a reflection on how the experiential collaborative activity impacted them, some of the students' comments are presented below:

"This activity helped me understand the importance of noise regulations in the city, since they are very important in my career" **Engineering student in music production.**

> "As **a student of the engineering degree in sustainable development**, I have understood that hearing pollution is very harmful."

"With the Urban Methodologies class, I became more aware of my surroundings, I know how I can boost the development of a better city" **Architecture student.**

"Bad design on streets or avenues increases noise pollution" **Civil Engineering Student.**

Habash [17] presents a recent study in engineering students of the implementation of experiential learning in which he answers several research questions about the success of EL, he states that EL provides an advantage in the development of skills in students, he also mentions that the part of collaboration, exhibition and sustainability have a positive impact on experiential learning. This coincides with what is observed in this paper.

Prapulla et al. [18] present a study on the different techniques for strengthening the development of critical thinking, in this study they mention that EL not only promotes self-learning, but also allows the application of the concept in problem solving, social concern and problem solving skills in the real world. In the present work we agree with their statement that EL is implemented in a specific way (thinking or feeling or perceiving, etc.) and that it occurs when new knowledge is added to existing knowledge and vice versa, therefore, we can affirm that the students who participated in this collaborative experiential learning activity achieved the development of critical thinking skills.

## 4 Conclusions

The students were able to record the sound decibel measurements in urban spaces, with the analysis of these results they were able to detect which spaces were above the permitted levels and thus be able to propose solutions to reduce noise pollution.

To acquire sound level data and identify the sources that produce it, live measurements (sound walks) of the sounds were carried out. The measured decibels have an average of 65 dB. From this information, noise maps can be made that allow us to expand the study in soundscapes, as well as to detect more clearly and assertively the sound sources that produce annoying sensations, to make a proposal for the improvement of the acoustic urban landscape, without affecting the improvement of the visual urban landscape. In the presentation of the analysis of the results by the students, it was possible to observe the development of the critical thinking competence, while they expressed how the activity helped them to generate awareness of the importance of knowing about noise pollution.

It can be concluded that the methodology presented here to carry out a collaborative activity of experiential learning that allows studies of soundscapes, can be reproduced in different cities and provide not only knowledge to students but a way to develop tools and skills such as critical thinking that allows them to make the best decision to make proposals that provide the optimal development of an urban soundscape that allows maintaining a visual landscape.

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# Design of Teaching Platform for Process Automation

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**Abstract.** Industrial controllers and plants are crucial tools for teaching in universities, colleges, and institutes to bridge the gap between academia and industry. This paper introduces a multi-functional industrial plant that employs a programmable logic controller (PLC) for process automation. The industrial plant consists of a pump, a heating system, various types of sensors (such as pressure and temperature sensors), and different valves (including manual acting, pneumatic, and proportional solenoid valves), which can be configured in different combinations to serve different process control purposes. To expand the input and output capabilities and distribute the input/output (I/O) modules, a Siemens SIMATIC ET 200SP I/O system is connected to a Siemens SIMATIC S7-1200 PLC using Profinet communication networks. A case study is provided to verify the effectiveness of the process control station.

**Keywords:** Industrial plant · programmable logic controller (PLC) · process control · process automation · education

## 1 Introduction

Laboratory and experimentation are vital for teaching and learning, especially in engineering fields where practical skills and problem-solving abilities are necessary for professional advancement, as it has already been highlighted by several studies [1–3]. In the field of control engineering, it is essential to provide students with accessible laboratory equipment that can prepare them for real-world challenges. While mathematical descriptions and theoretical concepts are important, practical experience is equally crucial for effective control education. Therefore, the development of teaching platforms that combine theoretical knowledge with practical applications is highly desirable. Such teaching platforms can enable students to gain hands-on experience and enhance their problem-solving skills, allowing them to tackle societal-scale challenges in the future [4].

As an important branch in automation and control, process control and process automation are closely related to industrial applications, thus, the education of process control is critical to bridging the gap between academia and industry. Real industrial plants are not often used for such teaching because they

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are more complex and more expensive than standard teaching setups like DC motors [5] or ball and beam systems [6], which are typical didactical setups that are representative of industrial plants with similar dynamics.

In addition to industrial plants, industrial controllers, for example, programmable logic controllers (PLCs), are also essential. PLCs have been used in teaching and learning, such as the control of test boxes [7], hardware-in-the-loop (HiL) simulation [8], and the control of the simulation of a process that runs in another PLC [9].

To address the aforementioned issues, in this paper, a teaching platform based on a complex real industrial plant and PLCs is constructed for process automation, which can be used for a variety of process control tasks, including water level control, flow control, pressure control, and temperature control, through different configurations of pumps, sensors, and valves.

## 2 Overall Platform Description

The platform includes a complex and multi-function process control plant, corresponding to a Siemens SIMATIC S7-1200 PLC controller, and a decentralized input/output (I/O) system (Siemens SIMATIC ET 200SP), connected to the PLC using Profinet. The platform can be called a process control station.

The process control station is designed for industrial automation training in vocational training and university education, which facilitates industry-oriented training. In addition, training can be delivered to instill team spirit, willingness to cooperate and organizational skills.

Through training projects, the following actual phases of a project can be taught: 1) planning, 2) assembly, 3) programming, 4) tuning, 5) operation, 6) maintenance, and 7) fault detection and localization. Didactic content covering the following topics can be taught:

1) *Mechanics*: Mechanical measurement and adjustment of a station.
2) *Pneumatic*: Connection of pneumatic components and linear pneumatic drives.
3) *Electrical engineering*: Correct wiring of electrical components and interpretation of schemas.
4) *Sensors*: Correct use of various types of sensors and adjustments.
5) *Tuning*: Development of a production system and sensor calibration.
6) *Troubleshooting*: Systematic troubleshooting in a production system.

### 2.1 Process Control Plant

The hardware of the process control plant is shown in Fig. 1. The process control plant combines four control loops, namely, level control, flow control, pressure control, and temperature control, with analog and digital sensors and actuators. By means of the appropriate controller, it is possible to use them individually or combined (for example, through a cascade control).

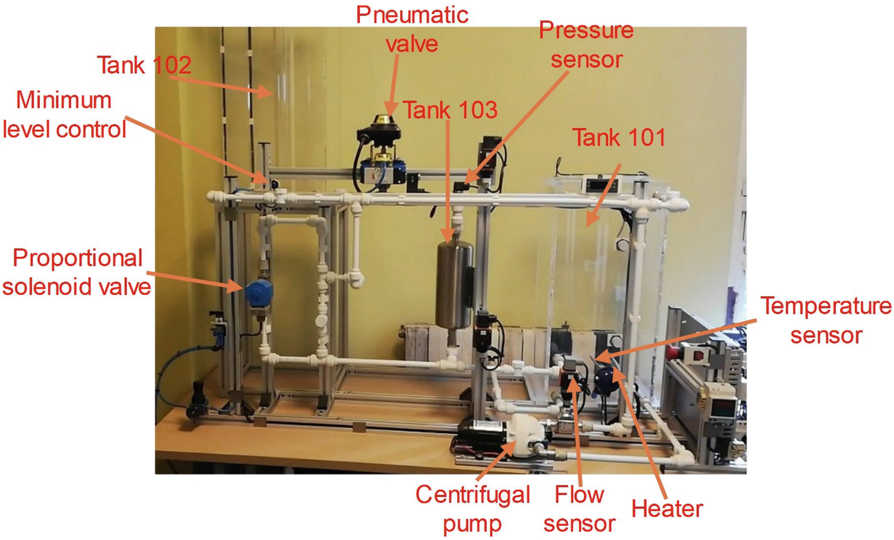



**Fig. 1.** Hardware of the process control plant.

The most prominent components of this plant are as follows:

1) *Pump*: The centrifugal pump is responsible for the distribution of fluid (water) from Tank 101 to the duct system. The pump is controlled by a variable speed drive with an input signal of 0–10 V, coming from an analog voltage output of the SIMATIC ET 200SP, and the variator provides a variable signal of 0–24 V proportional to 0–10 V, since the supply of the pump is 0–24 Vdc.
2) *Pneumatic valve*: The pneumatic valve, which is a ball-type valve, opens and closes by a pneumatic control of the SYPAR type. The control is carried out by a NAMUR-type solenoid valve, and the status of the solenoid valve is indicated by limit switches integrated in the indicator capsule (yellow-open, red-closed) mounted on the actuator. The valve can also be opened manually by means of a device located in the actuator.
3) *Level detection*: Two capacitive-type detectors are used for limit-level detection in Tank 101. They are located at the rear of the tank, mounted on a support. The activation signals are connected to the digital inputs of the SIMATIC ET 200SP.
4) *Proportional solenoid valve*: The proportional solenoid valve is a 2/2-way valve for fluid control. A coil allows the adjustment of the slide, so that it is possible to vary the flow through it by controlling the current that passes through it.
5) *Level, flow, pressure, and temperature sensors*: Different types of sensors are deployed to detect the level, flow, pressure, and temperature of a complex industrial plant for different control purposes.
6) *Heater*: Two submersible electric resistors allow heating of the liquid from the Tank 101, which are controlled by two relays. The heating elements are

of the On–Off type, so the pulse width modulation technique is used in their control.

7) *Manual acting valves*: The shut-off valves do not need any adjustment, which allows configuring the different hydraulic circuits of the plant quickly and easily.

### 2.2 Corresponding Piping and Instrumentation Diagram (P&ID)

In light of the constraints posed by the limited visual representation of the hardware discussed earlier, this subsection includes a P&ID, as shown in Fig. 2, to provide a clearer illustration of the industrial plant.

It can be seen that different process equipment, instrumentation, sensors, and actuators are labeled in Fig. 2, for example, the pump is identified as P101 and the pneumatic valve is identified as V102.

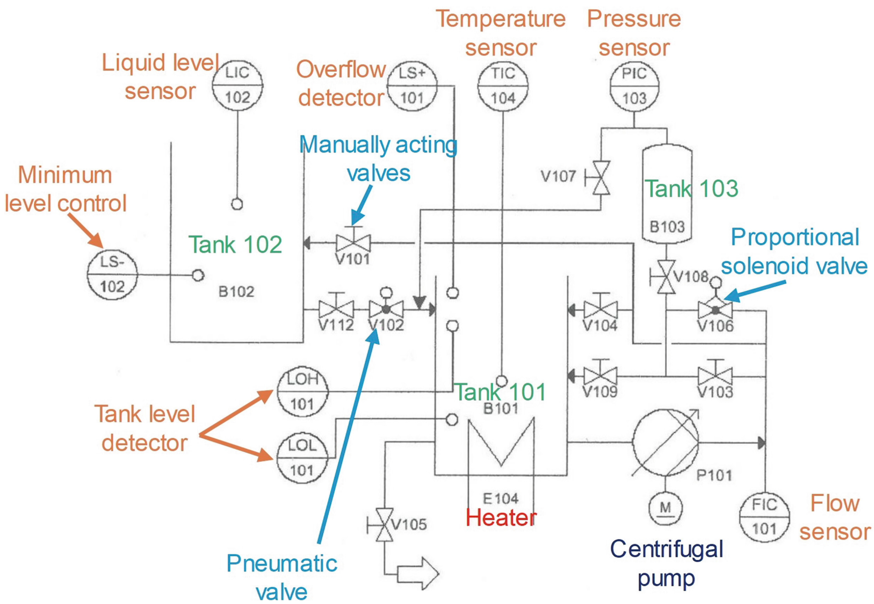



**Fig. 2.** P&ID of the industrial plant.

For the detection of the height of the water level in Tank 102, a level sensor (LIC102 in Fig. 2) was mounted above the tank in a methacrylate tube to avoid distorting the actual measurement of the sensor that uses ultrasounds. For flow measurement, a vane flowmeter (FIC101 in Fig. 2) is used, which provides a current output. The flow sensor is located at the exit of the P101 pump. The pressure measurement is performed by a pressure transducer (identified as PIC103 in Fig. 2) based on the piezoelectric effect. A temperature sensor (TIC104 in Fig. 2) of the PT100 type (platinum resistance), inside a standardized protection capsule, serves to measure the temperature, and is presented as a current value. The manually acting valves, including V101, V103, V104, V105, V107, V108, V109, and V112, can be opened and closed manually with a 90° turn.

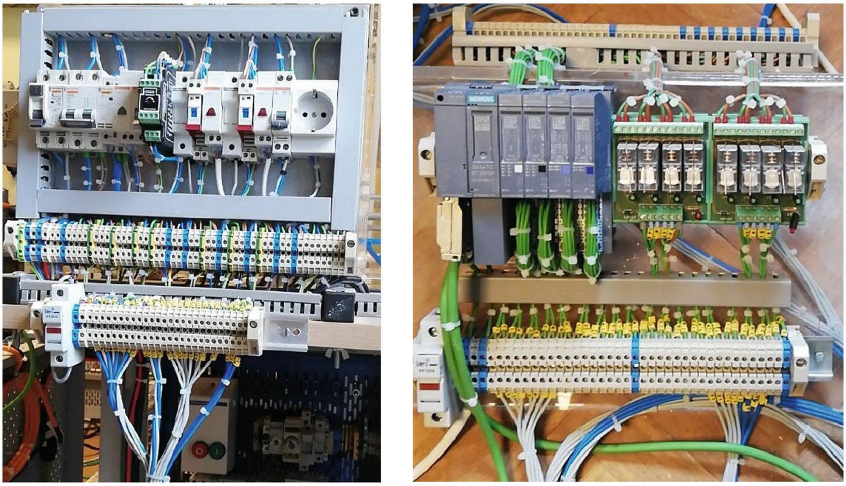
There are protections for the hardware system. For example, the maximum level of Tank 101 is monitored by a buoy that serves as an overflow sensor. If the level rises excessively, the cylinder floats and moves upward, activating a magnetic contact by means of two magnets located in the float. The digital signal is connected to the digital inputs of the SIMATIC ET 200SP. This signal should trigger an alarm, as well as some kind of safety sequence that, for example, closes valve V102 and pumps water to the Tank 102. It is identified as LS+101.

Depending on the design of the plant, it will be possible to perform different control tasks including: 1) Two-point level control via analog signal; 2) Continuous level control via analog signal; 3) Continuous flow control with a pump as a controlled system and pulse signal (frequency) of the system status; 4) Continuous flow control with a proportional solenoid valve as a controlled system and pulse signal (frequency) of the system status; 5) Continuous flow control with a pump as a controlled system and voltage signal (frequency to voltage conversion) of the system status; 6) Continuous flow control with a proportional solenoid valve as a system controlled and voltage signal (frequency to voltage conversion) of the system status; 7) Continuous pressure control with a pump as a controlled system and voltage signal of the system status; 8) Continuous pressure control with a proportional solenoid valve as a controlled system and voltage signal of the system status; and 9) Two-point temperature control with an analog system status signal. The functions of each control loop depend on the different combinations of elements, as well as on the control system and its parameterization.

### 2.3 Hardware of the PLC Controller and I/O System

To control the process control plant, a SIMATIC S7-1200 PLC controller is adopted, which constitutes the basis of the automation system [10] and is a widely used in industrial control, including manufacturing, building automation, and energy management. Figure 3 shows the hardware of the PLC controller and I/O system, in which Fig. 3(a) shows the general command and protection panel for control station processes.

Since the S7-1200 PLC has a limited number of inputs and outputs, which is not sufficient for this application, a Siemens SIMATIC ET 200SP I/O system is designed to work with the SIMATIC S7-1200 PLC, which can help to improve the flexibility and functionality of the control system. The ET 200SP I/O system provides additional digital and analog inputs and outputs, as well as specialty modules such as temperature control. In addition to expanding the input and output capabilities, the ET 200SP I/O system can also be used to distribute the I/O modules throughout a machine or process, which means that the I/O modules can be placed closer to the sensors and actuators they are connected to. This can reduce the amount of wiring required and make installation, maintenance,



(a) (b)

**Fig. 3.** Hardware of the PLC controller and the I/O system. (a) General command and protection panel for control station processes. (b) Decentralized I/O modules, ET 200SP using Profinet.

and troubleshooting easier. Figure 3(b) shows the decentralized I/O modules. By the use of Profinet communication networks, the I/O modules can communicate with the central PLC without the need for a physical connection.

### 2.4 Human Machine Interface

TIA (totally integrated automation) portal installed on a PC or the Siemens SIMATIC KTP700 Control Panel can be used as the SCADA system, also called the HMI (human machine interface). The HMI allows the user to operate the plant in an interactive way and to monitor the status of the plant in real time. For example, for the KTP700 Control Panel, in the case of the process control station, it is possible to perform basic maintenance and control tasks, and visualize the status of the different process variables through the screen. Thanks to the control panel, it allows access to the functions of the plant quickly and easily by a user with minimal experience.

The Control Panel is connected to the network via an industrial ethernet cable. If connections are correct, when the plant is put into operation, after a few seconds, during which the panel performs its internal checks, the system startup screen as shown in Fig. 4 appears.

Through the buttons at the bottom of the screen of Fig. 4, a user can access: 1) Configuration; 2) Alarms; 3) Level Regulation; 4) Flow Regulation; 5) Pressure Regulation; and 6) Temperature Regulation. Figure 5 shows the HMI for the water level control with a PID regulator.

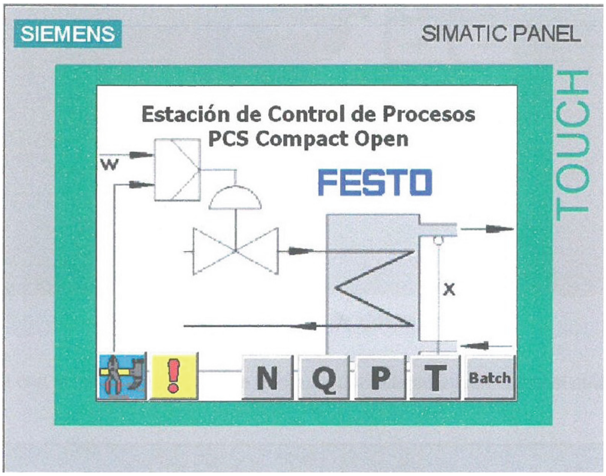



**Fig. 4.** The Home Screen of the KTP700 Control Panel.

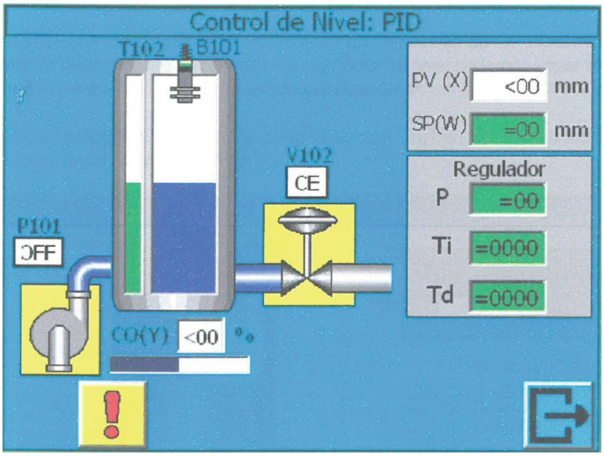



**Fig. 5.** Water level control with a PID regulator.

## 3 Process Control Functionalities

The system allows four control loops for different control purposes to be governed by different combinations of valves, sensors, and actuators. The following control functions can be performed: level, flow, pressure, and temperature control.

Table 1 lists the recommended hydraulic circuit configurations for the different control possibilities. Different valves can be opened or closed to work with the sensor, pump (P101), proportional solenoid valve (EV V106), and/or heaters (E104).

**Table 1.** Hydraulic System Configurations for Different Control Purposes

| Element | Level Control | Flow Control | | Pressure Control | | Temperature Control |
|---|---|---|---|---|---|---|
| | | Pump (P101) | EV V106 | Pump (P101) | EV V106 | |
| Sensor | LIC102 | FIC101 | | PIC103 | | TIC104 |
| P101 | Control | Control | 100% | Control | 100% | 100% |
| EV V106 | Off | Off | Control | Off | Control | Off |
| E104 | Off | Off | Off | Off | Off | Control |
| V101 | O* | C** | C | C | C | C |
| V102 | O/C | C | C | C | C | C |
| V103 | C | C | C | O | C | O |
| V104 | C | O | C | C | C | C |
| V105 | C | C | C | C | C | C |
| V107 | C | C | C | C | C | C |
| V108 | C | C | C | O | O | C |
| V109 | C | C | O | O/C | O/C | O |
| V112 | O | C | C | C | C | C |

* O: Open

** C: Closed

### 3.1 Water Level Control

Water level control of a tank by means of a centrifugal pump (P101) as the actuator, and an ultrasonic level sensor (LIC102) as the feedback system. According to the configurations in Table 1, Valves V101 and V112 are open by default, V102 can be opened or closed, and the rest of the manual valves are closed. The heaters (E104) and the proportional solenoid valve (EV V106) are in the OFF state.

The centrifugal pump transfers the liquid to the upper tank, Tank 102. The liquid level in Tank 102 is monitored by the ultrasonic level sensor, and is presented as a current value. The amount of liquid provided by the pump is the controlled variable. A two-point control or continuous control is possible. Valves V102, V103, and V104 can be used to create disturbances.

### 3.2 Flow Control

The velocity of a fluid that passes through a pipe system can be regulated. The centrifugal pump, P101, pushes the liquid into the piping system. The liquid flow at the pump outlet is monitored by the flow sensor, FIC101, and is presented as a current value. The amount of liquid provided by the pump is the manipulated value. Continuous monitoring is easily possible because it is a delay-free system.

As indicated in Table 1, there are two flow control possibilities.

**1) Flow Control by Means of the P101 Pump:** this is an analog control over the speed of the P101 pump. Three possible combinations of pump and valves for the control are: a) circuit flow P101-V104; b) circuit flow P101-V101-V112-V102; c) circuit flow P101-V103-V109.

**2) Flow Control by Means of the Proportional Solenoid Valve V106:** this is an analog control on the opening of V106 with the pump at constant speed. There is only one combination for the circuit flow, namely, P101-V106-V109.

For flow control, valves V101, V103, and V104 can be used to create disturbances.

### 3.3 Pressure Control

The pressure of Tank 103 can be controlled. Tank 103 must be partially filled with air (valves V107 and V108 can be used for filling and purging). The centrifugal pump, P101, pushes the liquid into the piping system. The flow rate is directed toward the base of Tank 103 by means of the valves: 1) V101, V107, and V104 closed; 2) V108 open; 3) V109 partially open (to cause the necessary resistance in the circuit) and 4) V106 or V103 open (depending on control type).

The valve V109 originates resistance to the output of the hydraulic circuit so that pressure appears in it, tending to fill Tank 103. The water pressure inside the Tank 103 compresses the air inside. This pressure is detected by the piezoresistive sensor, PIC103, and is presented as a current value. The amount of liquid provided by the pump is the control variable. The regulation conditions can be modified by varying the amount of liquid inside Tank 103 using the V107 aeration valve.

As indicated in Table 1, there are two possibilities for pressure control:

**1) Pressure Control by Means of the P101 Pump:** analog control over the speed of the pump, through the circuit P101-V103-V108-V109.

**2) Pressure Control by Means of the Proportional Solenoid Valve V106:** analog control on the opening of V106 with the pump at constant speed through the circuit P101-V106-V108-V109.

Valves V103, V108, and V109 can be used to create disturbances for pressure control.

### 3.4 Temperature Control

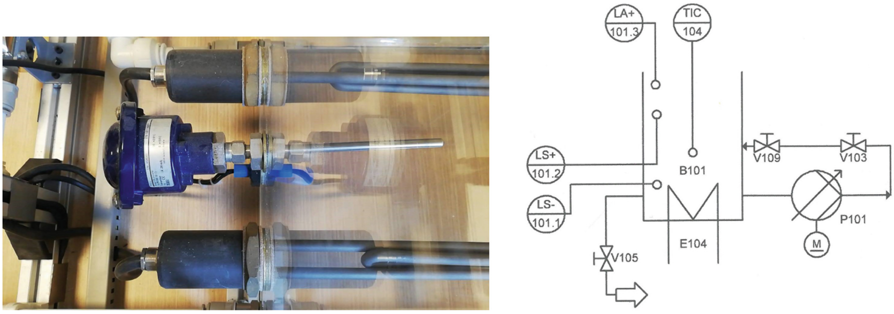
The temperature of the Tank 101 can be controlled by means of a heating system, as shown in Fig. 6, in which Fig. 6(a) is the hardware of the temperature control system and Fig. 6(b) is the corresponding P&ID. In this type of control, the time constant of the system is very large due to thermal inertia. The water in Tank 101 can be heated by E104 heaters. It is advisable for the P101 pump to have it run to homogenize the temperature of the tank liquid.

Any of the following recirculation circuits shall serve the control purpose: 1) P101-V104; 2) P101-V101-V112-V102; and 3) P101-V103-V109. A sensor, TIC104, of the type PT100 (platinum resistance) is used to measure the temperature, and is presented as a current value.

Disturbances in the system can originate by mixing water from Tank 102 to cause the temperature to change.

## 4 Case Study

In this section, a proportional-integral-derivative (PID) control of the temperature is conducted to demonstrate the effectiveness of the proposed system.




(a) (b)

**Fig. 6.** Temperature control system. (a) Hardware of the temperature control system. (b) P&ID.

By means of an SIMATIC S7-1200 PLC, it is desired to establish a PID temperature control of a heater so that the fluid inside has a temperature of 100°C. To heat the fluid, electrical resistances that transfer heat to the fluid are used. These electrical resistors require solid-state relays (SSRs) to connect them with a Wide Pulse Modulation (PWM) modulation.

TIA Portal is used for monitoring and control. To achieve the desired setpoint temperature value in a TIA ladder diagram project, two inputs and one output are necessary for the PID block. As shown in Fig. 7, the *Setpoint* input must be defined (100°C in this case) to force the desired setpoint temperature value. The second input is the analog input, *Input_PER*, used to read the integer temperature value of the PT-100 probe. *Output_PWM* should be wired to the control input of the SSR actuator. By combining these inputs, the PID block can calculate a control output signal based on the difference between the setpoint and the temperature value (from the *Input_PER* block) inputs, which is then converted to a PWM signal that is used to control the SSR and adjust the power to the heating element to reach the desired setpoint temperature.

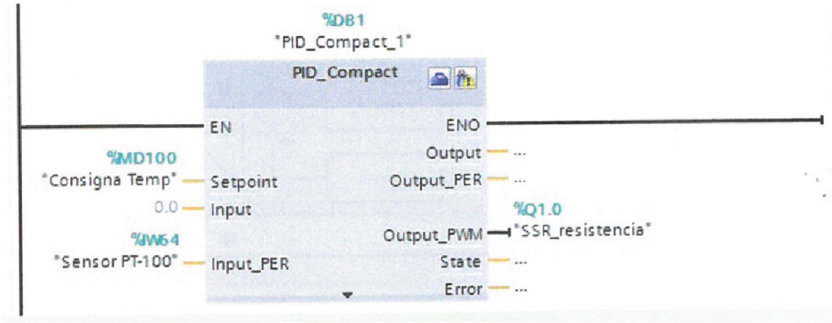



**Fig. 7.** The PID compact statement.

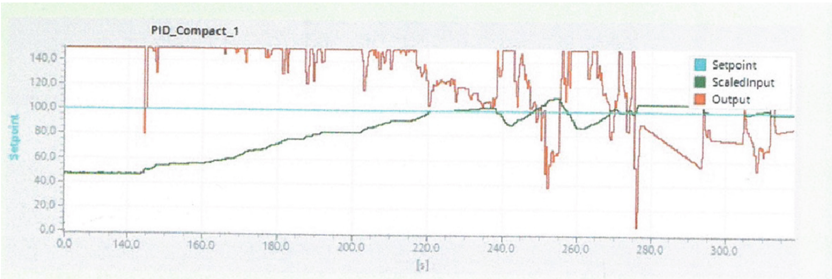



**Fig. 8.** Water level control result with a PID regulator.

It is necessary to load hardware and software into the device in order to establish an online connection with the S7-1200 device. By establishing an online connection, the user can ensure that the S7-1200 is functioning properly and responds appropriately to inputs and outputs. Moreover, this connection facilitates troubleshooting and allows for quick modification of the program if necessary, thereby enhancing the overall efficiency of the industrial automation system. Figure 8 shows the result.

## 5 Conclusion and Future Work

This paper introduces the design of a teaching platform for process automation. The overall teaching platform, including the multi-functional process control plant, a corresponding P&ID that can provide a clear illustration, a PLC controller and I/O system, and the HMI, are presented. The teaching platform can be used for different process control purposes, such as water level control, flow control, pressure control and temperature control, through the various configurations of the pump, sensors, and valves. The case study demonstrates the effectiveness of the system for process control by showcasing the PID control of the temperature. The results of the study highlight the potential of the teaching platform as an effective tool for process automation education. The system can potentially provide a practical and comprehensive solution for process automation education that bridges the gap between academic theory and real-world applications.

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# Psychology Students' Experiences with the Application of a Memory Workshop: A Case of Challenge-Based Learning

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**Abstract.** Challenge-Based Learning (CBL) is an educational methodology with positive outcomes for the training of health professionals, involving them in the healthy processes of the community and improving their communication, empathy, and knowledge. This study describes the experiences of final-year B.S. in Clinical Psychology students solving challenges in a CBL memory program for older people. The primary goal of our qualitative study with Interpretative Phenomenological Analysis (IPA) methodology was to describe the experiences of psychology students when they are solving the challenges of the memory program by CBL. Three students who implemented the memory workshop participated in this research. After obtaining informed consent, semi-structured interview of no longer than 40 min was used to collect the experiences during the CBL. This challenge helped them deepen real-world experiences and realize the importance of peer collaboration and communication. The latter were crucial for the student's success in the program, as they found the necessity to generate and fulfill roles. The students highlighted the respect for the skills of other teammates and the development of their cognitive flexibility through spontaneous situations. The contact with older adults helped students to break down prejudices about working with this population.

**Keywords:** Challenged-Based Learning · Real-World Experiences · Professional Abilities · Educational Innovation · Higher Education

## 1 Introduction

Higher Education Institutions always face the challenge of training citizens with the necessary skills to respond to life's challenges. For this, they must have systems or strategies that facilitate a close relationship with society so their graduates can solve and improve their immediate contexts [1].

According to Félix-Herrán [2], society demands professionals who can solve problems ethically and multi-disciplinarily with positive attitudes to address the issues that arise. Universities must graduate professionals with knowledge and skills who can apply

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them creatively [3], i.e., individuals capable of identifying, classifying, evaluating, and using scientific and validated knowledge [4].

Therefore, the quality demanded in the new era of higher education and online studies requires a focus on developing skills and competencies to prepare young people for real and global challenges to find creative and ethical solutions [5]. All of the above has led many universities to rethink their educational models. Membrillo-Hernández and others [6] point out that universities need educational models that keep up with the dizzying speed of societal evolution.

One of the models that has proven to respond satisfactorily to reducing the needs gap between universities and society is Challenge-Based Learning (CBL). The definition of CBL still perplexes the scientific community [7] because, as mentioned by Gallagher and Savage [8] and Leijón et al. [1], it has been described and interpreted in various ways, such as a framework, approach, model, and learning experience, among others. However, some agree on conceptualizing it as an approach due to the breadth of this term. In this sense, CBL is an attractive approach to multidisciplinary teaching and learning to resolve real-world problems through the collaboration of students, teachers, experts, and the community, where students must implement their skills developed in the educational institution [1, 8, 9].

CBL encourages students to live the experience with social responsibility; they develop and improve various clinical and transversal skills. In some successful studies, teamwork and communication skills development has been reported as essential for achieving the challenges [10]. They have highlighted the development of critical thinking, creativity, and metacognition among undergraduate students under this model [11], also entrepreneurial [12] and problem-solving skills [13]. Moreover, they emphasize the importance of adequate preparation among students and teachers to execute challenges [14].

Tecnologico de Monterrey adopted CBL [15] in its Tec21 Educational Model to train its students integrally with the necessary skills to face the challenges that the world demands and achieve international competitiveness. For this university, CBL is "a pedagogical approach that actively involves the student in a real, relevant problematic situation that links with the environment, which implies the definition of a challenge and the implementation of a solution" (p. 10).

This approach has been integrated into all the professional-level careers (majors) of Tecnologico de Monterrey [16]. One is the Bachelor's Degree in Clinical and Health Psychology (LPS), which aims to train professionals to apply psychology to promote mental health and its impact on integral wellbeing [17]. Like many disciplines, psychology must respond to several highly complex mental health issues, some revealed or magnified by the COVID-19 pandemic [18, 19].

Among psychology's most complex challenges are increasing demands for mental health services, addressing discriminatory and prejudiced behaviors, and caring for vulnerable communities. One of these communities is older adults, who historically are relegated and discriminated against by their supposed loss of efficiency and productivity, which leads them to loneliness and isolation as they face the natural deterioration of memory, which is the brain's ability to retain, store, and retrieve information and experiences, a fundamental skill for survival.

Based on the above, we designed a challenge for the students, which consisted of implementing a memory stimulation workshop for older adults (>65 years) under the guidance of teachers and with the support of a wellness care center, which served as a socio-trainer of the learning experience.

The main objective of this study is to describe the experiences of psychology students solving a real challenge with the CBL approach to identify the most significant learning experiences, know the impact of living with a vulnerable population, and determine the skills developed while resolving the challenge, such as empathy, decision making, adaptability, and greater motivation and relationships among the students. Implementing an actual memory workshop aimed at older adults potentiated all the above.

## 2 Method

### 2.1 Design

This qualitative study using Interpretative Phenomenological Analysis (IPA) aimed to investigate how individuals make sense of their experiences, as "*phenomenological studies focus on how people perceive and talk about objects and events, rather than describing phenomena according to a predetermined categorical system, conceptual and scientific criteria*" [20].

### 2.2 Participants

The convenience sample comprised intentional students studying under CBL; they were formally invited to participate in the research and the data collection when they were in the session number eleven and without any influence on their grade. Although five students applied for the memory program, only three participated after providing their informed consent. All were female and in their last year of the B.S. in Clinical Psychology and Health at Tecnologico de Monterrey.

### 2.3 Instruments

Semi-structured interviews were the data collection method. This technique consists of the researcher asking a series of open-ended and predetermined questions. In this type of interview, the researcher can follow the interview script and return or deepen at will in some topic of interest to meet the objective of the study [21].

Table 1 shows the categories and the pre-established questions to collect the required information.

### 2.4 Procedure

The learning activity occurred at the Academic Center for Integral Care and Wellbeing (CAABI) in Santa Catarina, Monterrey, Mexico. CAABI is an academic space offering nutrition and psychology services to the low-income population. Teachers of psychology and nutrition from the School of Medicine and Health Sciences at Tecnologico de

**Table 1.** Categories and Generated Questions

| Category | Generated Questions |
|---|---|
| Description of the challenge | • Could you describe the challenge you had to resolve?<br>• Could you describe the participants comprising part of the challenge?<br>• Could you describe how your experience was in the delivery of the workshop aimed at adults (challenge)? |
| Collaborative work (teamwork) | • What did you learn about your participants in the challenge?<br>• What did you learn about your classmates in the challenge? |
| Challenge-Based Learning | • What did you learn about yourself in the challenge?<br>• What professional skills did you develop during the workshop, and how did you manage to acquire them? |
| Initial Expectations | • What were your expectations of the challenge?<br>• What was your most significant experience in resolving the challenge? |

Monterrey supervise private consultations and psychoeducational talks with the adjacent population.

Next are the steps for planning, executing, and reporting the study and all the tasks that students had to lead to resolve their CBS:

1. Authorization by the Academic Center for Integral Care and Wellbeing (CAABI).
2. Planning the memory workshop:

   *Information on objectives and schedule*: During January 2023, the workshop supervisor explained to the students the learning objectives of the workshop professional practices that was part of the CBL they had to resolve. In addition, she informed them about the scheduled sessions.

   *Equipment and material*: During January 2023, students saw the materials and equipment they would use and received the necessary explanations. In that moment and a part of their CBL they were in charge to planning and organized visual equipment, material on each session for the students and the participants. However, they also learned about these during the execution of the workshop.

   *Test training*: Students learned to apply neurocognitive tests to the workshop participants.
3. Workshop implementation:

   *Promotion of the workshop:* During January 2023, the psychology students invited the community to attend a free Memory Workshop for adults through talks, chats, flyers, and posters in a Primary Care Center, an Ophthalmological Center, and CAABI. They were in charge of making and printing the promotional materials.

   *Application of the intervention*: The study students covered up to six scheduled workshop sessions depending on logistics, other university commitments, and rotation of clinical practices. The workshop continued with other students in the same major.

4. Description of the workshop:

   *Structure*: The workshop consisted of 12 structured sessions with an implementation manual for those conducting it. All five psychology students in their last year of professional practice for older adults (>65) taught the "Memory Workshop" program [22], althought three were voluntary interview. Workshop participants received from students a workbook to do at home and an activity booklet to do during the sessions.

   *Participants*: Informed consent was explained and read to participants before starting their second session. After they signed this, the students collected medical and sociodemographic data and applied a neurocognitive assessment and two scaled instruments to assess the number of forgetful events and the use-of-strategies frequency. Initially, eleven subjects participated (2 men and 9 women) with an average age of 55.18 years and an average schooling of high school level. Finally, seven people completed the workshop in full.
5. Implementation of the semi-structured interviews:

   *Informed consent*: All five students were later invited to participate in a semi-structured interview to collect their experiences implementing the workshop without any influenced of their grade in session number five. After obtaining three informed consent, they were summoned for an interview.

   *Interview*: One of the researchers conducted interviews no longer than 40 minutes between the 27$^{th}$ and 31$^{st}$ of March. The semi-structured interview was a data collection technique, focusing on specific topics conversationally to find topics of interest for the study. This is one of the best choices for deeply understanding people's motivations and behaviors and obtaining unanticipated information.
6. Interview transcription:

   *Recording*: The Zoom videotaped interviews were transcribed for analysis and coded.

   *Analysis*: The data analysis employed open and axial coding by the two authors of this work using Atlas.ti 23 to report the results. Open coding consists of reading the analyzed documents and identifying relevant information to convert into text; axial coding establishes relationships between categories [23].

# 3 Results

## 3.1 Collaborative Work Among Students

Collaborative work (teamwork), essential for groups' success, is a way of working where the members share and combine their knowledge, skills, and efforts to achieve a common goal, in this case, the resolution of a challenge to implement the memory workshop.

The students highlighted the importance of collaborative work to achieve the programmed activities. Figure 1 shows the codes comprising this category, where collaboration was the most popular among students, followed by communication and planning. However, they also mentioned the appropriation and assignment of roles, including leadership, time control, and the generation of a positive environment.

All this was highly valued by the students, who mentioned that "… *Communication with each other, among the teammates, is super key. Including when the pencil hits the paper. We realized that we had to talk about it and even put in the time to do that"*

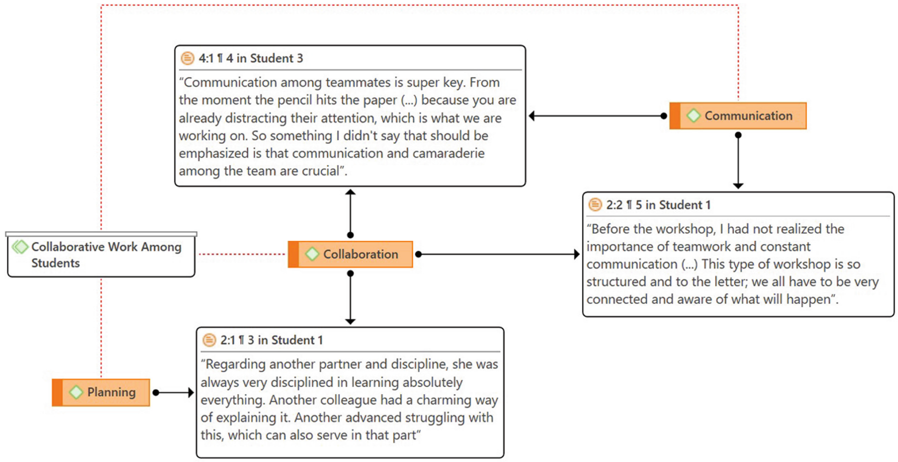


**Fig. 1.** Experiential characteristics of student collaboration

(Student 2); "*You can't just improvise and everyone acts as they want, you can't. There were several situations, nothing serious or anything, nothing for me was a big problem. Well, we can't all participate like that, offering nothing for nothing. If I have my part, it is mine; if it is yours, it is yours. And yes, I think that's very useful, right? It was very useful learning*" (Student 1).

## 3.2 Professional Abilities

In the category of professional skills or transversal competencies within psychology studies, the students reported that, although these theoretical remained in mind, the workshop allowed them also to develop and recognize skills such as empathy, self-knowledge, and active listening (see Fig. 2).

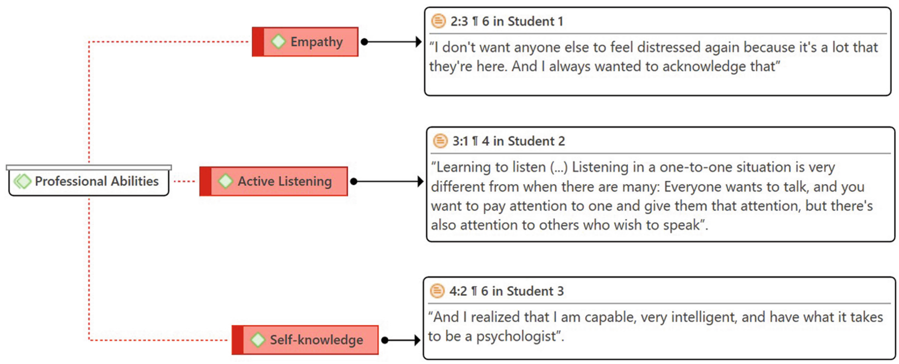


**Fig. 2.** Professional skills developed in the workshop

Approaching the population through the CBL methodology changed the students' general perception of the psychological approach in the profession toward the elderly with subjective memory complaints: "*If I had not taken the workshop, I would not have interacted with older adults. The truth is that I did not have this population in mind. I think today it is a population that psychology does not consider or treat much, but it is very important*" (Student 1); " *It's an area where in terms of psychology, we turn it around, and I include myself also because I also turn it around. After the workshop, I realized that it is not what I thought to work with older adults*" (Student 3).

Thus, the CBL approach awakened in the students the sensitivity towards the difficulties of daily life that this population faces, specifically, the following experiences: "*He began to tell us that he had gone to kindergarten to pick up his grandchildren, and when he arrived there, he could not remember the name of his grandchildren. So, he was there waiting and waiting, and the school didn't know who he was. Then they could not give him his grandchildren* (Student 2). Faced with this situation, the students developed the professional skills expected in the profession, such as empathy, active listening, and problem-solving skills: "*When he told us this story, everyone was silent. This gave us time to process what we would answer and how to give him the space to tell us the anguish he felt. It is like when he told us that what we told him was not exactly like that, I do not want to say how it was exactly (…), but you are here, and we are delighted that you are here because you are here to improve your memory. And this helps them so that it no longer happens so often. We try to lower their anguish a little"* (Student 2); "And *he asked me, "Doctor, how do I know when this is already a problem and what do I do?" And I sat there; well, I don't know, what do I say? I got scared; I felt empathy. I felt a lot of his frustration. How horrible that must be and more than anything because it must have accompanying guilt (…) the anguish that I perceived in that man made me feel this: 'Okay, I don't want anyone else to feel distressed again because it's a lot that they're here, and I always wanted to acknowledge that'"* (Student 1).

These experiences allowed students to realize the improvement in self-knowledge about the skills and abilities they developed, either new or reaffirmed: "*as if our work was this because we were doing it well. The fact that the person wanted to be there, was worrying about his mental health, worrying about being well, about wanting to be okay (*Student 1); "*I realized that I am capable and very intelligent, and I have what it takes to be a psychologist"* (Student 3); "*I believe I affirmed that I really like working with groups. This one, I've always liked, always. I always like to work with groups. But this has the possibility of how to lead a group and be able to teach them something. And I don't know, the activities and the tasks were something I really like*" (Student 2).

### 3.3 Challenge-Based Learning

The most frequent code in this category and the others was "Real-World Experience," which correlated to a great extent with sensitivity and prejudices (See Fig. 3). The results indicate that students' immersion in implementing a memory workshop for older adults helped them to reduce their biases towards this population.

The idea that due to schooling and age, the students could not understand or follow the activities was one of their negative expectations; however, through immersion, they changed their minds: "At the *time of applying the evaluation, I realized that they (the*

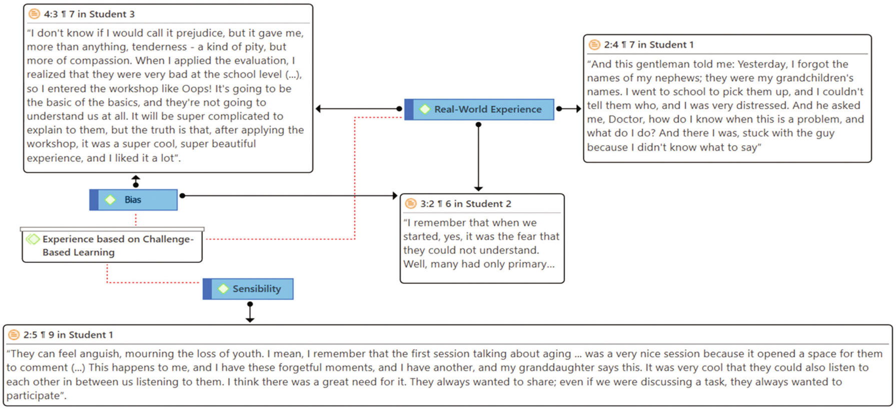


**Fig. 3.** Challenged-Based Learning Experience

*participants) were deficient at a school level, or that they didn't understand some evidence (…) so I did enter the workshop like that, like Oops! It will be the basic of the basics, and they won't understand us at all. It's going to be super complicated to explain to them. But the truth is that later, applying the workshop was a super cool experience, super beautiful, and I liked it very much"* (Student 3); "*Then that's when I said, Wow! I mean, anyway, I had the prejudice that everything would have to be simplified so they could understand. And there came a point where I no longer understood. Then, this…it did surprise me, and well, that's why I realized it was a prejudice that I had to take away from me*" (Student 2).

Also, the perception and experience after the immersion in the workshop helped students to assess that regardless of age, there is still an interest in learning and self-care on the part of older adults: "*I learned many things. I mean, many of them were very dedicated; they did their tasks and wanted to learn. They had this desire to learn and do things well. Very respectful people. That surprised me a lot, and I liked it. Like the dedication they had to be well. You could tell they wanted to be well and learn*" (Student 1); *It also took away from me that older people are boring. That adult gentlemen are dull. I didn't get bored at all during the sessions*" (Student 3).

## 4 Conclusions

The participants reported that their experiences from the CBL were successful. This approach allowed the immersion into a challenge that facilitates contact with the community and the population's psychological needs. From the student's perspectives, the participants' interest and their capacity for work and self-care reflected an adequate execution of the workshop and achievement of the objectives.

The students could identify preconceived ideas, primarily negative, that they held towards older adults, ideas that, had it not been for the challenge, would possibly have been maintained. They had the opportunity to learn how psychology can encompass their work and improve their perception of older adults. This result is similar to Félix-Herrán [2] reporting the benefits of CBL to make it easier for students to face and resolve challenges they cannot experience in the classroom.

Through the experience, students developed sensitivity to the needs of each participant concerning the difficulties they faced due to memory problems in their day-to-day lives and how social stigmas surround the abilities of older adults in the situation of aging. In this case, the students were able to become aware of these and assess new ways to improve the attention and wellbeing of the participants through the workshop, developing solutions during the challenge [13]. This result coincides with those of Willis, Byrd & Johnson [24], who reported that students learn, become aware of their learning, and become confident in their knowledge. This last point is also addressed by Membrillo-Hernández and others [6]), who mentioned that their students initially perceived themselves as distrustful. Still, they became involved with the challenge, finding it motivating because of its impact and correlation with real life.

Especially, active listening to older adults allowed them to identify the thoughts, difficulties, and situations of older adults dealing with their memory or aging problems. This interaction allowed them to develop empathy, recognizing the emotions and suffering the participants experienced. However, the students could be distant from those situations due to their age and life cycle and, therefore, acquire self-knowledge about their performance and see the effects of their interventions [6].

Finally, the students valued collaboration and communication as key skills to execute the challenge well, similar to other studies [6, 8, 10, 25, 26]. The collaboration related to planning and sharing their experiences highlighted the importance of teamwork so that the activities occurred in the planned way, requiring continuous communication among them.

Consequently, the CBL method allowed a real-world approach to the needs of society through implementing the techniques and the training of specific competencies by students to acquire collaborative work skills, empathy, self-knowledge, and reduction of prejudices to a part of the community [27]. It also makes educational activities more conducive to motivating students by letting them identify and work with real-life challenges [28].

Some of the limitations of this study were the number of students who participated in the interviews, so the experiences described cannot be generalized to the population of students in this psychology practice. On the other hand, for future directions an area of opportunity in relation to improving the needs of society was the verbalization on the part of the students to look for spaces where to talk about the life cycle changes that the adult does have.

Finally, it is essential to mention that more studies should focus on the impact of CBL in education and especially in psychology because most of the literature on this approach has been carried out in the engineering field [1]. Nevertheless, the outlook for the CBL approach seems optimistic. It helps close the gap between school and reality by granting unique opportunities for students to become professionals with the skills required in the work world.

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# Methodology and Conceptual Model for Digital Accessibility Assessment of Websites and Documents for People with Impaired and Lost Vision

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**Abstract.** A methodology for assessment websites and digital documents accessibility for blind people is presented. It includes testing and reviewing by both automated software tools and more importantly – blind people for the most accurate user experience results. More than 100 sites and documents in Bulgaria have been tested for accessibility during the research.

A conceptual model for an accessible digital representation of information for people with disabilities is proposed. An example of implementation of the proposed model is presented in case of the Regional Ethnographic Museum, Plovdiv, Bulgaria.

**Keywords:** Digital Accessibility · Conceptual Model · Methodology · People with Impaired Vision

## 1 Introduction

Since the beginning of the 21st century, especially in recent years, the issues of equal access and non-discrimination towards people with disabilities to various spheres and resources have become increasingly important. The development of modern technologies makes this question even more acute, since human daily life is increasingly closely connected with them, and their accessibility is at a very low level. Solving it requires taking relevant political and legislative initiatives, which find expression in two main directives related to digital accessibility. The first is Directive 2016/2102 on the accessibility of websites and mobile applications of public sector organizations, and the second covers the private sector, services and devices commonly used in everyday life.

The set minimum requirements aim to increase the accessibility of the digital sphere, as well as to gather legislation and practices in different European countries. The requirements include international standards.

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**Research Background**

This paper is part of a research project "Digital Accessibility for People with Special Needs: Methodology, Conceptual Models and Innovative Ecosystems" in Bulgaria (http://www.math.bas.bg/vt/ab/). The project relates to several research results and many publications on the topic in the last 3 years. The research develops useful guidelines and methodology for making more sites and digital tools accessible to people with special needs.

A total of over 100 Bulgarian sites were studied and tested as the methodology has been developed. 50 of the reviewed sites with their accompanying documents belong to state and municipal institutions, as well as to private companies with a public service assigned to them by law, such as heating companies, healthcare facilities, financial institutions, etc. Based on the results, it is established that most of the studied sites have low accessibility for people with disabilities, which leads us to necessary recommendations and the need to develop a testing methodology that can be used for more sites, especially in the field of public service sites and cultural heritage sites.

The paper "Accessibility of Bulgarian Regional Museums Websites" [1] describes in detail the automatic testing of 30 sites of museums in Bulgaria with the software applications - TAW, WAVE and Lighthouse is described in detail. The research and paper "Usage of Innovative Technologies and Online Media Tools for Digital Presentation of Cultural Heritage in Bulgaria" [2] explores usage of digital technologies in museums for improving accessibility and cultural experience and "Physical and Digital Accessibility in Museums in the New Reality" [3] presents user qualitative in-depth testing with the participation of a blind expert on 55 regional museum sites and their accessibility and digitalization extent. Based on the results authors offered conclusions and recommendations for the culture heritage field.

The research work and results of the team of the project are used for recommendations, results, guidelines, developing evaluation criteria and methodology for accessibility testing and improvement for websites (especially those in the field of public service, cultural heritage and education), documents, software, educational smart games. Also the following paper presents an example for application and usage of the developed accessibility methodology and standards with a new open digital audio guide system with accessibility for various and disabled audiences via Internet and QR code and Braille signs: http://www.math.bas.bg/vt/REMPlovdiv/ with QR codes has been developed. An online learning website has also been developed - http://www.math.bas.bg/vt/tp/ and is presented in another paper.

## 2 Methodology

Digital accessibility is a discipline that is constantly evolving and requires serious training of personnel. Furthermore, mechanisms for providing feedback from users to businesses and institutions put them in a position to explain accessibility issues for which both parties may not be sufficiently prepared.

For the purposes of the project and the development of the accessibility methodology and conceptual model, we studied articles by other authors related to the topic of accessibility testing and evaluation [4–8] and [9].

Accessibility challenges are numerous and the subject matter is varied and broad. Therefore, the development focuses on the problems faced by people with severe or completely lost vision. Testing according to the methodology should be carried out with a screen reader. The methodology takes into account, but does not strictly follow the Web Content Accessibility Guidelines (WCAG) and the European EN 301 549 standards, but the questionnaires are fully adapted to people whose vision is insufficient for independent and effective use of a monitor, mouse or another pointing device [10].

The methodology is based on a combination of automated testing according to certain criteria with specialized software or added functionalities to a browser and user testing by people with impaired vision [11]. Software testing can quickly capture a large volume of pages and test them for basic accessibility, but it cannot verify in detail the actual state of accessibility for users with disabilities. Measurement through the human factor can be much more precise, and in-depth, and covers the element of functional accessibility beyond basic access to information [12].

Figure 1 shows the methodology for testing and assessment of accessibility.

### 2.1 Testing Accessibility of Websites

The first step in the evaluation is to define a research area, which makes the results more objective, in-depth and measurable for the specific field (education, health, services, etc.).

Secondly, it is necessary to refine a set of webpages that are a representative sample of the specific research area and contain reference points, important information and essential functionality, as well as multimedia content and documents.

It is reasonable to conduct testing with automated tools to provide basic data on the state of accessibility. There are many automated software tools available with different sets of tests and interfaces. A key point is that they are accessible to screen reader users.

Considering that automated tools only cover between 25% and 40% of all possible errors, it is reasonable and recommended for the next step to be the verification of the automated testing results by a person with the appropriate screen reader skills.

The structure (how the content and interface are organized), technology use (is it used correctly), logic and consistency of websites' interfaces and content impact directly accessibility and usability. This relates to the way the user perceives, orients, navigates, understands and operates in that environment [13].

Perceivability is a component of accessibility that ensures that information and content are perceivable by all users, regardless of their sensory abilities. It involves designing and presenting information in ways that can be understood by individuals with various sensory impairments. Designing visually perceivable content means using appropriate color contrast, providing resizable text, and ensuring that important information is not conveyed solely through color.

Since some blind users are also hearing impaired, making audio content accessible to them by captioning and transcribing it, helps them perceive it easier in Braille and screen reading technology. Describing the images and labeling interactive elements is another aspect of perceivability.

Orientation involves clear and consistent navigation and structure by using semantic elements, ensuring consistent and logical layout, and offering orientation cues to

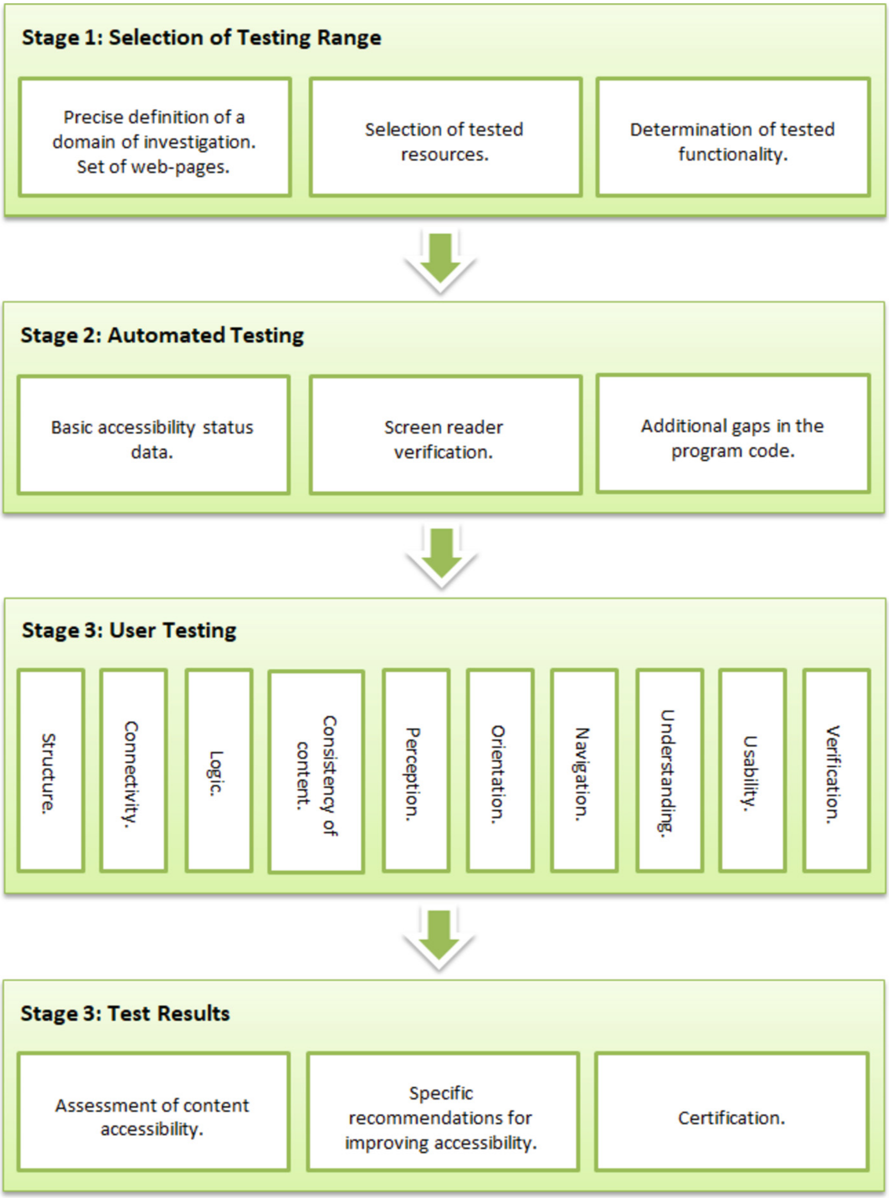


**Fig. 1.** Methodology for testing and assessment evaluation of accessibility.

help users understand and navigate the content effectively. It makes it easy for users to understand where they are and how to move around the site. This can be achieved by using unique page titles, hierarchical headings structure, navigation menus, sitemaps and search facility, distinctive and logically related page sections, consistent focus order which all can serve as orientation Cues [14] and [15].

Good navigation lays upon the previous points and includes semantic meaning of the elements on the page and their correct use. Semantics eases the understanding of meaning and purpose of all elements. Basic elements are regions and headings, as well as lists, tables, forms, etc. Non-standard custom elements pose a risk to accessibility [16].

The monolithic nature of unstructured interfaces and content makes it difficult to understand and navigate in the content. Visual logic is not always an expression of programming logic, and in these cases, accessibility is more difficult and most surely problematic for visually impaired users.

The usability defines the over-all impression of the degree, in which an interface and the information are perceivable and operable, without significant difficulties. It determines if the user can interact with the interface to perform specific tasks such as log-in, change settings, purchase items, create or edit content, publish comments, obtain information ETC [17].

The methodology offers 10 basic elements - features for interaction and their accessibility and easy usability are accepted as criteria for the website's accessibility. The features are: 1. Title; 2. Language; 3. Headings; 4. Readability; 5. Overall content structure – regions, headings, text; 6. Graphic content; 7. Interactive elements; 8. Forms; 9. Multimedia; 10. Media alternatives.

Accessibility research is done through a user testing questionnaire that covers the above elements and their state and properties.

The methodology does not aim to achieve a universal scale for assessing accessibility and is subject to development through further testing and improvement. The obtained results can distinguish several levels of accessibility, but the concretization of boundaries between individual levels is relative given the subjectivity of user judgment for some of the criteria and depends on the expertise of the analyst, not only on exact indicators.

A total of over 100 sites have been evaluated with the proposed methodology. 50 of the reviewed sites with the related attached documents belong to state and municipal institutions, as well as to private companies providing public services entrusted to them by law, such as heating companies, healthcare facilities, financial institutions, etc. The results show that most of the reviewed and tested sites have low accessibility.

Afterwards, detailed automatic testing of 30 websites of Bulgarian regional museums with the software applications - TAW, WAVE and Lighthouse was conducted in 2022 and described in detail in the paper "Accessibility of Bulgarian Regional Museums Websites" [1]. Specifics of automatic testing, result differences with the different software, errors, standards, limitations, as well as the potential for faster, much larger basic scope of site testing was explored.

Qualitative in-depth testing was also conducted in [3] with the participation of a blind expert in our project team. The research included short phone interviews with 22 questions on 55 museum sites, as well as additional testing and analysis of the accessibility of their sites and site elements. More details about the research and its results can be explored in [3]. Answers and results were used for collecting and analyzing information and formulating recommendations from the results to local institutions in the field of culture, responsible for taking decisions when developing new public-orientated sites.

The methodology in this paper is in the testing, improvement and development stages. The process needs a longer period of time and requires also some training of more testers for manual and automatic testing of more sites. The aim of the current paper of the authors is to outline and present the methodology and conceptual model devised.

### 2.2 Testing the Accessibility of Electronic Documents

Electronic documents are another important component of web accessibility. They often contain information about important decisions, requirements, legal norms and various forms. They may also be automatically generated as a final result of data processing. Because they are provided for download rather than being an integral part of the rendered content and have a different format compared to the website, they are subject to a separate test that is similar to web accessibility with minor differences. Same principles and requirements are valid for digital documents, but some specifics are related to filenames, document title, table of contents and links. The presence of different document formats also determines some specifics for each of them. The current methodology is primarily aimed at the PDF format, as the most common and problematic, and at documents of word processing software solutions. On the other hand, the European Accessibility Act pays special attention to book publishers and their electronic products.

This methodology aims to support people with severe or total vision loss in assessing accessibility and preparing feedback, as well as institutions and organizations preparing documents and offering public information and services online.

The first stage is again automated testing, but here the tool is again free, desktop and only suitable for PDF files. It checks accessibility against the PDF/UA standard.

The second stage relies entirely on the human factor, screen reader users. There is a peculiarity about PDF files when they represent a scanned image and do not present themselves as electronic text. Such a document is declared "inaccessible" without the need for further verification [18].

Again, the testers are visually impaired screen reader users. The investigated areas and criteria coincide with those tested for web accessibility: organization, orientation, navigation, comprehension, and usability.

## 3 Results and Application of the Methodology

The developed methodology is subject to additional testing and improvement. The obtained results can be classified into several categories of degree of accessibility, but it is difficult to create a universal way to accurately determine degrees, due to the differences and specifics of the individual objects analyzed. Since the testing is user-driven and some of the criteria and factors are subject to subjective evaluation, the analysis of the results is also somewhat subjective and depends on the expertise of the analyst, not just on exact metrics. The developed methodology offers steps, criteria and questionnaires for testing accessibility and electronic documents, which are extremely important for access to public information and services by people with disabilities and visual impairments.

The above-mentioned methods and approaches have been used in the research and development of a conceptual model for testing and evaluating digital accessibility for people with special needs.

The interaction between the user and interfaces and content is reviewed from the perspective of a conceptual object-subject model in which the user is at the centre and interface environments and objects adapt to his capabilities. The model has been applied in the field of robotics [19, 20] and [21].

The best practice for developing an accessible website is to take into account the needs of people with disabilities during the conceptual and design stages of website development. Instead of testing the site for accessibility only in its final version, it is good to consider all test criteria and elements at the beginning of the website making. This is the approach used for developing a new website http://www.math.bas.bg/vt/REMPlovdiv/ by a team of experts from IMI-BAS (Institute of Mathematics and Informatics at the Bulgarian Academy of Sciences), the Regional History Museum in Plovdiv and the IEFSEM-BAS (Institute of Ethnology and Folklore Studies with Ethnographic Museum). The website is an integrated system aiming to facilitate digital access to some of the exhibits and heritage objects and information of the museum, applying the models. This model with an accessible digital system with a website containing different types of media and related QR code access, multi-language and Braille signs at the physical location helps for providing accessibility for different modalities – sight, hearing and touch. This way people with special needs can access and understand the content easier.

# 4 Examples of an Accessible Digital System for People with Impaired and Lost Vision

## 4.1 Accessible Digital System with an Audio Guide, QR Codes and Braille Signs

A good example for an accessible digital platform is the digital audio guide system http://www.math.bas.bg/vt/REMPlovdiv/ of the Regional Ethnographic Museum – Plovdiv (REM-Plovdiv) with stories of cultural heritage in photos, audio, and text, as well as signs with QR codes and Braille text. The digital system was developed by the same team of scientists and experts from IMI-BAS and IEFSEM-BAS, who developed the accessibility methodology, described above together with cultural experts and employees of REM–Plovdiv. The digital system has been developed with the participation of a blind person and it was successfully tested via the accessibility methodology. The aim of the digital audio guide is to increase accessibility to the cultural routes, halls, and expositions of the museum and show some of the cultural information and local traditional music archive in the museum that hasn't been presented before.

The digital system is made as a tourist route with 8 stories, connecting 8 exhibits and information about them. Each of them represents a piece of the overall picture of the life of a shepherd and his bride in history. Information on the site such as text, photos, audio, and multimedia is presented and arranged to be suitable for both the general public and the visually impaired and blind people. The cultural heritage is also presented in an easy-to-understand and attractive way like intriguing stories of the past and it can be also used for educational purposes for children and grown-ups, as well as an audio tourist guide route for the cultural heritage of the museum.

A basic principle when developing such digital platforms is not to create additional difficulty for people with disabilities, by searching for certain buttons or a section of the site that is specific to them and difficult to find. As soon as the first page of the platform is opened, there is also information on how to get to the museum, including directions for people with special needs.

The site is functionally simplified in order for all users to easily navigate.

The site offers 8 cultural routes or so-called cultural "stories". The fascinating stories about traditional local life and traditions present different cultural objects, halls, and data on the cultural and historical heritage of the museum. Stories are short with text of 700–950 characters or 100–200 words. Each story is accompanied by 2–4 photos and an audio file with intriguing voices and authentic sounds of old musical instruments. Voice recordings of the guide also include navigation directions, as well as a description of the look of the traditional instruments, besides how they sound.

The 8 cultural route stories are directly on the first page of the website for easy and fast access. There is also a table of contents text for people with blind and impaired vision to easily navigate and go from one story to another without needing to listen to them in a certain sequence. Each story also has navigational links at the top and bottom of the page to the next or previous story. This way, a blind user does not have to go through all the text again, which would be slow and time-consuming, in order to go to another page and story. The text is arranged visually in sections without using tables in the software code, because tables would confuse the specialized reading software that people with impaired or lost vision use.

The photos on the site are captioned and tagged, and the titles and text descriptions are arranged in a logical order and as a semantic list. This way, a person using screen reader software can quickly navigate to different parts of the text. Suitable alternative text descriptions are provided for the images on the site, as well as for the logo. The colours used in the design of the site are suitable for people with impaired vision, selected, from the Web Accessibility Guidelines 3 website.

The site design and its content are structured and presented in a way to prevent confusion and delay for users. When presenting multimedia content, it is essential that the software used is accessible, convenient and easy to use, with the ability to meet the needs of a specific audience. Able Player, for example, offers functionality to control the speed of media content, as well as to move through the timeline. Some visually impaired people have higher requirements for sound than other modalities and often prefer to speed up speech. Able Player is suitable for this purpose and is keyboard friendly, which is a convenience for people with limited mobility for whom using a mouse is difficult or impossible. It also supports rendering and management of subtitles, transcription and audio description, as well as switching between multiple languages. For multilingual websites like this one (with Bulgarian and English languages), it is recommended that toggle elements are labeled with a text label. In case icons or other images are used to indicate the language, the use of alternative text is required for easy orientation.

The digital audio guide system with QR codes and Braille information sign boards for accessibility was officially presented in May 2023 in front of large audiences and media and tested on the spot via mobile phones and laptops. As soon as a visitor enters the museum – just next to the door is the first information sign board with Bulgarian, Latin, and Braille text, as well as QR code for phone scanning that guides to the digital audio–guide system and the next rooms and objects to see. An information board in Bulgarian and English is available for each exhibit and story. All similar signs in the museum are very stable, cannot be pushed, and their height is at the level of 1.2 m, around the average European human bust-waist height, in order to be convenient to use by grown-ups, and they can also be easily reached by children aged over 7 years old. All Braille signs with QR codes leading to the web digital system site are put next to a wall for tactile easy access of blind people who can touch the wall and there are no difficult obstacles between the doors of the rooms and the signs.

Testing and presenting results of the digital audio–guide system with accessibility to a larger audience were satisfactory and the team involved was motivated to continue presenting and disseminating more cultural heritage information in this accessible way. The example site https://ethnograph.info/audio-razhodka-v-muzeya/ and the methodology for testing behind are offered for more institutions to use and improve their presentation to a variety of audiences including people with special needs. The usage of more media on the cultural heritage sites will also have a more significant and attractive impact on all audiences as it involves more senses for the perception of information – sound, vision, and tactile guidance.

### 4.2 Ensuring Accessibility of Websites and Digital Systems for People with Special Needs

Developing sites and digital platforms with participating members that have impaired or blind vision is hard to achieve on a broader scale and that is why the usage of pre-developed accessibility standards and similar testing methodology for accessibility like ours described above are useful in order to make more sites accessible.

There are already a number of ready-made basic digital platforms (like https://colorlib.com/wp/accessible-wordpress-themes/ and https://cutt.ly/qK4Rw67) on the Internet and software applications and functionalities that can facilitate developers in the development of sites accessible to people with impaired vision. Most of them have appropriate colors, design and contrast, optimized for search engines, for working with a keyboard, for displaying devices with different display sizes (phone, tablet, and computer) and allow changing the size of the text on the site. Most offer easy navigation and content arrangement for screen readers, as well as a site search form.

Nowadays, the creation of accessible and functional sites for different audiences, including those with special needs, which are growing as a relative part of the population, is of great importance for reaching certain resources, information, cultural and historical sites, public or private service or product.

## 5 Conclusion

This research was conducted as part of the work of a team of scientists on a project to study and improve online accessibility for people with disabilities. The study presents and describes a step-by-step methodology for testing the accessibility of websites and documents, most often in pdf files, for people with severe or total vision loss. Over 100 sites have already been tested with the proposed questionnaires and methodology. Based on the results and analysis the team made certain conclusions and recommendations for web accessibility. The results are offered to institutions, public service providers and other interested parties who should and want to improve their digital accessibility for people with special needs and specifically blind people. The following paper also presents an example of a digital audio guide website system with QR codes and Braille signs for accessing it. The audio guide system meets the relevant accessibility criteria and guidelines for blind people or people with impaired vision. Due to a simplified, functional, and accessible design, the system can be used by a wide variety of audiences including tourists, people with special needs, children, and educators.

Understanding the issues that blind people face and their need for an accessible web environment is key to developing the right methodology, models, and future accessible, functional, and useful web ecosystems. The present work may be useful to both institutions and organizations in Bulgaria, and other countries, as well as to site developers, trainers, communication experts, and managers of organizations and businesses.

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# Reflections on Faith, Work, Profession and the Call to Salvation in Western Intellectual History – Early Modern Periods

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**Abstract.** The social teaching of religions has shaped the bases of cultures for thousands of years. My writing relation between faith and profession that has become the basis of the European citizenship's worldview through the tradition of Judaism and the social impact of Christianity will be presented by a broad historical arc. Protestantism considers work in the human world a task of life, a prerequisite for an invitation to salvation. What does the Bible teach about this? How did the need for tasks to be accomplished become the basis of moral order? What kind of philosophical explanations link the invitation to salvation and the profession as the everyday, functional level of social utility? Perhaps the most spectacular and best-preserved engineering achievements of a man who turned to God in the light of faith are the buildings erected as eternal symbols of the desire for salvation, the cathedrals.

**Keywords:** Work · Profession · Call to Salvation

## 1 Introduction

If we want to examine the arc of the evolution of the concepts of profession and the call to salvation, we need to work with Christian theology, ethics, comparative religious studies, philosophy, anthropology, cultural and social history within the framework of multidisciplinary research and from a historical perspective.

Here and now, we, as free citizens of Western civilization in the 21st century, may think this is a bit abstract, but it is actually the foundation of the world and the culture we live in.

What do these two concepts, profession and the call to salvation, mean? Profession is what one undertakes and performs during his earthly life as an activity, as a task for life, thereby serving themselves, their environment, this world on earth and the divine order. Call to salvation, according to the teachings of Christianity, is the divine gift that one can receive in the afterlife, after the end of one's honest and well-done work, faithful and believing life. Beyond generalization, we will need some theological and philosophical explanations in order to understand all this in detail and in a historical context.

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# 2 Interdisciplinary Context

## 2.1 Philosophical Fundamentals of Religion

Man, as a creature of God, has received his very existence, the basis and meaning of his being, and the necessary elements of existence from his Creator. Talent too. Thus, it is from the outset a divine gift as to where and what circumstances someone is born into, which can be augmented by their abilities. Because it is not enough for you to be talented in something, it is also necessary to have the conditions in which you can develop your talent and practice it for a lifetime. Overall, it can be interpreted as a heavenly reward to be able to pursue what you have the skills for and what you love to do in your life. In light of this, profession is already a kind of calling to goodness, beauty, happiness, that is, to the earthly image of something that believers imagine as heaven in its perfected form. If we add to this the analysis of transcendental qualities, i.e., the concepts of "good, beautiful, true, eternal, sacred", we come back to God on the theoretical side of the philosophy of existence and on the practical side of aesthetics [1].

"If, therefore, we include in sociology, as we should, the phenomena of one's spiritual life and their higher cultural aspirations, we must include in the concept of work all the higher human endeavours and activities which one undertakes for the sake of the beautiful, the good and the true" [2, p. 128].

How is the interchangeability of transcendental characteristics to be interpreted? Transcendental, or in its older form of the expression, the transcendent appeared as early as the ancient Greeks in the philosophy of Socrates and is none other than the Platonic "idea" or the Aristotelian "morph" [3]. Thus, it denotes an eternal value that is independent of the rules of this physical world and exists in itself and in reality, at the level of ideas. Our world of experience, however, is only a kind of imperfect representation of it, a kind of shadow image. The Greek philosophers in the 5th and 4th centuries BC arrived at the necessarily existing perfect reality not through faith, but through logical insight, which the scholastic philosophy of Christianity examines and interprets already in the light of faith. Accordingly, transcendental concepts are those qualities that are fully present only in God as a kind of eternal and perfect standard. These may be possessed by man, but as mortal only temporarily, partially, and to a limited extent. For it is bound to time, i.e., to a limited existence full of changes between birth and death. Therefore, the concepts of good, true, beautiful, eternal, existing and sacred are interchangeable, because they are synonymous with God, i.e., transcendental perfection [4]. Originally in scholasticism, the six transcendentales (ens, unum, verum, bonum, res, aliquid) are the existing, the one, the true, the good, the thing and the something. They gained their collective name from the fact that each of them crosses, goes beyond, transcends (transcendit) the category boundaries of the perceptible world [3].

From the point of view of religious philosophy, we must understand all this as all that is beautiful is good and true, but can only become sacred, that is, absolute, if it is able to maintain this state independently of space and time, that is, forever. However, this does not exist under the conditions here on earth [1, 5].

## 2.2 Antecedents of Architectural History – the Middle Ages

I would like to present the ethical basis on which the idea of the profession could have emerged in the 16th century primarily based on *The Age of the Cathedrals: Art and Society, 980–1420* by Georges Michel Claude Duby (1919–1996), a renowned French medieval historian. When work is no longer merely a communal sacrifice, but a manifestation of holiness, it praises the doer of the work before God's judgment seat [6].

To an earthly mortal, eternity is as incomprehensible as infinity. Time and space, as a medium created by God, allow the possibility, survival and development of matter, including man, the world and humanity. Since Plato (427–347 B.C.), who was following Parmenides (c. 540–460 B.C.), eternity has been interpreted as a way of being that excludes the possibility of any change. This was one of the ontological reasons for the perception and the long, seemingly unchanging world of the Middle Ages. It is important that in the revelation received from God, the temporal perspectives are not interpreted strictly, and the measurability of human life in decades does not play a role compared to eternity. Therefore, the fact that something lasts for a day, a year, or the whole life of a person in relation to earthly existence does not alter the eternity of the divine order. In fact, not even a historical period or the entire history of humanity does. Eternity is thus the subjective time interval of the transcendentally existing [1].

Under the influence of the Church's centuries-old teaching, medieval man could not appreciate the earthly existence full of sin but spent his whole life preparing only for his salvation after his death, "… the thousandth anniversary of Christ's Passion, the anniversary of God's death" [7, p. 54.] The written records of the 11th century were mostly preserved in the monasteries, with their unique ethics derived from people whose lives were determined almost exclusively by sacrifice and the pain of Christ's death on the cross [6]. The main task for monks was to pray for others. The individual is worthless, his work was one of many, his initiatives blended into common action and common responsibility.

Until the middle of the 12th century, creation had no other role than to offer all the riches of the earthly world to God, and people believed that these gifts made it possible to reconcile the punishing God. For it was possible to glorify God not only by prayer, but also by offering beauty and values. – In the discussion of religious philosophical foundations, transcendental concepts of eternal divine qualities were already discussed. – Accordingly, the perfection, beauty, and permanence of architecture are best suited to approaching the omnipotence of God [6]. In their fascinating existence, the cathedrals reproduce this transcendental perfection on a human scale, in the human world, as an incomprehensible achievement of human work. The function of architecture and art was sacrifice, not really aesthetics, but magic. For the world of thought of those at the highest level of culture was dominated by superstitions of fear, by irrational imagination [6]. Such a building may never be merely functional and self-existent, but a clear representation of its own age. It shows everything. In it we may basically find the sum of all sciences, and thus the ethics of the work that produced it.

Thus, the architects of the Middle Ages did not see themselves as the implementers of their creation, but saw God's work, "Opus Dei", realized in it. They believed that God had given them knowledge, or at least the opportunity to obtain knowledge, that He had helped them to carry out their work, and they prayed continually for every small detail of it. It was not about man but the work. Even the rivalries of power wished to transcend each other by glorifying God… which, we must admit, they did successfully. Even today's man cannot sit in a cathedral without looking up in amazement. This architecture strives to guide the creature towards the heavenly light „through palpable, visible beauty, the soul is elevated to that which is truly beautiful, and rising from the earth, where it was submerged, an inert thing, it is resuscitated in heaven by the radiance of its glory" [7, p. 89]. This is how *The Age of the Cathedrals* quotes Suger (1081–1151), the creator of Gothicism, the highly educated Benedictine abbot of the monastery of Saint-Denis.

Cities were necessary for the formation of the bourgeoise and its strengthening centuries later. In the 12th-13th centuries, cities north of the Mediterranean began to develop significantly in Europe, and slowly, some seven to eight centuries after the fall of the Western Roman Empire in 476 AD, they again became the centres of higher culture. "By definition, a cathedral was the bishop's church, hence the city's church; and what the art of cathedrals meant first of all, in Europe was the rebirth of the cities" [7, p. 93]. The renowned representatives of the Gothic era could already have their own personalities, for example, this is why we know the name of Jean d'Orbais (c. 1175–1231), the master builder of the Reims Cathedral. The possibility of the development of science and technology, that is, of engineering work and aesthetics, and in this sense, of art, depended on the progress of ecclesiastical thought. Therefore, if we want to understand the Middle Ages and the Early Modern Period, we must first turn to theology as the principal science of that era.

### 2.3 Theological Explanations

In his profession, activity and work, man is called to approach perfection and in his life, he can experience its fulfilment, which leads him to salvation, that is, it provides a straight path to the kingdom of heaven. According to the basic principle of Christian theologies, man is so important to God that he created him and then called him to follow Jesus in Christianity and, through Christ's death on the cross, called man to eternal life. "For God so loved the world that he gave his only Son…" *Jh 3,16* [8].

This sentence begins with "for", which is often omitted when quoted, but it really should not, because it would change the meaning of the entire Christian revelation. This is not a simple statement, although it would be a powerful one, but it is much more than that. This is the causal explanation of the existence of the world: It is the fundamental and all-pervading divine cause for which man can live on earth Love.

The world of the European Christian Middle Ages and its interpretation cannot be subjected to today's principles of political correctness. Let's not try and look for such interpretations here and now, but merely accept its authority as a determining fact even for science and its overwhelming legitimacy in the interpretation of the age under discussion.

In its modern interpretation and in a broader sense, therefore, profession is the daily work and task of man with added content, which he fulfils according to his conscience and moral attitude. Strictly speaking, it is the sum of tasks, services and duties that help the Christian man to achieve his ultimate goal of salvation during his earthly life. One's profession, that is, their call to holiness, is to a specific service to people and the world. Recognizing and accepting this helps one to fulfil their profession in society [9].

How beautiful it would be and how happy our life would be if we could live it so simply in its purity and beauty, that is, in its holiness! But this world is not only the scene of our happiness, but also of our trials and tribulations. Thus, this calling is complemented by the rough road we all take in our lives. And this is what we need a commitment to, that is, the very strong, we can say sacred determination to follow this path. According to Catholic terminology, however, the call to salvation is also a share in the suffering of Jesus' death on the cross. Thus, the total happiness of life on earth, that is to say, life without suffering, renunciation, fasting and repentance, was clearly a sin. But according to the Protestant concept of work, it is the way, the whole path of life itself, that leads to salvation. Where did these teachings come from and what are they based on? [1, 5].

### 2.4 Biblical Guides and Fundamentals

According to the teachings of the Abrahamic religions, God created this world only by the power of his words, out of nothing, that is, he was the Unmoved Mover. This action without activity and the power of the spoken word are important, but the importance of this will only be truly confronted in the European Middle Ages.

The Gospel of John also begins like this: "In the beginning was the Word, and the Word was with God, and the Word was God" *Jh1,1* [8]. That is, before creation, when there was nothing, it was first only the word spoken by God, which was His exclusive thought and will. "In the beginning God created the heavens and the earth. Now the earth was formless and empty, darkness was over the surface of the deep, and the Spirit of God was hovering over the waters. And God said, "Let there be light," *Gen 1,1–3* [8]. Since the spoken word means both the conceiver and the pronouncer of the spoken word, God and his word represent one and indivisible unity. The difference between creation and construction is that while in the act of creation God created something out of nothing, by the power of his own word alone – which happens to be the world –, construction comes into being out of a substance, through certain actions.

In the book of Genesis, the Old Testament already uses Old Hebrew words that also denote the creative activity of man, for example, God constructs, creates, shapes, and calls the world into existence. However, the basis of all this is an expression that means only the verbal and will act of the divine creation and cannot be used for any human activity, this is the verb bara = to create [9].

When God created this world and this man, He gave him a task. "Then God said, 'Let us make mankind in our image, in our likeness, so that they may rule over the fish in the sea and the birds in the sky, over the livestock and all the wild animals, and over all the creatures that move along the ground.' [...] God blessed them and said to them, 'Be fruitful and increase in number; fill the earth and subdue it. Rule over the fish in the sea and the birds in the sky and over every living creature that moves on the ground.' Then God said, 'I give you every seed-bearing plant on the face of the whole earth and every tree that has fruit with seed in it. They will be yours for food and to all the beasts of the earth and all the birds in the sky and all the creatures that move along the ground – everything that has the breath of life in it – I give every green plant for food.’ And it was so.” *Gen 1,26–30* [8].

“The LORD God took the man and put him in the Garden of Eden to work it and take care of it.” *Gen 2,15* [8].

## 3 Work and Profession in the History of Ideas of the West

Considering also etymological aspects, trying to create conceptual clarifications, it is necessary to define the definitions of work and profession. It is worth starting with the concept of work, because without this older and more general term, and without it, the concept of profession does not really make sense.

### 3.1 Work

Work is any activity that a person has to perform under the influence of external or internal coercion. Whether taking care of oneself, those entrusted to them, or responding to external forces that affect them in a non-contradictory way. It is not only physical activity that qualifies as work, but also all forms of mental effort [2].

In a large part of the ancient societies there was respect for work, clearly the legacy of the Greco-Roman legacy is the complete degradation of the value of work and the performer of the work. It is the level of the slave-holding society where working was considered the lowest activity. “In Greek, the concepts of work, toil, poverty, and torment were expressed in words from the same origin; in Latin, labor means effort, work, torment, and pain; and the Hungarian word for work (munka) was borrowed from Slavic and means pain, both in the Old Slavic and in the modern Slavic languages” [2, p. 130].

According to the Bible, man’s task is his work in this world. It is not degrading, as in Greco-Roman thinking, but a task ordained by God (Gen 1:28). The man of the Old Testament did not imagine the state of the Garden of Eden without work (Gen 2:15). Even the intellectuals of ancient Judaism, the scribes, had to learn a craft. It is a well-known fact that Jesus was a carpenter. This obligation proved valuable in eliminating the possibility of tensions between the educated and the working classes [10]. In fulfilling his task of work, man is dependent on God, for without him all effort is futile. Since God blesses the work of man, God is entitled to the first crop and to the tenth of the animals and grain. According to the social justice and Mosaic law, a person must offer a voluntary gift to God according to the degree of blessing received. Man’s task is to carry on the creative work of God through his life and continuous activity. According to the New Testament, Jesus did not teach about work separately, but since he spent almost his entire life as a carpenter and then as a teacher, he sanctified and clearly justified all human work, both physical and spiritual, in the elevated interpretation that the Old Testament provides. The Christian interpretation of the work can only be found in the Apostle Paul’s letters to the faithful of Colossians and Ephesians: this is a service to God, not to men. The work done in this sense is pleasing to God, and his actions accompany man who will one day be rewarded with eternal life [11]. They simply conceived work as a part of life, which is the indispensable natural basis for a believer’s life. Although, as the prohibition on working on the Sabbath shows, it had its own order and rules, it was not ethically associated with value, nor with eating or sleeping [10, 12].

In the Middle Ages, society was divided by divine selection. Modifying the understanding of ancient Judaism and the ancient ideas, there was a new interpretation in this system of the punishment in the Book of Genesis, that is work did not apply to the chosen ones. However, it did to social groups that were less favoured by their birth. If a person could, by the will of God, be a king, pope, emperor or other high dignity anointed with holy oil, he was exempted from the "punishment" of the earthly world and received the reward of the supposed divine order. The current Pope is the vicar of Jesus Christ on earth, so the Vatican State is still a theocracy. The kings and rulers were the guardians and custodians of the worldly order ordained by God. The royal and imperial command, that is to say, the power of the spoken word, evokes the word of creation, and is therefore sacred and binding, as it is when the current Pope, when speaking in terms of faith and morals, is infallible. Basically, the consecration to power, that is the divine legitimacy, served to defend and protect those under his authority, that is, the people under his rule, during their earthly life and to ensure the world of life through which they can reach eternal life after their death. In the medieval society of orders, this selection continued to be transferred but weaker with concentrical distance increasing from the centre of power. [5, 6, 13].

This does not mean that these social strata existed in a life without activity or in a vacuum without tasks. It simply means that in the society of orders, each person's task could be mostly determined at birth. As in the end of antiquity, in the Middle Ages and in the early modern era, all believers were waiting for the second coming of Jesus Christ, that is, for the end, or more precisely, the fulfilment, of the present order of salvation. According to the Apostle Paul guidance: "Let everyone remain in the position and in the secular work in which he was found by the'calling' of the Lord, and let him continue to work as before" (2, p. 137] As mentioned above, work has not yet been regarded as a moral value and as an ethical factor. This was due to a tradition of faith and a general experience of life, with which, even in the early modern era, the afterlife was not only more important, but in many ways more certain than this world. [12] Therefore, the people of the Middle Ages did not deal with the fullness of the world around them but focused their attention on the afterlife, nor did they deal with the emergence of a reality beyond the idea as an individual. They approached the present of their lives from the perspective of the afterlife, so it was only relevant for the preparation for salvation. Just as eternity logically excludes the possibility of change, so this age forbad development on the basis of theological principles, so changes could only have impact on the surface and were subordinated to divine providence. This was one of the ontological reasons for the perception and the long, seemingly unchanging world of the Middle Ages.

According to "The Protestant Ethic and the Spirit of Capitalism," written in 1905 by Max Weber (1864–1920), a German economist, social scientist, and father of modern sociology, from our modern-day perspective medieval man, in his trust in providence and God's grace, lived from one day to the next. Weber sees this confirmed in one of the most important prayers, the text of "The Lord's Prayer": "Give us this day our daily bread…". That is, an unconditional duty to God was identified with an unconditional acceptance of the given situation and the pursuit of a profit beyond one's own needs was considered a sin [12].

The bourgeoisie began to develop and gain ground only after the consolidation of the society of orders, so even though they tried to comply with these requirements and attempts were made to have them fit it through austerity measures and taxes, they never really melted into that society. In the light of his existence, their entitlement and the spirit of the Renaissance world, they were able and wanted to open up towards a new world order. It was in their ranks where the Reformation gained ground, among other things, because they were able to write and read due to their activities. – It is worth noting here that reading and writing was almost always created out of necessity. The oldest written records in the world are also commercial records, inventory books and seals. Religious texts could be learned and passed by word of mouth, but the constantly changing accounting data, inventories and accounts could not be kept in mind, verified and transmitted in an accountable form.

One of the most influential achievements of the Reformation, and of Martin Luther in particular, was increasing the value of secular occupations as opposed to monasticism. Calvin's teachings also brought a radical change in the ethical judgment and subsequent social acceptance of religious life and worldly activities [12].

## 3.2 Profession

Max Weber, the father of sociology and Sándor Giesswein, the leading figure of Hungarian Christian social endeavours, were contemporaries, both being modern-minded and broad-minded social scientists of their time, a mix of the German Protestant layman and the Hungarian Catholic cleric. It is interesting to read their thoughts about work and profession side by side, to witness their different points of view mixed with an always polite, objective tone in which basically they both say the same thing. In addition to Weber's above-mentioned work, I consulted Giesswein's 1929 work entitled "Társadalmi problémák és a keresztény világnézet" (Social Problems and the Christian Ideology).

Gerald Sailmann's monograph "Der Beruf – Eine Begriffsgeschichte", a conceptual history research on profession published in 2018, is a valuable scientific treatise on the subject. Another such example is a similar study by the theologian and professor of church history Karl Holl entitled "Die Geschichte des Wortes Beruf" in 1928. A longer analysis and interpretation are also offered by the German "Lexikon für Theologie und Kirche", which was first published between 1930 and 1938 at the initiative of Bishop Michael Buchberger of Regensburg [14].

According to Giesswein, a profession is something that a person voluntarily and willingly performs with competence and expertise, that is, implements with some kind of added (moral) value. There is a qualitative difference between work and profession. The difference can be most often measured not in the result of the task performed, that is, in the quality of the product, but in the spiritual content that, in addition to the perfection of the function, also complements it with the ideal and emotional surplus, that is, makes the outcome more valuable, more ideal, somewhat artistic. This is the level at which man does not merely work, but creates, implements, realizes something. Compared to his needs, he uses his talents, competencies in modern terms, to move forward not only his own life, but also the social unit in which he lives [2]. The definition itself is perfect, but Sándor Giesswein does not mention, nor does he necessarily consider important in his own Catholic world, an element that is a significant factor in the conceptual formation of the word "profession".

There are concepts that develop at a certain point in history, or someone starts using them for some reason. Such is the English "calling" that is "der Beruf" in German and "hivatás" in Hungarian. The Latin vocatio, however, was originally only a divine call to holy life. Max Weber elaborates on the etymology of this word and its antecedents in the available Bible translations, but states that before Martin Luther's translation of the Bible in 1522, no one had used this term specifically in the present-day sense [12, 15]. For us, the importance of this is that it was only after this date that it could take roots in the Hungarian language.

## 4 The Arc of the Ethical Evolution of the Concepts of work and Profession

Of course, even in antiquity and in the Middle Ages there was some respect for regular secular work, but it was not associated with religious and ethical complexity. "Like the meaning of the word, the idea is new, a product of the Reformation. [...] But at least one thing was unquestionably new: the valuation of the fulfilment of duty in worldly affairs as the highest form which the moral activity of the individual could assume. This was which inevitably gave every day worldly activity a religious significance, and which first created the conception of a calling in this sense." [16, p. 40].

Luther's linguistic and theological innovation was not a criticism of existing social theory, but only a changed interpretation and evaluation of human work, as I have already written with reference to Max Weber. Nevertheless, Luther's rediscovery of the religious and ethical element in work gave birth to the concept of profession in Germany. Two elements that significantly determined later social development were merged at this time: profession and work. However, the word "Beruf = calling" was initially used only in evangelical ecclesiastical language, and further differentiated in the theology of the Reformation.

According to Weber's definition, it is the profession that man accepts as a divine ordinance, to which he must unconditionally and necessarily adapt, because the performance of the profession is in some way the task that God has set for him. „Worldly duties were no longer subordinated to ascetic ones; obedience to authority and the acceptance of things as they were, were preached" [16, p. 45].

In Calvinist teachings, salvation, that is, the call to eternal life, is based on a kind of ordainment, the so-called predestination, in which no one can know whether he was chosen by the Lord. There was no mention, as in Catholicism, that one could be saved through repentance and conversion, as it would be a simple and too great a gift that one would only abuse in one's weakness. Thus, for the faithful, the most appropriate means of obtaining certainty about themselves, even under the guidance of the ministers, was the tireless pursuit of the profession. The supreme justification of true faith is the conduct of man's life in order to increase the glory of God. This already shows a clearer connection between life practice and the religious starting point than Luher, with which a quite different relationship has been established between religious life and earthly action than either by Catholics or Lutherans. "For a more intensive form of the religious valuation of moral action than that to which Calvinism led its adherents has perhaps never existed" [16, p. 70].

For Catholics, the grace of repentance, that is, the sacrament of confession, served as a means of compensating for their human frailty; however, according to the teaching of Calvinism, God did not expect certain "good deeds" from his followers, but rather salvation through systematized deeds. True repentance can really only be expressed in your lifestyle. The German term for this is "Werkheiligkeit = righteousness by works" [12, 17].

## 5 Conclusions

The Reformation transferred rational Christian asceticism and the method of conducting one's life from the monasteries of the monks to the field of secular lifelong profession. In this way, the rationalization gave a puritanical character to the Reformed religion, thus establishing its inner affinity as well as its specific opposition to Catholicism [12].

Just as the development of the concept of profession and its development into today's form is the product of Protestantism, the religious and ethical necessity of belonging to the Puritan world could never have been formulated by a medieval thinker.

What, then, was the key to the civil and economic development of the Dutch and Protestant regions? The unwavering effort to live the true faith and the desire for salvation which, with profound devotion and religious effort, inspired the work of the faithful to exercise their profession diligently. But sharing in the sufferings of Christ's death on the cross prevented a wastefully rich, lazy way of life and gave rise to a puritanical outlook on life. The man who has been called by God to follow Christ can be called to eternal life through his profession.

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# Criterion Challenges in Fostering Readiness to Create and Use Digital Educational Content

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**Abstract.** The term "readiness" is often referred to in pedagogical and psychological literature devoted to the organization of educational processes, especially in dissertation studies. Meanwhile, readiness is understood as the ability of a future specialist to perform a certain type of activity. This article suggests a feasible approach to solving criterion challenges that a teacher may face in fostering or developing readiness for any type of activity, illustrated by a specific discipline. Given the evolution of advanced skills, which today's specialists must possess for quick and effective problem solving, such skills as the use of technology, monitoring, and control are deemed relevant and well-timed. This is what this study is devoted to. Given the complexity and interconnectedness of the factors determining the future engineering teachers' readiness to create and use DEC in professional activities, it is imperative to input those assumptions whereby the obtained results would be valid. This article describes the developed indicators of readiness to create and use DEC and gives examples of their calculation.

**Keywords:** Readiness · Readiness Criteria · Digital Educational Content · Engineer-teachers

## 1 Problem Statement

Within an international innovative project known as the Transformation of Digital Pedagogy, much effort is now being invested in creating a new specialist of the future and developing his/her digital competence at the state level. According to the analysis of psycho-pedagogical references and scientific studies on fostering readiness and assessing the degree of development of new skills, the following is required: • determine the list and relationship of issues that arise in assessing the effectiveness of pedagogical influences on the formation or development of future engineering teachers' readiness to create and apply Digital Educational Content (DEC) in professional activities based on the example of such discipline as Digital Management Technologies (DMT); develop and test the possibility of calculating indicators for assessing readiness using real data and test cases.

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Current digital technology has completely overwhelmed today's specialists. Thus, a smart choice and modern digital tools enable qualitative training of the modern specialist in the age of Industry 4.0. Operative monitoring of training a specialist for new types of activities will save time for high-quality recruitment in modern enterprises and digital universities. Assessing the readiness indicators for the creation and utilization of Digital Educational Content was carried out using the offered coefficients, and it showed the effectiveness of the pedagogical innovations.

There are three criterion challenges faced in fostering future engineering teachers' readiness to create and use DEC in professional activities: challenge 1 consists of assessing the level of proficiency required to create and use DEC in professional activities, as part of the disciplines preceding the discipline known as Digital Management Technologies; challenge 2 consists of assessing the level of proficiency required to create and use DEC in professional activities, as part of the discipline known as Digital Management Technologies in the traditional organization of the educational process; challenge 3 consists of assessing the level of proficiency required to create and use DEC in professional activities, as part of the discipline known as Digital Management Technologies in the innovative organization of the educational process.

## 2 Analysis of Recent Research and Publications

The assesment criterion is a complex and acute problem for any pedagogical research and the most important problem for any activity in general. Therefore, when starting a study, it is necessary to take a serious approach to determining the criteria for evaluating its results.

Measuring the level of readiness for the fostering and use of DEC involves, first of all, the selection of scientifically based criteria and indicators that would most objectively and meaningfully characterize the content of the integral and multicomponent concept of "readiness".

The problem of readiness for activity has been considered by many domestic [1, 2] and foreign [3–5] researchers. The researchers Casner-Lotto J. and Horsley K. [6, 7] have drawn attention to the differences in the interpretation of the concept of "readiness", and it was found that psychologists in their scientific research of this problem were focused on establishing the nature of the links and dependencies between the state of readiness and the effectiveness of the individual's activity, while teachers focused on identifying factors and conditions, didactic and educational means by which it is possible to manage the process of formation and development of the individual's readiness for various types of activity. Since the set of criteria should sufficiently cover all the essential characteristics of the phenomenon under study, it is necessary to select the level of readiness components for the development and use of DEC as criteria.

Digital educational content is rapidly gaining popularity today, especially since the beginning of the pandemic COVID 19 and now during the period of military operations in Ukraine. Ukrainian scientists have long been researching the development and use of high-quality digital content of academic disciplines [8, 9].

Since DEC are now replacing traditional teaching tools, the urgent problem is to find and justify adequate criteria for assessing the quality of development and use in the educational process, namely, the search for criteria for evaluating digital educational content. Given that these criteria alone characterize only certain aspects of the formed readiness, it is necessary to develop a method of comprehensive assessment of readiness for the development and use of DEC based on assessments of individual components of readiness.

This study considers the criteria and indicators for assessing the operational component of readiness for the fostering and use of the DEC. This component characterizes the formation of skills that ensure readiness at the level of individual tasks and individual operations [10].

## 3 Statement of Basic Material and the Substantiation of the Obtained Results

*Criteria Problems. Accepted Assumptions and Requirements for the Readiness Requirements.* There are three criterion problems in fostering the readiness of future engineer-teachers to create and use DEC in professional activities:

- Problem 1 to assess the level of fostering of skills required to create and use DEC in professional activities, within the framework of the disciplines preceding the discipline "Digital Management Technologies";
- Problem 2 of assessing the level of fostering of skills necessary to create and DEC in professional activities, within the discipline " Digital Management Technologies t" in the traditional organization of the educational process;
- Problem 3 is to assess the level of development of skills required to create and use DEC in professional activities, within the discipline "Digital Management Technologies" in the innovative organization of the educational process.

In view of the multidimensional and multi-connected nature of the factors determining the readiness of future engineer-teachers to create and use DEC in professional activities, it is necessary to introduce the assumptions within which the obtained results will be valid.

1. The skills necessary to ensure the future engineer-teacher's readiness to create and use DEC in professional activity are formed at two stages: basic (within the disciplines preceding the DMT discipline) and professional (within the DMT discipline).
2. In the psychological structure of activities, skills at three levels should be distinguished when assessing the level of proficiency: at the level of operations, at the level of tasks activity and at the level of production function (as an activity).
3. The ability of the skills that ensure readiness at the level of individual tasks activity and individual operations can be assessed by the following coefficients:

$k_l^{ta}$ - the coefficient of skill fostering that ensures readiness at level l of the task activity ($l = 1, L$), where L is the number of tasks activity in the production function;

$k_{ml}^{op}$ - the coefficient of skill fostering which ensures readiness at the level of the *m*-th operation related to the l-th task activity ($m = 1, M_l$), where $M_l$ is the number of operations in the structure of the l-th task activity.

4. The coefficient of skill fostering that ensures readiness at level l of the task activity (l = 1,L) is calculated according to the formula

$$k_l^{ta} = \frac{As_l^{ta}}{As_{max}^{ta}} \leq 1, \quad (1)$$

$As_l^{ta}$ - expert assessments of the skills that ensure readiness at level l of the task activity;

$As_{max}^{ta}$ - the accepted maximum assessment of the skills that ensure readiness at level l of the task activity.

5. The coefficient of skills that ensure readiness at the level of the m-th operation related to the l-th task of the activity (m = 1, Ml) is calculated according to the formula

$$k_{ml}^{op} = \frac{As_{ml}^{op}}{As_{m,max}^{op}} \leq 1, \quad (2)$$

where $As_{ml}^{op}$ - the expert assessment of the competencies that ensure readiness at the level of the m-th operation related to the l-th task of the activity;)

$As_{m,max}^{op}$ - is the accepted maximum assessment of the skills that ensure readiness at the level of the m-th operation related to the l-th task.)

6. In view of the fact that the fostering of skills ensuring readiness at the level of operations related to the l-th activity task does not guarantee the fostering of skills ensuring readiness at the level of the same task activity, it is necessary to calculate separately the coefficients $k_l^{ta}$ (l = 1, L) and $k_{ml}^{op}$ (m = 1, Ml). This statement is due to the fact that operations related to the l-th task activity may be activity-dependent on each other (emergent effect).
7. When assessing $k_{ml}^{op}$ value, a situation may arise where it is difficult to assess the level of preparedness at the level of an individual operation, for example, it is difficult to assess the level of "Searching a new digital tools ". In this case, for the m-th operation it is acceptable to consider)

$$k_{ml}^{op} = k_l^{ta}$$

8. The means of monitoring learning achievement should be designed to assess the development of skills that ensure readiness at the level:)

- the training process should be designed in a traditional way and should be based on individual operations and individual tasks of the activity;)
- The teaching and learning process is organized in an innovative way (content, methods, technologies, tools and forms of teaching and learning are modernized);
- The individual operations and formed in the discipline DMT, based on the updated basic skills.

Assessment of readiness indicators. The following indicators:

$k_{bas}$- the coefficient of basic readiness of a future engineer-teacher to create and use DEC in professional activity; the coefficient reflects the level of formed skills within the disciplines preceding the DMT discipline and necessary for creating and using DEC in professional activity;

$k_{form}$ – the coefficient of fostering readiness of a future engineer-teacher to create and use DEC fostering within DMT discipline; coefficient reflects the level of fostering skills within DMT discipline at traditional organization of educational process, necessary to create and use DEC in professional activity;

$k_{tar.form}$ - the coefficient of target fostering (professional) readiness of a future engineer-teacher to create and use DEC in professional activity; the coefficient reflects the level of fostering of skills necessary to create and use DEC in professional activity, after studying the discipline DMT of innovative organization of educational process.

A student's level of readiness after the basic stage of fostering the relevant skills can be determined by averaging the grades for those disciplines that fostering the skills needed to create and use DEC in professional practice. Therefore

$$k_{bas} = \frac{As_{med}}{As_{max}}, 0 \le k_{bas} \le 1, \quad (3)$$

where $As_{med}$ is the student and discipline average of the skills required to create and use DEC in professional activities, after the basic stage of their fostering:

$$As_{med} = \frac{\sum_{i=1}^{n}\left(\frac{\sum_{j=1}^{m} As_{ij}}{m}\right)}{n} \quad (4)$$

$As_{ij}$ - the final assessment of the i-th student in the j-th discipline, which forms the basic skills necessary to create and use DEC in professional activities;

m - number of basic disciplines skills fostering;

n - number of students in the sample.

$As_{max}$ - the accepted maximum assessment of the fostering skills after the basic stage of their formation; for a four-point grading system $As_{max} = 5$, for a 100-point grading system $As_{max} = 100$.)

Example of $k_{bas}$ calculation. An exploratory experiment was conducted at the Ukrainian Engineering Pedagogics Academy, preceding the introduction of innovative organization of the teaching process in the discipline "Digital Management Technologies". Four groups were chosen for the experiment. The same groups are involved in a formation experiment. Students in two control groups (48 students) studied DMT according to the traditional methodology. 45 students in the other two experimental groups studied DMT using an upgraded methodology. Using the two-way Wilcoxon-Mann-Whitney test, it was found with significance level $\alpha = 0.05$ that the control and experimental groups were sufficiently homogeneous in the level of initial knowledge and skills to conduct the formative experiment. Therefore, it is acceptable to calculate one coefficient of basic readiness for control and experimental groups $k_{bas}$.

The following disciplines were identified as precursors to the DMT discipline and necessary for the creation and use of DEC in professional activities: "Informatics and Computer Technologies", "Psychology", "Engineering and Computer Graphics", "Methodological Foundations of Professional Education". Their selection is based on the analysis of educational and qualification characteristics and work programmers. The values of $As_{ij}$ are the final marks of the i-th student in the j-th discipline according to the results of examinations and tests in these disciplines in the module-rating system. The average score for the four groups and for four disciplines is 3.71. Consequently, according to (3) $k_{bas} = \frac{As_{med}}{As_{max}} = \frac{3{,}71}{5} = 0, 74$.

The assessment coefficient of formed readiness of a future engineer-teachers to create and use DEC, fostered within the framework of the DMT discipline, can be assessed by the value of

$$k_{form}^{abs} = \sum_{l=1}^{L} \sum_{m=1}^{M_l} k_{ml}^{op} + \sum_{l=1}^{L} k_l^{ta} \tag{5}$$

Expression (5) is called the absolute form of the coefficient of formed readiness. The additivity of expression (5) makes it possible to ensure the growth of $k_{DMT}^{abs}$ assesment with the increase in the number of skills actualized by innovative learning technology.

Formula (5) shows that $k_{form}^{abs}$ is a dimensionless value, expressed as a real number bounded on the right by the number of skills analyzed:

$$0 < k_{form}^{abs} \le \sum_{l=1}^{L} M_l + L. \tag{6}$$

This same coefficient of formed readiness in relative form is:

$$k_{form}^{rel} = \frac{k_{form}^{abs}}{\sum_{l=1}^{l} M_l + L}. \tag{7}$$

The level of student readiness after the professional stage of skills fostering and in case of innovative organization of educational process is defined in the same way as in case of traditional organization of educational process (see formulas (5), (7)). However, the growth of formed readiness coefficients at the level of individual operations and individual tasks activity is expected due to the actualization of students' knowledge and skills when using inter-subject and inter-thematic connections in the innovative organization of the educational process. Therefore, it is fair to assume:

$$k_{targ.form}^{abs} = \sum_{l=1}^{L} \sum_{m=1}^{M_l} k_{ml}^{op} + \sum_{l=1}^{L} k_l^{ta}. \tag{8}$$

$$k_{targ.form}^{rel} = \frac{k_{targ.form}^{abs}}{\sum_{l=1}^{l} M_l + 1}. \tag{9}$$

Example calculation. The structure of skills that ensure readiness after the professional stage of skills fostering in DMT discipline is presented in Table 1. The content of skills, expert and maximum assessments of the formation of skills, providing readiness at the level of operations and tasks activity, are shown in Table 1. The operations are assessed on a traditional 4-point scale, the tasks are assessed on a 6-point scale (7 - excellent; 6 - very good; 5 - good; 4 - average; 3 - satisfactory; 2 - unsatisfactory).

According to formula (7) we have:

$$k_{form}^{rel} = 8,78/(3+4+3+4+) = 0,49$$

To simplify the example, we will assume that the innovative organization of the learning process has increased all skill assessments, which ensure readiness at operations and tasks activity levels 1–3.5, by 12% and that skill number 4 is also formed. Then

$$k_{targ.form}^{abs} = 8,78 * 1,12 + (1 + 0,8 + 0,8 + 1) + 6/7 = 14,3,$$

$$k_{targ.form}^{rel} = 14,3/(3+4+3+5+4+5) = 0,6$$

The given methodical approach also allows comparing the effectiveness of two or several methodical systems that form the readiness of a future specialist for different types of activity. For this purpose let us introduce a $k_{int}$ - an integral coefficient of readiness of a future engineer-teacher for a certain type of activity and define it as follows:

$$k_{int} = k_{bas} * k_{form}^{rel} \quad (10)$$

**Table 1.** Assessments of the fostering of skills that ensure readiness at the level of operations and tasks activity

| $As_l^{ta}$ | $As_{max}^{ta}$ | Skills of tasks activity | Skills at the operations level | $As_{ml}^{op}$ | $As_{m,max}^{ta}$ |
|---|---|---|---|---|---|
| 5 | 7 | 1. Developing synchronous lesson tools | 1.1. Identify the functions of interactive boards | – | 5 |
| | | | 1.2. Select and configure tools for creating interactive boards | – | 5 |
| | | | 1.3. Create and customise interactive exercises | – | 5 |
| 4 | 7 | 2. Using the online testing tools | 2.1. Search and select online testing tools) | 4 | 5 |
| | | | 2.2. Identify tools of online test platforms | 3 | 5 |
| | | | 2.3. Create different types of tests and upload them to the test platform | 3 | 5 |
| | | | 2.4. Check test performance (link formation, settings, transmission methods) and process results | 4 | 5 |

(*continued*)

**Table 1.** (*continued*)

| $As_l^{ta}$ | $As_{max}^{ta}$ | Skills of tasks activity | Skills at the operations level | $As_{ml}^{op}$ | $As_{m,max}^{ta}$ |
|---|---|---|---|---|---|
| 5 | 7 | 3. Use of digital communication tools in the modern lesson | 3.1. Search for and select digital communication tools | – | 5 |
| | | | 3.2. Select and configure platforms for lessons | 5 | 5 |
| | | | 3.3. Connect users, use additional functions, record online lessons | 3 | 5 |
| 6 | 7 | 4. Creating and using gamification learning tools | 4.1. Search and select tools for creating game-based exercises | 5 | 5 |
| | | | 4.2. Create didactic material (questions, multimedia, infographics) for gaming applications | 4 | 5 |
| | | | 4.3. Develop game strategies | 4 | 5 |
| | | | 4.4. Download and customize game elements | 5 | 5 |
| | | | 4.5. Check the functionality of games (forming links, settings) and process the results | 5 | 5 |
| 3 | 7 | 5. Creating and using educational video tools | 5.1. Search and select tools for creating videos | 3 | 5 |
| | | | 5.2. Setting up technical parameters for recording video content (connecting a camera, microphone, additional elements) | – | 5 |
| | | | 5.3. Record video in different modes (camera, camera-desktop, desktop) | 4 | 5 |
| | | | 5.4. Edit, process, upload a video lesson | 3 | 5 |

For example, for a future engineer-teacher the integral coefficient of readiness to create and use DEC in professional activity on the basis of the above data $k_{int} = 0{,}74*0{,}6 = 0{,}44$. If we assume that students of the same specialty are target prepared to design and operate information systems and the values of $k_{bas} = 0{,}65$ and $k_{form}^{rel} = 0, 54$ then $k_{int} = 0{,}65*0{,}54 = 0{,}35$. The training of students in the design and use of DEC is of a higher quality than the training in the design and operate information systems.

Reliability and validity of the obtained results were ensured by conducting a pedagogical experiment of a real educational process for control and experimental groups.

## 4 Conclusions

This approach offers the main advantage of presenting a logical structure of skills that ensure readiness to create and use DEC at the operation and activity level. The following indicators are offered for consideration: $k_{bas}$ is the coefficient of basic readiness of a future engineering teacher to create and use DEC in professional activity; $k_{form}$ is the coefficient of the formed readiness of the future engineering teacher to create and use DEC within the DMT discipline; $k_{targ.form}$ is the coefficient of target formed readiness of a future engineering teacher to create and use DEC in professional activity.

In preparing this article, approaches to the development of professional competence of VET teachers in the specialty 015 Vocational Education (Digital Technologies) were used, which were formed at UEPA during the implementation of the Erasmus + project (609536-EPP-1–2019-1-DE-EPPKA2-CBHE-SP) “New Mechanisms of Partnership-Based Management and Standardization of Teacher Training in Vocational Education in Ukraine” (PAGOSTE).

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# Work in Progress: Integration of Adaptive, Intuitive, and Virtual Environments in the Classroom to Have an Enhanced Learning Experience and to Achieve Higher Student Success Rates

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**Abstract.** In this study, we examine several scenarios before, during, and after the COVID-19 pandemic to assess the effectiveness of adaptive and intuitive environments in enhancing both in-person and distance learning experiences. A key focus is the integration of remote and virtual laboratories to provide students with hands-on, real-world experience [1]. Data and results were obtained from the campus statistical databases, known as Decision Analytics and Institutional Research (DAIR). Through a comprehensive analysis of these dashboards, we gathered information on previous learning management systems and student success rates, comparing them to the latest technology in adaptive- based learning, remote and virtual laboratories, and their potential applications in real-life and future job opportunities for students.

The study's primary conclusions highlight the increased one-on-one interaction time between students and faculty through virtual meetings, which facilitated office hours and resulted in improved student performance and class success rates.

Furthermore, the new adaptive-based system offered a superior platform for faculty, enabling them to monitor each student's progress, time spent on modules or chapters, and areas of struggle. This allowed for immediate, remote interaction with students to resolve any issues and challenges encountered during assessments and quizzes.

**Keywords:** Simulation · STEM · Labster Software

## 1 Introduction

As the educational landscape continues to evolve rapidly, the integration of remote and virtual simulated laboratories offers students an exciting chance to gain real-world experience in a virtual environment. A new educational journey is about to begin in which

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traditional boundaries will blur and students will transcend the physical limitations of laboratories. By integrating remote and virtual simulated labs into the curriculum, we can provide students with hands-on, real-world experiences as never before. There are, however, both advantages and disadvantages associated with this emerging technology that must be considered. In this research paper, we explore the transformative potential of integrating virtual and remote simulated labs into the educational landscape based on data collected from a pilot program [1]. By analyzing student grades and collecting faculty and student feedback through surveys, we assess the impact of this technology on student learning outcomes and engagement. A further objective of this paper is to examine the pros and cons of integrating remote and virtual simulated laboratories, highlighting the advantages and potential risks associated with this cutting-edge methodology. Discover the possibilities of this innovative educational paradigm as we explore the future of hands-on, experiential learning in a digitally connected world [2, 3].

## 2 Methodology

The purpose of this research is to examine the effectiveness of the integration of simulated laboratory experiments in enhancing student learning outcomes in Biology 1406- Biology for Science Majors, Biology 2401- Anatomy and Physiology I, and Chemistry 1411- General Chemistry I. To comprehensively understand the intervention's impact, a mixed methods approach, combining quantitative data from student grades and qualitative data from teacher and student opinion surveys is justified.

Accordingly, this justification focuses on obtaining a holistic understanding of the intervention's outcomes and gaining deeper insight into the perspectives and experiences of the stakeholders. Having quantitative data derived from student grades is an integral part of this research. In addition to providing objective measures of academic performance, student grades enable the evaluation of the impact of an intervention on learning outcomes. In order to determine the impact of an intervention, we can analyze quantitative data to identify trends, patterns, and statistical relationships, which provide valuable evidence regarding its effectiveness. Furthermore, student grades provide a quantitative baseline to evaluate the impact of an intervention, contributing to the study's overall rigor and objectivity.

Surveys of teachers' and students' opinions contribute to the quantitative data by providing valuable qualitative insights regarding the implementation and impact of the intervention. It is valuable to hear the perspectives of both teachers and students to gain an understanding of the contextual factors that may influence observed outcomes.

Qualitative data from surveys help uncover the nuances, experiences, and perceptions of teachers and students, shedding light on their subjective experiences and allowing for a deeper exploration of the intervention's effectiveness beyond the quantitative measures alone. It captures the voices of those directly involved, providing a more holistic understanding of the intervention's impact on the educational ecosystem.

The integration of quantitative student grade data and qualitative teacher and student opinion surveys strengthens the overall research design. It is possible to triangulate findings by combining both data sources, thereby validating or challenging the findings obtained through each approach. As a result of this integration, the study has an enhanced level of validity and reliability because it provides a comprehensive evaluation of the intervention's effectiveness. Additionally, it assists in identifying discrepancies between the objective academic outcomes and the subjective experiences and perceptions of the participants.

The utilization of a mixed methods approach offers several key benefits. Firstly, it allows for a deeper understanding of the research question, going beyond the surface-level analysis provided by quantitative data alone. By incorporating qualitative data, researchers can explore the underlying mechanisms, processes, and contextual factors that may contribute to the observed outcomes. Secondly, a mixed methods approach provides a more comprehensive view of the intervention's impact, addressing both the "what" (quantitative) and the "why" (qualitative) aspects of the research question. This comprehensive understanding is valuable for informing future educational practices and policy decisions. Finally, the inclusion of multiple perspectives through the mixed methods approach enhances the validity and credibility of the findings by capturing a wider range of experiences and viewpoints.

In conclusion, the integration of student grades and teacher/student opinion surveys through a mixed methods approach is essential to gain a comprehensive understanding of the effectiveness of the educational intervention. The combination of quantitative and qualitative data provides a more nuanced and holistic perspective on the intervention's impact on student learning outcomes. By leveraging the strengths of both approaches, researchers can generate more robust and reliable findings, inform evidence-based decision-making, and contribute to the advancement of educational practices.

### 2.1 Participants/Sample Selection.

A total of nine instructors from three different STEM courses, Chemistry 1411, Biology 2401, and Biology 1406 were selected to undertake a curriculum redesign to incorporate simulation-based learning into the science labs. The student population of the classes consisted of 235 students enrolled in a local community college in Texas. In the group of students, a wide range of ages may be found, ranging from 18–32, with a median age of 25. Simulation assignments were given to all students in redesigned courses as part of this study. The software that was selected for this study and pilot was Labster, a software package that simulates lab environments. As a result of this redesign, there was the aim to integrate simulations within the actual lab environment so as to enhance learning.

Several reasons led us to decide to use simulations in the lab, as they offer several advantages and benefits. The following are some of the key reasons why we believe that simulations should be incorporated into the laboratory curriculum.

1. **Safety:** Simulations are used to conduct experiments and to train in a controlled and safe environment without exposing participants to the risks associated with actual scenarios. They provide students with a safe environment in which to explore and practice complex procedures without the risk of chemical exposure.
2. **Cost-Effectiveness:** Simulations are quite cost-effective compared to having to maintain an on-site laboratory for the purpose of performing experiments. The use of these systems eliminates the need for expensive equipment, materials, and ongoing maintenance. As simulations can be used repeatedly without incurring additional costs, they provide educational institutions with a financially viable option.

3. **Accessibility and Flexibility:** Students can access simulations remotely, allowing them to participate in lab activities regardless of their physical location. It allows for flexible scheduling and the possibility of accommodating a greater number of students. In addition to this, simulations can also be tailored to meet specific learning objectives and tailored to match different skill levels, thereby providing learners with a more customized and effective learning experience.
4. **Reproducibility and Control:** Simulations facilitate the replication of experiments in a precise and consistent manner. Thus, students have the opportunity to retry procedures, test different variables, and observe the results repeatedly. Simulations allow variables to be controlled and experiments to be modified so that they focus on specific learning objectives, which facilitates a focused and targeted learning experience.
5. **Realistic and Immersive Learning:** Simulations can provide learners with the opportunity to become immersed in a highly realistic learning experience. Through advanced graphics, interactive interfaces, and realistic scenarios, simulations can mimic real-life situations and assist students in developing critical thinking, problem-solving, and decision-making skills. By using them, students can engage in a hands-on, experiential learning process that is closely related to real-life applications.
6. **Time Efficiency:** It is often possible to accelerate or condense the timeframe of an experiment or simulation, thereby allowing students to complete experiments or simulations more efficiently. In this manner, a broader range of scenarios can be explored, more data can be collected, and complex processes can be simulated in a shorter period.
7. **Data Collection and Analysis:** Simulations allow the collection and analysis of vast amounts of data that may be difficult or time-consuming in real-world settings. It is possible to generate detailed data logs and receive immediate feedback on performance from simulations, allowing for in-depth analysis and reflection.
8. **Interdisciplinary Learning:** Simulations can be used to integrate various disciplines, allowing students to gain a deeper understanding of the intersections between different areas of study. Through this interdisciplinary approach, students are encouraged to collaborate, develop their critical thinking skills, and apply knowledge from a variety of domains, preparing them for the complexities of solving real-world problems.

The use of simulations in the lab provides an important educational tool that enhances the learning experience, provides a safe and controlled environment, and provides students with the necessary preparation for real-life applications. Combined with practical, hands-on learning and the flexibility and convenience offered by technology, they make valuable additions to the educational curriculum.

### 2.2 Data Collection and Analysis

We analyzed opinion surveys from participating faculty and students after using Labster for one semester in this mixed methods research. Eight out of nine faculty members responded to the survey, while only 64 out of 235 students responded. The faculty played a significant role in determining whether students participated in the survey, as well as how the survey was presented to them. While some faculty members made the survey mandatory or offered bonus points for completing the survey, others left it as an optional activity. Survey results show that most students felt that simulations are an effective way to reinforce in-class learning.

Overall, the responses indicate that the majority of participants agreed or mostly agreed with the effectiveness of Labster Simulations for learning, learning something through Labster, and finding Labster interesting. There was also a positive response to using Labster as a prelab experience, increased confidence in lab skills after completing Virtual Labs, ease of navigating the virtual labs, and the helpfulness of Labster Chat Support. However, there was some disagreement regarding the inspiration to work with laboratory analyses and the effectiveness of integrated Theory Pages (Fig. 1).

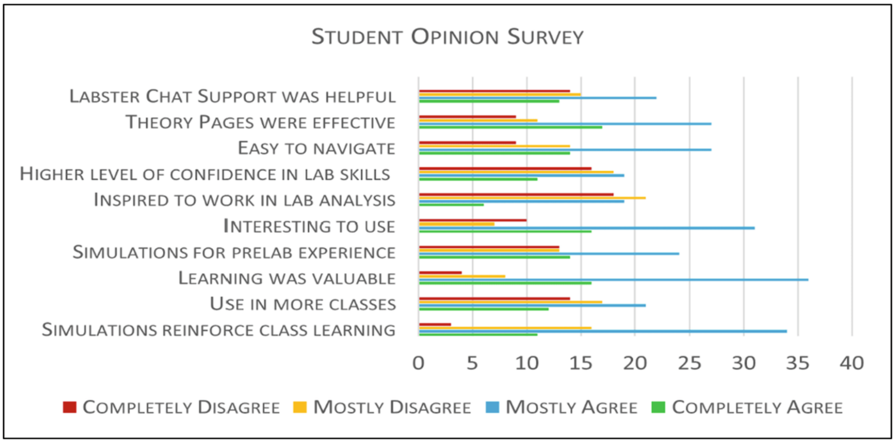



**Fig. 1.** Highlights the outcomes from the students' surveys from all the classes.

In the faculty survey, there is a general agreement that Labster Simulations are an effective way to learn, with most participants either completely agreeing or mostly agreeing with this statement. The majority also express a desire for Labster to be used in more classes and find it easy to integrate into their curriculum. However, there are mixed responses regarding Labster's impact on student engagement, with some agreeing and others disagreeing.

Regarding specific features, participants mostly agree that Labster presents relevant information aligned with course learning objectives, and the integrated Theory Pages are effective in helping students understand the content.

However, there is less agreement about the ease of navigation through the content, and there is limited interest in using Labster with a VR headset.

In terms of support, Labster Chat Support received varied responses, with some finding it helpful, while others disagreed. It is worth noting that a significant number of participants did not use chat support at all (Fig. 2).

Using quantitative data, we analyzed the grades students achieved in various classes correlated with the faculty's use of simulations. In accordance with expectations, the more frequently simulations were used, the higher the overall grades were.

The chart below provides average Labster grades, and the number of modules used for different courses. Here is a summary of the results: See Fig. 3 (a) and (b).

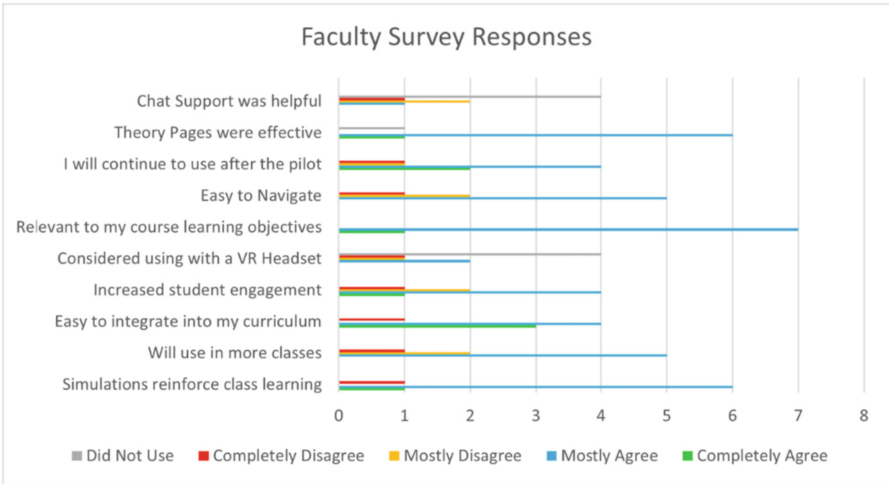


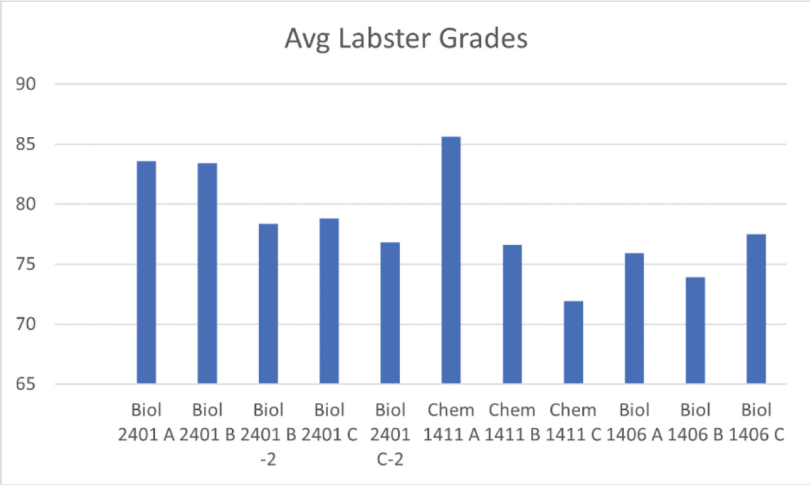

**Fig. 2.** Shows the data from the faculty responses on adopting Labster in the respective teaching curriculum.

Biol 2401 A: Average Labster grade - 83.6, Modules used -11.
Biol 2401 B: Average Labster grade - 83.44, Modules used - 8.
Biol 2401 B -2: Average Labster grade - 78.38, Modules used - 8.
Biol 2401 C: Average Labster grade - 78.818, Modules used - 7.
Biol 2401 C-2: Average Labster grade - 76.81, Modules used - 7.
Chem 1411 A: Average Labster grade - 85.62, Modules used - 7.
Chem 1411 B: Average Labster grade - 76.59, Modules used - 5.
Chem 1411 C: Average Labster grade - 71.9, Modules used - 4.
Biol 1406 A: Average Labster grade - 75.9, Modules used - 6.
Biol 1406 B: Average Labster grade - 73.9, Modules used - 5.
Biol 1406 C: Average Labster grade - 77.5, Modules used - 7 (Fig. 3).

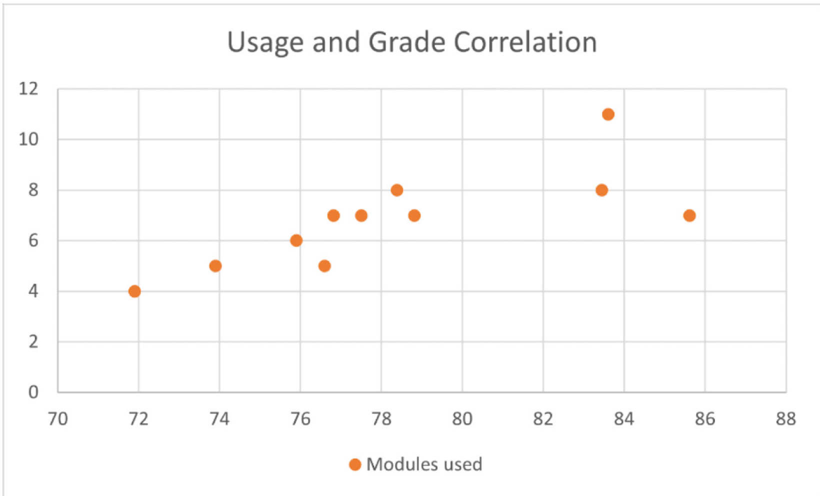
Based on the data provided, it can be observed that the average Labster grades for Biol 2401 A (83.6) and Chem 1411 A (85.62) are relatively higher compared to the other courses. These courses also utilized a higher number of Labster modules (11 and 7, respectively). On the other hand, courses such as Chem 1411 C, Biol 1406 A, and Biol 1406 B have lower average Labster grades (ranging from 71.9 to 75.9) and used a lower number of Labster modules (4 to 6).

It is important to note that the average Labster grades and the number of modules used may be influenced by various factors, including the course curriculum, student engagement, and individual learning preferences. Further analysis and consideration of these factors would provide a more comprehensive understanding of the relationship between Labster module usage and academic performance in these courses. Based on the provided data, we can hypothesize about the relationship between Labster module usage and average Labster grades in different courses:

Higher module usage may positively impact average Labster grades: The courses Biol 2401 A and Chem 1411 A, which had higher average Labster grades, also had a relatively




(a)




(b)

**Fig. 3** (a). The bar graphs that highlight the average grades obtained by the students that used Labster in the classwork. (b). The grades with the number of Labster assignments used.

higher number of Labster modules used (11 and 7, respectively). This suggests that students who engaged with more Labster modules may have had a better understanding of the course material, leading to higher grades.

Lower module usage may negatively impact average Labster grades: In contrast, courses such as Chem 1411 C, Biol 1406 A, and Biol 1406 B had lower average Labster grades and a lower number of Labster modules used (4 to 6). It is possible that students who did not use as many Labster modules may have missed out on valuable learning opportunities, which could have affected their performance and resulted in lower grades.

Other factors influencing grades: While module usage may be a contributing factor, it's important to consider that average Labster grades can be influenced by various other factors. These factors may include the difficulty of the course material, the effectiveness of the Labster modules in addressing specific learning objectives, individual study habits, and student engagement beyond Labster.

To further validate these hypotheses and gain a deeper understanding of the relationship between Labster module usage and grades, additional data and analysis are required. This could involve conducting surveys or interviews with students to gather their perspectives on the impact of Labster modules on their learning experiences and academic performance.

### 2.3 Ethical Considerations

All instructors are identified only by a research letter, A, B, or C following the unidentifiable course code. Students are not identified in any manner. All data was anonymized and stored securely to protect the participants' identities and personal information. Only authorized researchers have access to the data, and it is being used solely for research purposes.

### 2.4 Limitations

In this study, the number of survey respondents, faculty support of the integration of technology, and the time within the reporting period limited the scope of the study.

### 2.5 Validity and Reliability

In this study the student success is defined as the overall final they have achieved in the respective class. The chosen metrics were closely aligned with the intended learning outcomes of the course.

## 3 Results

The results of our recent study shed light on the positive correlation between the use of assignments in adaptive, intuitive, and virtual environments, and the subsequent increase in student success and pass rates.

Instructors who incorporated more assignments using these advanced educational tools, such as Labster, saw a noticeable improvement in student success rates. This can be attributed to the interactive and personalized learning environment these tools provide, catering to diverse learning styles and fostering better engagement.

Contrastingly, instructors who either refrained from using such technology or used it sparingly, incorporating only one or two assignments, experienced comparatively lower student success rates. This suggests that the minimal use of adaptive, intuitive, and virtual environments in the curriculum might not be sufficient to engage students fully or make a noticeable impact on their learning outcomes.

Our findings are in line with existing literature suggesting that these innovative educational technologies can foster a more engaging and effective learning environment. However, a balance must be struck to avoid over-reliance on these tools, as traditional methods continue to play a crucial role in learning.

## 4 Discussion

In conclusion, this research paper explores the integration of adaptive, intuitive, and virtual environments in the classroom to enhance the learning experience and improve student success rates. The study utilized a mixed methods approach, combining quantitative data from student grades with qualitative data from surveys of faculty and students. The findings highlight the benefits of integrating remote and virtual laboratories, such as increased one-on- one interaction between students and faculty, improved student performance, and enhanced monitoring of student progress [1–3].

The research indicates that the integration of adaptive and intuitive environments, specifically using Labster software, offers several advantages. Simulations provide a safe and controlled learning environment, reduce costs associated with maintaining physical laboratories, and offer accessibility and flexibility for students. They also promote reproducibility, realistic and immersive learning experiences, time efficiency, and interdisciplinary learning. Furthermore, simulations facilitate data collection and analysis, allowing for detailed feedback and assessment.

The survey results indicate a positive response from both faculty and students regarding the effectiveness of Labster simulations for learning. Most participants agreed that simulations reinforce in-class learning, and there was a consensus on the relevance of the content and effectiveness of the integrated theory pages. However, there were mixed opinions on factors such as ease of navigation and the use of Labster with virtual reality headsets.

Analysis of student grades revealed a positive correlation between the frequency of simulation usage and higher overall grades. Courses that utilized a greater number of Labster modules demonstrated higher average Labster grades. However, it is important to consider that other factors, such as course difficulty and individual study habits, can also influence grades [1–3].

To further validate the findings and gain a deeper understanding of the relationship between Labster module usage and grades, additional data and analysis are recommended. Nonetheless, the results of this study support the integration of adaptive, intuitive, and virtual environments in the classroom to enhance the learning experience and improve student success rates. These findings have important implications for the future of hands-on, experiential learning in a digitally connected world.

Overall, this research paper contributes to the growing body of knowledge on the benefits and challenges of integrating adaptive, intuitive, and virtual environments in education. The insights gained from this study can inform evidence-based decision-making and guide the implementation of effective educational practices that prepare students for real-life applications and future job opportunities. In conclusion, these findings suggest that a more extensive implementation of assignments within adaptive, intuitive, and virtual environments may prove beneficial in enhancing student success rates. Further research is needed to explore optimal implementation strategies and to understand potential limitations or downsides to this approach.

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Check for updates

# A LabVIEW Based Brain-Computer Interface for Accessing the Internet Resources by Using the Unicorn EEG Headset and the P300 Speller Board

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**Abstract.** The Brain-Computer Interface (BCI) is a multidisciplinary research field aimed at the assistance of people with neuromotor disabilities. This paper presents a new LabVIEW based BCI that should help disabled people to access the Internet by searching a video in YouTube, looking for a person in Facebook, opening a new email, or finding out significant information in Google. These people can achieve such tasks by wearing a GTEC Unicorn EEG headset and focus their sight to the P300 Speller board. This BCI application needs to be user friendly and cost effective. This way the disabled people could benefit of a higher degree of independence because they can communicate by the Internet and leverage the web resources like everyone else. The proposed BCI application consists of the UDP communication protocol employed in LabVIEW to enable the integration of the Unicorn P300 Speller board and the LabVIEW virtual instrument aimed at generating the Internet commands. Then, they should use the official GTEC P300 Speller board that randomly displays different palettes with various flashing symbols. The users need to focus their attention and sight to a single symbol so that they can mentally count all the displayed flashing lights. A symbol is chosen by the P300 Speller board based on the user selection. The UDP packet is sent to LabVIEW application, which is programmed to process these UDP data and link the user selection with the Internet command (search information by Google, search video by YouTube, search person by Facebook, open new email).

**Keywords:** Unicorn EEG Headset · P300 Speller · Brain-Computer Interface

## 1 Introduction

The Brain-Computer Interface (BCI) is an innovator multidisciplinary scientific area aimed at the assistance of people with neuromotor disabilities, by providing them additional channel for communication and control of the outside environment. This way the BCI systems can decipher specific brain patterns and translate them into commands for communication devices, virtual models [1], robotic equipment [2, 3] or medical assistive systems such as a wheelchair [4].

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This paper presents a new LabVIEW based brain-computer interface that should help disabled people to access the Internet by searching a video in YouTube, looking for a person in Facebook, opening a new email or finding out significant information in Google. These people can achieve such tasks by wearing a GTEC Unicorn EEG headset and focus their attention and eyesight to the P300 Speller board. This BCI application needs to be user friendly and cost effective. This way the disabled people could benefit of a higher degree of independence because they can communicate by the Internet and leverage the web resources like everyone else. The Internet and the computers should provide advanced and convenient ways of an easy accessibility, valuable content, and entertainment for all categories of users no matter their disabilities.

The proposed brain-computer interface application should be also used as an educational tool for introducing engineering students into the research field of brain-computer interfaces. During the experimentation of this BCI LabVIEW application, the users are capable to effectively understand the main working principle and they can also accurately accomplish the required tasks. The difficulties possibly encountered by the users are related to the mental effort and eye struggle to precisely focus on a single symbol for deciphering the correct P300 evoked potential. Moreover, some disappointment due to failed trails or other distractions may occur and influences the motivation and the success rate of the users during the experimentation of the BCI application.

## 2 Scientific Literature Review about P300 Based BCI Systems

The P300 is a positive deflection triggered across the parietal-central cerebral cortex [5] at 300 ms after showing an infrequent flashing stimulus. Also, the P300 evoked potential should be recorded from the Fz, Cz, and Pz sensors positions of the International 10–20 System aimed at the EEG electrodes localization [5]. The visually evoked P300 based brain-computer interface systems proved to be ergonomically attractive and efficient to control in a virtual environment providing the drone flight in both augmented and virtual reality [1]. Moreover, the P300 biopotential can be elicited by vibrotactile stimulation so that the haptic feedback enabled the control a lower limb from a limb rehabilitation robot [3]. Regarding the BCIs aimed at accessing the Internet resources, which is also the main research topic of the current paper, there is a previous scientific proof [6–8] showing the feasibility and significance of the control signal based on detecting and using the P300 evoked related potentials.

## 3 Research and Experimental Methodology

### 3.1 The Working Principle of the Proposed P300 based BCI Application

The proposed brain-computer interface application consists of the UDP communication protocol employed in LabVIEW graphical programming environment to enable the integration of the Unicorn P300 Speller board and the LabVIEW virtual instrument aimed at generating the Internet commands. The users should properly wear a Unicorn headset equipped with 8 EEG channels provided by the GTEC Medical Engineering Company from Austria. Then, they should use the official GTEC software application called Unicorn P300 Speller board that randomly displays different palettes with various symbols, such as letters, numbers, or even human faces, all of them being crossed by flashing lights at certain short time intervals (measured in milliseconds). The users need to focus their attention and eyesight to a single symbol so that they can mentally count all the corresponding displayed flashing lights. After approximately 10 s, a symbol is chosen by the P300 Speller board based on the user selection. At the same time, an UDP packet is sent to LabVIEW application, which is programmed in such a way to process these UDP data and link the user selection with the Internet command (search information by Google, search video by YouTube, search person by Facebook, open a new email).

### 3.2 Designing A Customized Unicorn P300 Speller Board

Both the first view including the dark (standard) symbols and the second view of the customized Unicorn P300 Speller Board comprising the flashing visual stimulus covering the third row is shown in Fig. 1.

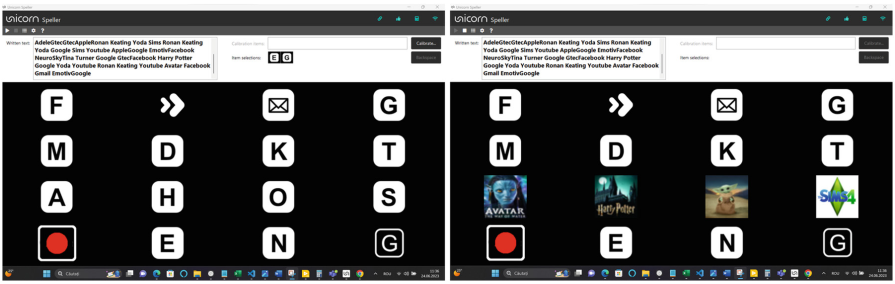


**Fig. 1.** The first (left) and second (right) view of the customized Unicorn P300 Speller Board with the dark (standard) symbols and the flashing stimulus covering the third row.

The proposed P300 Speller panel is a 4 × 4 matrix with the following structure aimed at increasing the attractiveness and versatility of the brain-computer interface based web browsing: the first row is built of four pictures showing the Internet navigation options (F - Facebook, YouTube, Gmail, and G - Google), the second row is composed of flashing photos presenting four famous musical artists (M - Michael Jackson, D - Adele, K - Ronan Keating, and T - Tina Turner), the third row is constructed of flashing images illustrating four animated characters from multimedia content (A - Avatar, H - Harry Potter, O - Yoda, and S - The Sims), and the fifth row is made of four logos with the appreciated brands (Apple, E - Emotiv, N – NeuroSky, and Gtec).

Regarding the stage of designing a customized P300 Unicorn Speller board, the major challenge consisted in selecting and uploading the proper pictures in terms of dimensions and size. Otherwise, the images undergone an editing process. The restrictions related to the dimensions and sizes of every picture were imposed considering an experimental observation during parallel running of the official Unicorn Speller software and the originally implemented BCI LabVIEW application. Thus, the size of every transferred

UDP data package is directly proportional to the size or dimension of each selected image from the P300 Speller board. Therefore, a larger UDP data package led to a longer time response transmitted by the LabVIEW BCI instrument aimed at performing the tasks for accessing the Internet resources. Moreover, in case of using high-quality pictures in the P300 Speller software, then it is difficult for LabVIEW to process the UDP received data and extract the useful command in real-time.

It resulted in the following dimensions for the uploaded flashing icons: Facebook: 7.76 KB, YouTube: 5.93 KB, Gmail: 7.28 KB, Google: 3.54 KB, Michael Jackson: 5.96 KB, Adele: 5.70 KB, Ronan Keating: 5.83 KB, Tina Turner: 5.95 KB, Avatar: 7.12 KB, Harry Potter: 6.09 KB, Yoda: 5.12 KB, The Sims: 8.18 KB, Apple: 6.80 KB, Emotiv: 954 B, NeuroSky: 8.59 KB, Gtec: 3.91 KB. This way, the minimum dimension was 954 B (bytes) for the Emotiv icon. Otherwise, the maximum dimension was 8.59 KB for the NeuroSky logo. Also, the pictures were edited so that the obtained dimensions were set to the following values: 100 × 100 pixels for the Apple, Emotiv, Facebook, Gmail, Google, YouTube logos, 80 × 80 pixels for The Sims images, and 50 × 50 pixels for the Ronan Keating, Adele, Harry Potter, Avatar, Michael Jackson, Yoda, Gtec, and Tina Turner pictures. Thus, the minimum dimension was 50 × 50 pixels and the maximum dimension was 100 × 100 pixels for the above-mentioned graphical icons.

In addition, it should be noted that the type of all the chosen P300 based non-flashing pictures was the PNG (Portable Network Graphics) file format.

The customized P300 Speller board also required the selection of the dark (non-flashing) standard images. These graphical icons (Fig. 1) were defined by the officially alphanumeric symbols: F, Double Arrows, Mail, G – light background (first row); M, D, K, T (second row); A, H, O, S (third row); Red Circle, E, N, G – dark background (forth row). The official icons were all standardized to the dimensions of 100 × 100 pixels. Also, their sizes were equal to 1.40–1.70 KB.

### 3.3 The Front-Panel of the Proposed BCI LabVIEW Application for Accessing the Internet Resources

Figure 2 presents the Front-Panel, or the graphical user interface of the proposed brain-computer interface developed in the LabVIEW programming environment. In the center of the LabVIEW user interface, there are displayed the two pictures corresponding to the main selection (the target item given as an input for the search option in the Internet) and the secondary selection (the modality – Google, Facebook, YouTube – how that item should be searched for in the Internet).

Moreover, the Front Panel contains text boxes for displaying the information about the selected item, the extracted UDP character-based command, and the output URL or the accessed web address. The left side of the graphical user interface includes a LabVIEW string control showing the entire content of the UDP data package. The right side of the user interface comprises some elements for the intermediate output data such as: the UDP data extracted after applying the originally LabVIEW developed algorithm and the UDP concatenated data showing all the received and extracted commands.


**Fig. 2.** The Front Panel of the LabVIEW Application developed for the P300 Based Brain-Computer Interface Aimed at Accessing the Internet Resources.

### 3.4 The Block-Diagram of the LabVIEW Function Aimed at Acquiring and Processing the UDP Data Package

Regarding the acquisition of an UDP Data Package in LabVIEW, transferred from the Unicorn P300 Speller official software, a simple algorithm was implemented by using the library functions aimed at opening the UDP port, reading the UDP content and closing the UDP port. More information about the LabVIEW implementation of the UDP data transfer between the Gtec Unicorn software and the LabVIEW instrument were described in a previous article [9] published by the author of the current paper.

The Block-Diagram, previously implemented as an original contribution in [9], or the source code of the LabVIEW function achieved the processing stage of the received UDP data package so that a character based simple command could be retrieved. As preliminary conditions, an important role is accomplished by the name given for the folder where the non-flashing pictures are stored. Then, an essential significance is achieved by the name given for each picture representing the non-flashing selections in the P300 Speller board. Both the folder name and the picture name, as well as the entire localization path are found in the content of the UDP data package. In fact, by experimenting with parallel running of the official Unicorn P300 Speller software and the originally implemented LabVIEW application, it is easy and quick to observe that the only change in the received UDP data package consists in the modification of the selected picture name. The current paper considered the folder name as "_Imagine" and the pictures names as a standard Unicorn template depending on the selected item: key_A_off (for Apple), key_C_off (for Ronan Keating), key_D_off (for Adele), key_E_off (Emotiv), key_G_off (Gtec), key_F_off (Facebook), key_H_off (Harry Potter), key_I_off (Gmail), key_K_off (Avatar), key_M_off (Michael Jackson), key_N_off (NeuroSky), key_O_off (Yoda), key_R_off (Google), key_S_off (The Sims), key_T_off (Tina Turner), key_Y_off (YouTube). Each picture name is finished with the extension given by a dot followed by "png". The path indicating the location of the folder and pictures is the following: C:\Users\oanaa\OneDrive\Desktop_Imagine\key_Y_off.png.

According to the LabVIEW algorithm for UDP data transfer [9], a For Loop, that also includes a conditional terminal, is used for reading the entire content (the String Length was added) of the received UDP package (Fig. 2 – left side). The Match Pattern function was applied to the entire UDP data for indicating the position of the searched string sequence: "_Imagine", but previously the Concatenate Strings function was also useful at combining the "_" character with the word "Imagine". The Increment function is also necessary to skip one character consisting of the "\" symbol. Then, the For Loop is running until finishing the reading of the string "key_Y_off.png". A String Subset function is used to extract each character located at the position calculated as a sum between the output of the previously mentioned Increment function and the i contor of the For Loop. If two special characters – Tab or Carriage Return – are encountered, then the For Loop finishes its execution because the next row of the received UDP package does not contained a useful data so that is should not be considered. Moreover, another Concatenate Strings function is necessary to obtain the string ".png" so that another Match Pattern function can indicate its position and displays the output string located before this position, resulting in "key_Y_off".

### 3.5 Implementing LabVIEW Code Sequences for Accessing the Web Resources

Some decades ago, the National Instruments software developers launched stable solutions based on the Connectivity menu palette, respectively the ActiveX library, including the Automation Open function, aimed at accessing the any Internet Resource (Facebook, YouTube, web browser) directly in the LabVIEW application. Nevertheless, now (in the 2023 year), it is not anymore convenient to leverage this deprecated solution involving the use of only supported Internet Explorer browser, considering that the YouTube website is not currently available in the Internet Explorer.

Therefore, the LabVIEW version 2022 provides the most efficient solution, that was also preferred and employed in the current research, namely the function – *Open URL in Default Browser*. This virtual instrument has an input argument consisting of the URL (web address) that the users intend to access in their default Web browser. The input element is given by a string control containing the text that will be found to the Internet, for example any information: "Avatar", "Gtec", "Michael Jackson". Moreover, it is possible to use the Concatenate Strings function so that a general web address is firstly set (for example: https://www.youtube.com/results?search_query =) and the search text (for example: "Michael Jackson") is secondly added, resulting in the URL: https://www.youtube.com/results?search_query=Michael%20Jackson. Therefore, this URL is the output value of the Open URL in Default Browser LabVIEW function. It should be noted that the "%20" symbol is automatically introduced during the execution of the LabVIEW function when it encounters a space character.

Figure 3 presents the LabVIEW simple implementation based on the above description by using the Open URL in Default Browser function to access the Internet resources indicated by the input web address composed of a general part (for example: the Facebook path: "https://www.facebook.com/search/top/?q =" or the Google path: "https://www.google.com/search?q =") and a customized part (the search text: "Ronan Keating", "Adele", "NeuroSky", "Tina Turner", or the other options found in the P300 Speller board).

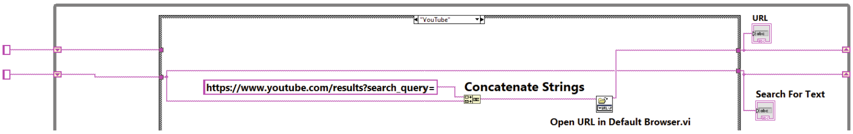


**Fig. 3.** LabVIEW code sequence for accessing the Internet resources.

### 3.6 The LabVIEW State-Machine for Enabling the Transition Across the Commands Aimed at the Alternative Accessing the Internet Resources

According to Fig. 4, the State-Machine paradigm designed in LabVIEW graphical programming environment includes the following standard elements: a while loop for continuous running of the application, a case structure for switching between alternate code sequences, type definition of enum constants for defining the commands, and shift registers to store the data – meaning the commands – from the previous states.

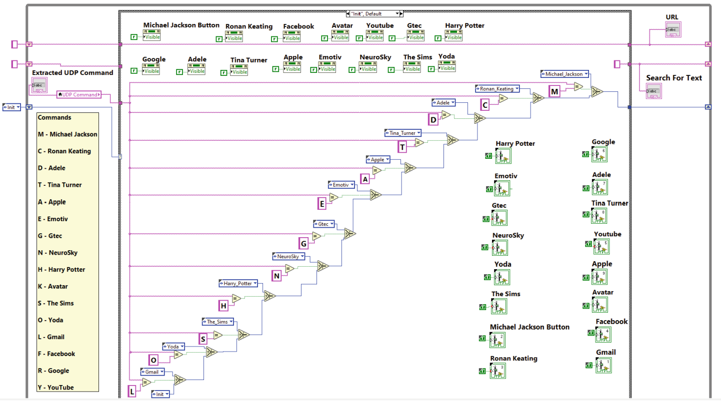


**Fig. 4.** LabVIEW code sequence for accessing the Internet resources.

The State-Machine designed for the brain-computer interface proposed in this paper includes the following states called as: Init, Michael_Jackson, Ronan_Keating, Tina_Turner, Adele, Apple, Emotiv, Gtec, NeuroSky, Harry_Potter, Avatar, The_Sims, Yoda, Facebook, Next_Facebook, YouTube, Next_YouTube, Google, Next_Google, Gmail, Next_Gmail. The same names are also set for the item list of the enum constant.

Figure 4 presents a code sequence from the Block-Diagram including the Init State. The Select LabVIEW function is like the alternative If function from the procedural programming so that it takes a decision based on the result (true or false) of the comparison between the expected and the actual character command. The actual read command refers to the extracted command as the received UDP package was acquired and processed after the accurate detection of the P300 evoked potential. The expected command is the character associated with each search option: M – Michael Jackson, C – Ronan Keating, D – Adele, T – Tina Turner, A – Apple, E – Emotiv, G – Gtec, N – NeuroSky, H – Harry Potter, K – Avatar, S – The Sims, O – Yoda, L – Gmail, F – Facebook, R – Google, Y – YouTube. Also, according to the Fig. 6, the Init sequence comprises the terminals of Boolean indicators associated with the buttons set to the pressed state being assigned to the true value. The true value assignment is related to the transition to a certain state where there is displayed a picture corresponding to the selected command (for example: NeuroSky and Facebook or Emotiv and YouTube). Likewise, the Init state includes property nodes for setting the false value to the Visible characteristic. Therefore, no button is set to visible state until the corresponding search option is achieved. This means that no image is displayed without the achievement of a specific command.

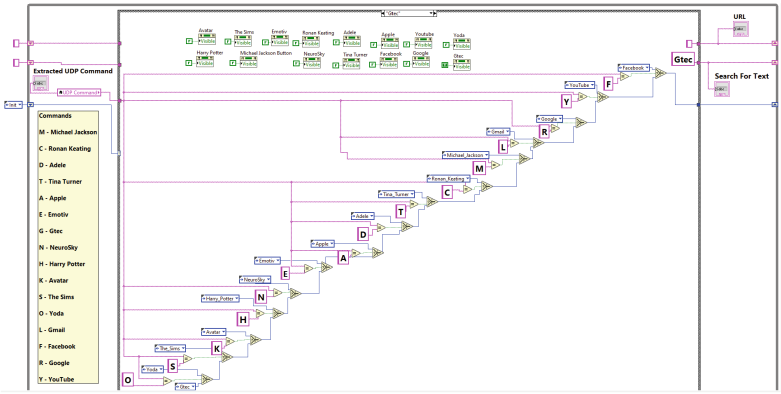


**Fig. 5.** The Gtec State from the LabVIEW State-Machine for displaying the Gtec picture and transitioning to the next state depending on the user option.

It should be noted that no Facebook, YouTube, Google, or Gmail commands can be sent during execution of the Init State. This way, at the beginning of running the BCI LabVIEW application, the user may only select a search option meaning an information such as "Tina Turner", "The Sims", "Avatar", and the others. After that, the user has the possibility to choose one of the commands aimed at executing the action of searching using the engines Facebook, YouTube, or Google.

Figure 5 shows a sequence code from the Block-Diagram of the LabVIEW BCI application, so that the content of the Gtec state is presented. Also, the Gtec state is quite similar to the other states called as the selected option: NeuroSky, Emotiv, Apple, Avatar, Harry_Potter, Michael_Jackson, and all the previously mentioned commands. In fact, all these states are based on the same structure as the Init State, considering additional conditions: by using the Select function, it is also checked if Facebook, YouTube, Google, or Gmail options were selected by the user so that the State-Machine paradigm can continue its execution into the related state and access that Internet resource (Facebook, YouTube, Google, or Gmail). Moreover, all the other UDP extracted commands are assessed so that a correct decision can be made. Therefore, after receiving the Gtec text-based option in LabVIEW, the user can select either one action command (Facebook, YouTube, Google, Gmail) or any other search text command (Ronan_Keating, Adele, The_Sims, Yoda). In addition, a true value is assigned to the node embedding the visible property associated with the Gtec button. This results in displaying the Gtec picture in the graphical user interface until the user selects the different command. It should be also mentioned that the transition to the commands determined by Facebook, YouTube, Google, or Gmail does not change the Gtec picture displayed in the Front Panel. Only if a text-based search option is coming, then the Gtec picture is replaced by the image corresponding to the most recent user selection.

Figure 6 presents the LabVIEW code sequence for the Facebook State, whose structure is the same as the YouTube State, above displayed in the Fig. 3. Likewise, a similar content characterizes the Gmail and Google states. Thus, the scope of the Facebook State is to obtain the entire output URL composed of the path aimed at accessing the Facebook website and the text-based option that the user wants to search for. Also, there are included three nodes with the Visible property set to the following values: Facebook is assigned to true; YouTube is assigned to false; Google is assigned to false; and Gmail is assigned to false. Therefore, only the Facebook logo is visible in the Front Panel. The pictures of YouTube, Google, and Gmail are hidden. Moreover, it should be noted that after performing these operations, the State-Machine automatically transitions to the State called *Next_Facebook*. Otherwise, by keeping running the Facebook state, then the LabVIEW is continuously accessing or opening the Facebook URL including the user search option. Multiple request of accessing the same webpage are sent so that the computer is too overloaded (Fig. 7).

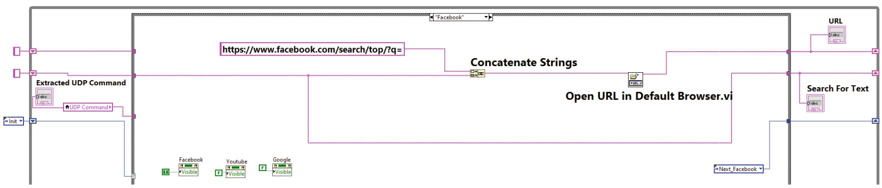


**Fig. 6.** The Facebook State from the LabVIEW State-Machine displaying the Facebook logo image and accessing the complete URL corresponding to the searched option in Facebook.

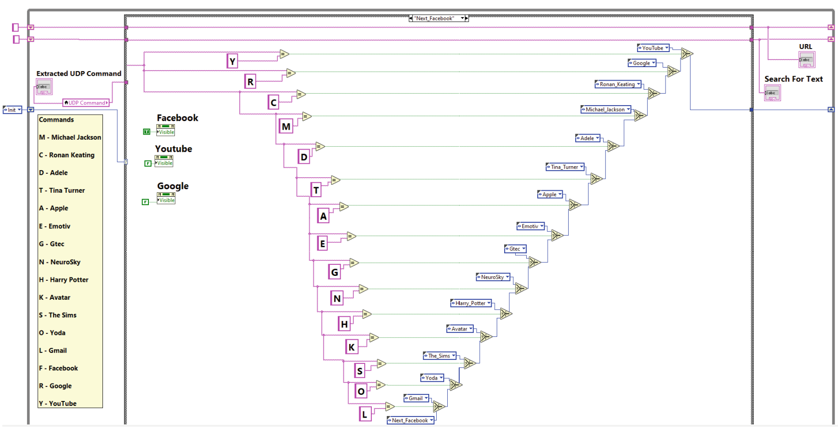


**Fig. 7.** The Next_Facebook State from the LabVIEW State-Machine.

## 4 Results and Discussions

The YouTube videos [10, 11] show two live demonstrations of the working principle and the two complete experimental sessions of the presented brain-computer interface, lasting for approximately 30 - 40 min that involved one healthy subject (girl, 31 years). Each one of the two sessions comprised four experiments (Table 1 and Table 2). The first experimental session was performed during the nighttime when the user was quite sleepy after the entire activities during the tiring workday. The second experimental session was accomplished in the morning of a weekend day when the user had an active mental state.

**Table 1.** The accuracy values and the number of user trials necessary for successfully detecting the selections across the P300 Speller board during the four experiments from the first session.

| Ex | Desired Selections in the P300 Speller Board based Brain-Computer Interface | | | | | | | | | | | Acc. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | M.J. $1^{st}$ | FB $4^{th}$ | Ade. $1^{st}$ | YTB $1^{st}$ | R.K. $1^{st}$ | Goo. $1^{st}$ | T.T. $1^{st}$ | FB $1^{st}$ | | | | 88% |
| 2 | Avtr. $1^{st}$ | Goo. $2^{nd}$ | Harry $1^{st}$ | YTB $1^{st}$ | Yoda $1^{st}$ | Goo. $1^{st}$ | Sims $1^{st}$ | YTB $3^{rd}$ | | | | 75% |
| 3 | App. $1^{st}$ | Goo. $1^{st}$ | Emo. $1^{st}$ | FB $1^{st}$ | Neuro $1^{st}$ | Goo. $5^{th}$ | Gtec $2^{nd}$ | FB $1^{st}$ | | | | 75% |
| 4 | Harry $1^{st}$ | Goo. $1^{st}$ | Yoda $1^{st}$ | YTB $1^{st}$ | R.K. $1^{st}$ | YTB $1^{st}$ | Avtr. $1^{st}$ | FB $2^{nd}$ | M 1 | E 1 | Go $1^{st}$ | 91% |

Also, the improved accuracy reported in the second session is associated with the fact that the user already gathered previous training experience. The abbreviations from the Table 1 and Table 2 refer to the following selections provided by the P300 Unicorn Speller customized board: Ex – Experiment; M.J. – Michael; FB – Facebook; Ade. – Adelle; YTB – YouTube; R.K. – Ronan Keating; Goo./Go. – Google; T.T. – Tina Turner; Avtr. – Avatar; Harry – Harry Potter; App. – Apple; Emo. /E – Emotiv; Neuro – NeuroSky; M – Gmail; Acc. - Accuracy. The first session was the initial interaction for the subject with the designed paradigm of the P300 Speller including the customized flashing pictures with the searching options and the dark images with the related descriptive symbol. The quality of the acquired raw EEG signal was perfect almost all the time. Nevertheless, the EEG signal quality got sometimes negatively influenced by the body movements, loud speaking, and possibly the used of non-official Gtec EEG gel for moisturizing the Unicorn sensors.

Tables 1 and Table 2 presents the established selections requested for the user to perform during the experimentation of the proposed brain-computer interface. It is also specified the number of the trial when the user correctly detected the desired selection in the P300 Unicorn Speller customized board resulting in searching the related option or text by Facebook, YouTube, or Google websites.

The first experiment referred to both selecting the symbols corresponding to the famous artists (Michael Jackson, Adelle, Ronan Keating, Tina Turner) placed on the second row of the P300 Unicorn Speller and searching them by Facebook, YouTube, and Google. According to Table 1, at end the first experiment from the first session, seven symbols were correctly reached even at the first trial and only one item (launching Facebook) was selected at the $4^{th}$ trial. Therefore, the accuracy of the succeeded selections was approximately 88%.

According to Table 2 that is related to the second session, all the eight searching options were correctly detected, resulting in the accuracy of 100%

The second and the third experiments were based on user trials of correctly detecting the selections from the third row (Avatar, Harry Potter, Yoda, and Sims), respectively the fourth row (Apple, Emotiv, NeuroSky, and Gtec) from the P300 Speller board.

According to Table 1, during both the second and third experiments performed in the first session, six selections were passed at the first user trial and two trials were failed until the $2^{nd}$ and $3^{rd}$ trial. The accuracy of the second and third experiment was 75%. According to Table 2, the second experiment proved to be the most challenging in the second session, resulting in the accuracy of 63% due to missing three selections at the first user trials. Regarding the third experiment from the second session, the accuracy of 91% showed an improved user performance with only one failed result.

The fourth experiment is considered more complex requiring 11 random selections (Harry Potter; Google; Yoda; YouTube; Ronan Keating; YouTube; Avatar; Facebook; Gmail; Emotiv; Google) from all the rows of the P300 Speller customized board. According to Table 1, it resulted in the highest accuracy value of 91% for the first session, meaning that 10 selections were correctly performed, and one selection was missed only in the first trial. Likewise, during the fourth experiment from the second session, the user obtained the maximum accuracy of 100% for correctly detecting all the items.

**Table 2.** The accuracy values and the number of user trials necessary for successfully detecting the selections across the P300 Speller board during the four experiments in the second session.

| Ex | Desired Selections in the P300 Speller Board based Brain-Computer Interface | | | | | | | | | | | Acc. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | M.J.<br>$1^{st}$ | FB<br>$1^{th}$ | Ade.<br>$1^{st}$ | YTB<br>$1^{st}$ | R.K.<br>$1^{st}$ | Goo.<br>$1^{st}$ | T.T.<br>$1^{st}$ | FB<br>$1^{st}$ | | | | 100<br>% |
| 2 | Avtr.<br>$1^{st}$ | Goo.<br>$1^{st}$ | Harry<br>$1^{st}$ | YTB<br>$3^{st}$ | Yoda<br>$2^{nd}$ | Goo.<br>$7^{th}$ | Sims<br>$1^{st}$ | YTB<br>$1^{st}$ | | | | 63% |
| 3 | App.<br>$1^{st}$ | Goo.<br>$1^{st}$ | Emo.<br>$1^{st}$ | FB<br>$1^{st}$ | Neuro<br>$1^{st}$ | Goo.<br>$2^{nd}$ | Gtec<br>$1^{st}$ | FB<br>$1^{st}$ | | | | 91% |
| 4 | Harry<br>$1^{st}$ | Goo.<br>$1^{st}$ | Yoda<br>$1^{st}$ | YTB<br>$1^{st}$ | R.K.<br>$1^{st}$ | YTB<br>$1^{st}$ | Avtr.<br>$1^{st}$ | FB<br>$1^{st}$ | M<br>1 | E<br>1 | Go<br>$1^{st}$ | 100<br>% |

Beyond the two above experimental sessions, the subject performed multiple trials using another customized Unicorn P300 Speller boards comprising dark items shown as intuitive pictograms in grayscale of black and white patterns. Unfortunately, even after further editing by reducing their dimension, also resulting in lowering the quality of the images, it was not possible to get a smooth UDP data transmission between the Unicorn P300 Speller and the LabVIEW based brain-computer interface application.

## 5 Conclusions

The proposed brain-computer interface application is an experimental prototype aimed for introducing novice researchers into practical tackling this innovator BCI system by using advanced EEG technology. The presented LabVIEW based application shows a simple, attractive and efficient way of demonstrating the BCI working principle, testing, leveraging and improving the current BCI P300 based communication methods even from home environments. Future research directions are related to exploring the results of a comparative analysis between the proposed BCI application (using Unicorn EEG headset and P300 evoked potentials) and a similar LaBVIEW based BCI application aimed at accessing the Internet resources by using a different EEG Headset (NeuroSky Mindwave Mobile with one sensor) and employing the voluntary eye-blinks performed by users. Further BCI experiments should be also performed by multiple subjects.

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# Will a "New" Leadership Style of Engineers as Family Entrepreneurs Foster Stability and Peace in Germany?

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**Abstract.** The new style of leadership in medium-sized, family-run companies by family entrepreneurs of the new generation in Germany, esp. The Siegerland Region, often enough engineers themselves, is indeed in the Socratic tradition: visions that concern one's own company and explaining the rules for the way there in a comprehensible way. Furthermore, establishing credibility, not least by setting an example of the rules, and leading by example. All this without forgetting the tried and tested principles of previous generations: Taking care of the employees and their families, keeping them all in mind and striving for monetary and non-monetary gains in equal measure. It is about a home-based sustainability of success beyond the day, about one's own well-being, that of one's own family as well as the families of the employees, and that of the region as well. By explaining not only the entrepreneurial vision but also one's own leadership style, an integration achievement of employees with a migration background can succeed beyond the economic success of the company. For this leadership style is not only in the Socratic tradition, but also in part in the Persian tradition. It is possible that the re-establishment of this style will set an example for peaceful integration, sustainability and economic success beyond Central Europe. It is also likely to strengthen the resilience of the corresponding business location.

**Keywords:** SMEs · Leadership · Integration · Peace

## 1 Approach

German SMEs face tough challenges in 2024. Climate protection targets must be met, sustainability requirements must be fulfilled, and the primacy of decarbonization demanded by the government must also be complied with. An end-to-end energy supply must be guaranteed and remain affordable. Digitalization, which is being touted as a panacea, threatens to siphon off locally generated, specialized expertise at production sites by third parties. However, the lack of young talent and thus of skilled workers is perhaps the greatest challenge. At the same time, the company must also be profitable [1]. Achieving these goals requires assertiveness and tact. It takes a versatile entrepreneurial leader who can lead smartly and respond deftly, who has more in mind than just corporate goals, who is credible and rooted locally. This enables commitment

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on the part of the employees and, if the intellectual roots of the new leadership style are explained, a possible expanded ability to integrate and connect with employees, including those growing numbers with a migration background [1]. Can a new leadership style of medium sized family entrepreneurs help to secure social peace in and beyond the company? As an endowed chair of the economy of the Siegen region, the Institute for Technology Didactics at the Vocational College (TVD) of the University of Siegen sees itself in the responsibility to provide scientific stocktaking and to point out viable solutions for the economy. Based on the assumption that entrepreneurial decisions as well as company cultures and leadership styles are determined and shaped by the owner-entrepreneur, the focus was placed on the entrepreneurs. Standardized questionnaires did not appear to be effective. Hardly any entrepreneur would have felt respected, "seen" and taken into account. It is also possible that he would not have filled it out himself. Questionnaires often only confirm previous assumptions disguised as knowledge. It is then difficult for new problem areas that the researcher has hardly known or not known at all to come into view [2, 3]. To be able to ask sensitive questions such as about values and leadership styles and to access sensitive data, an atmosphere of trust had to be created. Ultimately, the choice fell on the guided expert interview. Aware that the object of research might not yet have been precisely outlined and that some problem areas remained unidentified, this guideline was, however, still open in the sense of Roland Girtler [3]. The research plan basically allowed for modifications of the guide. In order to establish access and entry into the field, previous contacts of the institute director to entrepreneurs, e. g. via the Lions Club or via the Oldtimer Friends, were used. A pre-test was carried out with a friendly medium-sized entrepreneur, whereupon the questions were slightly adapted. The entrepreneurs were inquired first in all form directly in writing. If necessary, they were followed up in a friendly manner via their secretary's office. Finally, several discreet "fireside chats" were held in familiar surroundings, mostly at the "Haus der Siegerländer Wirtschaft". Due to scheduling problems of some entrepreneurs, a 45-min telephone interview was conducted four times. High-ranking members of the association were interviewed for flanking purposes, as were representatives of the press. A well-informed, longtime local journalist hosted for a four-hour background interview. All these interlocutions were forbidden to be recorded by any dictaphone. Otherwise, the interlocutions would have been stopped immediately. Handwritten notes were allowed. During the questions, people ate and drank. In Homeric questions and answers (in the sense of Roland Girtler) also on the part of the researcher well-dosed own things were revealed [3]. The results were then compared with other scientific publications. Thereby it was noticed that the results concerning the leadership style at least of the younger generation of entrepreneurs correspond with essential points of a millennia-old leadership breviary: The *Anabasis*, written by Socrates' student Xenophon [4]. For the younger entrepreneurs, this analogy provided an underpinning and justification for the timeless, ubiquitous correctness of their leadership style – and even the ability to connect for employees with a migration background. This is all the more so because this work combines essential elements of Homeric-Socratic and ancient Persian leadership culture, thus reaching into the Mediterranean and Middle East [5]. As it turned out, this may contribute to better mutual understanding and integration, too [6].

# 2 Actual or Anticipated Outcomes

## 2.1 Interest in Long-Term Sustainability and Resilience

An important solution to the entrepreneurial challenges was seen in the establishment of a new ancient leadership culture and an appropriate leadership style. The leadership style of the Siegerland entrepreneur tends to appear dependent on the generation to which he belongs. The older generation associates natural patriarchal authority with an appropriate leadership style. Representatives of the younger generation, however, claim for themselves a participative leadership style that clarifies meaning and conveys it. Part of this leadership culture is that sustainability has priority - it also seems to convey meaning to the young entrepreneurs. The typical older entrepreneur from Siegerland sees himself primarily as a "patron" and "caretaker". He knows "his people", and thanks to the overview he has gained over generations, he can take care of "his people" in the right place as if by magic. He promises help and assistance even beyond the purely professional, and he reliably keeps his promises. Younger entrepreneurs in the Siegerland region rely in addition on a corporate culture of responsiveness in both directions. They see themselves as translators of company goals and processes to their employees, even as "mediators of meaning". And they want to "show the big picture". In their own self-image, they stand for a departure from "alienated work". They are primarily concerned with comprehensibility: The younger entrepreneurs see themselves as translation providers. In order to win over multipliers and accelerators of their activities, they demand and promote quality circles. They advocate "bi-lingual generalists". For example, for industrial engineers, or the "screw engineer as a narrow-track engineer", which an industrial clerk can do. This can gladly be done from within the company. They are critical, but not dismissive, of innovations in digitization: However, digitization should not be "blindly pushed through", but only "when you have sounded out and have a plan". The goal is to "relieve the individual employee without replacing him or her". This seems to fit in with the typical Siegerland pietist Christian self-image as an entrepreneur [1, 7–9]. In any case, there do not seem to have been any long-lasting reservations about technical innovations in the industrial history of the Siegerland [10].

We see: A generational change of the entrepreneur from "patron" and "patron of the arts" to a "helping, mediating, sense-giving entrepreneur and visionary" has begun. But even after the generational change, the sense of responsibility for the homeland and its people remains. Entrepreneurs still strive equally for monetary and non-monetary gains – such as "high esteem of the neighborhood and parish" – beyond the day. Rootedness, long-term planning and thinking, and thus new patents, seem to be able to secure the future of their companies. Because unlike many start-up founders, the entrepreneurs from Siegerland, like the vast majority of German family entrepreneurs, are not concerned with building something up as a short-term "cash cow" and selling it as quickly as possible. Rather, they are concerned with the long-term, sustainable preservation of value beyond the present day: for the next generations of their own entrepreneurial family as well as for their employees and their families in the neighborhood and church congregation [1, 7, 8].

However, the underlying values here point beyond the pietistic Siegerland region, indeed beyond Central Europe, and not just spatially. As early as the 5th century B.C., a student of the philosopher Socrates, who for his part had been schooled in the Homeric management manuals Iliad and Odyssey, transferred their values in combination with the values of Persian management culture in parts to a large "company" and managed it according to comparable principles [11–14]. Xenophon, too, was not concerned with quick personal gain, but with that of the soldiers and, above all, the preservation of the organization as a whole. The timeless transferability of the lessons from the *Anabasis* (meaning marching up-country, advancement, career) were first noticed by Olaf E. Kraus in the *manager magazine* [15]. In addition, the author of the present study traced this in detail in his 2017 dissertation and in his consulting work of medium-sized companies and transnational corporations. With the term "Anabasis" is meant not only the rise to the Kurdish mountains, but also the rise of the organization directed according to Socratic leadership principles, a mercenary army (the "Ten Thousand") from deep desperation to "the road to Zeus" [16]. Likewise, the rise, the career, of the leader in this organization is meant [14]; on top of that, it is also, within certain limits, about the ethical and financial rise of the organization, the leaders and all involved meant [14, 16]. The leadership personality Xenophon serves Xenophon the author as a model and example for subsequent leaders, what Alexander the Great, the Scipions, Caesar and still Elizabeth I of England and Lawrence of Arabia knew how to apply [14, 17–20].

Xenophon was originally a student of the famous philosopher Socrates and a "classmate" of Plato. "In the oppressive atmosphere of Athens" after the lost Peloponnesian War, he saw no future for himself. On his search for new horizons of knowledge by means of warlike adventures and under the command of a dubious Persian prince, he is stranded with ten thousand battle-hardened Greek mercenaries (the "Ten Thousand") near today's Baghdad. Prince Kyros, who has turned out to be a usurper, meets his death in a battle against his brother, the Persian Great King [21, 22]. Kyros' Greek army commanders, on the march back, soon become victims of their own dissension, their inflexible personalities and, hence, their non-versatile leadership style [14]. The soldiers suddenly find themselves alone in the middle of enemy territory. But neither they nor their Persian opponents have reckoned with a student of Socrates. By means of Homeric and Socratic (and, as it turns out, Persian) principles, he succeeds in forming a well-ordered, battle-ready organization out of a desperately defeatist bunch. Xenophon rises to the top of their leadership circle. Over the next weeks and months, he and his people must have found themselves in an early VUCA world. For they face a variety of enemies and dangers: regular Persian troops pursue them; Kurdish, Armenian, and a host of other tribes block their path. Deceitful native guides and supposedly well-meaning emissaries from Greek colonies try to abuse them for their own purposes. The governors of the new Greek supremacy, Sparta, and Persian provincial governors spin their intrigues. Contract-breakers, hunger, cold, drugs, snow blindness and disorientation, but not least the ingratitude and forgetfulness of his own people especially after the most difficult stage goal, the Black Sea, has been reached (Thalatta!, Thalatta!) - and finally his own inner swine make life difficult for Xenophon. But after 15 months he succeeded in guiding a large part of his men into the safe Greek sphere of influence of Ionia. Richly endowed by his men, he, the ever correct one, takes some time off. Later he, the Athenian, who had joined without Socrates‘ approval a Persian prince and then collaborated with Spartans in the army command of the Ten Thousand, will receive political asylum in Sparta as an Athenian exile. Only very few (and certainly no Athenian) had succeeded in doing so. In the vicinity of Olympia, he spends most of his twilight years highly respected among his family and old comrades as a successful author, historian, estate manager, philosopher, government advisor and horse whisperer [4, 16, 23, 24].

### 2.2 Versatility

Before Xenophon the author introduces himself as a leader, he settles accounts with the failed leaders of the “Army” enterprise. These failed as a result of their personalities and the resulting ethically wrong goals and one-sided and thus unsuitable leadership styles. They were not willing and or flexible to adapt these goals and styles to new circumstances and situations or to their respective counterparts. The four army leaders failed irrevocably because of this personality flaw and personality-related inflexibility. In this respect, these portraits are a swan song to the ultimately useless, because rigidly one-sided. Xenophon, however, will combine and adapt the personal characteristics and leadership styles of the four depending on the respective situation and the respective counterpart. He will thus bring with him a characteristic that has been recognized as mandatory for U.S. general staff officer candidates since 1991: Xenophon’s versatile personality enables a correspondingly versatile leadership style [14, 25]. This is in no way inferior to the versatility of Zeus and his human equivalent Odysseus, mediated via the virgin goddess Athena as mentor. This is a common way how divine immortality can be achieved in Greece, the Levant and beyond [26].

Young family entrepreneurs have recognized the necessity of the versatile leadership style as well. According to their frequent knowledge of their employees, who come from the near and far environment, it is possible to address, motivate and lead them exactly. By broadening their horizons and developing their personalities by means of even distant study visits of the younger family entrepreneurs, the possibility of versatility is also broadened. The younger family entrepreneurs are just as successful in responding to employees who want to be addressed in a patriarchal manner as they are in explaining and “taking along” especially critical younger employees. Younger entrepreneurs are called upon to be “entrepreneurs who make sense”. However, this versatile, explanatory management style is not limited to the Siegerland region. It seems to be generally cultivated in Central European family businesses, regardless of the size of the company, but especially among the younger generation of entrepreneurs.

Further leadership components seem to correspond with Xenophon’s ascent manual *Anabasis* as apparent paradoxes: “personal modesty” correlates with “objective immodesty”, i.e., the “impossible” achievement of a goal against all odds. Whether it is to lead back an army of ten thousand mercenaries from the hostile Persian heartland to Greece as far as possible in one piece, or it is to invent the unique super-screw, to become market leader, to create the first or the second billion in sales, etc., the “personal immodesty” correlates with “objective immodesty” [8, 27]. At the same time, the horizons of thought and action relate only to a specific unit: that of one’s own organization, of which one is the leader [1, 4, 8]. Only secondly, if ever, it relates to the salvation of the whole world.

### 2.3 Respect

In Homeric, Socratic, Persian and Siegerland leadership cultures, leaders are respected, as they respect their followers. The verb "respect" is derived from the Latin "respicere", composed of "re- ": back, and spicere: to look, to see [28]. When leading, leaders who are rushing forward have to look back in order to keep their eyes on the people they are leading or at least to get their eyes back on them as quickly as possible: to their strengths and weaknesses, wishes and needs, but also hopes and expectations, values and norms, mood and motivation. Insofar as rules have been agreed upon or prescribed, and insofar as rewards for rule-conforming behavior and punishments for breaking the rules have been promised, the following applies: The rule-abiding themselves also want to be seen, perceived, respected, they want to be recognized for this, rewarded and distinguished in competition before others. This was already the case with the Homeric Odysseus, who respected his former employees, should they loyally stand by him in the showdown with the suitors of his wife Penelope: He saw his potential alleys‘ wishes, expectations and hopes and promised to reward them exactly [29]. Exactly this increased the feeling of the employees to be seen and respected; just as their loyalty towards their leader increased, who for his part had already proved that he "saw" them and respected them in their wishes and desires also in the kind of reward. Under the versatile and reliant leadership of Xenophon, courageous and resourceful volunteers equally want and can count on being mentioned praisingly in the army journal and thus acquiring everlasting fame. And, of course, to be rewarded materially [14]. As so often, this is a matter of a sense of justice. The soldiers want to be recognized in what they do. At least, if they adhere to the rules and beliefs previously communicated by the leader, which were communicated just as clearly and comprehensibly as the beckoning rewards for following the rules and the threatening consequences for breaking them. In this way, the organization‘s peace is ensured, careers can be planned, and the company is more likely to be successful. If volunteers can count on their glorious name being reliably conveyed to posterity by means of an army journal for their own initiative, they receive what they can reliably expect to receive, then they do it. In this way, they become and remain more loyal beyond the day than e.g., the obedience of the cadre and drill produced by an authoritarian style of leadership alone would be able to do. They are more likely to go through thick and thin with their leader, as *Anabasis* has shown, and as young Siegerland family entrepreneurs confirm [1, 14].

### 2.4 Credibility

Credibility, however, is also one of the supporting pillars of both Socratic and typical Persian leadership culture. The tradition of the latter essentially comprises the following points in brief: According to his divine model, trust and credibility are high on the list of priorities for a Persian leader, starting with the Great King. He has to be a charismatic and God-fearing guarantor of law and order, who, committed to the truth, should be a model of self-control and reliability for his followers. He, on his part, should be reliable in following the rules, in giving promised rewards for following the rules and threatened punishments for breaking the rules. Again: This is what makes it possible for subordinates to plan their own careers. Legitimacy and credibility are also generated by “stable odor”, by the well-known name that underpins a claim to leadership that is charismatic in name and heritage. Going through the typical Persian, the thoroughly agonal educational canon for young nobles contains (since the horse traditionally plays a major role in Persia) instruction in horseback riding, and in typical Persian martial arts: archery and spear throwing. Learning from the example of the governmental practice of the Great King, who should always be a role model by example, even in demonstrative munificence. From the Great King down, Persian leaders are responsible for the care of cultural and economic life. At the center, however, is the good relationship with the gods, which is demonstrated by love of truth and reliability, especially fidelity to contracts, as the basis of legal security and “career planning”, and, in a broader sense, as the basis of statehood and the functioning of the rule of law in general [30]. In management practice, this means reliability through dependable adherence to generally known rules and the dependable maintenance of law and order. Justice generates trust, and the leader, who is always under observation per se, must practice self-control, moderation, frugality, gratitude, reliability and love of truth. Thus, the relief of the Trilingue of Bistoun shows, how to Persian king Darius six (later seven) “lie kings”, contract-breaking neighbor rulers, are presented in fetters [31].

So: Typical Persian leader “stable smell” proves, who says the truth, who respects those being led, desires and expectations of the led and bespoke rewards (and over it again proves that he “sees” and respects the rewarded). Quite as is expected in Greek leadership culture, too. Whoever meets these expectations as a leader is also credible and can demand respect himself. Of course, it is also important that there is immediately visible evidence of this bona fides. Thus, the ruler knows how to combine physical fitness with martial-sporting know-how and to demonstrate it again and again impressively, also by substitute actions like riding at the show hunt. The horse enjoys thereby high esteem, which is considered in Persia likewise as typically Persian. The credibility is further enhanced by the fact that the scars can be visibly shown [30, 32]. Just as Xenophon would have to be credibly typical Greek and a Great King would have to be credibly typical Persian in order to be able to exist in crisis situations with his people, it seems that the typical Siegerländer value-emphasizing and value(pre)living also creates trust - and resilience. Particularly in matters of sincerity, but also personal modesty, the parallel to the piety and the Christian-based work of the reliable Siegerland entrepreneur is abundantly clear. “Pacta sunt servanda!”, with the godly ruler as with the honorable merchant and entrepreneur! Generosity is also evident, especially spectacular in the endowment of a gymnasium or in considerable contributions to a local art museum [26].

### 2.5 The Leader is Eminent - Hence, the Leader is Visible

Leaders stand out and are therefore always seen. The family entrepreneur as a good leader is taken by many as an ideal, perhaps as a beacon, but certainly as a projection surface. But precisely because of this, he at best is a valued (local) celebrity, who, to say it with Xenophon, is eminent, and as eminent thus stands out. Which is why he is seen, seen in everything, both what he does and what he leaves undone. The social context of a village, which Ilien and Jeggle laconically stated for the late 1970s in Germany in general (and Brüggemann and Riehle diagnosed somewhat more mildly for the 1980s), still applies in the Siegerland today [1, 33, 34]. Here, however, it is further mitigated by lived Christian pietistic values and is mostly viewed positively. In any case, as long as the entrepreneurs are "typical" in their leadership, the leadership follows corresponding rules and appears reliable and predictable through business success and leadership principles. And the balance (monetary as well as non-monetary) is of course "right" for all interested parties, entrepreneur, staff and neighborhood.

The executives at the Ten Thousand in the *Anabasis* were also "seen". What is demanded of others must be exemplified by themselves (role model by example), 24/7. Again and again, they also had to face 360-degree feedback. The plenary meeting convened at critical points had a controlling function here. It can be seen "as a permanent assessment" [15]. Sanctions for management deficiencies including negligent handling of company assets were severe. On the other hand, executives got a comparatively low compensation. They received only up to four times more pay than ordinary soldiers. Personal modesty was appreciated and princely rewarded by the employees involved only in the success at the end, when Xenophon had brought the company to a pleasing conclusion and took some time off. Today, this has its counterpart in the personal modesty of the family entrepreneur of whatever generation.

### 2.6 Serendipity and Reporting Systems in an Open, Clear Management Culture

Again and again, "serendipity" is mentioned as an important quality that employees should possess. Managers should naturally exemplify this, so that it can establish itself credibly and thus more quickly as a characteristic of a management culture. Winning entrepreneurs demand the independently thinking and acting employee, who recognizes problems independently and develops solutions independently. In addition to a solid education, serendipity is also considered to be the basis for new patents from within the company - and thus to help to secure resilience and the future, of the company and the neighborhood as well [1].

When the Ten Thousand at the border river Zentrites are heckled by straggling Karduchoi, and Persian and Armenian troops already lying in wait on the other side of the river, the independent thinking and serendipity of two young boys allow them to discover a ford. The open reporting system - it was known to all that Xenophon had set up a kind of reporting and consultation hour after breakfast - ensures that this discovery finds its way to the top. Indeed, in matters of wartime importance, Xenophon is, as is generally known to his men, reliably approachable at fixed times during breakfast and dinner. All this ensures that the new discovery is passed on directly and immediately to a part of the army leadership. The latter's collegial leadership style, in turn, allows the vital information to circulate immediately throughout the entire army command. The unanimity in the equally ticking collegium however lets these react immediately typically and with typical "stable smell" efficiently and after familiar rules [4, 14, 35].

### 2.7 Limited and Guided Participation

Also Xenophon, whose name whether by chance or as a deliberately chosen battle name means "(a) voice for the stranger/the foreign/the mercenary", appears always and from the beginning as a mediator of meaning, as a translator, as a strategy- and world-explainer in his speeches, but above all of the change of strategy and paradigm initiated by him at the beginning of his appearance: He is all about employee involvement – but only in tactical matters. He designs the strategy himself, but he explains it convincingly in the closest management circle. Then, if necessary, he submits it to the plenary meeting for a vote. It should be noted that he does not rely on employee participation in strategic matters, but only in matters of tactical and operational design and implementation of *his* strategy [14]. Even among modern German family entrepreneurs, we do not see strategies being sought jointly with all employees. However, their patient explanation, their meaning and their background (also that of a change of strategy) goes out tentatively on the part of the younger entrepreneur generation to all. Here, everyone should to be taken along. In the case of the shortage of skilled workers in Germany, this probably counts in a similar way to the withdrawal of the Ten Thousand from the Persian Empire, where every man could certainly be used.

In the management floors of medium-sized companies in the Siegerland region, there is a growing realization that the new old management style is a safe bet. Through my lectures, seminars and workshops of the IHK, the BVMW, the VDI and the MDZ, but also through in-house seminars, a growing number of young entrepreneurs and executives understand the beneficial possibilities (apart from an increase in performance) that this way can offer for a more satisfying atmosphere, not only in the company [6, 36–40]. As the younger family entrepreneurs agree: The ability to integrate and the integrity and independence practiced in the company lead to an increase in civic maturity among employees and managers alike and to the safeguarding of more than just industrial peace.

## 3 Conclusion

The leadership principles of many of today's medium-sized family entrepreneurs thus contain a great deal of supra-temporal validity. Thus, to a certain extent, much Western, but also Persian leadership culture, from Homer to Darius to Socrates, underlies the German gross domestic product. It is a matter of being rooted in faith and values and, building on this, a corresponding leadership style that also enhances the credibility of the entrepreneur. The credible and exemplary communication of a vision of the future directed at one's own company and rules that are always clearly communicated and credibly adhered to in order to realize this vision: Bespoke incentive systems and rewards, but also very clearly set guard rails and announcements, if not reprimands, in the event of rule violations or persistent poor performance. Knowing one's own people, "one's friends", with all their strengths and weaknesses, including their (and one's own) Achilles' heels. And last but not least, the principle of "leadership by example" to once again increase credibility. This contributes decisively to social peace and industrial peace as well. All this points beyond the present to ancient leadership manuals such as the Homeric epics and the works of Socrates' student Xenophon. Making these connections known can not only give entrepreneurs the self-confidence of being in a good tradition. They can also achieve the same successes as in the past. Communicated accordingly, the family entrepreneurs report that in the Siegerland region, the ability of employees with an immigrant background to connect with the company wants to be achieved in a beneficial way. The often invoked "clash of civilizations" is also mitigated, if not neutralized to some extent [41].

What remains to be said is this: Resilience is not an invention of modern degrowth prophets [42]. The renaissance of resilience seems to be all the more given when family entrepreneurs both reflect on the tried and tested and expand their management culture to include what has been successfully tested again and again for millennia in different areas and contexts: Reliably offering well-explained goals, involving people, respecting and inspiring them, and doing so within the framework of their (culture(s), which not infrequently have a considerable lowest common denominator [1]. Resilience can also be achieved through the art of leadership that has been tried and tested for millennia in both East and West. Is that not true sustainability?

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