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Short Paper

Pedestrian Bridge Application in a Fundamentals of Structural Analysis Course Inside an Architecture Bachelor Program

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Abstract—The paper presents an application of the Problem-Based Learning (PBL) methodology in a structural analysis course taught in English of the third year Architecture bachelor program at Politecnico di Torino (Italy). This experimentation regards a class composed mainly of international students. That is a heterogeneous audience with different backgrounds. In general, students struggle with the technical aspects typical of the structural analysis course. PBL has been found as a possible solution to this problem in Engineering programs. The aim of redesigning the course is to support students' learning while evaluating the PBL application in a non-technical context with an international audience. This article describes the structure and the results of the PBL implementation. In particular, the participation has increased compared to the previous academic year in terms of presence during the lectures, interest in the subject, the interaction between the lecturer and the students, and exams' results. These results are encouraging and confirm the validity of the PBL methodology as actually applied.

Keywords—structural analysis, PBL, architecture bachelor program, pedestrian bridge

1 Introduction

Fundamentals of Structural Analysis (FSA) is a third-year mandatory course of the Architecture bachelor program at the Politecnico di Torino. This bachelor's degree has two different tracks: one taught in Italian, with around 450 students (divided into three parallel groups), and one in English, with almost 75 students. In the Italian path, students are mostly coming from Italy. On the contrary, in the English one, there is an international audience with students coming from different countries, in particular from Asia and South America.

Due to its nature, the FSA course has high technical and engineering content. Usually, architecture students struggle in understanding both the theoretical aspects and the manual and numerical solution procedures. One of the aspects that non-technical students typically find hard is the shift from the theoretical concepts to the qualitative evaluation that this topic requires. This shift is unusual for students in general, but even more for the architectural ones that in their study are not comfortable with this approach. This difficulty is even more evident in the English track, in which students' backgrounds are very heterogeneous since they came from different nations with a variety of school systems. Although the courses in the first two years already tried to fill the preexisting educational gap.

In the past years, the methodology used in this course has been following a traditional face-to-face teaching model with a single lecturer supported by slides with some exercises on the blackboard. In the meantime, at the end of the course, only a few students succeeded in passing it. For example, in the academic year 2018/19 of the 55 enrolled, only five were successful at the final exam in the winter call (first call available). Moreover, the student's level of engagement during the course has been critical in terms of presence during the lectures and interaction with the lecturer.

Data from several studies suggest PBL (Problem-Based-Learning) methodology as an excellent solution to approach the learning difficulties typical of a structural analysis content inside technical schools [1, 2, 3, 4, 5]. In general, PBL is applied in many engineering courses as it seems to suit the professional requirement of a mix of technical and practical competencies [6, 7, 8, 9]. Using this methodology in a non-technical context, such as an Architecture bachelor degree, is not trivial and requires some shrewdness [10]. The present research explores the effects of this methodology in an Architecture bachelor degree with an international audience, such as the English curricula.

The main objectives to redesign the course were the overall subject framework, the themes and types of problems, and the proposal for PBL work. To do this, the Chandrasekaran and Al-Ameri study [6], together with the Bridges' critical review [10], played a fundamental role. The first one investigated the engineering students' experience in team learning practice and in particular in project/design-based learning and found out that [6]:

- Students prefer to have a balance between lecture and design class, with a possible unbalance in favour of design class
- The assessment should equally include the project and a formal individual exam. In general, engineers prefer to be assessed individually rather than through teamwork
- Group size should be between three and five students distributed based on their own preference
- A group leader is perceived as fundamental, although the self-estimation of participation can vary among members.

Said this, the non-technical environment typical of Architecture education has some different features compared to the Engineering one. Therefore, the lecturer must work with educational specialists and decision-makers to design an architectural version of PBL [10]. Bridges has also underlined some focal points that we used as a guideline in the designing stage:

- the complexity of the problem: it should be enough complex and actual to attract students but simple to be affordable with their knowledge
- open-endedness of the problem: it should favour a brainstorming activity fostering the team to evaluate different solutions

- duration of assessment: students should have time to be meaningfully engaged with the problem
- degree of collaboration amongst students: the design should support students' interaction inside the team
- explicit incorporation of reflection: reflection on learning outcomes support the learning itself. Students need to become confident with the new skills and awareness of the personal learning achievement
- variety of skills required: the project solution should develop different skills by requiring different project presentation formats (i.e., images, reports, oral presentations, elevator speeches)
- diversity of media: the solution can require the use of various media, for example, hand vs software calculation or traditional manual drawing vs CAD modelling
- use of precedents: students should have access to sufficiently detailed and accurate sources of material to work with
- collaborative development of problem definition: joint participation of students in the problem definition will make the project more effective.

Moreover, referring to the typical theoretical learning principles that De Graaff and Kolmos identified [11], the course framework has been defined as reported in Table 1.

Table 1. Course design based on the typical theoretical PBL learning principles (the first column refers to [11])

Typical PBL theoretical learning principles	**FSA redesign framework**
Problem-based learning: the problems are based on real-life issues which have been selected and edited to meet educational objectives and criteria	The chosen problem is the design of a pedestrian bridge and its structural analysis.
Participant-directed learning processes: students have the opportunity to determine their own problem formulation within the given subject area guidelines	The teacher will provide the students with a detailed guideline to support the problem approach and help them identify a feasible solution.
Experience learning: to link the formulation of the problem to the individual's world of experience increases motivation	Each team of students can choose the location, the shape, and the material to be used for the bridge design
Activity-based learning: requiring activities involving research, decision-making and writing	Students will need to submit reports periodically. Moreover, in the initial design stages, they will need to make decisions based on personal research; while in the structural analysis, they will need to review the results obtained and make proper changes critically
Inter-disciplinary learning: teachers do not just consider objectives within the known subject-oriented framework but also consider problems or real situations	To solve the pedestrian bridge problem, students need to consider the mechanical properties of materials, the esthetical aspects, and the environmental constraints that they have learnt in previous courses
Exemplary practice: The students must acquire the ability to transfer knowledge, theory, and methods from previously learned areas to new ones	The teacher will foster the ability to generalize the learning knowledge
Group-based learning: whereby the majority of the learning process takes place in groups or teams	The students will work in teams of 3-4 people each

This paper highlights the general results obtained by implementing the PBL methodology in an FSA course starting from the work in progress outputs presented at the EDUCON 2020 Conference [12]. Section 2 provides a general description of the context and states the research questions. Section 3 describes the methodology used and the course implementation, Section 4 analyzes the results obtained, and Section 5 draws conclusions and discusses future developments.

2 Background

In the international context, the difficulties typical of the structural analysis have been addressed with a PBL implementation [1, 2, 3, 4, 5]. While solving the problem, students learn how to carry out the calculation and how to address metacognition. In qualitative analysis research, which measures the impact of the PBL in this topic, Justo et al. highlight the main strengths: teamwork, self-directed learning, continual assessment, practical approach, and faculty involvement. Although, in the meantime, the study identifies some drawback points such as the disorientation experienced by the students at the beginning and the different degree of involvement and workload of team members. These findings suggest the importance of tutorship in approaching the project and on the orientation and evaluation of equal task distribution inside the team [3].

Moreover, tutoring activities have been identified as key for improving the conceptual understanding of students. However, a significant improvement in the comprehension of bending moment distribution seems to be hard to reach with only the tutors' support [4]. Moreover, the lecturer needs to guide the shift in the learning techniques [13].

Then, another essential aspect becomes the integration of the project into the course topics. Morgan and Barroso suggest creating an explicit tie between the project tasks, outcome and the course contents. Establishing this clear link helps the students understand that the project itself is a way to put together the different concepts personally [5].

Considering the assessment side, it must fit the objectives of the learning process. That is, to verify the competence acquired rather than a limited test on individuals' knowledge [11].

2.1 Course context and purpose

At Politecnico di Torino, FSA is taught in the traditional face-to-face way: the teacher at the blackboard with slides or chalk, and students take notes. It lasts one semester, from October to January, and, as for other courses, the assessment is limited to a multiple-choice test to evaluate the students' knowledge. Students have four available dates to do the final exam: two right after the end of the course (one in January and one in February), one after the second semester (in July) and one after the summer period (in September).

The technical content and methodology used during the lessons make it hard for architecture students to approach the subject's study properly. It is important to remark that FSA is an introductory course. Therefore, the following Structural Engineering courses during the Master degree will cover a comprehensive discussion about the appropriate technical standards, load combinations, elastoplastic design, seismic actions, structural details. Although the basic nature of the course, students are asked to familiarize themselves with Nòlian, an Italian FEM analysis application [14]. This tool is frequently used by Italian professionals but is not available in English, and this represents a partial problem for the international audience of this course.

This approach highlighted a few problems and limitations: lack of interaction with the students, poor results at the final evaluation that seems to show a poor understanding of the topics and a long time passing the exam.

These aspects are more evident in the English track, where there are also differences in students' background knowledge. Students are coming from worldwide and may have different experiences and expertise, although sometimes they don't have sufficient math preparation. We analyze their results in the academic year 2018/19: only 11% succeed in the exam at the end of the course during the winter session, 73% pass the exam during the other sessions, and 16% did not succeed in any sessions.

2.2 Objectives of the study

This study will analyze two different relationships with the PBL:

- How can the PBL favour the learning of a technical subject in an Architecture program?
- How can the PBL favour the learning of a class composed of international students with a heterogeneous background?

Different qualitative aspects are collected and analyzed, thanks to direct observation, structured project revision, presentations and final survey to answer those questions.

3 Redesign implementation and methodology

This new course design aims to support students' learning, particularly considering the technical aspects key for the structural analysis. This change will apply only to the English track that seems more penalized by the traditional approach. In order to implement the PBL methodology, the entire course organization needed to be reviewed. First of all, the project that the students need to develop has to be defined considering the traditional content of the course.

For this reason, it needs to have the characteristics of a preliminary study with simple calculations. In the meantime, although the goal of the course is not to do a complete standard-compliant design, the project needs to consider the national regulation to help the students understand the complexity of real-life structural analysis. A small/medium size footbridge (about 15 m to 20 m) has been chosen as a project theme following these characteristics. This theme is simple enough to be examined with the tools provided during the lessons, and it can be partially solved manually and/or by using structural software, like Nòlian.

The reference project has been identified in the pedestrian bridge developed by the DC Structures Studio of Cambridge (NZ) [15], which introduce the project by saying:

If you find these designs useful or have any improvements, please leave us a comment. Our team is driven by a passion for bridge design (we love bridges!). Hence, we are very proud of this set and hope to see it used throughout NZ. We would really appreciate hearing any feedback you might have: Is this standard bridge useful? What changes would make it better? Would you consider using it? What updates or additions would you like to see?

Thanks to the interaction with the DC designers, the whole project was made available for the course (Fig. 1 shows an example) [15], together with other sources of inspirations [16, 17, 18, 19]. Students can design and imagine possible variations to improve this original project's architectural and structural aspects or create a new one with similar characteristics. Moreover, considering the international audience, each team of students can locate the bridge somewhere in Italy or their country of origin and choose as building material one typical of their region. However, to define the material properties, each team must be coherent with the country selected and, therefore, needs to consider the building regulation that varies country by country. If the national regulation is not readily available, the lecturers with the tutors can decide to use the Italian and EU regulation as a reference [20, 21]. In general, the project needs to follow the KISS principle, that is, Keep It Simple Stupid [22].

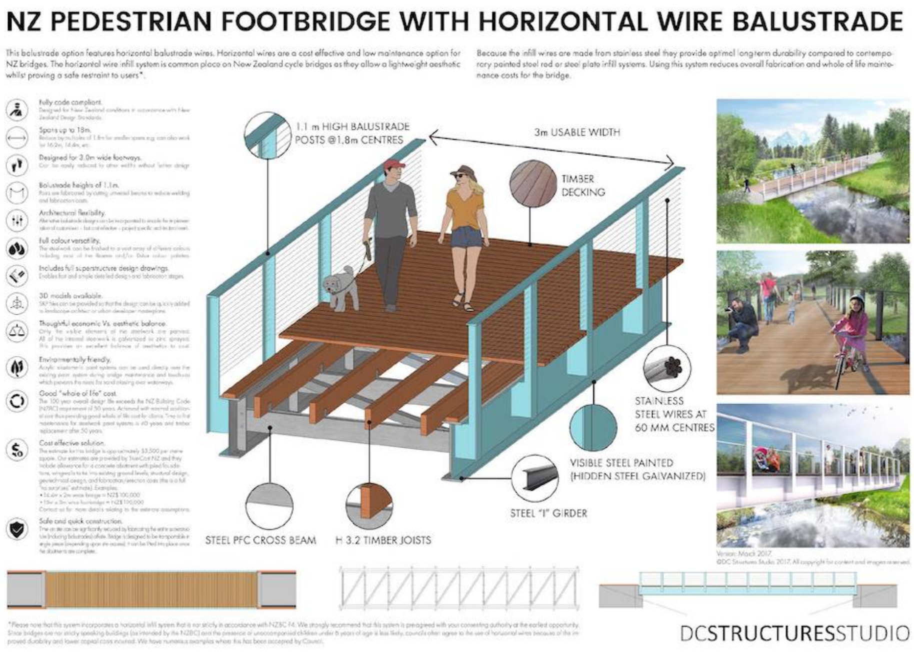


Fig. 1. New Zealand standard footbridge design (elementary 18 m pedestrian bridge).

Considering the course content, the critical technical aspects of the project have been identified and adequately included in the course material. In particular, the course will be divided into

- theoretical lessons (30%): lecturer guides the students into the project contents
- teamwork (30%): each group apply the theoretical concepts to the bridge design
- tutoring activities (30%): each group can meet a tutor to share doubts and ideas
- presentations (10%): time in which each group present a specific step of the bridge design.

The theoretical lessons follow a traditional approach; the lecturer uses both slides and a blackboard. The content has been reorganized, neglecting the more general parts of elasticity and continuum mechanics and stressing the contents strictly related to the project (i.e., with new comments, exercises, data and suggestions). Moreover, for the topics related to the project, a yellow background in the slides has been used to help the students easily recognize it.

The students have three times a week a formal activity following the calendar shown in Table 2.

Table 2. Calendar of the activity divided by week

Week number	Lesson 1	Lesson 2	Lesson 3
1	Lecture	Project description and team formation	Lecture
2	Lecture	Tutoring	Lecture
3	Lecture	Team 1st presentation	Lecture
4	Lecture	Tutoring	Lecture
5	Lecture	Tutoring	Lecture
6	Lecture	Team 2nd presentation	Lecture
7	Lecture	Tutoring	Lecture
8	Lecture	Tutoring	Lecture
9	Lecture	Tutoring	Lecture
10	Lecture	Team 3rd presentation	Lecture
11	Lecture	Tutoring	Lecture
12	Lecture	Tutoring	Lecture
13	Lecture	Tutoring	Lecture
14	Tutoring	Final presentation	Final presentation

At the end of the course, during the final presentation, the best projects and related reports will be voted by a committee of academic lecturers and experts in the field. Then, the studio's website will publish the best ideas.

As part of the redesign, also the assessment has been modified. The Italian education system foresees a final exam for each course evaluated over a scale of 30. The exam is considered positive with a score of 18/30. In particular, the final exam is composed of a multiple answers test (18 points) and the bridge design (12 points). The project evaluation includes the observations and the votes done by the committee during the final presentation. For those students who did not deliver any final project, the assessment remains like in the previous academic year: a 30 questions multiple answers quizzes.

3.1 Methodology

This paper presents a qualitative analysis of a study case that includes only the English track, which, in the academic year 2019/20, is composed of 62 students. Only 4 of them coming from Italy, while the others are mainly from Asia and South America.

Each team has a maximum of 4 people to ensure good and homogeneous cooperation between them. The team size is crucial to enriching soft skills such as teamwork, communications, organization, and leadership.

As said in the redesign, the new course will be structured in theoretical lessons (30%), teamwork (30%), tutoring activities (30%), and presentations (10%). The teamwork is autonomously organized and is not included in the official course schedule.

The tutoring sections consist of 15 minutes sessions in which every team can personally discuss its project with one tutor. The tutors are civil engineer master students selected through a call, available for a maximum of 60 hours each during the entire course. For the academic year 2019/20, three tutors have been assigned to the FSA course, which guarantees a strong interaction in terms of time with the teams. In the past, tutoring sessions were also available on a reservation basis to help the theoretical understanding.

The presentations are four, distributed over the entire semester. During each of them, each team is required to explain the progress of the design. The first three presentations last 3 minutes each. Instead, the final presentation lasts 10 minutes and will be in a video conference with DC Structures Studio. Overall, students are expected to deliver a well-structured, one-page report in the first three presentations and a complete project report with all the design details in the final one.

During the first lesson, the new course design has been explained to the class with a deep look into the project requirements. This includes the instructions regarding the content that each team needs to present inside the 3 minutes speech:

- 1st presentation: students should explain a basic structural scheme, materials, load, design and location of the bridge
- 2nd presentation: students should present the deformability and stability
- 3rd presentation: students need to show the strength, horizontal loads and bracing effect, and the 3D numerical model.

While for the final 10 minutes presentation, each team must present the whole project.

Regarding the project characteristics, the building regulation chosen as a reference needs to be used for the loads' calculation, including dead load, live load, self-weight, snow, a horizontal force on the balustrade. At the same time, wind and earthquake loads are neglected. The structure calculation entails being partially solved manually by using equilibrium equations for which the structure should be statically determined. Only after this manual approach, the structure is solved using the structural software Nòlian.

In this stage, students should evaluate the numerical results comparing the analytical solution in terms of stress (strength), displacements (stiffness), instability (stability) and the numerical solution. Moreover, they need to discuss horizontal bracing by applying horizontal forces (10% to 15% of the vertical forces). If the team chooses an Italian area, the national regulation is already present inside the FEM software; otherwise, it must consider the national restrictions manually.

For the final report (about 5-10 pages long), a detailed guideline is made available to students and covers the following points:

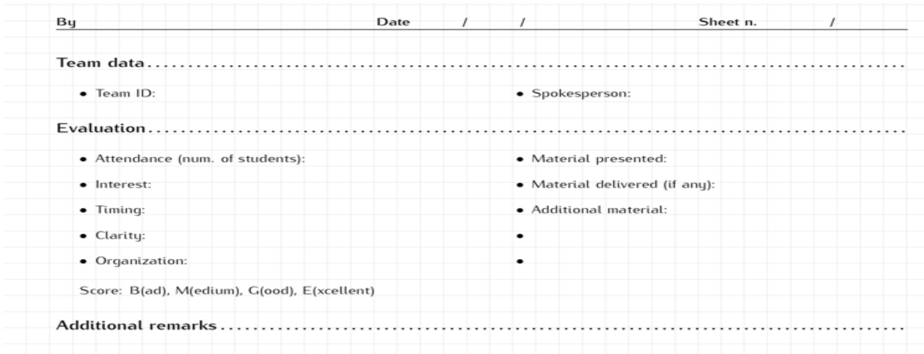
- summary (description of the problem)
- introduction (overview and main issues)
- problem description (assumptions, drawings, solution procedures, theory assumptions)
- results (presentation, explanation, supporting theory, numerical results, implications)
- conclusions and recommendations
- references (technical standards, other helpful material)
- appendices.

Moreover, some insight references have been given to support further the students' writing process [23, 24].

Looking at the assessment, the evaluation includes a test and the project work. The test is made of 18 items, 12 theoretical and 6 related to the software application. It is considered passed if 12/18 are answered correctly, independently on the type of questions. Regarding the project evaluation, in addition to the final presentation, the entire evolution of the solution will be considered (the three minutes presentations, the material delivered, and the tutoring sections).

We used different qualitative approaches to analyze the implementation of the redesigned course:

- observation of the course flow done by a researcher unfamiliar with the course topic that considers the methodological approach and the class responses and by a technical expert that looks at the contents
- team revision's sheets (Fig. 2) filled by the tutors during the tutoring activities
- presentations' material that each team delivers during the course (reports and final presentation)
- course survey evaluations that students anonymously return at the end of the course.


By Date / / Sheet n. /

Team data ....

- Team ID:
- Spokesperson:

Evaluation ....

- Attendance (num. of students):
- Interest:
- Timing:
- Clarity:
- Organization:
- Material presented:
- Material delivered (if any):
- Additional material:
-
-

Score: B(ad), M(edium), G(ood), E(xcellent)

Additional remarks ....

Fig. 2. The form that the tutor needs to fill after each team revision.

The team revision's sheets should be weekly and include both general skills and technical aspects. For example, by looking at them, one can suppose the workload distribution inside the team (general skills) and the ability to correct mistakes and include the tutor's suggestions (technical aspects).

The central administration manages the anonymous student survey delivery and evaluation for all courses. Students can fulfill it starting from the last weeks of the course until the first exam session starts. It is not mandatory, but students are highly encouraged to complete them. Six modules make it with Likert-scale answers [no, more no than yes, more yes than no, yes]:

- Attendance (Question 0): Students must indicate the attendance rate. The general statistics considers only students with >50% of frequency
- Academic terms organization (Question 1 to 2): These questions are designed to analyze students' perception of the general semester workload
- Lectures organization (Question 3 to 8): They focused on students' perception of the course itself; such as the available materials, the clarity of assessment rules, the prerequisites and the course activities
- Teaching delivery (Question 9 to 13): This module includes the analysis of the lecturer performance; such as the lecture timeline, the availability, the clarity
- Facilities (Question 14 to 15): They evaluated the infrastructure and the software available
- Interest and satisfaction (Question 16 to 18): Students give general feedback on the course content independently from how it was delivered.

The aggregated data generates four indices that are used to evaluate the overall course: course index I1 (average of questions 1 to 18), lecturer index I2 (average of questions 9 to 13), course satisfaction S1 (% positive answers 1 to 18), lecturer satisfaction S2 (% positive answers 9 to 13).

4 Discussion

The revised FSA started in October 2019 and lasted until the end of January 2020.

Because the literature review highlighted as fundamental for a successful PBL implementation the tutoring support, before starting the course, the lecturer organized a meeting with the three assigned tutors. It explained the new approach and pointed out the critical role they play in the learning process. This meeting was the occasion for them to familiarize themselves with the team revision's sheet that, like a diary, keeps organized all the information regarding the tutoring sections of each team.

During the first lesson, the lecturer presented the new structure to the students, and they autonomously organize in 20 teams. The first tutoring section took place the second week of the course, and all groups attended, but only 13 were ready for a discussion with the tutors. Considering the overall tutoring sections, students highly attended them. Most of the teams were involved in their complete composition, and the members were actively speaking and interacting with the tutors. By looking at each team's revision sheets, it is clear that they started from a brainstorming stage with different ideas that evolved at different speeds. This personal learning path can be considered a positive thing because it allows students to regulate their learning and learn autonomously [25].

At the first presentation, 17 teams presented their idea. The quality of the presentation was well responding to the request. Each of the proposed bridges had a simple but different design. Considering the location, some of them chose a spot in their country of origin (mainly China, Colombia, Indonesia, Italy, Vietnam), others preferred a country external to the team, such as Sweden or Netherlands. Looking at the materials, some groups chose unusual ones like containers and bamboo while others employed more standard elements, like wood and steel. Four teams' ideas showed possible problems coming up in the following steps of the project. For this reason, after a quick talk with the teams, the lecturer explained to the tutors the possible structural issues to help the teams with the structure design and materials during the subsequent revision sessions.

Some teams decided not to show up at the following presentations because they struggled with structural issues, mainly trouble in calculations. In particular, at the second presentation, 10 teams succeeded in the speech, and at the third presentation, only 9 were positively addressing the lecturer's requests. In the meantime, the tutors tried to guide the teams through the difficulties they were facing. That explains why 17 teams delivered the reports and presented the final project at the end of the course. The lecturer commented on all the reports and returned them to prepare their final submission properly.

Regarding the issue related to the software Nòlian, the lecturer has provided a glossary reporting the English translation of the main commands and warning messages. The bridge design solution requires a 3D model evaluation with the related calculations using Nòlian. This exercise represents a real-world application and not a simple didactical training as it was in the old version of the course. That is, students become more familiar with Nòlian modelling.

Another difference has been observed in the assessment stage. Students approached the evaluation as soon as the course ended, which means they have been on track during the semester and felt familiar with the technical content. This on-time preparation translated into an increase in the average score in the winter exam's session. Table 3 reports the number of students that passed the exam and the average score in the different exam' sessions.

Table 3. Students distribution at the assessment and their average score

	academic year 2018/19			academic year 2019/20			
Exam session	***# students***	***Test results***	***Average score***	***# Students***	***Test results***	***Project results***	***Average score***
Winter	5 (11%)	21,4 /30	21,4 /30	41 (66%)	14,82 /18	10,29 /12	25,26 /30
Summer and Autumn	33 (73%)	23,2 /30	23,2 /30	11 (18%)	14,18 /18	8,55 /12	22,78 /30
None	7 (16%)			10 (16%)			
Total	45			62			

By looking at the anonymous course survey, there are no substantial differences in the overall evaluation between the two academic years under study. In the academic year 2019/2020, the indices were I1 3.19/4, I2 3.22/4, S1 83%, S2 81%. The only statistical difference exists on the question related to supplementary learning activities (question 8). With the introduction of PBL, the students' perception moved from 3.08 to 3.48/4, increasing 20% in the satisfaction rate (from 76% to 96%). Some students reported a different workload distributed during the entire semester and a better understanding of both the theoretical contents and the software application.

5 Conclusion

In general, the course participation has increased compared to the previous academic year in terms of presence during the lessons and interest in the subject. In particular, the interaction between the lecturer and the students increase. The students' requests are mainly addressing discussion about alternative computational solutions and specific material characteristics. This remark stimulated the lecturer to implement in theoretical lessons some active learning activities.

These results suggest a positive relationship between PBL and FSA in a non-technical program, such as an Architecture program. Architecture students are used to working in teams and are often asked to develop a project inside a course. In this way, the technical aspects, usually found to be the hardest ones, are better understood thanks to the tutoring activities and the peer-to-peer interactions. This process cannot be ensured to all the students because the PBL has a degree of freedom in the involvement and participation in the proposed activities (lessons, revisions and presentation). Indeed, 17 over 20 teams decided to constantly participate in the PBL approach with a personal and unique timing and flow in design creation. Moreover, the assessment's result strengthens the hypothesis of a better understanding of the technical structural analysis characteristics thanks to a concrete simple project design.

Considering the second research question, the possibility of locating the bridge all around the world and choosing materials that are more familiar for them is a positive aspect of this new methodology. Indeed, this freedom acts as leveraging on personal interests reinforcing and supporting the learning process. Another important aspect related to the heterogeneity of the class is the increase of peer-to-peer activities that have been registered since the beginning of the course. This informal and spontaneous interaction supports not only the computational side but includes in some cases also a theoretical discussion and study support activity.

Considering the positive results obtained during this first PBL implementation, starting from the academic year 2020/21, the FSA course is included in a design laboratory. Precisely, a design laboratory is a multidisciplinary course that involves different subjects' areas with a more complex project to be realized in teams.

6 Acknowledgement

For the development of this renewed version of the course, the interaction with DC Structures Studio has been crucial.

We also want to thank Giuseppe Brancaccio, Francesco Figura, and Emanuele Lavecchia, who play the critical role of tutors. Without their contribution, it would be hard to implement the PBL methodology properly.

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The Effects of the Gamified Flipped Classroom Method on Petroleum Engineering Students' Pre-class Online Behavioural Engagement and Achievement

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Abstract—In the recent times, the flipped classroom method is used commonly in higher education where pre-class online activities have a vital role. However, one of the most significant issues is the lack of participation of the students in pre-class online activities. In this study, a Gamified Flipped Classroom (GFC) environment proposes a solution to this issue. A true-experimental design was used in the study and the effects of teaching in this environment on students' online behaviors and achievements were investigated. The participants were fourth-year undergraduate petroleum and natural gas engineering students enrolled in a natural gas engineering course. The experimental group students learned with the gamified flipped classroom (GFC) method, while the control group students learned with the conventional flipped classroom (CFC) method. Data were collected from a natural gas concept test (NGCT), weekly quizzes, and data logs from Moodle. The research results indicated that teaching in the gamified flipped classroom (GFC) method showed a significant increase in the students' participation in the pre-class activities of the flipped classroom compared to the control group. Moreover, there was a significant increase in the achievement levels of the experimental group as compared to the control group. The results of this study provide evidence that the use of gamification elements in the pre-class phase of the flipped classroom method not only enhanced the students' pre-course online behaviour but also significantly improved their achievement.

Keywords—flipped classroom, gamification, higher education, online behavior

1 Introduction

Teaching in higher education is achieved through the traditional method, where the transfer of knowledge is carried out by the lecturers. However majority of students who have been educated by traditional methods do not have the sufficient skills for a successful career. [1]. To improve the quality of education and prepare students better for successful careers, new methods such as flipped classroom can be effectively used [2].

The flipped classroom (FC) is a rapidly evolving pedagogical method consisting of both pre-class and in-class activities [2]. In this method, the instructor delivers the course content with videos and various online materials. The students watch the lecture videos before coming to class. In the class, activities that encourage the participation of the students, such as problem solving and discussions, are carried out [3]. One of the most important problems of FC implementation is that students do not spend time on online pre-classroom learning activities and come to class with inadequate knowledge [4]. In this case, the unprepared students will not be active in-class activities and their performances will negatively be affected [5].

To overcome this problem, researchers suggest different strategies. The most commonly used strategy is the implementation of mini-quizzes at the end of the online practice or the beginning of the class hour [6]. Another way of ensuring that students watch the videos is to add questions into these videos [7]. A different strategy is to include pre-class online activities to a portion of their grade [8]. There is no single formula to ensure that the students come to class prepared and the design factors that increase students' online participation should be known.

In education, using a gamification strategy could be an effective tool to increase student engagement and learning compared to the traditional methods [9]. Gamification can be defined as the application of game-like mechanics to non-game situations or contexts [10]. According to another definition, gamification is a system that changes the behaviour of people by applying game design elements to non-game contexts. The main purpose of gamification is to motivate users to perform certain activities [11].

In the literature, limited studies have examined the effects of using gamification with the flipped classroom method [4]; [12]; [13]. However, they have investigated the effects of gamification in the in-class phase of the FC. In the literature, no studies have specifically investigated the effects of gamification on the pre-class phase.

Therefore, this study aims to investigate analyze whether the gamification strategy will be effective on students' participation in pre-class learning activities. For this purpose, the study seeks to answer the following research questions:

1. What is the effect of the Gamified Flipped Classroom Method on students' online behavioural engagement in the pre-class activities?

- The time spent in an online environment by the groups
- The number of messages sent by the groups to the online forum.
- The number of students who complete the weekly quizzes in both groups.
- The number of students' who watched the videos in both groups.

2. What is the effect of the Gamified Flipped Classroom Method on students' achievement?

- Weekly pre-class quiz scores of the both groups.
- Whether there is a significant difference between both of the groups' Natural Gas concept (NGCT) post-test scores.

The paper is organized as follows: Section 2, reviews studies on gamification and the use of gamification in flipped classrooms. Section 3 presents the methodology of this research which provides information about research design, participants, data analysis, instructional design, the Gamified Environment that has been developed, as well as data collection tools. Section 4 describes implementation results. Section 5 concludes and discusses the study that is presented within this paper. In the last section limitations as well as future research plans are discussed.

2 Literature review

2.1 Gamification

Gamification is used in non-game situations in order to ensure that students learn through motivation and loyalty with game thinking, aesthetics, and game mechanics [14]. Gamification strategy is the most common context for experimental research in the field of education and learning [15]. With the increasing use of the gamification strategy in the field of education, it can be said that the use of the gamification strategy is also increasing in online courses and virtual learning environments [16].

The components of gamification are points, badges, levels, experience points (XP), and leaderboards. Additionally, some of the dynamics that reflect the users' interaction with the system are rescue, cooperation, exchange, advancement, and relationships. Mechanisms such as challenges, competitions, operations, changes, cooperation, feedback, winning an award, ranks, and notifications are the elements that keep students engaged in the system [17].

The results of the studies on the effects of gamification on learning outcomes in e-learning environments have shown that this strategy increases the motivation towards the course, as well as the success and participation. For example, Stamatios Papadaki [18] applied the combined use of App Inventor and the game development method in a Computer Science course and assessed students' achievement and motivation in basic programming skills. The results of the study showed that the game development method increased students' motivation and basic programming success [19].

In another study conducted with high school students, the effect of game elements in the gamification strategy on students' knowledge, and engagement was examined. The study demonstrated that the overall productivity of students could be improved when leaderboards are used therefore it could be worth implementing it in classroom. Böckle et al [20], conducted a systematic literature review in order to understand the functioning of adaptive gamification and the presented solutions. In this study, 43 studies were analysed. According to the results of the research, the researchers identified five research difficulties and made suggestions for researchers who intend to conduct studies in this field. The research indicates that adaptive gamification in the field of gamification in particular has become an increasingly studied field in terms of ensuring the long-term loyalty of the learners.

Gil, Cantador, and Marczewski studied the mechanics and the circumstances of the player types in the e-learning environment. In the study, the gamification mechanics were combined with numerous learning activities, and their functions in the e-learning system, their effectiveness in learning, their connections between the mechanics, and the types of players associated with them were all analysed. According to the results of the research, learners who conformed to the achiever, socialized, and philanthropist player types were found to do the activities easier; however, the explorer player type learners seemed to be more ineffective in the learning activities [21].

Considering the effect of the gamification strategy in the literature on e-learning environments, it has commonly been assumed that teaching in an appropriate flipped classroom environment is a beneficial learning approach for increasing students' participation in online activities.

2.2 Gamification and Flipped Classroom (FC)

The strategy of gamification of in-class activities in FC implementations could be an efficient method. However there is only a limited number of studies in the literature examining gamification elements in the application of the FC method. Some of them have the strategy of gamification in the in-class phase of the flipped classroom. For instance, Latulipe, Long and Seminario carried out the teaching of a computer science course by integrating the flipped classroom method into the in-class phase by using the gamification strategy combined with teamwork. The results showed that students achieved higher final grades than in previous years. However, the specific factors (flipped classroom, teamwork or gamification) that led to better performance were not stated in the study [22].

A research was conducted to examine how educational science students' learning and motivation affected by a gamified flipped classroom intervention. The results showed the benefits of gamification on learning efficiency. The study further reported favourable effects of gamified in-class activities on intrinsic motivation and social relatedness, however no crucial effect was observed on competence need satisfaction. [12]. Hung, used the Kahoot application in class to evaluate students on an undergraduate English course carried out with the flipped classroom approach. The usage of gamification in this application was limited to the face-to-face session of the flipped classroom. In other studies, gamification elements were used in both pre-class and in-class phases of the flipped classroom method [23]. For instance, Yildirim, integrated the gamification elements into both the pre-class and in-class phase of the flipped classroom in the teaching of a Principles and Methods course to second grade Mathematics teaching students. He used points, badges, levels, experience points and leaderboards in the course, which was opened on the Moodle system. According to the results of the study conducted using a true experimental design, it has been determined that the flipped classroom method based on gamification had a positive effect on students' success and attitudes towards the course [24]. A study stated that the artefacts produced by the experimental group students using the gamification strategy and the self-determination theory based on flipped classroom method were of better quality than the artefacts of the control group students in which only the FC applied [11]. Measles and Abu-Dawood, analysed the game and learning processes by examining the relationships between gamification, learning and games in their literature-based study. They emphasized the use of this strategy in e-learning environments could have a helpful effect on the students' engagement and motivation [25].

In response to the present research gap, this research will contribute to the literature in terms of the problem of students coming to the classroom without suitably preparing the pre-class materials in the application of the flipped classroom method to the course.

In this context, the study analyses students' participation in pre-class tasks by integrating the gamification elements into the activities in the pre-class phase of the flipped classroom.

3 Methodology

3.1 Research design

A pre-test and post-test experimental design with a control group were used. The students were randomly assigned into groups. While the experimental group students were taught with the gamified converted classroom (GFC) method, the control group students were taught with the conventional flipped classroom (CFC) method. The experimental procedure is shown in Figure 1.

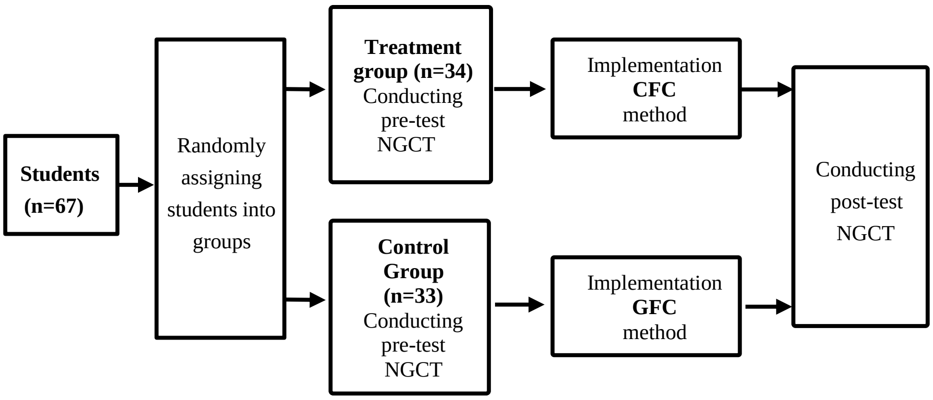

Fig. 1. The Research Design

3.2 Participants

The participants comprised 67 (22 females and 45 males) fourth-year undergraduate petroleum and natural gas engineering students enrolled in a natural gas engineering course at a private university during the fall term of 2019. The experimental group (n=34) used the GFC method while the control group (n=33) used the CFC method. All participants in the experimental and control groups were between 21 and 25 years of age. The same instructor taught both groups. Both groups used the university's Moodle platform. Each class was delivered for a total of 9 weeks.

Before the experimental implementation, Natural Gas Concept Test (NGCT) was applied as a pre-test to determine whether the students of both groups were equal in terms of natural gas engineering knowledge. Independent sample t-test results according to the NGCT pre-test results are shown in Table 1.

Table 1. The pre-test of NGCT

Group	N	Mean	SD	*t*	*p*
Experimental	34	44.85	12.09	1.997	0.960
Control	33	44.69	13.69		

Statistical results determined that the natural gas concept knowledge pre-test results did not show a significant difference between the groups ($t=1.997$, $p > 0.05$). This finding indicates that before implementation both groups had equal knowledge of natural gas concepts.

3.3 Data analysis

In the data analysis, basic descriptive statistics (the number of frequencies -n) and independent t-test were conducted to analyze the data. The significant level was considered as $p<0.05$. All statistical analyses were done with SPSS program version 24.

3.4 Instructional design

Separate course pages for both groups were created by the researchers in the Moodle learning management system. Students entered the course with their username and password. Before the experiment procedure began, the control group was informed about how the courses were going to be carried out with the flipped classroom without gamification strategy (CFC method). Furthermore, the experimental group was informed about how the course was going to be carried out with the gamified flipped classroom (GFC). While one student in the control group had the experience of online learning, two students had such experience in the experimental group.

The Moodle course pages for both groups were enriched with events such as forums, instant messaging, feedback, and quizzes. In addition, the experimental group course page was enriched with gamification components through gamification plug-ins. The gamification components were not used in the control group's course page.

The students of both groups decided for themselves whether to complete the out-of-class activities or not. The purpose of giving students this chance is to compare the experimental group students using the gamification strategy with the control group that does not use gamification in terms of completing their out-of-class activities.

The course contents of the two groups were the same for 9 weeks (Table 2). Both groups also attended class once a week (90 min.) on different days. Ethical approval was obtained from the university before implementation.

Table 2. Topics taught to the experimental and control group students by weeks

Week	Topic
1	Definition and components of natural gas, processing of natural gas
2	Review of gas properties compressibility, formation volume
3	Natural gas hydrates
4	Water content of natural gas
5	Gas reservoirs volumetric method, material balance method calculations
6	Gas reservoirs, water influx, water influx models example
7	Gas flow in porous media, deliverability tests
8	Natural gas measurement, gas gathering and transport
9	Gas compression

Control Group. The courses in the control group were taught with the conventional flipped classroom (without gamification).

Before Class—For the control group, two days before the course, a video prepared by the researchers with a length of 15-20- mins and a quiz related to the course were uploaded to the Natural Gas Engineering course that had been created on Moodle. Students watched the videos at home and write questions about the parts they couldn't understand. In the forum module of the control group, students exchanged ideas about the topic.

During the class—Students discussed the parts they did not understand during the class time. Meanwhile, the instructor guided the discussions and made the necessary explanations to prevent false learning. Furthermore, problem-solving activities were carried out on the subject. The gamification components were not used when applying the flipped classroom method in the control group.

Experimental Group. It is stated in the literature that it is important to explain what the students will be doing and the reason why they are going to do it in the game environments [26]. Therefore, a clear explanation was given to the experimental students who were going to use the flipped classroom method together with the gamification strategy. However, in order to prevent students from constantly aiming to score points, the information on the scores of the tasks was kept confidential. The guidelines containing the information explained by the instructor were added to the Moodle course page. Figure 2 shows the structure of the experimental group.

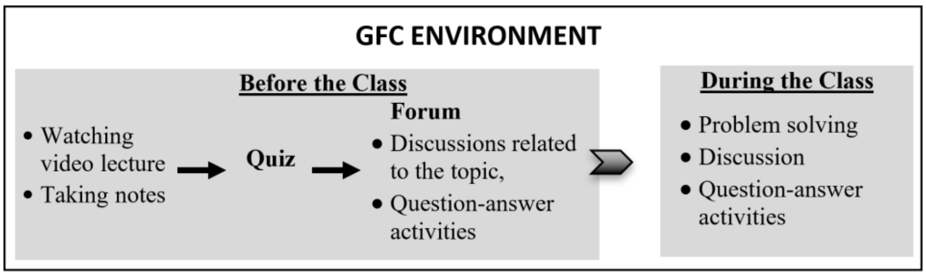

Fig. 2. The experimental group study design

Before Class—The course videos and quizzes uploaded for the control group each week were sent to the course page of the experimental group two days before the course. Students watched the videos and took notes. They prepared questions on the parts they did not understand. The first student who watched the whole course video and completed the sent quiz correctly each week was given a petroleum engineering badge. Moreover, a helper badge was given to the student who gave quality answers to the other students in the forum and also participated in the discussions.

During the class—In class, students asked each other the parts about the parts they did not understand in the course video. Meanwhile, the instructor guided the discussions in order to prevent false learning and made the necessary explanations. Furthermore, problem-solving activities were carried out on the subject.

3.5 Gamified Environment

The Time Spent in Online Environment. To determine the time participants spent in the online environment, the "block configurable_reports" plug-in was used on Moodle. The plug-in enables data and time reports on the start and finishes times of any action of the user to be generated. The data obtained with this plug-in was converted into seconds and the time spent online of the experimental and control group participants were compared.

Badge. Badges are used for feedback purposes to reward the behaviours of the participants and also to identify their positions in the virtual environment [27]. Two different badges were used in the study. Firstly, the first student who watched the course video every week and completed the quiz correctly earned a petroleum engineering badge. Secondly, the student who helped the most in the forum and participated in the discussions earned a helper badge.

Experience Point. Moodle's "XP-Experience Point (block_xp)" plug-in was used for the GFC experiences of the students'. The students earned experience points by sending quality messages to the forum before the class regarding the subject. When the students shared a post regarding the objectives of the course, they earned 40 experience points and they earned 10 experience points when they read the posts. Experience points were effective in improving the student's level, moving them up the leaderboard and winning the helper badge.

Leaderboard. It is stated in the literature that the leaderboard is a powerful tool used to encourage students [28]. A leaderboard was created according to the points earned by the students in order to compare their achievements with the achievements of their friends. Only the names of the top 3 students of the week were written on the leaderboard.

Level. It is recommended that students are given feedback on the experience they gain in the gamified environment and that their progress is shown in the gamified system [14]. For this reason, the levels were formed based on the experience points and the scores obtained from the quizzes. Students were considered to be at Level 1 when they first signed in to the system and they remained at that level until they reached 500 points. The levels, the required experience points to reach those levels, and explanations have been given in Table 3.

Table 3. Levels and the required experience points

Levels	Titles	Experience points
1	Junior engineer	500
2	Senior engineer	1000
3	Lead engineer	3000
4	Head engineer	8000
5	Manager	13000

Instant Feedback. In the literature, it has been stated that it is important to give feedback to the students and show their progress on the experience they have gained in the gamified environment in order to direct them to the intended behaviours [27]. Therefore, the gamification elements used in the study were badge, experience point, leaderboard, level, and feedback (Table 4).

Table 4. Gamification elements used in the GFC

Element	Criteria
Petroleum Engineer Badge	The first student who watched the video every week and completed the quiz correctly earned the petroleum badge.
Helper badge	Helper badge was given to the student who was the most helpful in the forum before the class time and to the student who participated in the discussion.
Experience Points	The student who made a quality post to the questions in the forum earned 40 points. Students who read the forum messages earned 10 points. There was no scoring in the second posts which had the same content.
Leaderboard	The top 3 students of the week were announced at the end of the week on Moodle. It was used for the students to track their own learning progress, compare their performance with their peers and to increase the competition.
Level	Levels were formed according to the experience points.

3.6 Data collection tools

The Pre-class activity data (Time spent in online environment, the number of messages posted in the online forum before the class time, watching the course video weekly and weekly quiz completion) of the students' from both groups, which had to be completed before the deadline, were analysed in order to answer the research questions about online behavioural engagement. For the Achievement research question, the quiz scores and NGCT post-test (50%) scores of each group of students were compared (Table 5).

Natural Gas Concept Test (NGCT). The NGCT was developed by a lecturer in the Petroleum and Natural Gas Engineering Department. The test, consisting of 22 multiple choice questions, was created on the subjects to be taught. There were five options for each question. The concept test was examined by three lecturers from the Petroleum and Natural Resources Department in order to ensure validity. According to the opinions of the experts, two questions were removed from the test and the total number of items was reduced to 20.

The NGCT test was used as a pre-test before the experimental process to determine whether the knowledge of the students of both groups were equal. It was also used as a post-test to compare the success of the groups at the end of the experimental process (after 9 weeks).

Weekly Quiz. Quizzes were sent together with the course videos in order to evaluate whether they understood the content of the videos or not. Each quiz consisted of 5 multiple choice questions, which were each assigned 1 point. Students who answered all of the questions in the weekly quiz correctly were awarded 5 points students who answered all of the questions incorrectly did not get any points. The scores obtained from the quizzes were effective as an indicator of the students' achievement and in earning Petroleum Engineer badge.

Table 5. Measures for online behaviour engagement, and achievement

Dependent variable	Indicators
Students' online behaviour engagement	The time spent in the online environment
	The messages posted in the online forum
	Watching the course videos weekly
	Weekly quiz completion
Students' achievement	Weekly pre-class quiz scores (50%)
	Post-test NGCT (50%)

4 Results

4.1 Students' online behaviour engagement

The time spent in online environment. The records of the time spent in the online environment by the two groups of students were kept and converted into second. The descriptive findings of the mean time (s) spent by the groups in the online environment have been presented in Table 6.

Table 6. Descriptive and t-test findings related to time spent online.

Group	N	Mean	SD	*t*	*p*
Experimental	34	8858.82	2787.21	1.997	0.000
Control	33	4305.45	3008.35		

Significant at the 0.05 level.

The mean times spent by the groups were examined with a t-test for independent samples and a significant difference was found in favor of the experimental group ($t=1.997$, $p< 0.05$). Based upon these findings, it can be said that gamification increases the time spent by students in the online environment.

The number of messages posted in the online forum. The number of messages sent to the online forum found on the course pages was used as an indicator of the behavioral engagement of students in both groups. The descriptive findings of the high-quality messages for the content that the groups sent to the online forum are presented in Table 7.

Table 7. Descriptive and t-test findings regarding messages posted

Group	N	Mean	SD	*t*	*p*
Experimental	34	7.02	1.62	2.002	0.000
Control	33	4.90	2.36		

Significant at the 0.05 level.

The number of messages sent by the groups to the online forum was examined with a t-test for independent samples and a significant difference was found in favor of the experimental group ($t=2.002$, $p<0.05$). Based upon these findings, it can be said that gamification increases the number of messages posted on an online forum by students.

Weekly number of watching videos. As previously mentioned, the natural gas engineering course lasted for 9 weeks. Course videos that explained the course subjects were sent to both of the groups each week for nine weeks. The number of students who watched the videos before the deadline has been presented in Figure 3.

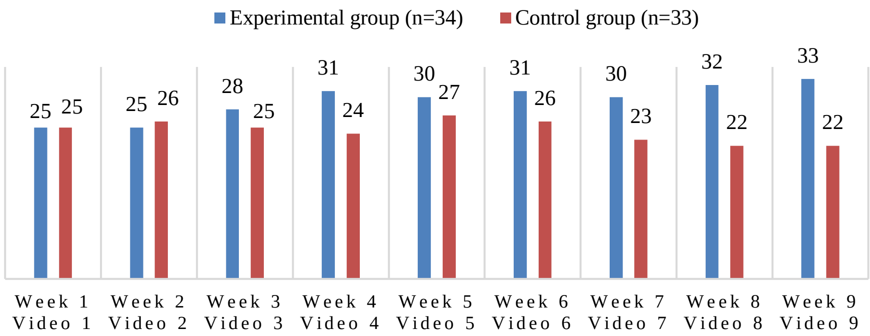

Fig. 3. The number of students who watched the videos before the weekly deadlines

According to Figure 3, the number of students who watched the course videos each week for 9 weeks was greater in the experimental group than in the control group. The number of students (n=25) who watched the videos in both of the groups in the first week was the same. On the other hand, from the 3rd video onwards (3rd week), differences began to appear. While the number of students who watched the video before the deadline on the last week (9th week) was n=33 in the experimental group, in the control group, n=22 students watched the video. The descriptive data showed that as the weeks passed, the number of students who watched the videos increased in the experimental group and decreased in the control group.

Weekly quiz completion. The natural gas engineering course lasted for 9 weeks. Quizzes were sent to each group each week for 9 weeks related to their course subjects. The number of students in the experimental and control groups who completed the weekly quizzes before the deadline has been presented in Figure 4.

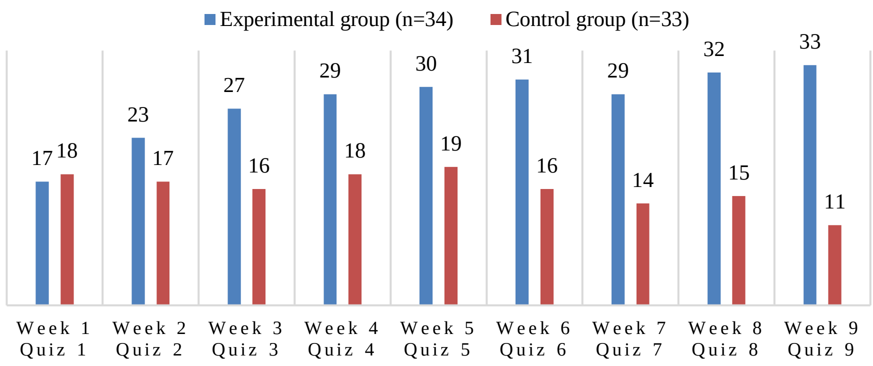

Fig. 4. The number of students who completed the quizzes before the weekly deadlines

As can be seen in Figure 4 the number of students who completed the quizzes for 9 weeks before the class time was higher in the experimental group than in the control group. The number of students who completed the quiz in the first week in each group was similar: experimental group (n=17) and control group (n=18). However, the differences became apparent beginning from Quiz 2. In the last week (9th Week), the number of students in the experimental group who completed the quiz before the deadline was n=33, while in the control group, it was n=11. The descriptive data showed that as the weeks passed, the number of students completing the quiz before the deadline increased in the experimental group and decreased in the control group.

4.2 Students' Achievement

Natural gas concept (NGCT) post-test scores. In the study, NGCT was used as a post-test to determine whether there were any changes in the level of knowledge of both groups after the experimental process completed. An independent sample t-test was conducted on the NGCT post-test results of both groups (Table 8).

Table 8. Descriptive and t-test findings related to time spent online.

Group	N	Mean	SD	t	p
Experimental	34	60.73	14.83	1.997	0.003
Control	33	49.54	15.23		

Significant at the 0.05 level.

The statistical results revealed that the results of the natural gas conception knowledge post-test significantly differed between the control and the experimental groups ($t = 1.997$, $p < 0.05$). According to this result, it can be concluded that the integration of the gamification elements into the pre-class stage of the flipped classroom method can have a positive effect on the students' achievements.

Weekly pre-class quiz scores. Students completed the quizzes that were prepared in relation to the course subject each week after watching the course video. In this way, the student's understanding of the contents was assessed. The quizzes consisted of 5 questions and each question was awarded 1 point. The students who answered all the questions correctly received 5 points. The scores of the students who did not take the exam were evaluated as missing data for each group. Both the control and experimental groups' scores were collected and analysed. A comparison of the weekly quiz scores for the quizzes completed before the deadline for both the experimental and control groups has been presented in Figure 5.

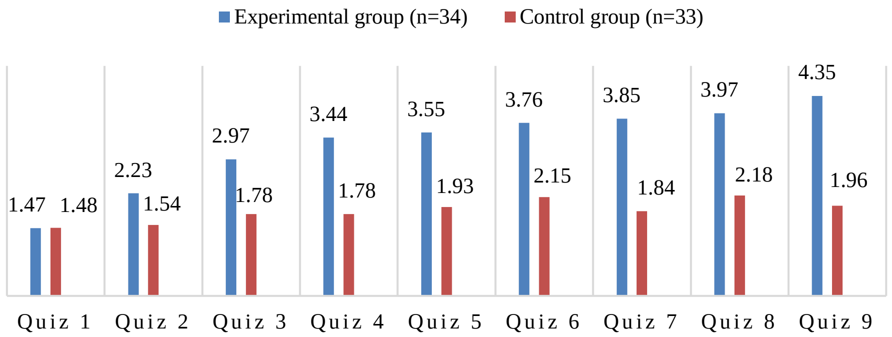

Fig. 5. Weekly pre-class quiz scores before the deadlines.

As can be seen in Figure 5, the quiz scores of the experimental and control group students in the first week were very close. However, while the score for the control group was 1.54 in the second week, the score for the experimental group was 2,23. In week nine, the quiz score of the experimental group was 4.35 and it was 1.96 in the control group. The descriptive data showed that as the weeks passed, the quiz scores increased in the experimental group and decreased in the control group.

An independent sample t-test was conducted to analyse whether statistically significant differences were between the experimental and control groups (Table 9).

Table 9. Weekly pre-class quiz scores

Group	**N**	**Mean**	**SD**	***t***	***p***
Experimental	34	3.28	0.91	2.262	0.001
Control	33	1.84	0.23		

Significant at the 0.05 level.

The results of the weekly pre-class scores significantly differed between both groups ($t = 2.262$, $p < 0.05$). According to the results, the gamification elements integrated into the pre-class stage of the flipped classroom method had a positive effect on making the students solve the questions in the quiz correctly.

5 Discussion and conclusions

The study investigated the effect of the gamification elements that were integrated into the pre-class phase activities of the flipped classroom method on the students' online behaviour engagements and achievements.

Students' online behaviour engagement. The research results have shown that integrating the gamification elements in the pre-class phase of the flipped classroom method had a positive effect on the students' online behaviours. Pre-class activity data that were analysed included students' time spent in the online environment, the number of messages posted on the online forum before the class time, the number of students watching the weekly course video, and weekly quiz completion numbers.

According to the findings of the study was a significant increase in the number of messages posted in online forums, number of students watching the videos weekly, and weekly quiz completion numbers in the experimental group compared to the conventional group. Furthermore, it has been identified that the experimental group students spent more time in the online learning environment compared to the control group students.

In the current study, some elements may have encouraged students to complete their tasks on time and accurately. This result is in line with research demonstrating students participate in learning activities [29]. Badges sent as feedback to students completing their tasks on time and correctly may have strengthened their behaviours. A study stated in their study that students felt good and they began to work more in the pre-class and post-class activities when they received positive feedback (e.g., badges) [30]. Given the view of Robinson and Bellotti that badges trigger a sense of curiosity, the badges used in the study are thought to have affected students' online participation positively [31].

Another gamification element that increased the experimental group students' online participation could have been the experience points. The experience point might have led to competition due to the possibility of students' increasing their level and being listed on the leaderboard. This finding is compatible with the view of Song et al which suggests that competition encourages individuals to work harder. However, some studies in the literature suggest that leaderboards can lead to negative competition among learners and may adversely affect the motivation of those in the lower ranks [32]; [26]. In our study, the leaderboard was used to give feedback to individuals. Only the top 3 students' names were written on the leaderboard each week. Thus, the students' in the lower ranks were prevented from losing motivation. On the other hand, feedback was sent to each student regularly via Moodle as a private message. According to Werbach and Hunter, each individual can be motivated by following his/her own development [27]. Therefore, the game elements, leaderboard, badges, experience points, and levels were used in our study to give feedback to the students. This finding is consistent with the findings of prior studies [33]; [12] who suggested that gamification positively affects online participation. Similarly, Amriani et al. stated in their study that including gamification in the environment increases online participation, whereas exclusion from the environment decreases online participation [34]. Furthermore, this parallels with results from Kalogiannakis, Papadakis, and Zourmpak's study, which determined that the learning outcomes that students were most affected by were motivation, participation, and, achievement. [35]

Students' achievement. According to another result of this study, it has been shown that the integration of the gamification elements into the flipped classroom methods' pre-class phase had a positive effect on the students' achievements. It has been identified that the NGCT post-test and weekly quiz scores of the experimental group who were using the gamified flipped classroom method were higher compared to the control group.

In the flipped classroom method, the fact that students came to the class prepared after performing the pre-class activities might have facilitated deeper learning in the classroom. This result is in line with the idea that incorporating the gamification strategies of Landers' into the teaching process allows students to use their time more efficiently on the relevant task, which consequently leads to better student achievement scores [36]. As Thanachawengsakul and Wannapiroon stated, it is important to encourage online participation in order to provide online learning [37].

The present study showed that integrating gamification elements in the flipped classroom pre-class phase had a positive effect on the students' online participation and achievement.

6 Limitations and future research

This study, as with any other empirical study, has certain limitations. Firstly, only quantitative data were used in the study. Future studies can be conducted by doing further analysis using qualitative data collection tools. Secondly, the participants of this study only comprised of students who were studying in a private university. Thus, the results cannot be generalized nationally. The study can be conducted with students from public universities and with more participants. Thirdly, in order to prevent student interactions in the distance learning processes, separate classes were created in Moodle for the experimental and control groups. However, the interaction between the group members was not analysed. These student interactions can be analysed in future studies. The most important challenge in conducting the research is that students have internet connection problems while working with pre-lesson materials or that there are no students who do not have internet.

The online learning enriched with gamification was realized through the Moodle platform. Although many gamification components can be used in Moodle, the gamification components used in the study are limited to Moodle's plugins. Finally, the findings of the research cannot be generalized to all courses in higher education. Therefore, to validate the findings of this study, we suggest conducting studies in the teaching of courses in different fields. Moreover, for future research, the impact of the applied model on academic and administrative staff can be examined.

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Enriching Undergraduate Mathematics Curriculum with Computer Science Courses

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Abstract—Traditional mathematics curriculum faces several issues nowadays. The gap between course materials and students' real-life mathematical experiences, the scattering of knowledge in different courses, and the lack of mathematics applications to other subjects all hinder the learning of students. The emerging trends in data science, machine learning, and artificial intelligence also impel higher education to enrich and refine mathematics education. In order to better incubate students for future, the experience of enriching undergraduate mathematics curriculum with computer science courses is introduced in this study. The curriculum is designed and implemented for students who major in applied mathematics to better stimulate the learning, participation, exercise, and innovation. It provides students with comprehensive theoretical and practical knowledge for the challenges and industrial requirements nowadays. Evaluations, major findings, and lessons learned from three refined courses are discussed for more insight into the following deployment and refinement of the curriculum.

Keywords—curriculum design, mathematics, computer science

1 Introduction

Traditional mathematics curriculum faces several issues nowadays. As stated by Coffland and Xie [1], the gap between course materials and students' real-life mathematical experiences, the scattering of knowledge in different courses, and the lack of mathematics applications to other subjects all hinder the learning of students [2][3][4]. The emerging trends in data science, machine learning, and artificial intelligence also impel teachers to make corresponding changes in mathematics education [5][6]. Several experiments and improvements are thus carried out, including integrated curriculum, multidisciplinary programs [7], collaborative learning [8], blended learning [9], and capstone courses [10]. In order to better incubate students for future challenges, curriculum refinement and enrichment in mathematics should be performed [11].

Based on the aforementioned issues for mathematics education, literature reviews and course reviews were performed in the department of applied mathematics in one university to get more insight into the possible curriculum improvements [12]. For instance, programming languages taught in the computer programming course are C or Java for students in the department of applied mathematics. The course materials mainly focus on the syntax of programming languages. The concepts and language constructs are usually instructed separately. In that circumstance, students just memorize the programming languages and cannot accumulate computational thinking [13] [14] and problem-solving skills [15]. Students usually feel bored in the class and forget what they learn after the semester. Moreover, the connection between mathematics and computer programming is weak. Without curriculum refinement and enrichment, students cannot realize how to use programming languages and apply both computational thinking and problem-solving skills to their learning or research in mathematics. Besides, in the statistics course, students usually learn the theoretical knowledge and take practices in textbooks by topics. However, the scenarios described in textbooks are often limited in a certain scope or designed in a simpler form. A critical gap exists between theoretical understanding and the actual problem in the real world. Furthermore, students have no experience in the leverage of knowledge and skills from mathematics, statistics, and computer science, which are essential for research and industry nowadays.

According to the issues identified from previous studies and the course reviews, undergraduate mathematics curriculum is refined and enriched with computer science courses to achieve the following goals, including (1) The development of the capability to realize specific computation or problem solution by programming through computational thinking, (2) The development of the capability to solve real or complex problems thoroughly by mathematics, statistics, and computer science knowledge and skills [16][17], and (3) The accumulation of cross-domain capabilities, skills, and experiences for emerging challenges nowadays [18].

The curriculum is designed and implemented for students who major in applied mathematics to better stimulate their learning, participation, exercise, and innovation based on the knowledge of mathematics, statistics, and computer science. It aims to provide students with comprehensive theoretical and practical knowledge for the challenges and requirements nowadays [19]. Major courses selected and discussed in this study include “Computer Programming” in the freshman year, “Data Processing and Analysis” in the junior year, and “Statistical Software for Data Analysis” in the junior year. Evaluations, major findings, and lessons learned from the refined courses are also discussed in this study for more insight into the future deployment and refinement of the curriculum.

The remainder of this study is organized as follows. Section 2 introduces the design of the refined curriculum in the department of applied mathematics. Section 3 describes the evaluations of introduced courses from the perspectives of students. Section 4 depicts major findings and lessons learned from the courses. Finally, Section 5 presents the conclusion and future works of this study.

2 Curriculum design and implementation

The overview of computer science courses enriched and refined in the department of applied mathematics is depicted in Table 1. The courses in freshman year, including "Introduction to Computer Science" and "Computer Programming," are compulsory courses for students to acquire fundamental knowledge and skills in computer science. "Introduction to Computer Science" is the first course of computer science concentration in the department of applied mathematics. The goal of "Introduction to Computer Science" is to give the global view and understanding of fundamental computer science topics, including hardware, software, operating system, programing languages, network, web development, and data analytics. "Computer Programming" is the first programming course for students to learn and gain fundamental capabilities in computational thinking, problem-solving, and coding.

Table 1. Overview of computer science courses in the department of applied mathematics

Year	Course	Credit
Freshman Year	Introduction to Computer Science	3
	Computer Programming	3
Sophomore Year	Internet Practice	3
	Object-Oriented Programming	3
Junior/Senior Year	Data Structure	3
	Introduction to Mathematical Software	3
	Data Processing and Analysis	3
	Statistical Software for Data Analysis	3
	Capstone Course (I/II)	2

The courses in the sophomore year, including "Internet Practice" and "Object-Oriented Programming," are elective courses for students to learn front-end development and advanced programming knowledge and skills. "Internet Practice" provides students with modern web design and implementation skills (e.g., HTML, CSS, JavaScript, jQuery, and so on). The topic of data visualization for high-quality presentation of quantitative information will be emphasized during the course [20]. Students can integrate what they learn in statistics and "Internet Practice" to present and visualize data on websites. Based on the knowledge and skills learned from "Computer Programming," students can enroll for "Object-Oriented Programming" to learn advanced programming skills and gain valuable experience in the design and implementation of complex applications. The accumulated knowledge and programming skills are useful for the learning of advanced courses such as "Data Processing and Analysis" and "Statistical Software for Data Analysis." Finally, the courses in junior year and senior year, including "Data Structure," "Introduction to Mathematical Software," "Data Processing and Analysis," "Statistical Software for Data Analysis," and "Capstone Course," are elective courses for students to gain the knowledge, skills, and experience from mathematics, statistics, and computer science for real-world problems and complex applications. "Data Structure" provides students with advanced knowledge about the design of data structure, associated manipulations, and algorithms based on the knowledge learned from "Computer Programming" and "Object-Oriented Programming." Topics such as tree structure and graph structure are discussed from the perspectives of "Data Structure" in computer science and "Graph Theory" in mathematics. Thus, students can get more insight into mathematical theories and corresponding real-world applications. "Introduction to Mathematical Software" introduces useful software tools and programming languages for students in their advanced learning and research tasks, including LaTeX, Mathematica, Matlab, Octave, Anaconda, SageMath, and so on. Both "Data Processing and Analysis" and "Statistical Software for Data Analysis" provide students with the knowledge, skills, and hands-on experience in each step of data processing and analysis process from the perspectives of mathematics, statistics, and computer science. Python, R programming language, and associated data science packages will be introduced for students. Finally, in the "Capstone Course," students are encouraged to integrate what they learn in the past and conduct researches based on their interests [10]. The research topics include but not limit to financial mathematics, graph theory, statistics, data mining, mathematics education, and so on.

In the following subsections, education goals, syllabuses, and the corresponding course designs of "Computer Programming," "Data Processing and Analysis," and "Statistical Software for Data Analysis" are described.

2.1 The Design of the Computer Programming Course

The education goal of "Computer Programming" course helps students to develop the capabilities of computational thinking and problem solving with specific programming languages. Table 2 describes the syllabus of "Computer Programming" course designed and implemented in the department. The design of the "Computer Programming" course is divided into two major sections, including the introduction of Alice and the introduction of Python programming language.

Table 2. Syllabus of Computer Programming

Topic	Description
Alice Introduction	Introduction to Alice
Object, Methods, and Properties	Using variables and objects
Flow Control	Using if statements and loops
Event Control	Managing keyboard and mouse events
Game Design	Game design and implementation
Python Introduction	Introduction to Python
Variables and Data Types	Using variables and fundamental data types
Flow Control	Using if statements and loops
Data Structures	Using lists and dictionaries
Input and Output	Manipulating file and network I/O
Function	Functions design and implementation
Exception Handling	Exception handling and testing

Alice, developed by Carnegie Mellon University, is an educational software for teaching computer programming in a 3D environment [21]. Through the 3D environment and the interactive interface provided by Alice, students can learn and practice the concept of programming while creating their animations, stories, or games. Any implementation or changes to Alice programs can be executed and examined through the 3D environment instantly. Thus, students can practice and realize major programming concepts, including objects, methods, properties, flow control, and event control, visually and efficiently. During the learning of Alice, students are expected to do their assignments and group projects with particular programming concepts (e.g., operators and flow control) and export their works as videos and share it over the Internet.

In the second section of the "Computer Programming" course, Python will be introduced for students. In addition to general application development, Python is highly used in numerical computation, signal processing, statistics, symbolic mathematics, and algebra. Python also has lots of useful packages in data science, including machine learning, text mining, image processing, and so on, which are tightly related to the knowledge and application of mathematics. Therefore, Python is more suitable for students in the department of applied mathematics rather than programming languages like C and Java [22]. The materials of Python include variables, data types, flow control, data structures, input and output, functions, and exception handling. Students can acquire fundamental programming knowledge and skills for further programming courses and data science courses, such as "Object-Oriented Programming," "Data Processing and Analysis" and "Statistical Software for Data Analysis." It is expected that the capability of computational thinking, the skills of problem-solving, and the understanding and practice of programming concepts can be developed effectively and efficiently in the refined "Computer Programming" course.

2.2 The design of data processing and analysis course

The "Data Processing and Analysis" course helps students to learn and experience every important step of data processing and analysis tasks by the leverage of knowledge and skills in mathematics, statistics, and computer science. Table 3 describes the syllabus of "Data Processing and Analysis" course designed and implemented in the department of applied mathematics.

In the beginning of the course, the steps of data processing and analysis, including problem definition, data collection, data cleaning, data management, data modeling, data analysis, data visualization, and findings presentation, are introduced for students to develop a global picture and an overall understanding. Students can get more insight into the roles of mathematics, statistics, and computer science in data processing and analysis. Open data [23] and big data will also be introduced for students to understand real-world trends, challenges, and problems they will encounter nowadays. After the preliminary introduction, the course introduces each step of data processing and analysis. More specifically, students can learn and experience how to perform data processing and analysis through Python and related data science packages based on the knowledge and skills accumulated in mathematics, statistics, and computer science courses. Important Python packages, including NumPy, Pandas, SciPy, SymPy, and Matplotlib, are also introduced as fundamental tools for students on data science and scientific computation [24]. In addition, open data will be used as major materials for learning and practice throughout the course. Popular formats of open data, including CSV, JSON and XML, and the corresponding manipulations will be introduced for students to perform data collection, data cleaning, data management, data modeling, data analysis, and data visualization tasks [25]. During the course, students are encouraged to do their assignments and group projects based on open data and to innovate based on their interests and creativities.

Table 3. Syllabus of data processing and analysis

Topic	Description
Course Introduction	Introduction to data processing and analysis
Process of Data Processing and Analysis	Major steps in data processing and analysis
Open Data	Introduction to open data and formats (CSV, JSON, and XML)
Python Basis	Python review
Data Collection and Management	Using NumPy and Pandas packages for data collection and management
Data Modeling, Analysis, and Visualization	Using statistics library and Matplotlib package for data analysis and visualization
Network and Graph	Using NetworkX package for network and graph modeling
Text Mining	Using Beautiful Soup, lxml, NLTK, and jieba packages for text mining
Image Processing	Using OpenCV package for image processing and recognition
Machine Learning	Using machine learning packages for classification, clustering, and regression
Advanced Topics or Case Studies	Selected topics in machine learning in different domains

After students are equipped with solid knowledge and skills of data processing and analysis, advanced applications such as network and graph modeling, text mining, and image processing will be introduced. Emerging topics and corresponding frameworks for machine learning can also be introduced. For instance, students can learn and use frameworks like Scikit-Learn, Tensorflow, PyTorch, and Keras for particular machine learning problems based on their interests. It is expected that a thorough understanding of data processing and analysis, the cross-domain capability based on mathematics, statistics, and computer science, and the programming skills for complex data processing and analysis tasks can be developed in the refined "Data Processing and Analysis" course.

2.3 The design of statistical software for data analysis course

The goal of "Statistical Software for Data Analysis" course helps students to learn and experience every important step of data processing and analysis using R programming language. R programming language provides efficient facilities for data manipulation, calculation, analysis, and visualization [26]. Both R programming language and Python are popular tools for data processing and analysis tasks. Therefore, it is worthwhile for students in the department of applied mathematics to learn and practice those skills for various data processing and analysis requirements. Based on previous knowledge of mathematics, statistics, and computer science, students can acquire additional capabilities in this course when performing data processing and analysis tasks in the future.

Table 4 depicts the syllabus of the "Statistical Software for Data Analysis" course designed and implemented in the department of applied mathematics. Similar to the "Data Processing and Analysis" course, the steps of data processing and analysis are introduced at the beginning for students to develop the overall understanding. Open data will also be introduced and used as course materials for students to learn and experience the data collection, cleaning, management, modeling, analysis, and visualization tasks by R programming language. Students are encouraged to do their assignments and group projects based on open data and to innovate based on their interests and creativities. Exploratory data analysis, descriptive statistics, predictive statistics, and selected topics in machine learning, including clustering, classification, and regression, are introduced for students. Students can also get more insight into the applications of data processing and analysis through case studies on financial mining, text mining, and social network mining [27]. It is expected that the thorough understanding of data processing and analysis, the cross-domain capability based on mathematics, statistics, and computer science, and the skills of R programming for data processing and analysis tasks can be developed in the refined "Statistical Software for Data Analysis" course.

Table 4. Syllabus of statistical software for data analysis

Topic	Description
R Introduction	Introduction to R programming language
Process of Data Processing and Analysis	Major steps in data processing and analysis
R Basis	Variables, vectors, and fundamental operations
Data Structures	Using matrix, array, list, and data frame
Open Data	Introduction to open data and formats (CSV, JSON, and XML)
Data Collection and Management	Data management and manipulation in R
Flow Control	Using if statements, switch, and loops
Data Visualization	Using R for data visualization
Statistics	Using R for descriptive and predictive statistics
Machine Learning	Using R for classification, clustering, and regression
Advanced Topics or Case Studies	Financial and social network mining by R

3 Course evaluation

At the end of every semester in the university, a course questionnaire is provided to students to carry out the evaluations from the perspectives of the course and the teacher. The evaluation statements are stated as the following.

1. The course was delivered based on the syllabus (C1)
2. The course was stimulating and interesting (C2)
3. The course objectives were achieved (C3)
4. Course materials were clear, appropriate and helpful (C4)
5. Assessment methods of the course were appropriate (C5)
6. The teacher was enthusiastic about teaching (T1)
7. The teacher presented in a clear and organized manner (T2)
8. The teacher presented appropriately based on the stated level of the class (T3)
9. The teacher was helpful when student had difficulties or questions (T4)
10. The teacher provided useful feedback and guidance (T5)

The level of agreement to the evaluation statements includes "Strongly Disagree," "Disagree," "Neutral," "Agree," and "Strongly Agree." Thus, score 1 to score 5 are given to the above levels correspondingly. Table 5, Table 6, and Table 7 present the evaluation results of "Computer Programming," "Data Processing and Analysis," and "Statistical Software for Data Analysis" based on refined curricula by the students in the department of applied mathematics, respectively.

Table 5. Course evaluation for Computer Programming

Statements	**Level of Agreement**				
	Strongly Disagree	***Disagree***	***Neutral***	***Agree***	***Strongly Agree***
C1	0	0	1	5	14
C2	0	0	1	10	9
C3	0	0	0	5	15
C4	0	0	1	5	14
C5	0	0	1	7	12
T1	0	0	0	5	15
T2	0	0	1	7	12
T3	0	0	1	6	13
T4	0	0	1	5	14
T5	0	0	0	6	14
Average Course Score					4.63
Average Score of Courses Offered by the Department					4.37
Average Score of Courses Offered by the College					4.34
Average Score of Courses Offered by the University					4.34

It was found that all the courses got better scores (4.63, 4.49, and 4.61) than average scores of courses offered by the department of applied mathematics (4.37, 4.37, and 4.38), the college of science and engineering (4.34, 4.34, and 4.34), and the university (4.34, 4.34, and 4.29). It shows that significant improvements are achieved through the curriculum refinement and enrichment. From the perspective of course materials (C4), the average scores of "Computer Programming," "Data Processing and Analysis," and "Statistical Software for Data Analysis" are 4.65, 4.46, and 4.74, respectively. It is confirmed that the corresponding course materials based on the refined curricula are clear, appropriate, and helpful for students in their learning tasks.

Table 6. Course evaluation for Data Processing and Analysis

Statements	**Level of Agreement**				
	Strongly Disagree	***Disagree***	***Neutral***	***Agree***	***Strongly Agree***
C1	0	0	1	14	9
C2	0	0	3	12	9
C3	0	0	0	12	12
C4	0	0	1	11	12
C5	0	0	0	12	12
T1	0	0	1	6	17
T2	0	0	0	9	15
T3	0	0	0	12	12
T4	0	0	0	9	15
T5	0	0	1	12	11
Average Course Score					4.49
Average Score of Courses Offered by the Department					4.37
Average Score of Courses Offered by the College					4.34
Average Score of Courses Offered by the University					4.34

Table 7. Course evaluation for Statistical Software for Data Analysis

Statements	**Level of Agreement**				
	Strongly Disagree	***Disagree***	***Neutral***	***Agree***	***Strongly Agree***
C1	0	0	2	4	13
C2	0	0	2	4	13
C3	0	0	0	10	9
C4	0	0	0	5	14
C5	0	0	1	4	14
T1	0	0	1	4	14
T2	0	0	0	7	12
T3	0	0	1	8	19
T4	0	0	1	4	14
T5	0	0	1	7	11
Average Course Score					4.61
Average Score of Courses Offered by the Department					4.38
Average Score of Courses Offered by the College					4.34
Average Score of Courses Offered by the University					4.29

From the perspective of course contents (C2), the average scores of "Computer Programming," "Data Processing and Analysis," and "Statistical Software for Data Analysis" are 4.4, 4.25, and 4.58, respectively. In addition, 95%, 88%, 89% of students in three courses agree that the courses were stimulating and interesting. Based on the statistics, it is believed that students can be inspired to learn, participate, exercise, and innovate by the refined and enriched curricula efficiently. Finally, from the perspective of course objectives (C3), all the students in three courses agree that the course objectives were achieved. Thus, according to course evaluations, the deployment of computer science courses based on the refined and enriched curricula brings lots of benefits and positive impacts on the students in the department of applied mathematics.

4 Major findings

In this section, major findings and lessons learned from the course implementations based on the refined and enriched curriculum are introduced. Several findings and experiences during the courses, including "The Use of Educational Software for Programming," "The Connection between Course Content and Real Life," and "Interdisciplinary Learning," are introduced and discussed. These findings, experiences, and lessons learned provide more insight into further deployment and refinement of the curriculum.

4.1 The use of education software for programming

One of the recommendations for current mathematics education is "targeting computational thinking and coding [28]." However, previous programming courses in the department of applied mathematics mainly focused on the syntax of programming languages. The concepts and language constructs are usually instructed separately. In that circumstance, students just memorized the programming languages and cannot accumulate computational thinking and problem-solving skills. Tough and boring course materials could make students lose interest and give up too early [29]. What is even worse is that many students hesitate to study the following computer science courses.

Therefore, when designing the "Computer Programming" course, Alice is used in the first section of the course. For students in the department of applied mathematics (or other non-computer science departments), Alice (or other educational software for programming such as Scratch and MIT App Inventor) could be a better choice to inspire the interests of students and teach programming concepts than programming languages like C and Java [30] [31]. Through the 3D environment and the interactive interface provided by Alice, students can learn and practice different programming concepts while creating their animations, stories, and games. Based on the visual presentation of program execution, students can get insight into the effects of programming concepts and language constructs (e.g., if statements and loops) effectively and efficiently. In addition, students show more interests and perform more proactively by using Alice for learning [32]. Innovation and creativity can also be incubated during the class, assignments, and group projects in the course.

Figure 1 depicts the racing game and the puzzle game designed and implemented by Alice in the midterm project of the "Computer Programming" course. In the racing game, the player can use keyboard to control the vehicle to pass checkpoints and avoid to hit obstacles. A countdown mechanism and a scoring system are implemented through the corresponding programming concepts and language constructs. In the puzzle game, the player can use keyboard to control the rabbit to explore the whole area and use mouse to interact with objects in the game (e.g., open a refrigerator) to find all the hidden carrots.

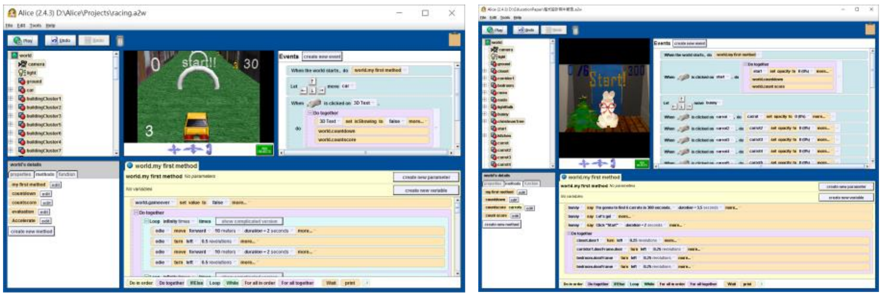

Fig. 1. Games designed and implemented by Alice

By reviewing assignments and group projects by students, it is confirmed that important programming concepts, including objects, methods, variables, loops, flow control, and event controls, are exercised and learned effectively and efficiently. In addition, students show great enthusiasm for developing their own animations, stories, and games. Based on accumulated programming concepts and development experience through Alice, students have better performance when learning other programming languages (e.g., Python and Java) and are not afraid of coding for particular tasks in the future [33]. Therefore, for students in the department of applied mathematics (or other non-CS major students), educational software for programming is a better choice to stimulate and inspire the learning, participation, and exercise in the beginning [34]. This also facilitates the development of the capability to realize specific computation or problem solution by programming through computational thinking.

4.2 The Connection between Course Content and Real Life

One of the issues about traditional mathematics curricula is the gap between course materials and students' "real-life" mathematical experiences [1][4]. For instance, based on course reviews, students enrolled in the statistics course usually learned the theoretical knowledge and did limited or simplified practices in textbooks by topics separately. A critical gap exists between theoretical understanding and actual problem in real life. Students have no experience in the leverage of knowledge and skills learned from mathematics, statistics, and computer science, which are essential for research and industry today.

Therefore, both in “Data Processing and Analysis” and “Statistical Software for Data Analysis” courses, open data is used as materials for learning and practice [35] in addition to limited or simplified examples in textbooks. Through the introduction of open data in the courses, students can find and use interesting open data for further analysis, application development, and even innovation. Based on statistical theories and programming skills, students can learn and practice how to explore, collect, clean, manage, model, analyze, and visualize actual data from open data portal. The analysis results usually reveal interesting findings which are beneficial to the general public and the society. Thus, students can not only realize the data processing and analysis methods but also get more insight into the applications of statistical theories and programming skills in the real world.

Figure 2 present the assignments implemented by Python and R based on government open data. The first one is to process, analyze, and visualize the dengue fever cases reported in major cities in Taiwan by Python, NumPy, Pandas, and Folium in “Data Processing and Analysis” course. In the implementation, users can select a period of time and observe the associated dengue fever cases through the map service. The information of descriptive and predictive analytics of dengue fever cases is also provided. The second one is to collect, process, analyze, and present travel information in Tainan city in Taiwan by R, ggplot2, ggmap, and googleVis in “Statistical Software for Data Analysis” course. Students collect and integrate several travel-related open data from government open data portal, including accommodation, attractions, and Wi-Fi hotspots, and develop a travel application for travelers. As shown in Figure 2, the location of Wi-Fi hotspots in Tainan city is presented for travelers. Travelers can use the application to plan, navigate, and acquire corresponding travel resources efficiently.

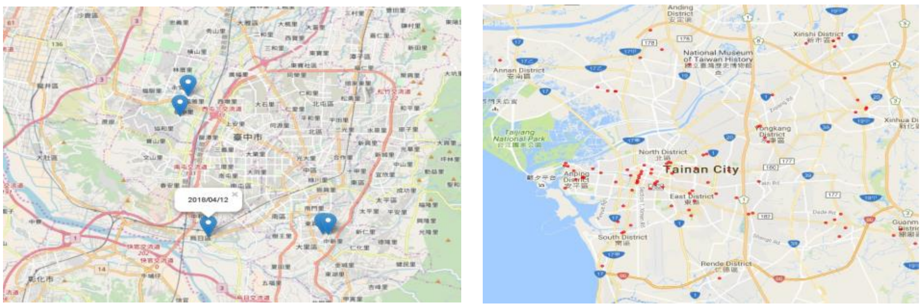

Fig. 2. Data visualization by Python and R

Through the connection between course content and real-life application based on open data, students can realize the global picture of data processing and analysis, and practice major steps in data processing and analysis comprehensively rather than limited or simplified examples in textbooks. In addition, complexities and problems during the processing and analysis tasks, including data cleaning, data munging, en-coding problems, and so on, can help students to develop solid knowledge and skills which are useful for future research and career. It is discovered that students show great enthusiasm for learning and practice due to the use of open data. Students will search and choose open data they are interested in. Innovative applications of data processing and analysis can be found in the assignments and group projects during the courses. According to these positive results, the connection between course content and real-life is successfully established for students. This achieves the development of the capability to solve real or complex problems thoroughly by mathematics, statistics, and computer science knowledge and skills. In the future, more connections can be further identified, designed, and deployed to all the mathematics, statistics, and computer science courses for students.

4.3 Interdisciplinary Learning

Another issue about traditional mathematics curricula is the lack of "the connection between mathematics to other subjects as an interdisciplinary approach [3][36]." In traditional mathematics courses, students usually learn an abundance of mathematical theories and calculations. However, the applications of those theories in different domains are less mentioned. For instance, the graph theory can be used to build recommendation engines in e-commerce or social networks [37]. In addition, the knowledge of matrix and associated manipulations can be applied to image presentation and processing. In order to facilitate the learning, practice, and knowledge accumulation in an interdisciplinary approach, lots of assignments and group projects based on mathematics, statistics, and computer science are designed. Students are encouraged to integrate what they learn in different courses and to innovate based on their interests and creativities.

Figure 3 presents the projects built by students during the "Data Processing and Analysis" course. In the first project, students integrated what they learned in front-end development, computer programming, data processing and analysis, statistics, and data visualization methods to build a responsive web page for their travel in Japan. The web page presents the route, the photos, the expense statistics, and the activities in timeline of their travel. The project also got an award in the competition held by college of science and engineering in the university. Based on the feedback from one student, she said it was a wonderful experience to integrate what she learned in the past and develop a great website from scratch. Through the course and the project, she had more confidence and was not afraid of computer-related tasks in the future. In the second project, a student who also enrolled in "Graph Theory" course tried to model and implement a graph coloring algorithm to present the coloring result. Although the student encountered many difficulties, he solved those problems and completed the implementation by searching, learning, and trying numerous online resources and code examples. Based on the feedback from those students, they gained interdisciplinary knowledge, hands-on experience, and problem-solving skills through the projects or assignments. They also got great pleasure and confidence when they completed the tasks. The interdisciplinary learning achieved by the refined and enriched curriculum makes students learn, practice, and accumulate various knowledge and skills in different disciplines efficiently [38] [39]. Besides, confidence, innovation, and creativities of students can be incubated during the learning activities.

Fig. 3. Projects based on interdisciplinary knowledge and skills

5 Conclusion

Many universities begin to propose several innovations and refinements in education, including teaching improvement, integrated curriculum, multidisciplinary programs, and capstone courses to better incubate students for future. In this study, the experience of enriching undergraduate mathematics curriculum with computer science courses is introduced. Based on the original focus on mathematical and computation theories, the employment of computer science courses provides students with comprehensive theoretical and practical knowledge for the challenges and industrial requirements nowadays. It is anticipated that students can (1) realize specific computation or problem solution by programming through computational thinking, (2) solve real or complex problems thoroughly by mathematics, statistics, and computer science knowledge and skills, and (3) accumulate cross-domain capabilities, skills, and experiences for emerging challenges. The design and implementation of three computer science courses, including “Computer Programming,” “Data Processing and Analysis,” and “Statistical Software for Data Analysis,” are introduced. Based on the course evaluations from students’ perspectives, the deployment of computer science courses and the refined and enriched curriculum bring lots of benefits and positive impacts on the students in the department of applied mathematics. Major findings, course experiences, and lesson learned from the course implementation, including “the use of educational software,” “the connection between course content and real life,” and “interdisciplinary learning,” are found to be highly beneficial to the learning activities. Computational thinking, interdisciplinary knowledge, problem-solving skills, confidence, and creativities of students can be incubated during the courses effectively and efficiently. According to current implementation results, future works include further evaluation and curriculum refinement. More information about the design and implementation of computer science courses can be accumulated and analyzed as time goes on. In addition to the questionnaire designed by the university, several IT systems can be built and leveraged to collect and analyze the learning status of students. Thus, more qualitative and quantitative analysis can be performed to further evaluate and refine the curriculum in the future. Finally, the feasibility of deploying computer science courses to the undergraduate program in other disciplines can also be explored. Through the findings and lessons learnt, a more improved curriculum can be developed to incubate students for a better future.

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Evaluation Results of an Online Teacher Training Course Specialized in Engineering Education

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Abstract—The purpose of this article is to present the results of the evaluation of the implementation of a teaching training course in Engineering Pedagogy (EP) at a Chilean university of applied sciences. The research questions that guided the research process were: (i) How do the participants evaluate the course in general? (ii) How do the participants evaluate the didactic design of the course? (iii) How do they evaluate the teaching competencies? (iv) How do they value the usefulness of the learning outcomes for their teaching practice? (v) How they self-evaluate their participation and their learning process? Based on different authors a questionnaire with closed and open-ended questions was developed and implemented online. For the statistical analysis was applied an exploratory-descriptive analysis. The training course consists of two online modules with 90 working hours in LMS, and was designed by the Center of Engineering Education (CIEI) at the University of Talca, according to the IGIP Curricula of the IGIP center at the Technische Universität Dresden (TU Dresden, Germany). From the first results of the pilot project, it can be noted that there is a high level of motivation and interest to participate in a teaching training course based on EP, which has been specially oriented and designed to meet the specific requirements of the academic staff of engineering schools.

Keywords—university teacher training, engineering pedagogy, online teaching program, online learning in engineering

1 Introduction

1.1 Engineering pedagogy and education in Chilean context

Although Engineering Pedagogy (EP) has a long tradition in German-speaking are as (particularly in Dresden, with a tradition of more than 60 years) [1, 2, 3], the concept of "EP" is relatively recent in Spanish-speaking countries. In the specific case of Chile, the application of this concept has been made possible thanks to the projects: "Engineering Pedagogy in Chilean Universities 2014-2018" (PEDING Project) and "Strengthening engineering training at Chilean universities through practice partnerships" (STING Project) [4, 5]. Several authors recognize the different factors and aspects that condition the engineering pedagogy and education and the training of the teaching staff in engineering careers [6, 7, 8, 9, 19, 20, 21], but the societies of the 21st century evidences diverse demands derived for example from different actors of the society, the economy and the scientific engineering fields, among others. Gormaz-Lobos et al. [10] shows multiple factors that condition and influence the EP: (i) the production and service structures of each country (needs determined by the labour market), (ii) the society and culture (the needs for the development of technology and technique is also determined by cultural and social aspects), (iii) the engineering sciences (needs determined by matters of research, methods and technologies at the engineering subjects), (iv) the academic staff or university teachers (with specific competencies of the engineering fields but also of with pedagogical competencies), and (v) the learners (students) or individuals studying engineering (with age-specific psychological characteristics, individual needs, characteristics of the personality, values, attitudes among others). Specifically, Melezinek defines EP as a discipline oriented to the engineering education process which connect the engineering sciences and techniques with pedagogy and the educational system [6]. The author describes various component elements for EP such as: (i) engineering fields (sciences) themselves, (ii) natural sciences, (iii) psychological and sociological approaches, (iv) educational sciences, (v) communication sciences, (vi) information and communication technologies (ICT), and (vii) ethics, among others [6]. Based on different authors, Figure 1 presents the interaction of some fields that should be considered for the development of a conception of engineering pedagogy and education [1, 2, 3, 4, 6, 7, 22, 23].

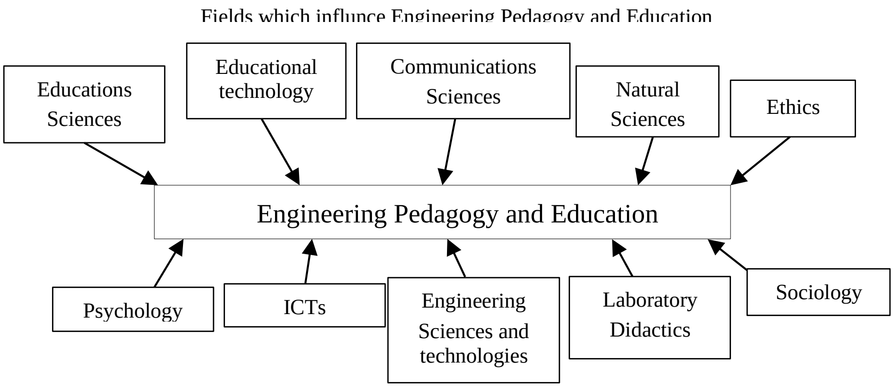

Fig. 1. Fields which influence engineering pedagogy and education

1.2 Proposal for a training course based on Engineering Pedagogy

In 2019, the International Center for Engineering Education CIEI (University of Talca, Chile) developed a proposal for a teacher training program in EP based on the IGIP Curriculum offered at the IGIP center at the TU Dresden and the results of the PEDING and STING projects (see Figure 2) [24].

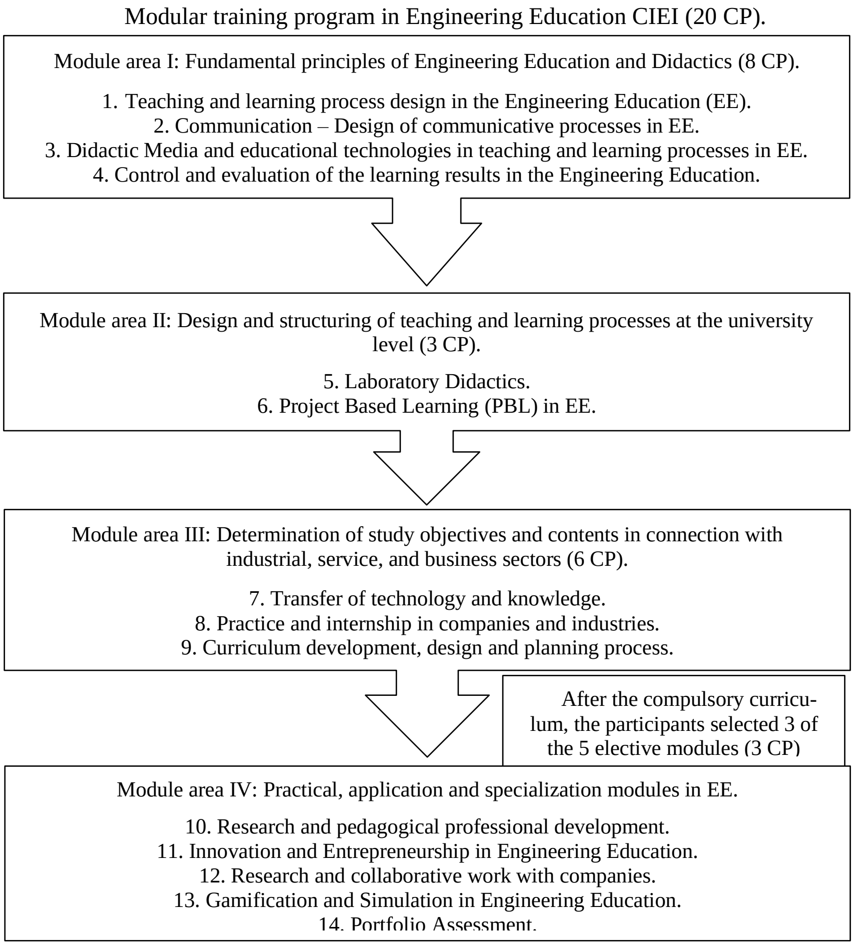

Fig. 2. Modular curricula (Program) for teaching staff in Engineering Education CIEI UTALCA.

Figure 2 shows a general overview with the structure of the training program (curricula). According to IGIP, the training program contemplates a total of 600 hours for all learning activities, including lectures, presentations, workshops, short reports, and group activities, among others. The program will be carried out through an Online Learning and also Blended Learning modality: including classroom sessions (face to face or videoconferences) and remote learning through a digital learning platform (LMS). The teaching-learning program seeks to expand the field of Engineering Pedagogy and Education in Chilean context and also to improve the competencies profile for university and non-university teaching staff (teachers and trainers) in engineering faculties and vocational education institutions.

The main educational objectives of the training program in Engineering Pedagogy and Education are [24]:

1. To development and improvement of pedagogical competencies of the academic staff (teachers and trainers) in engineering education and similar fields,
2. To improvement of teaching and learning (planning, resource development, among others) and evaluation methods in scientifically and technical subjects,
3. To development of practice-oriented curricula that correspond to the needs of students and employers, and strengthening the university-industry collaboration,
4. To development and strengthening of innovation and research competencies,
5. To facilitate the acquisition of theoretical-practical knowledge about curriculum design and development,
6. To promote the use of media in university and technical teaching, and
7. To development of communication competencies and strategies for online (synchronous and asynchronous learning) and face to face learning.

1.3 The first teacher training in EP at INACAP: a pilot project

INACAP (Universidad Tecnológica de Chile/ Instituto Profesional/ Centro de Formación Técnica) is a Chilean vocational school (post-secondary education) and university of applied sciences, with campuses (more than 27) in all regions of Chile. The main programs for undergraduate students are related to health and engineering fields. The teacher training programs for the academic staff are frequently not strongly linked to their pedagogical practice in the scientific and technological fields [11, 23]. For this reason, the authorities from INACAP decided to specialize the teacher training, and generate a cooperation strategy with the CIEI at the University of Talca (Chile), under the pedagogical support of a group of academics of the TU Dresden (Germany), Faculty of Education. The activities started with a pilot project to strengthen specifically engineering teaching and technical and professional education, through an online program for teachers in different fields of EP. But before starting the course, the research group decided, as the first step, to recognize and analyze the training needs of the academic staff with a pilot group: a group of academics in engineering fields at INACAP at the Talca campus.

Based on the results obtained in the surveys about multiple needs on Engineering Education and Pedagogy were identified [11]:

a) “Evaluation and assessment of learning achievements”,
b) “Knowledge about theoretical and practical approaches of the didactics for the teaching and learning in engineering”,
c) “Structuring of teaching and learning processes for engineering education”,
d) “Use of learning resources and information and communication technologies” (ICT),
e) "Use, development and evaluation of new didactic means in the training of engineers”, and
f) “Knowledge about how to design effective measurements of the learning accomplishments” among others.

From these results, was developed a training course that consists of two modules of the training course in Engineering Education (training program) designed at CIEI (see

Figure 2), with specific contents [11, 22, 23, 24, 25, 26, 27], according to INACAP teacher training needs. An overview of the modules, goals, and units is presented in Table 1.

Table 1. Description of the teaching training course modules for INACAP-Pilot Project.

Description of the teaching training modules for INACAP-Pilot Project. (* summarized version for this publication)		
	Teaching and Learning Process Design in the Engineering Education (2 CP)	
	Goal	***Units***
M1	Participants will be able to structure teaching and learning processes to train engineers, taking into consideration the specific scientific knowledge of the discipline they teach, focusing on the learning process of the students.	Unit 1 - Trends, future perspectives, and approaches for engineering education. Some new national and international trends, perspectives, and approaches that support the context of Engineering Education and the formation of Engineers of the 21st Century. Unit 2 – Basic principles of Engineering Teaching. Fundamental principles, theoretical foundations and terminology associated with Engineering teaching and learning. Unit 3 - Structuring of the teaching and learning processes in Engineering Sciences. Components of the teaching and learning process to meet the requirements of the professional profile of students graduated from Engineering. Unit 4 – Fundamental principles for the elaboration of didactic Media. Fundamental principles, approaches and concepts for the elaboration and design of didactic Media.
	Learning Assessment in Engineering Education (2 CP)	
	Goal	***Units***
M2	Participants will be able to design control and evaluation processes of the learning results based on scientific and theoretical foundations.	Unit 1 –Theoretical fundamentals and approaches about the learning assessment at the university level. Theoretical fundamentals and approaches that support the functions of the assessment of learning outcomes at the university level, applying these fundamentals and approaches by the structuring of evaluation processes. Unit 2 – Operationalization of the learning objectives and outcomes. Components that characterize a quality evaluative process and the different areas that need to be evaluated, considering these to operationalize the learning objectives and the expected learning outcomes of the learning processes, to make them evaluable according to the learning objectives. Unit 3 – Evaluation methodologies and strategies, and register of learning outcomes. Different methodologies, strategies, and procedures to design evaluation processes and registers of the learning outcomes, analysing their limitations and potentialities, for developing and selecting an appropriate method according to the object or item to evaluate. Unit 4 – Evaluation of learning outcomes and key competencies of engineers. To know and identify different forms, strategies, and evaluation systems and register of the learning outcomes, developing and selecting an appropriate procedure, according to the professional profile for the training of engineers, based on its expected knowledge, key competencies, and skills.

The course was offered in online learning form (with (synchronous and asynchronous activities) between January and May 2020 with the participation of a group of 24 academics of INACAP Talca campus. Most of the academics are part of four Engineering Schools of INACAP at the campus Talca: Electrical Engineering, Industrial Engineering, Information and Computer Engineering and Mechanical Engineering. Three participants had no teaching responsibilities: two are supervisors and one is department director of this campus. The course contemplated a work of 4 Credit Points (CP) (each Module 2 CP), also 120 hours of training according to the SCT-Chile system. The course design was based on a mix of synchronous activities carried out on the Zoom platform (30 hours), together with work on a Moodle-based LMS platform for asynchronous independently and collaborative work (90 hours). The course evaluation was formative and based on the independent work materials. At the end of the course, was requested a final product (with planning, development of learning and evaluation material plus rubrics, among others), that allowed to evaluate the competencies by each participant along the course.

As an evaluation form of the project, the research group implemented a survey to obtain feedback about the course from the participants, its design, topics, and effectiveness among others. Although different authors [9,21,23] show the need for training in technical and engineering-related disciplines, research on the effects and evaluation of university teaching training programs has not been widely reported in the specialized literature for the Chilean context. For this reason, the authors of this paper would like to know the valuation and opinions of the teaching staff who participated in this course.

2 Evaluation results of the teacher training course in EP

2.1 Methodology

The main goal of the study was to identify the perception of the participants of the training course (academic staff) about their experiences and valuation of the competencies development during the course. The research questions that guided the research process were:

1. How do the participants evaluate the course in general?
2. How do the participants evaluate the didactic design of the course?
3. How do they evaluate the teaching competencies?
4. How do they value the usefulness of the acquired knowledge for their teaching practice?
5. How they self-evaluate their participation and their learning process?

Based on [12, 13, 14, 15, 21] and their previous experience in engineering pedagogy research projects in Germany and Chile [5, 16], the authors developed a categories system with indicators for the instrument design. The instrument consists in a questionnaire with closed and open-ended questions organized in five main categories with their respective items. The five categories or dimensions to be evaluated are (see Table 2):

1. The development of the course (in general), with 4 items
2. The didactic design of the course, with 9 items
3. The teaching competencies, with 5 items
4. The perceived utility of the acquired knowledge for their own teaching practice, with 12 items
5. Self-assessment of the own learning process, with 4 items

Due to the location of the participants (Chile), the questionnaire was developed in Spanish and consisted of 34 items on a Likert-type scale (5 levels) grouped into five categories (see Table 2).

Table 2. Dimensions and conceptual items for the evaluation instrument [5, 16]

Dimensions and conceptual items (Summarized version for this publication)	
Categories / Dimensions	***Conceptual Items***
1. General evaluation of the development of the course	1.1. Satisfaction level with the information about course goals. 1.2. Satisfaction level with the development of the course. 1.3. Satisfaction level with the duration of the course. 1.4. Satisfaction level with the course progress.
2. Evaluation of the didactic design of the course	2.1. Satisfaction level with course modality (online) for the learning process. 2.2. Satisfaction level with the use of the online platform and educational resources. 2.3. Satisfaction level with units and learning resources on the platform. 2.4. Satisfaction level with learning activities for autonomous professional development. 2.5. Satisfaction level with synchronous learning activities. 2.6. Satisfaction with learning resources and tools for competencies development. 2.7. Satisfaction level with planning and duration of each module. 2.8. Satisfaction level with learning activities for the teaching reality. 2.9. Satisfaction level with the applicability of acquired contents to the own teaching context.
3. Evaluation of teaching competencies	3.1. Satisfaction level with different competencies of the teachers. 3.2. Evaluation of motivation and teaching organization of the teachers. 3.3. Clarity of teachers to guide the teaching-learning process. 3.4. Evaluation of the attitude of the teachers for monitoring the learning process and assessment. 3.5. Satisfaction with teacher´s attitude for monitoring the online learning process and assessment.
4. Evaluation of the perceived utility of the acquired knowledge for the own teaching practice	4.1. Utility of the contents and methods for the own teaching practice. 4.2. Satisfaction with the applicability of contents on real teaching context. 4.3. Applicability of acquired knowledge in modern teaching environments. 4.4. Usefulness of contents for the development of different teacher competencies. 4.5. Usefulness of workshops for learning process and competencies development. 4.6. Usefulness of asynchronous learning activities for competencies development. 4.7. Usefulness of synchronous learning activities for competencies development. 4.8. Usefulness of each module for professional development. 4.9. Usefulness of each module for teaching reality in engineering. 4.10. Utility of the acquired knowledge for the teaching practice. 4.11. Utility of the acquired knowledge for the work with other colleges. 4.12. Utility of the acquired knowledge for the professional development.
5. Self-assessment of the own learning process	5.1. Commitment and motivation with the course. 5.2. Motivation for a new training in EP. 5.3. Satisfaction level with the participation in the course. 5.4. Dissatisfaction with the participation in the course.

2.2 Population, available sample and procedure.

The sample of the research was composed of 24 participants at the training course for INACAP at the Talca campus. Only 21 questionnaires were considered for the analysis because they were fully completed (three questionnaires were incomplete). The instrument was applied online, ensuring the anonymity of the participants. The first part collected information of the participants about gender, subject matter, fields and years of teaching experience, previous teacher training, among others. The second part consists in the information collection of the closed questions. For the statistical analysis was applied an exploratory-descriptive analyze [17, 18].

2.3 Characterization of the sample

Table 3 presents the characterization of the sample from INACAP. In total, 21 academics answered fully the questionnaire: 29% are women (6) and 71% men (15). Regarding the age ranges of the respondents, 90% (19) of the participants are between 30-39 years old and 10% (2) are between 40-49 years old. There no participants older than 50 years. Related to the participant´s distribution by engineering school, most of the participants work in mechanical engineering (38%) and industrial engineering (24%). The same number of participants works in the fields of computer sciences (18%) and electrical engineering (18%).

Table 3. Characterization of the sample.

Categories	Sample
Number of respondents (valid)	21
Age	
Between 30 and 39 years old	19
Between 40 and 49 years old	2
Between 50 and 59 years old	0
More than 60 years old	0
Gender	
Female	6
Male	15
Engineering fields	
Mechanical engineering	8
Computer sciences/ engineering	4
Industrial engineering	5
Electrical engineering	4
Teaching experience (in years)	
Between 0 and 5 years	17
Between 6 and 10 years	3
More than 10 years	1
Previous experience at teacher trainings	
Yes	18
No	3

Concerning the years of teaching practice experience, 81% have between 0-5 years (17) and 14% have between 6-10 years (3). Of the total number of respondents, approximately 86% (18) have already participated in some teaching training course.

2.4 Results of INACAP´s survey.

Closed questions. The results about the perception of the respondents regarding the evaluation of the training course are presented in this section. Table 4 exposes the results for the 34 considered items (see Table 2).

Table 4. Results of the closed questions

ITEM	**% of Answers**		
	Low	***Medium***	***High***
	[1][2]	***[3]***	***[4][5]***
1. Satisfaction with the information about course objectives.	0,0	0,0	100,0
2. Utility of the contents and methods for the own teaching practice.	0,0	0,0	100,0
3. Satisfaction with the applicability of contents on real teaching context.	0,0	0,0	100,0
4. Applicability of acquired learning and knowledge in modern teaching environments.	0,0	0,0	100,0
5. Usefulness of contents for the development of different teacher competencies.	0,0	0,0	100,0
6. Satisfaction with the development of the course.	0,0	0,0	100,0
7. Satisfaction with the duration of the course.	0,0	19,0	81,0
8. Satisfaction with course progress.	0,0	4,8	95,2
9. Satisfaction with different competencies of the teachers.	0,0	0,0	100,0
10. Evaluation of the motivation and teaching organization of teachers.	0,0	0,0	100,0
11. Satisfaction with course modality (online) for the learning process.	0,0	14,3	85,7
12. Satisfaction with the use of the online platform and educational resources.	0,0	14,3	85,7
13. Satisfaction with units and learning resources on the platform.	0,0	9,5	90,5
14. Satisfaction with learning activities for autonomous professional development.	0,0	4,8	95,2
15. Satisfaction with synchronous learning activities.	0,0	0,0	100,0
16. Usefulness of workshops for learning process and competencies development.	0,0	0,0	100,0
17. Usefulness of asynchronous learning activities for competencies development.	0,0	14,3	85,7
18. Clarity of teachers to guide the teaching-learning process.	0,0	0,0	100,0
19. Satisfaction with learning resources and tools for competencies development.	0,0	0,0	100,0
20. Commitment and motivation with the course.	4,8	19,0	76,2
21. Usefulness of synchronous learning activities for competencies development.	0,0	0,0	100,0
22. Satisfaction with planning and duration of each module.	0,0	19,0	81,0

ITEM	% of Answers		
	Low	***Medium***	***High***
	[1][2]	***[3]***	***[4][5]***
23. Usefulness of each module for professional development.	0,0	0,0	100,0
24. Usefulness of each module for the teaching reality in engineering.	4,8	0,0	95,2
25. Motivation for a new training in EP.	0,0	9,5	90,5
26. Satisfaction with the participation in the course.	0,0	0,0	100,0
27. Satisfaction with learning activities for the teaching reality.	0,0	0,0	100,0
28. Dissatisfaction with the participation in the course.	100,0	0,0	0,0
29. Utility of the acquired knowledge for the teaching practice.	0,0	0,0	100,0
30. Utility of the acquired knowledge for the work with other colleges.	0,0	0,0	100,0
31. Satisfaction with the applicability of acquired contents to the own teaching context.	4,8	0,0	95,2
32. Evaluation of the attitude of the teachers for monitoring the learning process and assessment.	0,0	0,0	100,0
33. Satisfaction with teacher´s attitude for monitoring the learning process and assessment.	0,0	0,0	100,0
34. Utility of the acquired knowledge for professional development.	0,0	0,0	100,0

In general, all aspects were as high (4 points) or very high (5 points) valuated (more than 75% of the preferences). The most relevant aspects are related to the dimensions "Evaluation of the didactic design of the course", "Evaluation of teaching competencies" and "Evaluation of the perceived utility of the acquired knowledge for the own teaching practice" (see Table 2) with more than 85% of the preferences. Specifically, 22 indicators of these categories were valuated with 100% of the preferences as high (4 points) or very high (5 points). An example for this are the items: *"Satisfaction with synchronous learning activities", "Usefulness of workshops for learning processes and competencies development", "Clarity of teachers to guide the teaching-learning process", "Satisfaction level with the learning resources and tools used for competencies development" and "Utility of the acquired learning for professional development"*. The item with the lowest relevance is related to the category "Self-assessment of the own learning process" (under 80%), and was: *"Commitment and motivation with the course"*. The item *"Dissatisfaction with the participation in the course"* was valuated as *very low* or *low* with 100% of the preferences.

Another important aspect is the perception of the participants about the relevance of the different items /questions by gender. Figure 3 shows the differences between the participants related to the relevance of the indicators. For the female participants of the teacher training course, most of the items were low valued, except the items *"Satisfaction with the development of the course"* and *"Satisfaction with the duration of the course"*.

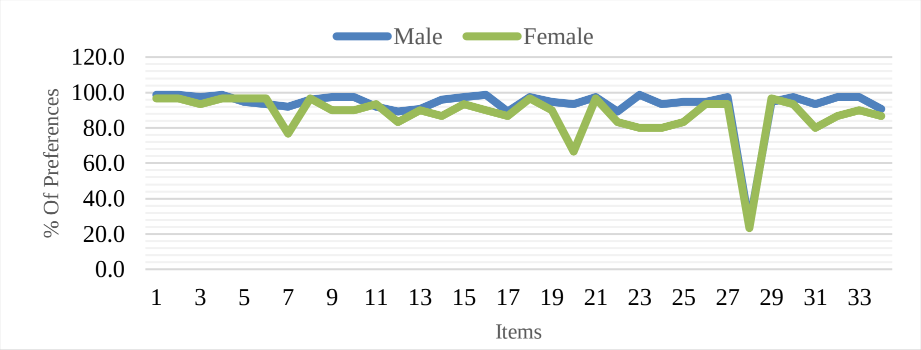

Fig. 3. Preferences of the different items related to the evaluation of the training course in EP by gender.

By grouping the participants by engineering fields (Figure 4), the participants from *Computer sciences* gave the high average of preferences in the valuation of all items (96,76%) and the participants from *Mechanical engineering* the lowest average with 89,49%. (*Industrial engineering* with 91,06% and *Electrical engineering* with 90,59%).

Figure 5 shows the differences between the relevance of the items for the participants by years of teaching experience. For the participants with up to 5 years of teaching experience, the average value of preferences in all items was 92,11% and for participants with up to 10 years was 92,35%. For participants with more than 10 years of teaching experience, the most of the "indicators" were low valued (average of 77,65% in all items).

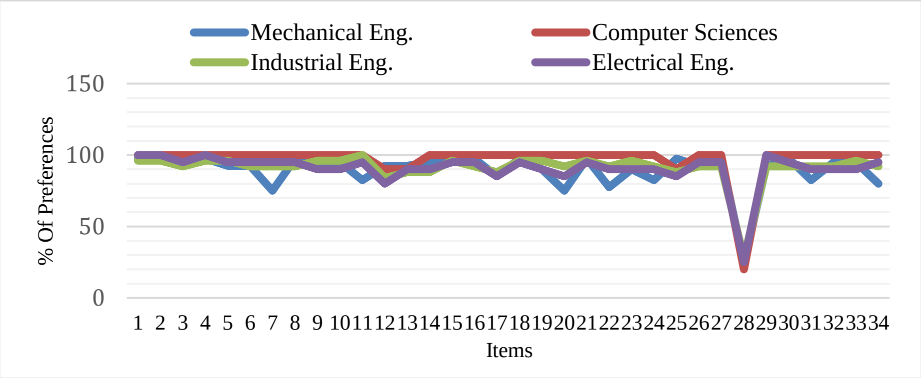

Fig. 4. Preferences of the different items related to the evaluation of the training course in EP by engineering fields.

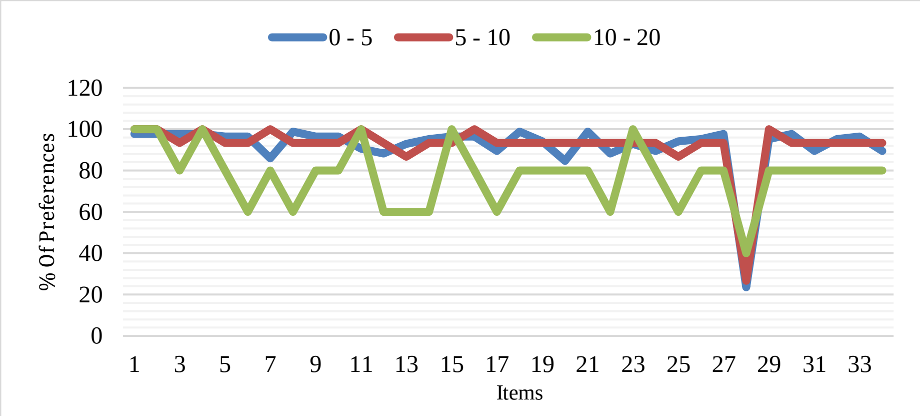

Fig. 5. Preferences of the different items related to the evaluation of the training course in EP by years of teaching experience.

3 Discussion and conclusion

The main goal of the study was to identify the perception of the participants of the training course (academic staff) about their experiences and valuation of the competencies developed during an online course. Concerning the categories "Evaluation of the course development (in general)", "Evaluation of the didactic design of the course", "Evaluation of the teaching competencies" and "Evaluation of the teaching competencies" - in line with other studies [15,16, 28] - all aspects related were as high valuated. The item "Dissatisfaction with the participation in the course" was valuated as low with 100% of the preferences. These results coincide with the comments of the participants during the teaching-learning activities. The findings confirm the relationship between the average of evaluations with the years of teaching experience of the participants [16, 28]: participants with up to 5 years of experience evaluated the course better, and participants with over 10 years of teaching experience tend to evaluate the course lower; something that had already been demonstrated in the literature [16]. The item with the lowest relevance ("Commitment and motivation with the course") is related to the category "Self-assessment of the own learning process". That can be explained because most of the participants had a high amount of teaching time and said that they wanted to dedicate more hours to the program but could not because of their other responsibilities.

This pilot research project and training program was aimed to show the different training needs in Engineering Education and Pedagogy, and to implement and evaluate an online training course for the teaching staff of engineering schools of INACAP at the Talca campus. The project directors recognize the challenge and the hard work involved in specializing the development of competencies of academic staff in the field of EP because this is relatively "new" in Spanish-speaking countries and also in Chile. For this reason, an international university working group has been formed to promote the EP and the specialization of the teaching profile of academics of engineering fields.

This group is formed by academics from the Technische Universität Dresden (Germany), the University of Talca, and INACAP (Chile). From the first results of the pilot project, it can be noted that there is a high level of motivation and interest to participate in a teaching training program in EP, which has been specially oriented and designed to meet the requirements of the specific academic staff of engineering schools.

The evaluation results of the training course and its online implementation showed a high valuation of the course by the participants. However, due to the "pilot nature" of this project and the small sample of academics who participated (24 people), some questions remain open about the impact and valuation that this type of training course can have on other INACAP campuses throughout Chile. Due to the size of the sample, the authors consider that the results of the research cannot be generalized. However, they serve to analyze (case study) the teachers' experience about a training course specifically oriented towards EP. For this reason and as future work, the authorities of the institution and the project directors want to design a complete training plan for 2021 that includes other modules of the CIEI program that may be relevant for the teaching staff from other campuses. This program will be evaluated by implementing quantitative and qualitative methods, to incorporate consistency and data triangulation into the research findings. To contribute to the development of the concept and the effects of EP in engineering schools, the authors of this paper hope to continue expanding the teaching training in Engineering Education in universities and vocational institutions in different regions of Chile.

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Evaluation of Programme Outcomes Under the Psychomotor and Affective Domain for Diploma Civil Engineering Students Through Industrial Training:

A Statistical Study from Employers' Perspective in Malaysia

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Abstract—The psychomotor and affective domains are important to assess student's achievement during the industrial training period. Students are exposed to engineering practices, real civil engineering environments, and the required ethical and communication skills through industrial training. Previous research primarily has relied on the employers 'perspectives on non-technical skills of engineering graduates. Still, there are none of the studies depends on student achievement in the psychomotor and affective domains. This study aims to identify the employer's evaluation of the student's performance for psychomotor and affective domains during their industrial training. 272 students undergoing the Industrial Training in session II 2019/2020 are involved in this study. The portion of marks from the industry evaluation for the psychomotor domain is 40% and for the affective domain is 10%. The marks were analysed using descriptive statistical analysis. The Pearson correlation (r) was used to identify the relationship between each Program Outcomes (PO) with the related domain. The t-test analysis was completed to evaluate any significant difference between the performance evaluation of student’s gender. The statistical analysis discovered that most of the students were excellent in the psychomotor and affective domains. Furthermore, the r-value for each POs shows a moderately positive correlation. Therefore, the findings indicate that the designed curriculum of the program meets the industrial requirement. However, improvements will always be made to keep nurturing a good quality of future civil engineering technical personnel.

Keywords—assessment, psychomotor, affective, students’ performance, employers

1 Introduction

1.1 Engineering education in Malaysia

Engineering educators play an important role in ensuring the expected educational goals are achieved. Among the approaches used to achieve educational goals is Outcome-Based Education (OBE) that has been implemented in the engineering education system in Malaysia [6]. Outcomes of engineering education focus on the knowledge, skills and attitude required for employability. Generally, learning can be classified into three domains, namely, cognitive, psychomotor, and affective.

According to Anderson [4], engineering education was designed to produce skilled engineers in the cognitive, psychomotor, and affective domains. The cognitive domain can be defined as knowledge and the development of thinking skills. This domain involved 6 levels: knowledge, comprehension, application, analysis, synthesis, and evaluation. Meanwhile, the psychomotor domain can be defined as skills and abilities that require a physical component. This domain categorised into 7 levels: insight, preparation, controlled mobility, process, specific mobility, solution, and novelty. Hassan [13] stated that learning in the psychomotor domain presents students' practical skills. The psychomotor domains are related to the display of equipment or tools in laboratories, classrooms, and workshops. The focus of the psychomotor domain's is to see students' ability to perform motor activities accurately, smoothly, and quickly.

Besides that, the affective domain is another important element in curriculum design. The affective domain focus on personality and behavioural characteristics that involve feelings, attitudes, and emotions. This domain is categorised into 5 levels, from lowest to highest level: receiving, responding, valuing, organisation, and characterisation. According to Lynch [19], the affective domain has connection and importance in achieving vision and direction of engineering knowledge, skills, and abilities. The elements of affective domains that students must acquire, as mentioned in [5] including communication, business and management, safety, legal and social, leadership, teamwork, attitude, life-long learning, professional and ethical responsibility.

According to Zainudin [35], cognitive, psychomotor, and affective are significant domains in Programme Outcomes (POs) and are used to assess the achievement of learning objectives. In Malaysia, 12 Programme Outcomes (POs) have been established in the Engineering Technology Accreditation Council Manual 2020 to meet the cognitive, psychomotor, and affective domains [7]. PO1, PO2 and PO3 are classified under the cognitive domain used to measure knowledge and problem-solving. PO4 and PO5 are related to the skills and practices used by the students to solve the given problem. Meanwhile, the affective domains are assessed through PO6, PO7, PO8, PO9, PO10, PO11 and PO12, related to students' attitudes and feelings. Table 1 shows the 12 Programme Outcomes (POs) that students need to fulfil throughout their study in the programme enrolled.

Table 1. Programme Outcomes (Pos) in the Engineering Technology Accreditation Council Manual, 2020

PO1	Students should have fundamental knowledge related to science and mathematics.
PO2	Students should be able to analyse the specific problem related to the application of engineering.
PO3	Students should occupy with the design of the solution for a specific problem by considering the health and safety, environmental, and social aspects.
PO4	Students should be able to know how to conduct the investigation using the catalogues, standard tests, and measurements on given problems.
PO5	Students should be able to use appropriate modern techniques, resources, and information technology to solve a specific engineering problem.
PO6	Students should be able to know about the safety, legal and social. Thus, this can help to solve a specific problem related to the application of civil engineering.
PO7	Students should have knowledge and understanding of the environment and sustainability. Thus, this helps them to solve any given problem that related to the environment and society.
PO8	Students should understand their role and should adhere to professional ethics as a civil engineering technicians.
PO9	Students should have the skill to act efficaciously as an individual and as a member of a team.
PO10	Students should be able to have effective communication skills; thus, this leads them to communicate on the given problem, give and receive the instruction when involved with the engineering project.
PO11	Students should understand how to manage engineering projects and finance and able to manage projects in various disciplinary. They should be able to have the skill as a technical team or as a leader in the assigned project.
PO12	Students should be able to have the skill to participate in independent learning and able to engage with the latest information or techniques in civil engineering.

Recently, the education system in Malaysia, including the engineering education system, has been criticised by the industry for the low performance of graduates and the inability to apply the knowledge and skills learned to the job task. Therefore, the government has prepared a comprehensive action, namely the Education Blueprint, to overcome this problem [24]. Thus, this paper only focuses on the engineering education system in Malaysia to see the extent to which the effectiveness of the action taken by the government by getting perspectives from employers on civil engineering students undergoing industrial training before they start working.

Technical skills are an important element that needs to be developed for every engineering student. With good technical skills, students have a better chance of getting a promising career after graduation. In Malaysia, students in engineering must engage in industrial training to improve students' technical skills and fulfil graduation conditions. Industrial training is a program conducted to provide exposure to professional engineering practices and the real civil engineering industry. The objective of industrial training is to provide practical experience by exposing engineering professionals' practice in civil engineering to produce competent engineers or assistant engineers. Students' work experience while undergoing industrial training is beneficial as they enter the career field [17]. The industrial training has been incorporated in the Diploma of Civil Engineering curriculum by the Faculty of Civil Engineering UiTM Pahang, Malaysia, since the 2013/2014 session to align with the university's desire to increase students' diversity of experiences. The faculty has allocated a course code with 9 credits hours for the industrial training. The industrial training is compulsory for students in semester six (6) for a minimum period of 18 weeks and as a requirement to meet the 'Engineering Technician Accreditation Council' (ETAC) accreditation qualification.

2 Literature review

Like other universities in the world, universities in Malaysia are also concerned about graduates who can be employed and can meet the needs of the industry after graduation. In realizing the importance of producing a high competence engineering graduate for the future, the Malaysian Ministry of Higher Education (MOHE) has placed a big priority to the high learning institution to produce engineering graduate who is competitive in the future marketplace. Currently, having knowledge in the academic field alone is no longer enough to ensure that students able to get good jobs. There is an urgent need to be improved for engineering education programs in Malaysia, especially in non-technical skills among students [14]. The seven non-technical skills verified by the Ministry of Higher Education Malaysia (MOHE) that need to be applied to students are communication skills, creative thinking and problem-solving skills, teamwork skills, lifelong learning and information management, entrepreneurial skills, morale, professional ethics and leadership skills [24].

Through an industrial training program, cooperation between universities and industry can help universities provide high skills and knowledge to students and meet the industry's requirements where they are working later [26], [8]. Industrial training is defined as training that exposes students to professional skills and experience in industrial engineering practice. The Engineering Accreditation Council (EAC), Board of Engineers Malaysia (BEM) explained that industrial training is exposure to professional engineering practice in an engineering-practice environment [11]. Mat Isa [22] stated that many lecturers lack the practical experience to relate the theories and exercises presented to students. This situation causes students not to see the actual case related to engineering. Apart from gaining practical experience and new knowledge while undergoing industrial training, the students also could practice the knowledge they have learned in class [10], [20].

The outcomes of an industrial training program are not limited only to providing and enhancing students' skills but also polish their professional growth and experience. Various researchers have argued that industrial training programs are beneficial to the trio involved in the programs: the students, the universities, and the host organisations [1]. Kamarulzaman [17] and Mat [21] reported that engineering students perceive industrial training as beneficial. It can increase their knowledge, skills, and attitude. The engineering students also agreed that it offered guidance for their future careers, added value to their career opportunities and improved their qualifications after graduation. According to Zehr [36], while students undergo industrial training, they can increase their knowledge in experimentation, fieldwork, and workplace learning. Through industrial training programs, employers can also provide feedback on whether the institution's curriculum is appropriate or needs to be improved [2]. In addition, industrial training can also provide an opportunity for employers to guide and assess student talent. Mohd Shariff and Saad [25] stated that industrial training needs to be well planned so that engineering students can obtain optimal professional skills and experience that can be used in their future careers.

Several previous studies in Malaysia highlighted the importance of employability skills required from Malaysian engineering graduates based on the employers' perception. The employability of an individual depends upon assets in terms of knowledge, skills and attitudes, the way these assets are used and deployed, the presentation of assets to potential employers and the context within which the individual works [15]. Saad [29] revealed that most employers of different categories (government-linked companies, multinational companies, government agencies and small-medium enterprises) ranked effective communication skills as very important because they will affect productivity. According to Zaharim [34], most employers stated that engineering graduates still lack communication skills, and employers are not satisfied with it. Employers also reported that health and safety skills, self-management skills and teamwork skills are among the generic skills of the highest importance for employability [27].

Based on the previous studies, it was found that most of the research conducted until recently has focused on the advantages of the industrial training program and its benefits to the students. Some studies show that employers' perspectives on engineering graduates in terms of non-technical skills. However, no studies were conducted to obtain a comprehensive employers' perspective on student achievement in the psychomotor and affective domains. The evaluation and feedback from industry supervisors are essential for the faculty to ensure the curriculum content aligns with the industrial requirement. Besides, to maintain the performance and quality of industrial training programs and engineering students' professional learning. Therefore, this paper aims to present the employer's perspective on students' psychomotor and affective domains undergoing the industrial training program.

2.1 Research questions

Research questions can be summarised as follows.

1. What is the trend of students' performance for the psychomotor and affective domain?
2. Is there any significant difference between gender for students' performance according to the psychomotor and affective domain?

3 Background

3.1 Description of the Industrial Training course

Industrial training (course code ECM377) is a course that civil engineering students must take before they graduate. Through this industrial training, students are exposed to real experiences related to civil engineering work. The students must complete 18 weeks of Industrial Training during the final semester at a relevant organisation related to civil engineering works. The application for the placement was on their effort to apply with proper resume and supporting documents. The faculty supervisor was appointed to monitor and guide the students along the process. This course addresses the programme outcome which related to; (1) able to design solutions for well-defined problems, (2) able to explore the well-defined problems, (3) able to use techniques, resources, engineering tools and IT equipment to solve well-defined engineering problems, (4) understand the work ethic of the technician and be committed to the job, (5) able to communicate well on well-defined engineering activities, and (6) able to engage in innovations related to technical knowledge. The assessment of Industrial Training involved all domains in learning outcomes: cognitive, psychomotor, and affective domains. The faculty supervisor and industrial supervisor made the evaluations of this course.

3.2 Assessment method

Assessment is a method required to evaluate the developmental level of student learning and the achievement of skills. Findings from student assessment may help the lecturers and university to improve their weaknesses and plan further steps for the improvement of teaching and learning [9]. The assessment for this course consists of an Industrial Supervisor evaluation which contributes 50% of the total assessment and will be highlighted in this paper. Another 50% was distributed as follows; 15% from evaluation by Faculty Supervisor, Student Placement report contribute 15%, and 10% contributed by student logbook and colloquium respectively. In addition, the domain involved in this subject are Psychomotor 50% (40% from evaluation by Industrial Supervisor and 10% from evaluation by Faculty supervisor), Affective 40% (10% from Industrial Supervisor, 5% from Faculty Supervisor, 10% from student placement report, 5% from the Student logbook and 10% from the colloquium. The cognitive domain contributes 10% from student placement reports and student logbooks with 5% each. The summary for the respective assessment is depicted in Table 2. The assessments were measured through the designated rubric to assess the respective domain according to the assessment method. The students were assessed based on their performance during the tenure of industrial training.

Table 2. The assessment method for the course

Course / Code	Method of Assessment	Domain
Industrial Training ECM377	50% of Industrial Supervisor 15% of Faculty Supervisor 15% of Student Placement Report 10% of Student Logbook 10% of Colloquium	P (40%) and (10%) P (10%) and A (5%) C (5%) and A (10%) C (5%) and A (5%) A (10%)

Note: C – Cognitive, P – Psychomotor, A-Affective

4 Sample and method

272 students of ECM 377 involved in this study, and the selection of these students are according to the total number of students enrolled in this course in Session II 2019/2020. The students' results were analysed to evaluate the psychomotor domain and affective domain's attainment from the employer's perspective during their indus-

trial training period. The analysis was made based on the overall achievement comprising the percentage (%) of marks obtained for the domain involved. Besides, descriptive statistical analysis of the data involving mean, median, mode, minimum, and maximum marks is also presented. The Pearson correlation (r) was used to measure the relationship between each POs and domain, thus identifying the direction and strength of the relationship. Finally, the t-test analysis was completed to identify any significant difference between male and female students' performance.

This study focused on the Industrial Supervisor's evaluation that consists of 40% of the psychomotor domain and 10% of the affective domain, as shown in Table 1. Meanwhile, Table 3 displays the POs that mapping with the psychomotor and affective domains.

Table 3. Mapping of Pos with the psychomotor and affective domain

Domain	Programme Outcome (PO)		%
Psychomotor	PO4	Students should be able to know how to conduct the investigation using the catalogues, standard tests, and measurements on given problems.	20%
	PO5	Students should be able to use appropriate modern techniques, resources, and information technology to solve a specific engineering problem.	20%
Affective	PO8	Students should understand their role and should adhere to professional ethics as a civil technicians.	5%
	PO10	Students should be able to have effective communication skills; thus, this leads them to communicate on the given problem, give and receive the instruction when involved with the engineering project.	5%

The specific rubric has been provided to the industrial supervisor as a guideline for them to assess the students' capabilities. Table 4 present the evaluation criteria of the psychomotor and affective domains.

Table 4. Evaluation criteria

Domain	PO	Criteria
Psychomotor	PO4	Ability to recognise the given task and capable to relate with the relevant codes/ standard measurement.
		Ability to conduct well-defined problems, locate and search relevant codes/ catalogue/ standard.
		Ability to execute the task given with the application of knowledge / appropriate technique.
		Ability to perform, gather and interpreting data which leads to the findings on the given problem.
	PO5	Able to recognise the suitable standard/ appropriate techniques and modern engineering or IT tools to the civil engineering problems.
		Able to imitate the appropriate techniques and modern engineering or IT tools to solve civil engineering problems.
Affective	PO8	Comply with time management and punctuality
		Adhere to ethics as a civil technician and behave according to safety integrity.
	PO10	Aware and receive well to the task given.
		Communicate effectively oral and written to the task given and being able to comprehend the work.

The overall performances for each POs that reflected psychomotor and affective domain were analysed by a percentage of 100. It was then classified according to the scoring guide referred to the Examination Unit, Academic Affairs of the university. The scoring guide is shown in Table 5.

Table 5. Interpretation of the marks

Marks	Grade	Interpretation
90 – 100	A+	Excellent
80 – 89	A	
75 – 79	A-	
70 – 74	B+	Good
65 – 69	B	
60 – 64	B-	
55 – 59	C+	Satisfactory
50 – 54	C	
47 – 49	C-	Fail
44 – 46	D+	
40 – 43	D	
30 – 39	E	
0 – 29	F	

5 Result

5.1 Psychomotor and affective domain performance

Figure 1 presents the distribution of students' performance in the psychomotor domain. According to Figure 1, it shows that 262 out of 272 (96.32%) students were excellent in PO4, which obtained marks between 75% – 100% and another 10 students (3.67%) are considered good in the ability to conduct an investigation using standard measurement on the given problem. These performance's pattern slightly differs in PO5. It indicates that one of the students (0.3%) performed a satisfactory level of achievement. Meanwhile, 16 students, which contributed to 5.88%, are good, and 225 students (93.82%) are excellent in using modern techniques and tools to solve the specific engineering problem during industrial training. These, due to the students, has given the proper practical scale and updated knowledge regarding new technologies in the market [30].

Typically, students' future behaviour influenced by affective variables such as students' attitudes, interests, and values [33]. Indicators of academic achievement and other factors such as awareness, self-efficacy, self-performance effectiveness, and time management are also essential. Therefore, the student's achievement of the affective domain related to PO8 and PO10 is displayed in Figure 2. During industrial training, the affective domain was observed by a respective supervisor on the students' attitude and communication skills. About 99.26% (270 students) and 95.96% (261 students) obtained excellent evaluation from their industrial supervisor in PO8 and PO10, respectively. Another 0.74% (2 students) are good at understanding their rules and ethics, and 4.04% (10 students) are good in communications skills.

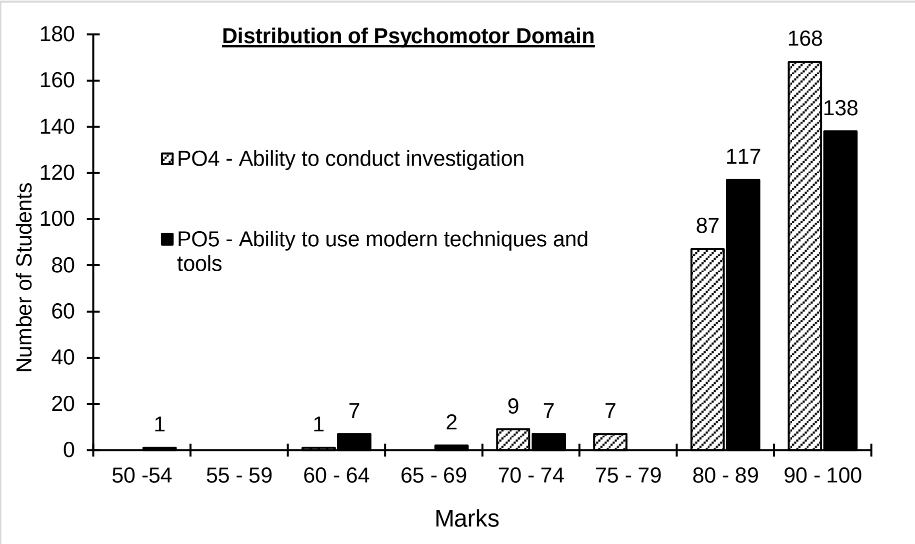

Fig. 1. Distribution of students' performance according to the psychomotor domain

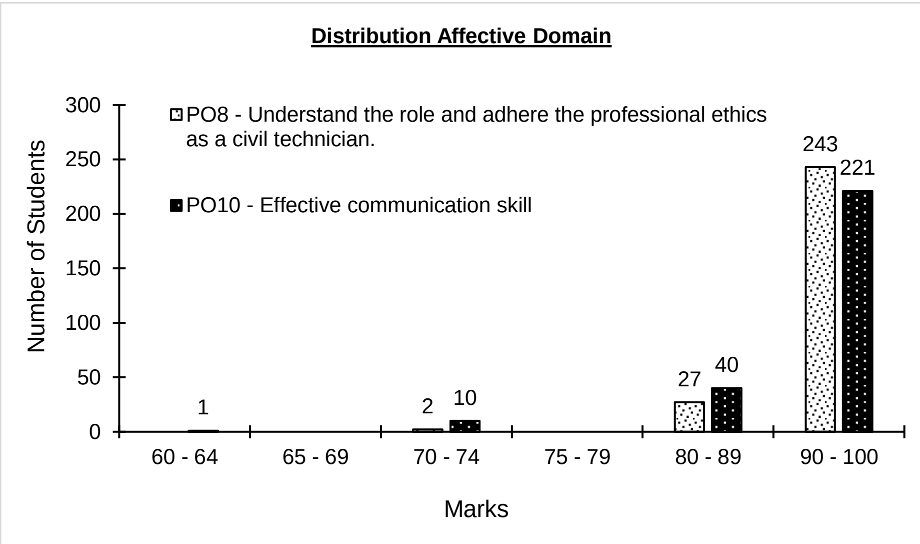

Fig. 2. Distribution of students' performance of Affective Domain

Furthermore, Figure 3 visualised the descriptive analysis of the POs in terms of median, mean, mode and minimum and maximum marks. The data trends are similar among each other except for the mode and mean analysis of PO5. It indicates that the mode value is 80%, and the minimum is 53% compared with PO4, PO8 and PO10. It was believed that some of the students are not well familiar with new software or tools used in their placement organisation since the industrial training was their first exposure to the real environment of works. Thus, they need additional time to learn that stuff.

Moreover, the analysis demonstrated that students obtained excellent evaluation for the affective domain (PO8 and PO10). The mean, median, mode and maximum marks were in the range between 88% to 100%. Gupta [12] described that students refined their social competencies, attitudes, and professionalism towards developing the profession from industrial training. Skill obtained by going through lots of exercises at university that involved communication such as group work, lab work, and presentations before undergoing industrial training has minimised conflict occurrences to understand their roles. It is important to develop soft skills through the courses at university because it positively impacts cooperation at work and personal relationships [16]. Thus, this helps them expedite the job and perform well during the industrial training session [28].

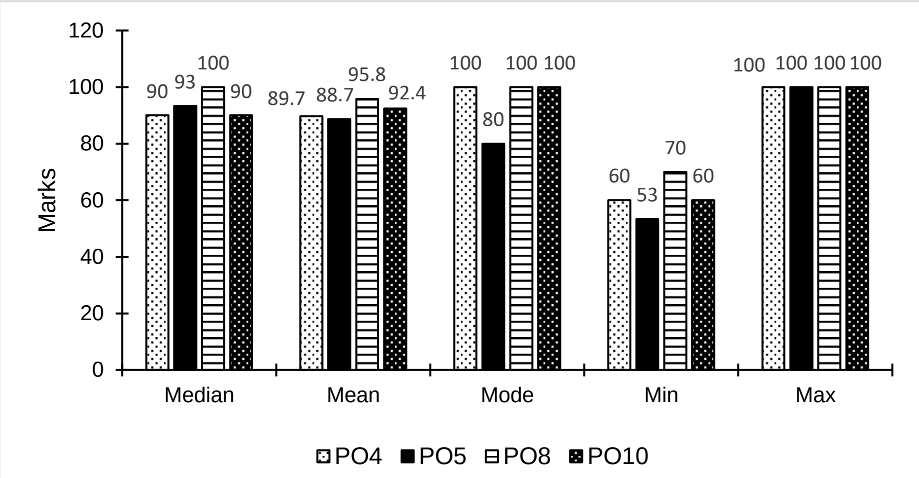

Fig. 3. Descriptive analysis for each PO

Figure 4 presents the matrix correlation between the psychomotor domain and the affective domain. It shows that the correlation (r) between PO4 and PO10 is 0.673, while the correlation (r) between PO4 and PO5 is 0.555. Both are among the highest r-value compared to others. Referring to Akoglu [3], the r-value in the range +0.4 to +0.69 was interpreted as moderately positively correlated. Thus, it also considers that another POs has a moderate association with correlation (r) value +0.44 to +0.48. Overall, it shows that communication has a significant relation with every PO. The ability to integrate effective communication (verbal, written, virtual and graphical) would turn into work products [19]. Without proper communication skills, they will not be able to ask questions, clarify doubts, cooperate with team members, and share ideas. Hence, it will affect the works' productivity [12], [29].

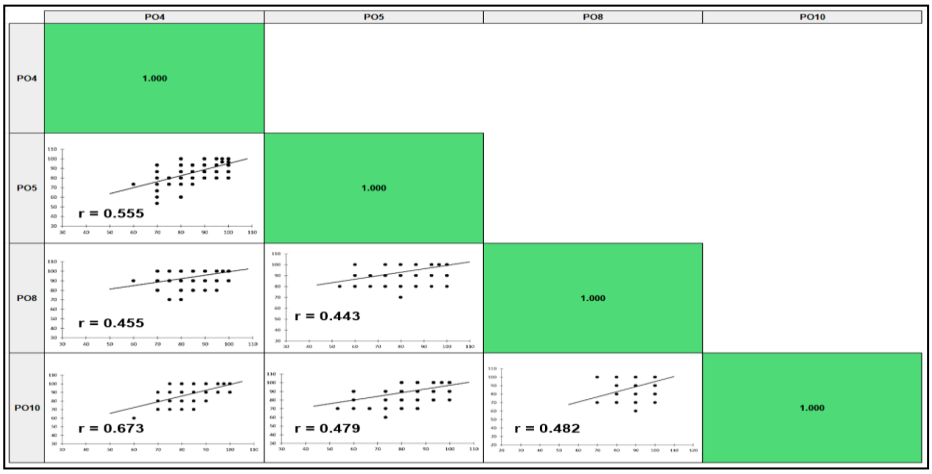

Fig. 4. Correlation matrix between each PO

5.2 Students performance based on Gender

There are 142 females and 130 males' students in this sample. Figure 5 shows the comparison of female and male attainment for each PO. From this finding, the overall results indicated that female students performed slightly better than male students in the psychomotor and affective domains. Thus, the t-test was completed to validate any significant difference between females and males. It was tested for each PO among female and male students with the null hypothesis (Ho) that female and male students' performance is equivalent. This finding seems to be agreed with the study conducted by Woodfield [32] and Megat Mohd Nor [23], where the female students performed better than the male students during the industrial training.

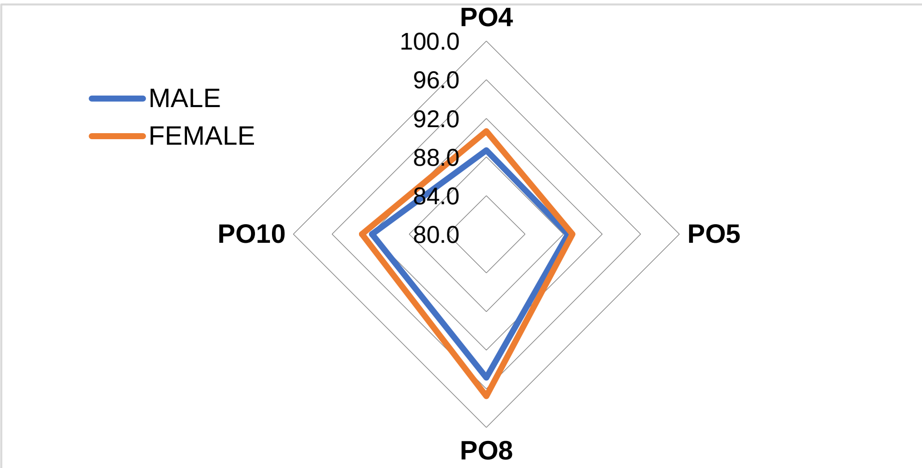

Fig. 5. Comparison of female and male students of the average marks' attainment for each

The results obtained through the t-test correlation coefficient should be able to fulfil one of the following hypotheses:

H_0 : there is no significant difference in achievement (p-value more than 0.05).

H_1 : there is a significant difference in achievement (p-value less than 0.05).

Based on the t-test result in Table 6, it is proved that the differences in achievement for PO4, PO5 and PO10 among male and female students were not significant. The data shows the t-Stat is less than t-critical, and the p-value is greater than the significance level (α). However, PO8 shows a little significant difference between females and males when the p-value is less than 0.05. These are due to the considerable difference in variance value even though the mean value has slightly different. If compared with PO5, even its variance differs, but it has an equivalent mean value. Furthermore, the rest of the comparison only have slight differences in means and variances, as presented in Table 7. These seem to be agreed with Sena [31] based on the study on the gender differences in students' assessment in fluid mechanics, which indicated that the female students having the highest mean marks compare to the male students but statistically insignificant between female and male students.

Table 6. T-test Result

PO	α	t-Stat	t-critical	p	Result
PO4	0.05	1.9027	1.9687	0.0581	Accept H_o
PO5	0.05	0.3904	1.9688	0.6964	Accept H_o
PO8	0.05	2.2944	1.9688	0.0225	Reject H_o
PO10	0.05	0.9947	1.9687	0.3207	Accept H_o

Table 7. Mean and Variance based on gender analysis

PO	Female		Male		% Different	
	Mean	***Variance***	***Mean***	***Variance***	***Mean***	***Variance***
PO4	90.67	75. 17	88.69	71.14	2.2	5.4
PO5	88.92	86.51	88.46	102.52	0.5	15.6
PO8	96.76	41.91	94.85	53.07	2.0	21.0
P10	92.88	76.00	91.85	72.53	1.1	4.6

5.3 Strength, limitation, and usefulness of the study

The study provides information on the evaluation of the industrial employer towards the undergraduates' students while undergoing the internship at their organisation. Hence, the findings can be considered an indicator of whether the curriculum and syllabus designed have met the industrial needs of the technical skill and soft skills required for diploma-level students or vice versa. The evaluation from the organisation reflects the quality of the students. The data obtained could also help identify psychomotor and affective elements that need to be strengthened in the syllabus. The feedback from the industry is essential to ensure the quality of the syllabus contents relevant with time. Consequently, the employability rates of graduates could be increased.

The findings of this study have to be seen in the light of some limitations. The data of students' evaluation only from one of the universities in Malaysia that offered the Diploma in Civil engineering program; thus, this represents the students' performance from that institution. Besides that, there is a lack of references to similar studies, especially regarding the psychomotor and affective domain of Civil engineering students and the involvement of the industrial evaluation. Hence, this study could also motivate higher education institutions to undertake similar studies to cover a more comprehensive comparative study. Then, strategies to enhance the syllabus content and teaching method can be developed to prepare a better quality of graduates.

6 Conclusion

This study indicates that most students excelled in the psychomotor and affective domain based on the employer's evaluation. The overall finding shows that 96.32%, 93.82%, 99.26% and 95.96% of students were excellent in fulfilling the elements of PO4, PO5, PO8 and PO10, respectively. The main reason for that achievement was that the industrial training took place in the final year and final semester of the study period due to the curriculum design. The students have been exposed to the industry's related skills needs while learning all the courses from Semester I until Semester V. They have learned while doing laboratory works or experimental learning related to psychomotor skills. Besides that, they also learned from the tasks that involved communication skills like group work and presentations that improved their affective domain quality. All the knowledge they acquired were implemented during the practical training. As a result, they obtain good evaluations from their industrial supervisor.

Moreover, the study revealed that the r-value for each POs showed a moderate positive correlation. It means that each PO are related to others. The study also discovered that female students performed slightly better in the psychomotor and affective domain than male students. However, the t-test result confirmed that the differences in achievement for PO4, PO5 and PO10 among male and female students were not significant, while PO8 indicated little significant difference. Finally, perhaps the findings of this study can help educators recognise the most reliable and beneficial elements in preparing the graduates full of the employability capacities required by the industries.

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Student-Collaboration in Online Computer Science Courses – An Explorative Case Study

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Abstract—As a result of the current Covid-19 pandemic, a shift in teaching and learning from face-to-face to video-based online instructional settings has occurred in higher education. For online teaching, strategies are required to allow collaboration and interaction between learners, similar to face-to-face teaching. Therefore, it is essential to identify how students perceive group work in online classes in order to be able to draw relevant conclusions for the design of online classes. This paper examines the learning climate and the perceived key features of collaborative learning in two different computer science courses with (N = 9) pre-service teachers in computer science and (N = 7) computer science majors, which took place in the virtual gathering space *gather.town*. We choose this platform to provide a wide opportunity for interaction, especially during collaborative group work. Even though we can draw no conclusions that the possibility of interaction in gather.town platform had an impact on the learning climate, results indicate that the learning atmosphere was perceived as similar to that of in face-to-face courses. Furthermore, the results based on the qualitative content analysis indicate that students perceived a high activation as working better in online collaboration than in face-to-face settings.

Keywords—online teaching, student collaboration, group work

1 Introduction

Recently, there has been a significant shift from face-to-face teaching to online-only teaching at all levels of education as a result of the Covid-19 pandemic. Although concepts for online teaching have been the subject of research and practice for some time [1], there has been increased attention to this topic, particularly, more recently [2]. In this context, video conferencing systems, such as Zoom, WebEx and others, have been used to deliver online teaching. Although these tools are suitable for lectures and meetings, it can be assumed that they have some disadvantages during collaborative phases of teaching and learning. In particular, break-out rooms in standard videoconferencing systems have shortcomings, such as not interacting with participants in other groups [3]. This paper describes how we used an online learning environment in two higher education courses of computer science to design group work which enabled a setting of collaborative learning similar to face-to-face teachings. To this end, we choose a web-based tool that differs from standard conferencing systems and integrates an interactive virtual meeting space, namely the online platform *gather.town*[1]. The aims of this case study are: (1) assess the community atmosphere in an online-based learning platform that provides an environment of high interactivity between the learners and (2) identify key features of computer-supported collaborative learning that learners perceive in this particular setting. In the following sections of this paper, we first describe the theoretical background of computer-supported collaborative learning environments and introduce the research questions. Then we outline the specific course settings and the research methods we used, followed by the research findings. The paper concludes with a discussion and conclusions on integrating a virtual meeting room as a learning environment.

2 Background

The importance of fostering team skills through group work has already been recognized in computer science classes, where it has been found that a student-centered atmosphere has an impact on the development of team skills [4]. Small group collaboration is seen as an important factor in building social presence in online-learning [5]. According to [6], the learning climate also impacts self-efficacy, interests and active participation in a learner's group. This is also related to the student-centered approach and the classroom climate, affecting students' attitudes and learning outcomes [7], [8], [9]. Moreover, social skills, active learning and collaborative skills are essential along with cognitive and interpersonal aspects, which are relevant for the effectiveness of learning processes [10]-[13]. Online instruction also opens up new obstacles in communication, such as cameras being turned off or passivity reflected when teachers intended to include more interactive and collaborative online instructional sequences [14]. Hence, the importance of considering social interactions in online teaching is evident and it is shown that social presence, active social participation, and group phases are key features for perceiving learning environments as beneficial [5], [15], [16]. Friedrich & Mandl provide in [17] an overview of the learning strategies and how they influence learning. They highlight strategies of cooperate learning as one learning strategy. To identify how collaboration and group work is perceived, determining the degree of community provides insight into students' perceptions [18]. Computer-supported collaborative learning aims to bring learners into a situation where they solve problems together, exchange knowledge and opinions, and analyze their learning progress together with the help of digital tools [19]. However, according to [20] collaborative learning should take place particularly in complex learning situations and tasks in order to avoid cognitive overload [21]. Learning environments that include collaborative learning phases where a small learning group can achieve a learning goal, have shown to have a substantial impact on students' progress [18], [19]. Computer-supported collaborative education is designed to put students in situations where they use digital tools to solve problems together, share knowledge and opinions, and analyze their progress

[1] https://gather.town

together [8]. The aim is to prompt learning through computer-supported collaborative instruction so that the group of students acquires more knowledge than they would have alone [20].

3 Research questions

Based on the theoretical assumptions on computer-supported collaborative learning environments and the impact on learning, the following research questions are driving this study:

RQ1: How is the community atmosphere perceived in collaborative learning settings?

RQ2: What are key features that are perceived relating to collaborative group work on gather.town?

The aim was to explore students' experiences with the tool by assessing their perception of implemented collaborative learning through a post-questionnaire.

4 Method

In this section we describe the empirical examination of two virtual computer-supported collaborative learning environments, which took place in undergraduate and graduate computer science programs at two different universities. We chose a [22] mixed-methods design, because this allowed a more detailed perspective than would have been possible with an exclusively quantitative or qualitative approach [22], [23]. The design of this case study (see Table 1) was a between-subject design. Different groups of learners participated and evaluated the courses they attended.

Table 1. Case study design

	Quantitative approach	**Qualitative approach**
Didactics of Computer Science	Ratings of pre-service teachers of the feeling of community and the quality of group work and the perception of learning achievement	Open-ended questions on the quality of group work
Software Product Line Engineering		

One university has an educational focus (Course 1) and the other has an engineering focus (Course 2). Even though both courses addressed different topics, both courses used the *gather.town* platform. The first course aimed to prepare and specialize pre-service teachers to take a pedagogical perspective when appropriately choosing teaching methods in computer science. The other course aimed to enable computer science majors to take the application-oriented view of computer science and software development. Table 2 shows the number of students data were collected from:

Table 2. Overview courses evaluated

	Name	Students
Course 1	Didactics of Computer Science	9
Course 2	Software Product Line Engineering	7

The following two subsections describe both courses in more detail.

4.1 Course 1: Didactics of computer science

The seminar "Didactic of Computer Science" is a compulsory subject within the undergraduate part of the teacher training program. The course aims to enable pre-service teachers to consider the basics of learning and instruction in their lesson planning and to bring their pedagogical knowledge to a higher level. This will allow them to be well prepared to teaching computer science at the lower secondary level. Each course session is characterized by a work phase that lasts 5-25 minutes, depending on the task. The pre-service-teachers are asked to individually choose at which table and with whom they want to collaborate. This was done to provide a setting where students can decide self-determined and thus motivated choose which topics they want to treat in more detail [24]. To provide an example, during small group work, students worked together to develop ideas for methodological applications for a given subject content from computer science. They also discussed the content of lectures, worked out questions or consulted on lesson plans. The small group phases were always initiated with a clear work assignment or framework. The course thus provides a framework for students where interactive or reflective exchange is encouraged. Gather.town offers the simple possibility to efficiently conduct spontaneously scheduled small group phases during the course, even without a technical intervention of the teacher.

4.2 Course 2: Software product line engineering

The lecture "Software Product Line Engineering" is an optional subject within the master curriculum of computer science. The course aims to enable students to develop and maintain software product lines by providing them an overview of different goals, methods, concepts, and techniques [25]. Although the course is classified as a lecture, it fosters interaction by including small surveys for individual students and breakout discussions for groups. For breakout discussions, students form groups of up to six people at the tables and are tasked to apply a specific method presented in the lecture. During the breakout discussions, the lecturer visited the tables to answer the students' questions. After the breakout discussion, the students successively gathered around the group tables, where one of the group's members presented their solution (on the virtual whiteboard) to the other students. Usually, students highlight essential questions and design decisions during that phase. The breakout discussions' tasks employ an ongoing example; in that each task focused on a different phase in the software product line engineering process. This permitted students to retain previous results on the whiteboard and continue their discussion in stable groups throughout the course.

4.3 Online gathering tool gather.town

The virtual platform gather.town was employed as the course platform. Since it is possible to customize the platform's map, we designed it like a seminar room. Figure 1 shows how this platform was tailored to our needs. We chose to set up a plenary seating arrangement in the center of the room and surrounded it by five group worktables with virtual whiteboards at each table. The system works so that students and the lecturer as avatars can move freely on the map using keyboard controls. If two avatars come into close proximity, the video function is activated, and they can talk via the integrated video conferencing system *Jitsi*[2] [26].

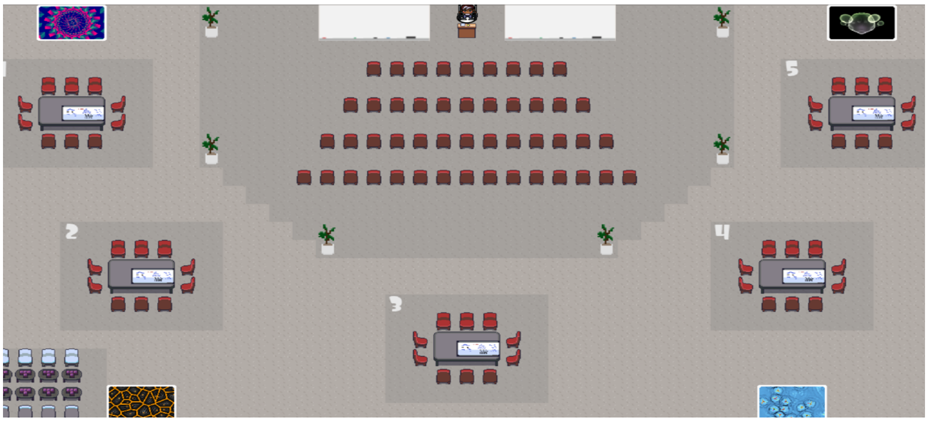

Fig. 1. Lecture hall with five tables with whiteboards

If a person moves to the lecture table in front of the room, they can be heard and seen by everyone in the room. Each virtual whiteboard can be used collaboratively by everyone at the corresponding table.

4.4 Methodological procedure

We chose a quantitative and qualitative approach to analyzing the empirical data. To examine the learning atmosphere and the perceived collaborative group work, we selected the following assessment scales, which are based on instruments that have proven to deliver valid and reliable results.

- *Community questionnaire*: The community questionnaire based on [27], [28] included group work characteristics as measuring aspects of community building. Examine the degree of community is essential for assessing perceptions of group work as it is an indicator for promoting effective collaborative learning [18].
- *Perception of group work:* To identify students' group work perceptions, additional items from [29], [30], were included to determine students' experiences in group work on a community and technical level.

[2] https://meet.jit.si

– Furthermore, we asked students, if they have learned less/equal or more during online group-work compared to on-site courses. ("*Compared to on-site courses, I learned less/equal/more during group work in this online course."*)

Furthermore, we assessed the student's perception of group work in their collaborative learning phases through the following open-ended questions.

– *Open text responses:* To allow a more detailed perspective on students' experiences of group work and learning in groups, we asked them the following questions:

- How did you perceive group work in this course online compared to face-to-face courses? Briefly describe it.
- Which aspects did you perceive to be efficient in group work in this online course? Briefly describe it.
- What problems did you experience with group work in this online course? Briefly describe it.

4.5 Reliability of the questionnaire

To examine whether the items worked, we examined the reliability of the items and the scales. Analyses of the internal consistency are presented in Table 3 and revealed a Cronbach's alpha for the scale learning environment of 0.91 which is excellent. For the scale perception of group-work a Cronbach's alpha of 0.70 was examined, which is sufficient. All items in this scale (perception of group-work) were not normally distributed. Those items which were normally distributed in the scale of learning environment are listed in the Table 3. All other items were not normally distributed. The item that assessed learning was also not normally distributed.

Table 3. Internal consistency through Cronbach's Alpha

Scale	α	Kolmogorov-Smirnov-Test
Community questionnaire	0.91	
Experiencing being heard		n.d.
Shared initiative/leadership and responsibility		n.d.
Experiencing connectedness and community		n.d.
The group is perceived as a whole rather than the sum of its parts		n.d.
Perception of group-work	0.70	n.n.
Learning		n.n.

5 Analysis

We used descriptive analysis for the assessment scales and identified the open-ended questions by means of the qualitative content analysis [31], [32]. The assessed key features of technology-enhanced learning in collaborative settings were analyzed applying a theory-based approach that was oriented on aspects of technology and pedagogy. This enabled in a further step to classify the two seminar groups into key features that worked well or less well from the educational and technical points of view. Two trained raters rated them using a coding guide (see Table 4) and sorted them into the categories of constructive and obstructive key features and into the subcategories of technical, educational or other issues. We additionally assessed the categories according to their *degree of expression* (-1= worse than online teaching, 0 = same as face-to-face teaching, 3= online worked better than face-to-face). This was done in order to gain a deeper understanding of the features of technology-enhanced learning. The aim was to identify initial trends to adapt a study design for further investigations. [31], [32].

Table 4. Coding guide for qualitative content analysis

Variable	Subcategory	Definition	Anchor Example	Coding Rule
C1: Successful Key Features of Technology-enhanced Learning	C1.1: Technical issues that succeeded concerning Technology-enhanced Learning	The student describes a situation, where technical issues worked well.	„The possibility to work at the same time in the same document. "	Whenever there is a new semantic meaning, the sentence will be split into two or more categories. In particular when technical, educational or other issues are mentioned in the same statement.
	C1.2: Educational issues that succeeded concerning Technology-enhanced Learning	The student describes a situation, where educational issues in respect to learning worked well.	"The group size was very good to work together."	
	C1.3: Other issues that succeeded concerning Technology-enhanced Learning	The student describes a situation, where other aspects worked well.	"I did not need to drive one hour to take part in the course."	
C2: Obstructive Key Features of Technology-enhanced Learning	C2.1: Challenging technical issues concerning Technology-enhanced Learning	The student describes a situation, where technical issues worked less well.	„Connection problems with the learning environment." "It is difficult to interact with those group mates whose microphones did not work properly."	Whenever there is a new semantic meaning, the sentence will be split into two or more categories. In particular when technical, educational or other issues are mentioned in the same statement.
	C2.2: Challenging Educational issues concerning Technology-enhanced Learning	The student describes a situation, where educational issues in respect to learning worked less well.	„If the other group mates are not motivated to communicate, it is difficult to deal with the topics in more detail."	
	C2.3: Other challenging issues concerning Technology-enhanced Learning	The student describes a situation, where other aspects worked less well.	"I had another course at the same time."	

The analysis of categories follows the qualitative analysis approach [33], where first the students' text answers are categorized, and then in a next step each category is described or interpreted in the overall context. Finally, the responses were analyzed using an inductive approach. This was done in order to develop categories and sub-categories that describe the key features that were perceived during collaborative learning.

6 Results

This section presents the main findings of this case study. It investigates how group work was perceived in gather.town and what difficulties were identified. The objectives were: (1) investigate the community atmosphere in an online-based learning platform (2) identify key features of computer-supported collaborative learning. We analyzed the mean scores and standard derivatives of each course.

6.1 Quantitative

The questionnaire was completed in full by a total of 9 out of 9 students in Course 1 and by a total of 7 out of 25 students in Course 2. This section describes the descriptive overview of the mean scores of all items regarding the feeling of community (see "Community Questionnaire" in Figure 2) and the perception of group work (see Figure 3). It reveals that both courses perceived the community feeling similar to that of face-to face teaching. (0 indicates that the feeling of community was perceived similar in the online course compared to face-to-face teaching). The feeling of community while using the online-based learning platform was perceived to be slightly higher in Course 2 in comparison to face-to-face teaching. Whereas in Course 1 the perception of community was not equal to that of presence-teaching. In Course 2, the participants perceived attentive listening, the ability to achieve common goals and having direct concern for the group process more likely in the gather.town-environment than in face-to-face group work. Both courses perceived the item "tolerance for ambiguity and conflict" similar: Course 1 $M=0.44$, $SD=1.33$ and Course 2 $M=0.71$, $SD=0.95$. Both courses perceived the items "having direct concern for the group process" differently: in Course 1 with $M=-0.89$, $SD=0.93$ and in Course 2 with $M=1.57$, $SD=1.72$. The multivariate analysis of variance, MANOVA, was used to examine differences between the groups systematically. As the data were not normally distributed, we have chosen a Welch-ANOVA in order to examine differences because this is robust when the variances are not homogenous. The following items revealed a significant difference between the groups: "communicating owned feelings and meaning", "having the ability/power to achieve common goals", and "having direct concern for the group process".

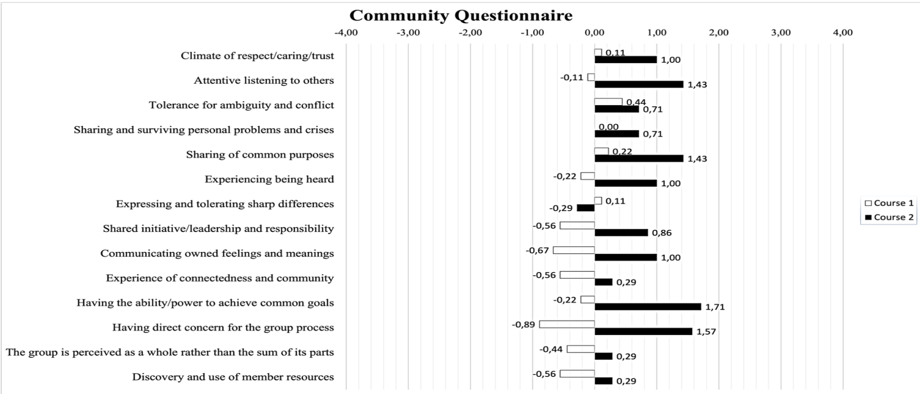

Fig. 2. Change in aspects of community in both courses, questionnaire designed by [28] and integrated in the context of computer science by [27]. The bars depict the mean value, scale from -4 (declined) to + 4 (improved), n=9 (Course 1) and n=7 (Course 2)

Figure 3 illustrates the second part of the questionnaire, which includes the perceptions of group work. The results indicate that both courses rated the items similarly. Figure 3 shows that the group work was not perceived particularly monotonous in Course 1 with *M=1.78, SD=0.67,* nor in Course 2 with *M=2.29, SD=0.76*. The support of the teacher was perceived as very high in both courses: in Course 1 with *M=4.44, SD=0.53* and in Course 2 with *M=4.43, SD=0.79*. Similar high results were found in the transitions from teacher to group work with *M=4.22, SD=0.67* in Course 1 and *M=4.29, SD=0.49* in Course 2. The item "I felt like I was with people who were in the same virtual space during the group work" resulted in *M=4.22, SD=0.67* in Course 1 and *M=4.14, SD=0.69* in Course 2.

As the data were not normally distributed, we have chosen again a Welch-ANOVA in order to examine differences. No items reveled a significant different between the groups.

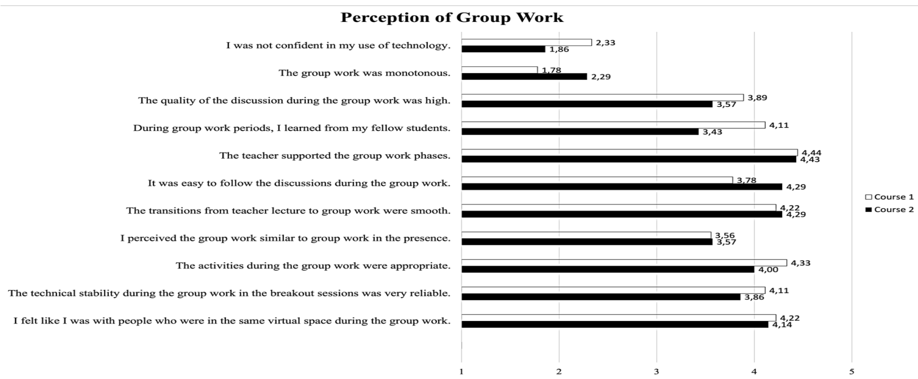

Fig. 3. Perception of group work in online courses, questionnaire based on [29], [30]. The bars depict the mean value, scale from 1 (not at all) to 5 (fully agree), n=9 (Course 1) and n=7 (Course 2)

Results from the question whether students learned less (1), the same (2), or more (3) in online group work show that students from Course 1 scored $M=1.89$, $SD=0.60$ and in Course 2 scored $M=2.57$, $SD=0.53$. The average of both groups is $M=2.23$. As the data were ordinally scaled, we have chosen a Mann-Whitney-U-Test in order to examine differences. There were again no significant differences between the groups.

6.2 Qualitative

Table 5 shows the number of key features found within the groups concerning constructive and obstructive educational and technical issues. Most key features were found in educational issues that were constructive. Overall, more issues were found that were constructive than obstructive. In aspects that were obstructive, more issues were found concerning technical issues than to educational issues. The *Krippendorff* revealed $r = 0.79$, which is good.

Table 5. Number of technical and educational key features

	Group A	Group B	Total
Technical constructive key features	11	14	25
Educational constructive key features	29	25	54
Other constructive key features	1	0	1
Technical obstructive key features	12	6	18
Educational obstructive key features	6	7	13
Other obstructive key features	0	0	0
Total	59	52	111

Table 6 illustrates the results of the inductive qualitative content analysis. The subcategory has a *Krippendorff* of $r = 0.88$ and of the degree of expression a *Krippendorff* of $r = 0.62$. The examination of the category revealed a *Krippendorff* of $r = 0.77$, which is sufficient. In addition, a third trained rater rated the coding scheme that were developed by the two raters in order to assure that this coding scheme can be transferred. There was intercoder reliability in accordance with *Krippendorff* of $r = 0.88$ for the main categories. The subcategories revealed a Krippendorff of $r = 70$ between the first two raters and the third rater and a *Krippendorff* of $r = 59$ in regard to the degree of expression. Table 6 and 7 show the examined categories and sub-categories as well as the degree of expression with regard to key features that succeeded as well as were obstructive from the technical and from the educational point of view.

Table 6 and 7 reveal the main categories and sub-categories that were found in the students' responses. It also reveals the degree of expression (- indicating that face-to-face teaching works better than online-teaching; 0 indicating that it worked neither better nor worse in both settings; + meaning that these issues worked better in the online-teaching than in face-to-face teaching). Both courses addressed technological as well as collaborative learning issues that succeeded with regard to technology. Whereas the first course mentioned stability and synchronous work as being key features that worked from the technological perspective, the second course highlighted aspects of active participation in collaborative learning and stability and usability as key aspects which succeeded from the technological point of view.

With reference to the main category of collaborative learning, both group of students perceived aspects of synchronous work and of active participation as being better in online-learning compared to face-to-face teaching. With regard to learning climate those issues that were constructive were perceived as neither being better nor worse compared to face-to-face teaching. With regard to the main category of group work, in both groups there were found issues like group building process, group organization and time management as factettes of student collaboration which worked rather better in the online settings compared to face-to-face teaching.

Both courses addressed communicational issues as obstructive. Whereas the first course mentioned asynchronous communication as hindering, the second course referred to the willingness to communicate as an obstructive issue. The stability and usability were addressed in both courses as technological key features that were obstructive. Group work factettes were found in both lectures as obstructive. The first course highlighted aspects of group organization and group presence as challenging whereas the second course mentioned time management as obstructive.

Table 6. Qualitative analysis Course 1

	Main category	**Sub-category**	**Deg. of expr.**		
			-	0	+
Technical constructive key features	Technology	Stability	0	1	6
	Collaborative learning	Synchronous Work			2
Educational constructive key features	Communication	Listening communication			3
		Willingness to communicate			1
	Collaborative Learning	Synchronous work			2
		Active participation		1	3
		Learning climate		4	
	Group work	Group building process		6	2
		Group organization		1	2
		Time management			1
		Group presence		3	
Technical obstructive key features	Communication	Asynchronous communication	3		
	Technology	Stability	6		
	Technology	Usability	2		
Educational obstructive key features	Communication	Asynchronous communication	3		
		Listening communication	1	1	
	Group work	Group organization	1		
	Group work	Group presence		1	

Table 7. Qualitative analysis Course 2

	Main category	Sub-category	Deg. of expr.		
			-	0	+
Technical constructive key features	Collaborative Learning	Active participation		3	5
	Technology	Stability		3	2
		Usability			1
Educational constructive key features	Collaborative learning	Active participation		1	7
	Collaborative learning	Learning climate		2	
	Collaborative learning	Synchronous work			1
	Group work	Group building process		1	4
	Group work	Group organization		2	1
	Group work	Group presence		2	2
	Group work	Time management			2
Technical obstructive key features	Technology	Stability	3		
	Technology	Usability	3		
Educational obstructive key features	Collaborative learning	Active participation			3
	Communication	Willingness to communicate	2	2	
	Technology	Usability		1	
	Group work	Time management	1		

6.3 Comparing the results

The following examples compare the open-ended questions with items from the assessment scales. Concerning group work, the previous section showed that the group building process and group organization were key features that worked better in the online setting than in face-to-face classes.

The following examples illustrate this:

In terms of group processes, in Course 1, the commitment to group work was described by student *S1* as:

S1: "*It is easier to disengage as a group member than in on-site group work*." or also:

S2: "*I find it difficult when the groups are too large. It is then easy to lose the overview and it can quickly become chaotic.*", both were categorized as "Group organization (Group work)".

which also influenced communication in Course 1:

S3: "*I find communication to be difficult*",

S4: "*One disadvantage I found was that you can't talk at the same time, you always have to wait until someone has spoken.*" both of which were rated as working better in face-to-face teaching "Asynchronous Communication (Communication)" category. While overall, students from Course 1 rated an average of *-0.24* on the Community Questionnaire, the two students (S3/S4) rated it *-0.46*.

By contrast, in Course 2, students commented on the group work:

S5: *"Some don't participate, but still more than on-site.*", which was defined as active participation (in the Group work category), or

S6*:* "*It is easier to organize in groups because you don't have to walk through the lecture hall.*", which was categorized as group building process and rated to work better in online-teaching. While overall the students of Course 2 rated the perception of group work an average of *3.61*, the two students (S5/S6) rated it higher at *4.14*. There were noticeable differences in the item "The technical stability during the group work in the breakout sessions was very good." (Course 2: *3.86* and S5/S6: *5.00*).

Although the quantitative data indicate a high level of technical stability, some problems became apparent through the students' open feedback. In Course 1, one student reported that:

S7: "*The white board in the middle of the group worktables could be improved." and* "*Occasional connection problems of the end devices and the learning environment.*"

or in Course 2:

S8: "*The tool is technically quite unstable and not necessarily intuitive to use.*"

The item of technical stability during the group work, was rated on average for both groups with *M=3.50 (indicating something between disagreeing and agreeing).*

However, S7 and S8 rated the item of not being confident in using technology with *M=1.50 (totally disagreeing to disagreeing).* The overall averages of both groups were *M=2.10 for this item*, thus showing a rather high self-confidence regarding technical issues.

Furthermore, the positive functionality of the platform's whiteboard was also highlighted, as in Course 1 (this student completely disagreed with regard to the statement of: I was not confident in my use of technology") and hence shows a subjective high technical experience:

S3: "*The possibility to work simultaneously/parallel and together on a whiteboard.*"

In Course 1, it was also reported that the easy ability to move around the room and quickly find each other in groups are key benefits:

S9: "*Alternating phases: i.e., being able to discuss an aspect for just a few minutes in small groups. In other conferencing systems this always takes forever. In gather.town you can simply move freely on your own.*"

From quantitative data, this student (S9) identified a subjective technical expertise ("I was not confident in my use of technology.") with *M = 1.0* (average of both groups was *M=2.10*)

7 Discussion

Due to the Covid-19 pandemic, university teaching has been transitioned to using video in teaching in all disciplines. Due to the need to quickly respond to the urgency of using video-based systems in teaching, systems such as WebEx, Microsoft Teams, or Zoom were adopted in early 2020. Even though these systems allow a great interactivity between the participants, online-platforms enable a self-determined choice of freely moving as an avatar on a virtual map and easily communicating with other course participants. In this paper, we chose *gather.town* in order enable a high interactive way of cooperating with other learners. The aims of this study were: (1) assess the community atmosphere in an online-based learning platform that provides an environment of high interactivity between the learners, (2) identify key features of computer-supported collaborative learning that learners perceive in this particular setting, which lead to two research questions:

RQ1: How is the community atmosphere perceived in collaborative learning settings?

RQ2: What are key features that are perceived relating to collaborative group work on gather.town?

The community questionnaire showed that compared to studies in higher education, the scores were relatively low. In related work where team-work was promoted in on-site courses in computer science, the community questionnaire showed that results are usually > *2.0.* – Even though we did not assess the learning climate explicitly, results indicate, that the community atmosphere is perceived as similar as in face-to-face courses. The questionnaire in this explorative case study showed that these values of both courses investigated are below *2.0* in all cases and in most cases even below *1.0*. Furthermore, it was found that students learned at least just as well in gather.town as they would have been in face-to-face settings. This indicates that the students perceived the degree of learning similar to face-to-face student collaboration. This implies, that gather.town provided a platform to collaboratively learn as well as face-to-face collaboration. So far, we have not examined student collaboration in realized face-to-face-settings.

The analysis of the open-ended questions showed more key features that were constructive – both with regard to educational and technical issues – than that were obstructive. In addition, there were found more educational key features that were constructive in contrast to technical issues in both courses. It may be assumed that the educational aspects concerned with learning issues were perceived more dominantly in this online platform due to the focus on fostering student collaboration. In other words, the focus was more so on collaborative learning than on using the technical options properly. In a course on using digital tools the focus on student's perception maybe would have been on technical issues rather than on educational issues.

Moreover, categorizing the open-ended questions through the qualitative content analysis revealed that group work or collaborative learning were identified as a dominant issue of student collaboration in both groups. This underlines the findings from above that student's focus was more on student collaboration than on technical or communicative issues. This may imply that when designing collaborative group phases, technical and communicational issues do not need to be emphasized as much as, for instance, activating participants or processes of group building.

The results of the open-ended questions revealed that synchronous work and active participation were perceived by students as being better in gather.town compared to face-to-face teaching. This may give a first hint of the impact of interactive collaborative learning on students' perception.

From the method mixing qualitative with quantitative data, it can be assumed, that higher subjective technical experience leads to higher satisfaction with course system but also shows more critical views on usability. Different perceptions of group processes from qualitative data could also be an indication that the item "Having direct concern for the group process" results in the divergences described above. In particular, group size is likely to be an important aspect of online group work. From experience and literature, optimal group size is from 2-5 students for each group [34].

In summary, this is in line with the above-mentioned high values for the item "The transitions from teacher lecture to group work were smooth".

8 Limitations

This study reports our experiences using the online tool gather.town for online teaching in the field of computer science. This case study is limited to various points that must be addressed in future work. First, it included only a low number of learners and a limited choice of disciplines. Therefore, we can make no systematic conclusions. Consequently, future research must include more subjects and examine a broader range of topics. Moreover, a detailed insight into the concrete student collaborative setting is needed in order to better understand learning sequences better. As a consequence, in future research video data should also be implemented as well in order to gain more insight.

Even though the data collected with questionnaires and free text answers provide a detailed picture in terms of mixed methods, the possibility of generalization is still limited. Also, the small number of learners and the unbalanced response rate of both courses causes a certain bias, which we have pointed out in the area of feeling for community. Future studies need to focus on different settings of learning to analyze which setting has the most impact on collaborative learning.

9 Conclusion

This paper described a case study in which student's perception of learning climate and group work in realized computer-supported collaborative learning settings were analyzed. We examined the learning climate in two courses in computer science as well as perceived key features that were regarded to have an impact on learning. We aimed to provide insight into the both learning climate in online-courses and perceived key features of student collaboration in computer science.

To examine the learning climate student collaboration, we referred to well-established items. However, it must be clearly stated that we can draw no conclusions that the possibility of interaction in the gather.town platform had an impact on the learning atmosphere, as we have not assessed the course atmosphere in courses which provide a different degree of interaction possibilities. In addition, we have not assessed the learner's atmosphere outside the course or even before it started.

In the future, we will further investigate the differences between online teaching and face-to-face teaching, different settings of collaborative learning, and how the lack of interpersonal perceptions can be compensated.

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Online Engineering Education:

A Proposal for Specialization of the Teacher Training in Engineering

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Abstract—The context of the COVID-19 pandemic produced new immediate needs in the field of university teaching related to distance learning and forces the universities to transform their "traditional" face-to-face teaching methods, particularly with the implementation of online education. This situation represented a challenge not only for the universities but also for the teachers because they need to transform their teaching work in the classroom to online strategies for online learning environments. To meet these needs for effective online education an online pilot training course in Engineering Education based on the IGIP Curriculum of the TU Dresden was designed and implemented. The course "Introduction to online teaching and learning in engineering" (in Spanish: "Introducción a la Enseñanza-Aprendizaje Online en Ingeniería") consisted of 4 modules implemented on a mix of online communication strategy of synchronous activities carried out on the Zoom platform, together with asynchronous work on a Moodle-based LMS platform. The course was offered between May and June 2020 for a group of academics of the Faculty of Engineering of a public Chilean University. This paper describes the designed online pilot training course in Engineering Pedagogy and presents the results of the evaluation of its implementation. For this a survey was applied and filled by the participants to evaluate the course and to know their perceptions about their competencies development to improve online learning in engineering.

Keywords—University Teacher Training, Online Engineering Pedagogy, Distance Learning, IGIP Curricula

1 Introduction

1.1 Teaching in higher education

Normally, the training of university teachers plays an important role in ensuring the quality of university teaching programmes. However, the quality of teaching competencies in higher education has been underestimated compared to the quality of research competencies. One explanation for this is that for a long time it was believed that teaching competencies were strongly linked to the research competence of academics and their expertise in each research area. Nevertheless, many studies have shown that this link between research and teaching quality is very weak or non-existent [1, 2, 3]. However, due to the importance of research performance for career progression in higher education institutions, most academics have prioritized research over teaching [4, 5, 6, 7].

Regarding the form of university teaching, an interesting point of view was offered by Ventura [8]. The author presented in a study with Latin American academics that university professors teach as they learned in their university training phase. Regarding the relationship between learning preferences (particularly their own history as a student) and the teaching preferences of the professors themselves, they indicated that most professors taught according to their teaching preferences, attending to the disciplinary structure of the scientific field and to a lesser extent to the characteristics of their students. In this sense, evidence was found to support the idea that learning styles operate in teachers' preferred ways of teaching [9].

Psychology teachers, for example, say they prefer to teach and learn by reading texts on theories and concepts, underlining the central ideas, establishing relationships with other texts and repeating the concepts aloud [10]. Likewise, in terms of teaching preferences in Engineering, the teachers expressed that they preferred to interpret the theory of the subject by solving concrete problems and to represent it graphically through tables, graphs and drawings. Related to this, problem and project-based learning and laboratory work are some of the most applied and effectiveness methodologies in engineering education, because they allow not only to increase the motivation of the students, but also solving real-life problems in an organized, interdisciplinary and social learning environment [31].

In order to strengthen teaching work and the development of competences in students in modern societies in different fields, and to update methodological and technical tools in the teaching-learning process, there are proposals from different parts of the world that attempt to train university teachers in pedagogical competences [11, 12, 13, 14]. But in what specific aspects should a university teacher be trained? Taking into account the different tasks of academic staff in higher education institutions, a profile for university teachers was proposed in 2014, with the following eight dimensions being mastered [15]:

1. *Scientific competence* (being specialised in a scientific field).
2. *Teaching competence* (knowledge of learning strategies at university level, effective performance of teaching functions and responsibilities).
3. *Transdisciplinary competences* (having transversal skills: communication and teamwork skills, linguistic skills, IT skills, etc.).
4. *Relational skills* (to facilitate dialogue and relationships with students, to perform appropriate tutoring activities).
5. *Vocation and dedication to teaching* (to have motivation for teaching-learning activities; commitment to the teaching profession and interest in stimulating the learning process of students).

6. *Experience in the university context* (knowledge of the reality of higher education institutions and of the teaching profession at university level).
7. *Self-evaluation and professional development* (ability to improve the teaching practice and activity through the development of the capacity for self-reflection and self-criticism and through continuous professional training).
8. *Research competence* (having the skills to carry out research activities concerning to the educational process, to the own scientific field, or both to improve the teaching-learning process).

Different authors show how difficult it can be to fulfil all or some of these aspects effectively. In many universities it is known that academics are inadequately prepared for their teaching tasks [11, 12, 13, 14]. For this reason, higher education institutions develop and implement various strategies and activities for the professional development of their academics. However, the emergence of the COVID-19 pandemic forced many lecturers to confront their own teaching competencies and their competencies to face distance learning to be able to use online platforms and educational technologies appropriately (with pedagogical foundations) and to ensure and to evaluate their students' learning in this new context [32, 38, 39]. But what happened when teachers have no experience with online learning? What kind of teaching way could they follow or use in this case? Although online learning has been a trend in some universities for many years, these dimensions have been defined with a preference for traditional forms of university teaching, such as face-to-face lectures. However, many of these competences can be applied (and updated) in online learning environments, considering the special requirements of the discipline taught.

1.2 Teaching in engineering

A key concept for teaching in engineering is Engineering Pedagogy (EP). EP can be defined as an interdisciplinary scientific subject that includes and combines the “needs” and “demands” of engineering and technical sciences, pedagogy and didactics, and the educational system, with the goal to design implement and evaluate quality teaching-learning process in engineering fields [16, 17, 18, 19]. The tradition of EP was established through the development of three European “schools of Engineering Pedagogy”: Dresden, Prague, and Klagenfurt [20]. The experiences and work of these European schools of EP became the basis for the founding of IGIP (International Society of Engineering Pedagogy) in 1972 in Klagenfurt, Austria. The main work lines and research initiatives in the field of EP of the first three EP schools and the “most recent” schools (e.g. in Russia and Estonia) have significantly influenced and contributed the formation of the international movement in Engineering Education (EE), which is concretized by the worldwide activities of IGIP and IFEES (International Federation of Engineering Education Societies) and other organizations. An important contribution of IGIP to the international scenario of the EE is its curriculum for engineering teacher training. Table 1 presents an overview of the training program of the Estonian School of EP [20] and the Dresden School of EP [21].

Table 1. Overview of the training programs of the Dresden and the Estonian School of EP.

IGIP training program of the Technische Universität Dresden (Germany) [21]	
Module I: Engineering didactics fundamentals (10,5 CP)	
Units	***Qualification goals***
I.1. Design of teaching-learning processes	Designing teaching and learning processes in engineering education according to the target group on the basis of pedagogical scientific foundations.
I.2. Didactic media for teaching in Engineering	Acquiring and expanding knowledge of the conceptualization of didactic media, the functions of didactic media in teaching and learning processes, the areas of action of didactic media and basic design approaches.
I.3. Communication	Designing and implementing appropriate communicative processes for the own teaching practice on the basis of pedagogical scientific foundations and considering the characteristics of the communication partners.
I.4. Evaluation of the learning outcomes in Engineering	Designing of appropriate learning evaluation processes (qualifications, competences) based on scientific results.
Module II: Structuring of teaching-learning processes in a university context (4,5 CP)	
Units	***Qualification goals***
II.5. Lectures (theoretical courses)	Planning, implementing and executing courses of lectures/seminars/ according to the expected qualification objectives.
II.6. Laboratory practical training/ self-study	Designing teaching and learning processes in laboratory work, in exercises as well as in self-study based on purposeful scientific results.
II.7. Engineering internships, written reports, research colloquium	Planning, implementing and executing academic courses of the type Engineering Internship/Documentation/Research Colloquium in accordance with the expected qualification objectives.
Module III: Determination of objectives and contents in engineering study programmes (3 CP)	
Units	***Qualification goals***
III.8. Determination of the study programme objectives	Determining the course and study module objectives for engineering curricula in the own engineering specialization field.
III.9. Defining the engineering study programme contents	Selecting, structuring and presenting appropriate study program or study module contents based on the established study program objectives.
Module IV: Practical module (2 CP)	
Units	***Qualification goals***
IV.10. Case discussion	Applying schemas for documenting, reflecting and evaluating exemplary teaching situations.
IV.11. Classes observation	Documenting, analyzing, evaluating and reflecting a lecture to achieve a continuous professionalization of the own teaching practice.
IV.12 Final Colloquium	Planning a final colloquium with the help of a planning scheme, then implementing and finally evaluating it.
IGIP training program of the Tallinn University of Technology (Estonia) [20]	
Modules	***Qualification goals***
1. Engineering Pedagogy in Theory and Practice	Designing of learning units using concrete technical subject matters, considering the specific standards and components that regulate and determinate this process (objectives, teaching resources and media, psychological and social structure, and teaching methods, among others).
2. Laboratory Didactics	Structuring of the teaching work in the laboratory, controlled experiments and experimental technical work and research, considering different components

	such as stating the problem or research questions, hypothesis formulation and testing, design of experiments, results and conclusions.
3. Psychological and Sociological Aspects	Acquiring knowledge about the bases and conditions of learning, the learning process, motivation, talent and educability (know-how, understanding and intelligence), the functioning and (inter-)dependence of social groups.
4. Ethical Aspects and Intercultural Competencies	Obtaining general information on European thinking advancement in the cultural-historical framework from the beginning of continental philosophy to the present. Another goal is providing knowledge about socio-pedagogical issues focusing on the multicultural Education.
5. Rhetoric, Communication and Scientific Writing	Acquiring basic knowledge and developing skills in fields such as history of rhetoric, speech technique, and vocal hygiene. In addition, meeting the requirements of research work.
6. Working with Projects: Curriculum Analysis	Providing a clear link to a teaching experience through the teaching project. As teaching project can be considered, for example, a textbook or a (small-scale) research study on the selected topic.
7. Media (Teaching Technology) and E-Learning	Acquiring knowledge about the applications and integration of technical devices, equipment and systems to support learning activities and e-learning.
8. Multicultural Learning Environment	Providing knowledge of socio-educational issues, focusing on multicultural education, to promote tolerance and to avoid prejudice, racism and xenophobia resulting from a lack of knowledge about other cultures.
9. Electives	Working at the following elective subjects: Portfolio Assessment; Coaching and Mentoring in Engineering Education; Creative and Critical Thinking; Teamwork and PBL; Standards and Quality in Engineering Education; etc.

1.3 A proposal for teacher training in online Engineering Pedagogy

Based on the IGIP Curriculum developed by the TU Dresden [21] and the demands for effective online education [22, 23, 24, 25, 26, 38, 39] (also caused by the COVID 19 Pandemic) a pilot training course for the teaching staff of the Engineering Faculty at the Universidad de Talca (UTALCA) was developed. The course was called "Introduction to the online teaching and learning in engineering" and was offered in e-learning modality between May and June 2020 with the participation of a group of 35 teachers of UTALCA. Most of the participants are part of the career of Industrial Engineering, Mechanical Engineering, Electrical Engineering, Mining Engineering, and Computer Engineering.

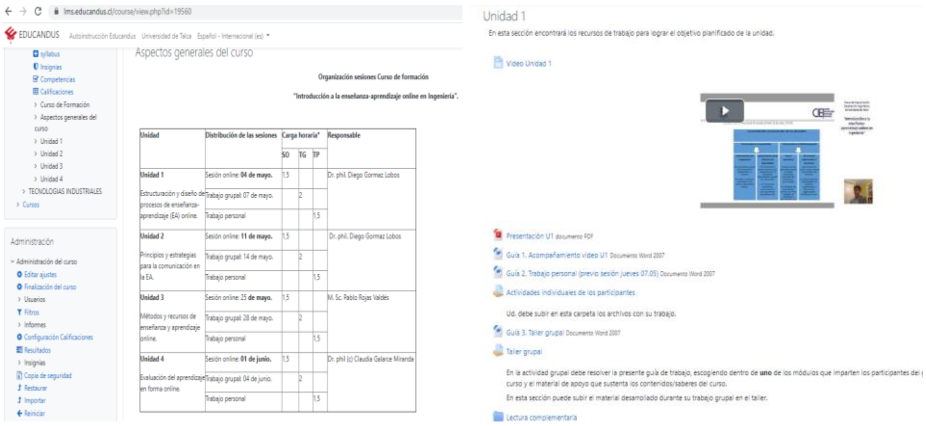

Fig. 1. Overview of the main page of the pilot course in EP at EDUCANDUS. https://lms.educandus.cl/course/view.php?id=19560

The course contemplated a minimum work of 1,5 Credit Points (also 45 hours of training according to the SCT-Chile system). The course consists of four modules according to the objectives and contents of the IGIP Curriculum (see Table 1) and deepen aspects of the effective online training of university students. The choice of content considered the areas in which teachers urgently needed support to transform and effectively adapt their traditional classroom methods to be applied in online education, such as structuring teaching and learning processes, designing and using educational technologies, structuring communicative processes, and assessing student learning in online learning environments. An overview of the modules and units are presented in Table 2. The design was based on a mix of online communication strategy of synchronous activities carried out on the Zoom platform (20 hours), together with asynchronous work on a Moodle-based LMS platform (EDUCANDUS platform) for asynchronous independently and collaborative work (25 hours approximately). The pedagogical design was formed for expository, practice, and collaborative teaching-learning strategies.

The student role contemplated listen and text read activities, to solve problems individual activities or in collaboration with peers. The course evaluation was formative and based on the independent work materials at LMS. At the end of the course, each participant presented a final product to demonstrate the developed competencies along the course (planning of online teaching activities, development of online learning, and evaluation material, among others).

At the last stage of the implementation, the research group implemented an evaluation survey with the goal to obtain feedback about the course.

Table 2. Description of the modular structure of the online training course for the UTALCA-Pilot Project.

Description of the modular structure of the online training course for the UTALCA-Pilot Project.* (* abbreviated version for this journal)	
M1	***Design of Teaching and Learning Process in Engineering Education***
	Unit 1 – Principal and fundamental aspects of Engineering Education. Fundamental concepts associated with teaching and learning in Engineering. Unit 2 - Teaching and Learning Processes in Engineering: Organization and Structuring Structuring the teaching and learning process to meet the requirements of the professional profile of engineering graduates.
M2	***Design of didactic media in online Engineering Education***
	Unit 1 – Function and applications of the didactic media. Concepts associated to didactic media design and some criteria to select didactic media for the own teaching practice. Unit 2 – Basic principles for the elaboration of didactic media. Fundamental educational principles for the development of didactic media in engineering.
M3	***Communicative processes design in online Engineering Education***
	Unit 1 – Introduction to online communicative processes design. Different communicative intentions in online teaching and learning process and their applications in synchronous and asynchronous learning situations. Unit 2 - Organization of the Communicative Processes in the online Engineering Education. Structuring synchronous and asynchronous communicative procedures for teaching and learning situation in Engineering.
M4	***Evaluation of the learning results in Engineering Education***
	Unit 1 –Operationalization of the learning objectives and outcomes. Components that characterize a quality evaluative process, considering these to operationalize the learning objectives and the expected learning outcomes of the learning processes, to make them evaluable according to the learning objectives. Unit 2 – Online evaluation methodologies and strategies, and register of learning outcomes. Different methodologies, strategies, and procedures to design online evaluation processes and registers of the learning outcomes.

2 Evaluation Results of the Teacher Training Course in EP

2.1 Methodology

The research was designed under the quantitative-descriptive method [29, 30]. The main research question was to know how the participants evaluate the course regarding the didactic design, the teaching competencies of the instructors, the usefulness of the achieved learning, and their own learning process. The main objective of the research was to identify the perceptions of the participants of the pilot training course (academic staff) at the Universidad de Talca about their experiences and valuation of the competencies developed during the online course. Based on [22, 24, 27, 28] and their previous experience in engineering pedagogy research projects in Germany and Chile [19, 21], the authors defined categories and developed indicators for the instrument design. The instrument applied was a questionnaire with closed questions organized in five main categories with their respective items. Thus, the five categories assessed were:

1. The course development (in general) [13,19], with 4 items
2. The didactic design of the online course [19, 21], with 9 items
3. The (online) teaching competencies [21, 24, 28, 38], with 5 items
4. The utility of the achieved learning for the online teaching practice in engineering [24, 28, 33], with 12 items
5. Self-assessment of the own performance and learning process [21, 24, 28], with 4 items

Due to the location of the participants (Chile) and the conditions derived by the COVID pandemic, the questionnaire was developed in Spanish with use of the Google questionnaire tool and consisted of 34 items on a five-point Likert scale grouped into the five categories (see Table 3).

2.2 Population, available sample, procedure and reliability.

The study sample was composed of 22 participants at the training course for UTALCA of the Faculty of Engineering. Because two questionnaires were not fully completed, only 20 questionnaires were considered valid for the analysis. The instrument was applied online through the Google questionnaire tool, considering ethical aspects according to the criteria of the Chilean social sciences research and ensuring the anonymity of the participants. In the first part (P1), general information about the participants (gender, subject matter, fields and years of teaching experience, previous teacher training, etc.) was collected. The second part (P2) corresponds to the information collection of the closed questions [29]. The statistical analysis applied was exploratory-descriptive [30] with the use of the software SPSS24. For the total number of questionnaire items (34) included in P2, the total reliability was assessed through Cronbach's alpha and the correlation. The calculated values of Cronbach's alpha for all items was = 0.939 sowings a high internal consistency of the designed research collection tool [29].

2.3 Sample Characterisation

In total, 20 academics answered fully the questionnaire: 25% are women (5) and 75% men (15). Regarding the distribution by age group, 85% (17) of the participants of the survey are between 30-39 years old, 10% (2) are between 40-49 years old and 5% are older than 50 years (1). With regard to the distribution of the participants by engineering school, most of them work in mechanical engineering (35%) and industrial engineering (25%). The same number of participants work in the fields of computer engineering (15%) and electrical engineering (15%), and two participants work in mining engineering.

Concerning the years of teaching experience, 50% have between 0-5 years (10), 35% have between 6-10 years (5) and 15% more than 10 years (3). Of the total number of participants, 100% have already participated in university teaching training course.

2.4 Results of UTALCA´s survey.

The results about the perception and opinion of the survey respondents regarding the evaluation of the training course according the designed five categories are presented in this section. Table 3 exposes the results for the 34 considered items.

Table 3. Survey results by categories

ITEMS	x̄	S.D	IT-Cr	Average		
				Low	***Med***	***High***
				[1][2]	***[3]***	***[4][5]***
Category 1: Evaluation of the course development (in general)						
Satisfaction with the information about course objectives.	4,65	0,49	0,4	0%	0%	100%
Satisfaction with the development of the course.	3,85	0,75	0,731	0%	35%	65%
Satisfaction with the duration of the course.	3,25	1,12	0,133	20%	35%	45%
Satisfaction with course progress and achievements.	3,5	1,32	0,848	20%	30%	50%
Category 2: Evaluation of the didactic design of the online course						
Satisfaction with course modality (online) for the learning process.	3,95	1,05	0,671	10%	25%	65%
Satisfaction with the use of the online platform and learning resources.	4,35	0,81	0,212	0%	20%	80%
Satisfaction with units and learning materials on the platform.	4,5	1	0,543	10%	5%	85%
Satisfaction with learning activities for autonomous professional development.	4,1	0,97	0,343	10%	10%	80%
Satisfaction with synchronous learning activities.	4	1,21	0,619	20%	10%	70%
Satisfaction with learning materials and instruments for the online competencies development.	4,15	0,88	0,825	10%	0%	90%
Satisfaction with planning and time of each module.	3,95	1,15	0,324	10%	5%	85%
Satisfaction with learning activities for the online teaching reality.	4,05	1,15	0,813	20%	0%	80%
Satisfaction with the applicability of contents for the own teaching reality.	3,5	1,39	0,773	15%	45%	40%
Category 3: Evaluation of (online) teaching competencies						
Satisfaction with different teacher competencies.	4,3	0,92	0,52	10%	0%	90%
Evaluation of the motivation and teaching organization of teachers.	3,95	0,99	0,622	10%	20%	70%
Clarity of teachers to guide the teaching-learning process.	4,05	1,05	0,765	10%	20%	70%
Evaluation of teacher´s attitude for monitoring the learning process and assessment.	4,2	0,77	0,519	5%	5%	90%
Satisfaction with teacher´s attitude for monitoring the learning process and assessment.	4,2	0,95	0,522	5%	5%	90%
Category 4: Evaluation about the utility of the achieved learning for the online teaching practice in engineering						
Utility of contents and methods for the own online teaching practice.	4,3	0,87	0,599	0%	25%	75%
Satisfaction with the applicability of the contents on real teaching context.	4,25	0,98	0,513	10%	5%	85%

Applicability of the achieved learning in the online teaching.	3,85	0,88	0,345	0%	45%	55%
Usefulness of contents for the development of different teacher competencies.	4,35	0,59	0,59	0%	5%	95%
Usefulness of workshops for learning process and competencies development.	4,2	1,2	0,406	10%	0%	90%
Usefulness of asynchronous learning activities for competencies development.	3,95	1,15	0,441	20%	5%	75%
Usefulness of synchronous learning activities for the online competencies development.	4,2	0,83	0,665	0%	25%	75%
Usefulness of each module for the online professional development.	3,35	0,99	0,37	10%	55%	35%
Usefulness of each module for the online teaching reality in engineering.	3,25	1,07	0,695	35%	15%	50%
Utility of the achieved learning for the teaching practice.	4,25	1,07	0,753	10%	15%	75%
Utility of the achieved learning for the work with other colleges.	3,85	1,35	0,802	20%	5%	75%
Usefulness of the achieved learning for professional development.	3,75	0,91	0,769	0%	55%	45%
Category 5: Self-assessment of the own performance and learning process						
Own commitment and motivation with the course.	4	0,8	0,448	0%	30%	70%
Motivation for a new training in EP.	4,1	1,12	0,606	10%	25%	65%
Satisfaction with the participation in the course.	3,75	1,12	0,837	20%	15%	65%
Dissatisfaction with the participation in the course.	2,65	1,5	0,102	55%	10%	35%

$\bar{x}$ = Mean; S.D. = Standard Deviation; IT-Cr= Corrected item-total correlations.

In general, 19 aspects were as high (4 points) or very high (5 points) valuated (more than 4.0 of average). The high-valuated aspects are related to the category "Evaluation of teaching competencies" and "Evaluation of the didactic design of the online course" (average of 4.14 and 4.06 respectively in all items). Specifically, 13 indicators of the categories were valuated with more than 80% of the preferences as high (4 points) or very high (5 points). An example for this is the items: "Satisfaction with the applicability of the contents on real teaching context", "Usefulness of contents for the development of different teacher competencies", "Satisfaction with learning activities for autonomous professional development", "Usefulness of workshops for the learning process and competencies development", "Satisfaction with learning materials and instruments for the online competencies development" and "Satisfaction with learning activities for the online teaching reality". The lowest category was "Self-assessment of the own performance and learning process", where the item "Dissatisfaction with the participation in the course" was evaluated as very low or low with 55% of the preferences. Other lowest-rated (low and very low: average lower than 3.75) items are "Satisfaction with the duration of the course", "Satisfaction with course progress and achievements" and "Usefulness of each module for the online teaching reality in engineering".

Another important aspect is the perception of the participants about the relevance of the different items by gender. Figure 2 shows the differences between the participants related to the relevance of the indicators. In general, men gave a high average of preferences in the valuation of all items than women (93.06% and 87.45 respectively). For the female participants of the teacher training course, most of the items were low valued, except for example the items “Satisfaction with different teacher competencies”, "Usefulness of the workshops for the learning process and competence development", "Satisfaction with synchronous learning activities" and "Usefulness of asynchronous learning activities for competence development". In particular, "Dissatisfaction with course participation" was rated higher than men, showing more dissatisfaction with the course.

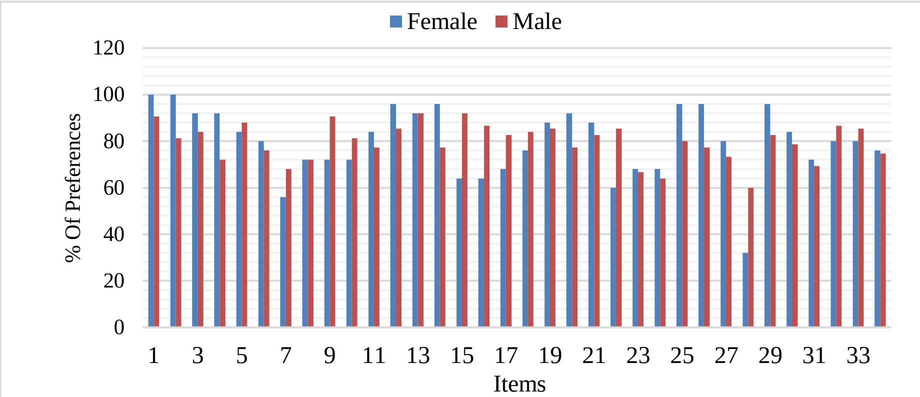

Fig. 2. Preferences of the different items related to the evaluation of the online training course in online EP by gender.

By grouping the survey respondents by engineering fields (Figure 3), the participants from Computer engineering and Mining engineering had the highest average of preferences in the valuation of all items (89.41% and 88.43 respectively), the participants from Industrial engineering had the lowest average with 71.88% (Mechanical engineering with 78.24% and Electrical engineering with 81.37%).

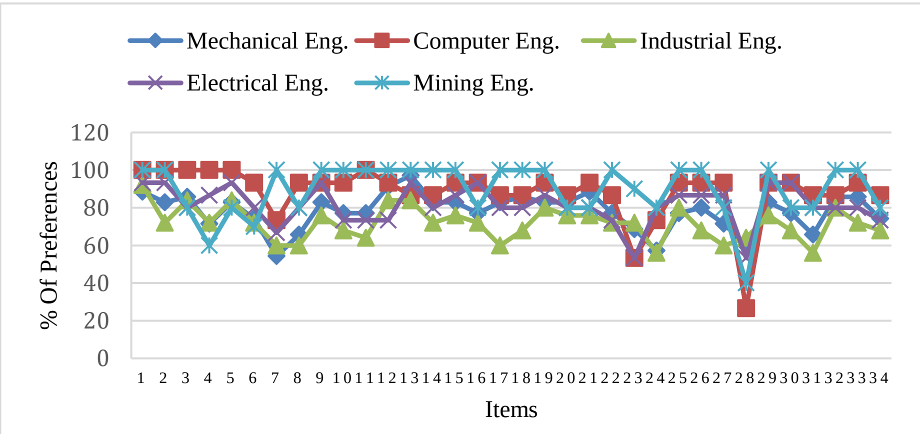

Fig. 3. Preferences of the different items related to the evaluation of the online training course in online EP by engineering fields.

The relevance of the items for the participants by years of teaching experience is presented in Figure 4. For the participants with up to 5 years of teaching experience, the average value of preferences in all items was 83.82% and for participants with up to 10 years was 78.32%. For participants with between 10 and 20 years of teaching experience, most of the "indicators" were low valued (average of 66.18% in all items). With more than 20 years of teaching experience, the average of the value of all items was 76.47%.

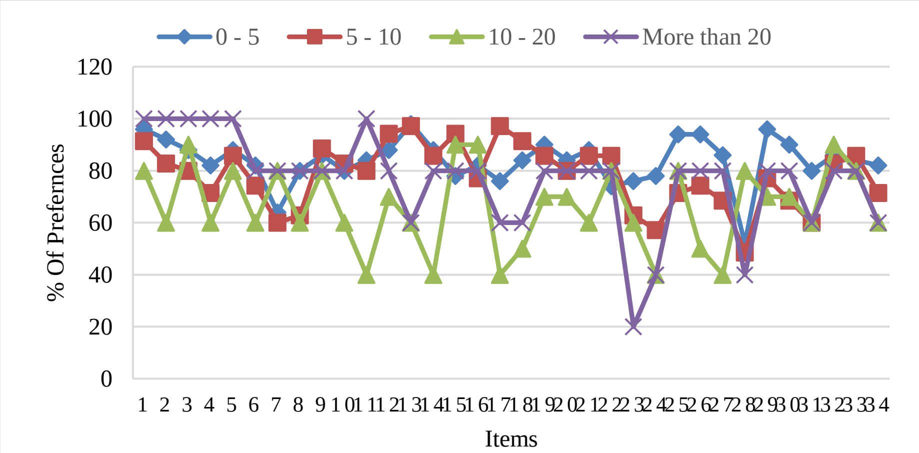

Fig. 4. Preferences of the different items related to the evaluation of the training course in online EP by years of teaching experience.

3 Discussion and conclusion

Based on the IGIP Curriculum developed by the TU Dresden [21] and the immediate needs and demands for effective online education during the COVID-19 pandemic [22, 23, 24, 25, 26] the pilot training course in e-learning modality "Introduction to the Online Teaching and Learning in Engineering" for the teaching staff of the Engineering Faculty at a Chilean university was implemented.

The main goal of the study was to identify the perception of the participants of this online course (teaching staff) about their valuation of the competencies developed during a course specifically oriented in online EP. Concerning the categories "Evaluation of the course development (in general)", "Evaluation of the didactic design of the course", "Evaluation of the teaching competencies" and "Evaluation of the teaching competencies" - in line with previous studies [26, 33, 34] - all aspects related were as high valuated. The item "Dissatisfaction with the participation in the course" was valuated as low with 55% of the preferences. These results coincide with the comments of the participants during the teaching-learning activities. The findings confirm the relationship between the average of evaluations with the years of teaching experience of the participants [33, 34]: participants with up to 5 years of experience evaluated the course better, and participants with over 10 years of teaching experience tend to evaluate the course lower; something that has already been demonstrated in the literature [33]. Other relevant findings are the perception of the participants about the relevance of the different items by gender. In general, men gave a high average of preferences in the valuation of all items than women. These results coincide with the findings of previous studies [34-36]. The item with the lowest relevance ("Dissatisfaction with the participation in the course") is related to the category "Self-assessment of the own learning process". This can be explained by the fact that most participants experienced an increase in the amount of new "tasks", especially caused by the COVID-19 pandemic, such as the adaptation to online learning and assessment, development and application of educational technologies, and ICTs. For this reason, they expressed their interest and need to dedicate more work hours to the course. However, for many of them, this was not possible, as they also had to respond to other urgent "tasks", e.g. in the field of research.

The literature specialized in online learning showed that in the Chilean context (before the pandemic) the e-learning modality already existed in few universities (the whole teaching and learning process and assessments were carried out through virtual platforms, ICTs, software among others). Only 14 universities of a total of more than 60 offer online training programs. Currently, only 6 universities offer undergraduate programs, but in a special form of continuity of previous studies [37]. During the COVID-19 pandemic, this reality changed radically, and therefore, the teaching competencies of the teachers had to be rapidly updated. The results and findings of the present research show the evaluations of this Chilean university teaching staff about an online training course and reveal several aspects that should be considered and improved for future university training programs for academic staff, thus serving to analyze (case study) the teachers' experience of a training course specifically oriented to EP. On the other hand, these results are also a (scientific) record of teachers' experiences at a time of major adaptations when their teaching competencies are still being tested. It is important to mention that in the Chilean context the number of research studies focusing on teachers' experiences in university training courses and online teacher training is quite small. Despite the limited time spent working on the pilot training course, the results of the evaluation carried out by the participating academics show the positive effects that this type of pilot course specializing in PE can have.

However, due to the "pilot nature" of this project and the small sample of participants (22 at the course and 20 at the survey), the authors consider that the findings cannot be generalized, therefore some questions remain open about the impact and valuation that this type of training course can have on others academics (for instance from other universities). On the other hand, the participants recognize that a course like this should have more time to deepen the contents and the development of online teaching and learning resources for their courses. For this reason and as future work, a more complete online EP course will be implemented during 2021 based on the same modules, but with more working time and new participants. In addition, and to incorporate consistency in the research results, the authors will implement qualitative and quantitative methods for the evaluation of the new online training course in EP.

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Massive Open Online Courses Model with Self-directed Learning to Enhance Digital Literacy Skills

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Abstract—The Massive Open Online Courses with Self-Directed Learning model (SDL MOOCs model) was developed by researchers as a tool to promote learning outside the classroom for digital age learners. The concept is based on the combination of new technologies and teaching methods in order to create new ideas and innovations that can enhance learning for modern learners and, at the same time, respond directly to their learning experiences. Thus, instructors are responsible for organizing the environment and creating learner-friendly learning materials using existing technology, which can lead to a digital university learning society. The contributions of this article are: 1) to synthesize the conceptual framework of the SDL MOOCs model, 2) to develop the SDL MOOCs model, 3) to develop instructional processes with self-directed learning to enhance digital literacy skills (SDL process), and 4) to study the results of developing the SDL MOOCs model. The suitability of the SDL MOOCs model was assessed by 15 experts with extensive experience in the fields of online education design and development, computer science and information and communication technologies for education. The results of this research show that: 1) the SDL MOOCs model consists of 4 main elements (input factors, instructional process, output, and feedback), 2) the SDL process consists of 4 stages (preparation, web-based self-directed learning, post-testing, and certificate approval), and 3) the developmental adequacy of the SDL MOOCs model is at a very high level.

Keywords—massive open online courses, self-directed learning, digital literacy skills, digital university

1 Introduction

Innovative teaching methods of modern university teachers in the Era 4.0 are so important that modern teachers should pay attention to them and apply them these days. The current study aims to assess the overall advancement of research on digital technologies in Education 4.0. The main agenda is to find the direction and improvement of research related to the educational structure and change in the learning process of digital technologies. The recent development of digital technologies in many fields is prompting researchers to improve the quality of instruction by using these resources [1]. The Office of the Higher Education Commission (OHEC), Ministry of Education, in collaboration with the Office of the Permanent Secretary of the Ministry of Information and Communication Technology, has set up a project to develop Thai e-universities and is pioneering the development of a central system for Thailand's massive open online courses (MOOCs). Thailand's Massive Open Online Courses or Thai MOOCs, which will be used as an information technology architecture to host the "Lifelong Learning Space", which should promote self-learning [2]. At the same time, it will greatly improve the quality of social services, especially in the field of education. The exchange of knowledge, interactivity through social networks and the simultaneous consumption of multiple media channels allow Thai people to have unlimited access to information [3].

Massive Open Online Courses (MOOCs), or open public education system [4], are the format used to present a variety of lessons on different topics via the Internet network; thus, learners must register and then learn said lessons online via websites and web applications. MOOC content is produced primarily for teaching large groups of people, rather than specific content intended for classroom teaching that requires analysis of individual learners. Marrhich et al [5] mentioned the benefits of integrating MOOCs into an academic setting, including convenience, flexibility, accessibility, and increased completion rates. In addition, MOOCs provide learners with access to challenging courses

Self-directed learning (SDL) is a popular form of learning today, as information technology plays an important role in the learning of new generation learners. This form of learning emphasizes active learning through media and information technology. This form of learning emphasizes active learning through media and information technology in order to encourage learners to engage in self-directed learning experiences. Learners are also expected to develop more skills and be able to make their own learning plans, self-study, search for learning resources, and assess their learning outcomes on their own, with the help and support of instructional activities [6].

The fourth industrial revolution is driving a paradigm shift in educational policies and reforms in many countries. Developed nations are steadily adapting to technological change, filling the skills gap required, and opening doors to new resources [7]. Digital transformation is occurring in all fields, including higher education, bringing new challenges and opportunities for higher education development [8]. Digital literacy skills are associated with the understanding and application of digital technologies that encourage learners to develop lifelong learning. These skills should also enable the creation of a learning society based on the application of information technologies. In addition, digital literacy skills are seen as the 21st century skills needed by learners. Creating new knowledge is at the heart of all basic literacies. Similarly, generating new information digitally by adapting, applying, designing, inventing, or writing information is also central to digital literacy [9].

According to the above principles and reasons, the researcher has the idea of developing the model of massive open online courses with self-directed learning to enhance digital literacy skills (SDL MOOCs model) as a guideline to further develop the MOOCs system with self-directed learning to promote online learning outside the classroom through web applications. In addition, learners are expected to be self-directed, which responds to student-centered learning policies and lifelong learning in Education 4.0.

Specifically, this article makes the following four contributions:

1. A comprehensive synthesis of the conceptual framework of the massive open online course model with self-directed learning to enhance digital literacy skills.
2. The development and implementation of a massive open online course model with self-directed learning to enhance digital literacy skills.
3. Implementing instructional processes with self-directed learning to enhance digital literacy skills.
4. A discussion of the results of developing the massive open online course model and teaching processes with self-directed learning to enhance digital literacy skills.

The structure of this article is as follows. Section 2 presents the methodological aspects of the study. Section 3 presents the main results and discusses the relevance of the proposed approach. Section 4 gives the main conclusions of this work, as well as some research perspectives.

2 Research methodology

This research concerns the development of a model of massive open online courses (MOOCs) with self-directed learning (SDL) to enhance digital literacy skills. The development concept presented here is mainly based on the approach and design of the ADDIE instructional system model [10]. Furthermore, the theories of MOOCs and self-directed learning are applied in said design and development.

2.1 Population

The population for this research includes the 15 experts who have experience in the areas of web-based instructional design and development, computer science, and information and communication technologies for education.

2.2 Data collection and analysis

In developing the model of MOOCs with SDL to enhance digital literacy skills in digital universities, the researchers relied on the following tools for development and data collection: (1) the developed model of massive open online courses with self-directed learning, (2) the teaching processes with self-directed learning to enhance digital literacy skills (SDL process), (3) the design adequacy evaluation form of the developed model of massive open online courses, consisting of scoring questions (5 levels), and (4) the Design Adequacy Assessment Form for Developed Instructional Processes with Self-Directed Learning to enhance Digital Literacy Skills, consisting of scoring questions (5 levels). Statistics used for data analysis include mean (Mean) and standard deviation (SD).

2.3 Design and methodology

As shown in Figure 1, the methodology of this research is divided into 4 stages.

At the first stage, the researcher studied the theories, articles, and literatures related to instructional system [10–12], massive open online courses [4, 13–15], self-directed learning [6, 16], digital literacy skills [9, 17–19], achievement, and satisfaction. After that, the relevant theories were analyzed and synthesized in order to find out the correlation of the theories above to identify the conceptual framework of research.

At the second stage, the researcher designed the structure and elements of the open online courses model based on the concepts of instructional system design that consists of systematic elements, processes and steps (system approach) [10–12], combined with instructional elements of massive open online courses [4, 13–15].

At the third stage, it is concerning the design and development of instructional processes with self-directed learning to enhance digital literacy skills, which is based on the theories of self-directed learning [6, 16]. These instructional processes would be used as a prototype for further application in the system of open online courses (SDL MOOCs system), which would be further developed.

At the fourth stage, this is the stage that is related to the study of suitability on the development of the SDL MOOCs model and instructional processes with self-directed learning to enhance digital literacy skills (SDL Process). The study of suitability herein was conducted by the 15 experts specialized in the fields of design and development of web-based instruction, computer science, and information and communication technology for education. The criteria for data analysis are on the basis of interpretation of Kanasutra [20].

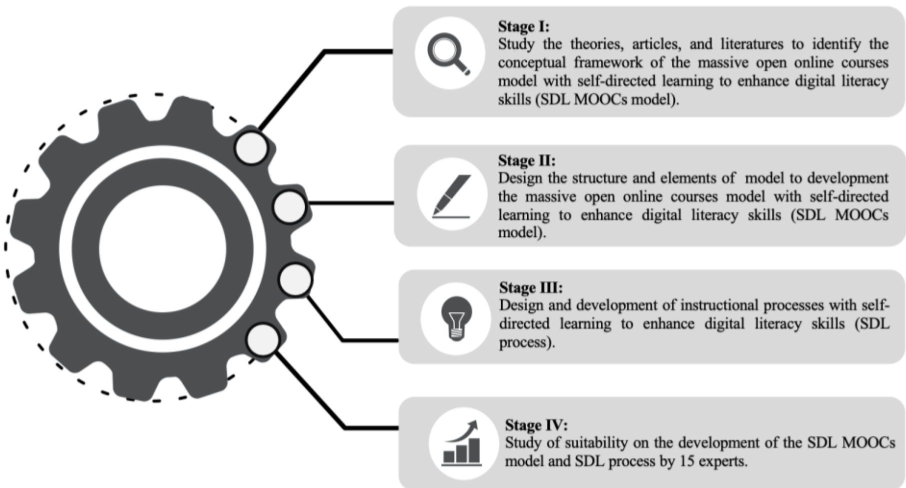

Fig. 1. Research methodology

3 Main results and discussion

3.1 Relevant theories to be used as a conceptual framework for the model of MOOCs with SDL to enhance digital literacy skills

Correlation between educational system theories and the development of the SDL MOOCs model. The educational system is considered as a presentation of concepts applied to the management of different elements in such a way that they are correlated to each other and lead to the desired goal. This requires the ability to distinguish said essential elements and manage their correlation so that they can promote each other in an orderly manner [10–11]. The design of an educational system consists of four elements: (1) the input, which refers to the elements involved in the introduction of something into the system, (2) the process, which is the management of the correlation of the elements within the system so that they correlate with each other and pave the way for the achievement of the objective, (3) the output, which is the result of the work process, and (4) the feedback, which is the information obtained by analyzing the relationship between the output and the objectives, which will help to improve the process and the input, so that they are consistent with the output [12]. In this study, the appropriate pedagogical elements of the educational system are in accordance with the developed model of open and massive online courses, representing its clear structure. It is possible to distinguish the elements related to the developed model of massive open online courses, which can improve digital literacy skills.

Correlation of theories of MOOCs with the development of the SDL MOOCs model. MOOCs are the use of distance learning technology and open online learning innovation (open education) [21] as components of the developed massive open online courses model. The primary objective thereof is to accommodate a number of users with no limitation of age and knowledge background. The system also allows learners all over the world to access any subjects based on their own aptitudes or interest [4] free of charge, regardless of what institutions they belong to. In this research, the appropriate instructional elements of massive open online courses were studied and used as guidelines to develop the massive open online courses model herein. There are 4 elements [13–15], i.e., (1) M: Massive refers to something very large, (2) O: Open refers to free admission, (3) O: Online refers to online working, and (4) Cs: Courses refer to a variety of courses. It is also concerning a study of fundamental principles of the massive open online courses so that the massive open online courses model to be developed herein could have the clear-cut elements and approaches and could efficiently promote the learning society by making use of instructional technology and learning innovation.

Correlation of theories of SDL with the development of the SDL MOOCs model. The SDL is a learning model that encourages learners to be responsible for developing their own learning plans based on their skills and abilities. Learners will seek knowledge and experiences based on their needs, identify their learning goals, make their learning plans, complete the learning activities in the learning plans, and self-assess their learning to achieve their goals [6]. In this research, the process of teaching with self-directed learning [16] was studied and synthesized into steps to be used in the process of teaching with self-directed learning to enhance digital literacy skills (SDL process), which was then applied in the development of the SDL MOOCs model.

Correlation of theories of digital literacy skills with the development of the SDL MOOCs model. Digital literacy skills are considered one of the 21st century learning skills that promote understanding of how to use digital technology, so that learners can have lifelong learning, leading to a learning society that can use information technology. In this study, the correlation of desired characteristics of digital literacy skills [18, 19], related to relevant theories, was considered and used as an outcome of the developed model of MOOCs.

Correlation of theories of achievement and satisfaction with the development of the SDL MOOCs model. The learning outcome is the result of the learning process in the developed model of massive open online courses. It is the result of learners' knowledge, represented as a score or level of competence derived from tests or exercises [22]. Learning success is, therefore, an important assessment that can confirm learners' knowledge and abilities obtained from lessons. Satisfaction is the result in the form of attitudes and feelings that appear when the results are achieved as expected. In this research, the result obtained during the learning process of the developed massive open online course model (SDL Process) was studied and used as feedback to improve the effectiveness of the developed MOOC model. With reference to the synthesis of theories and the correlation of relevant theories above, the conceptual framework for this research was derived as shown in Figure 2.

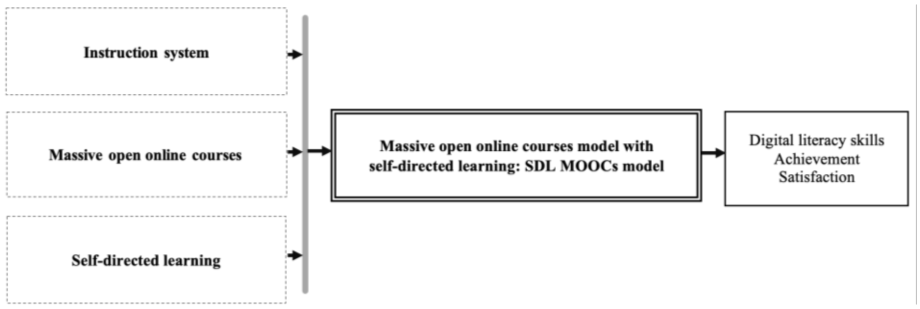

Fig. 2. Conceptual framework of the SDL MOOCs model

3.2 Results of the development of the massive open online courses model with self-directed learning to enhance digital literacy skills

In developing the model of massive open online courses with self-directed learning to enhance digital literacy skills (SDL MOOCs model), the researcher relied on the concepts of instructional systems design that consist of systematic elements, processes, and steps (systems approach), combined with the pedagogical elements of MOOCs, as shown in Figure 3.

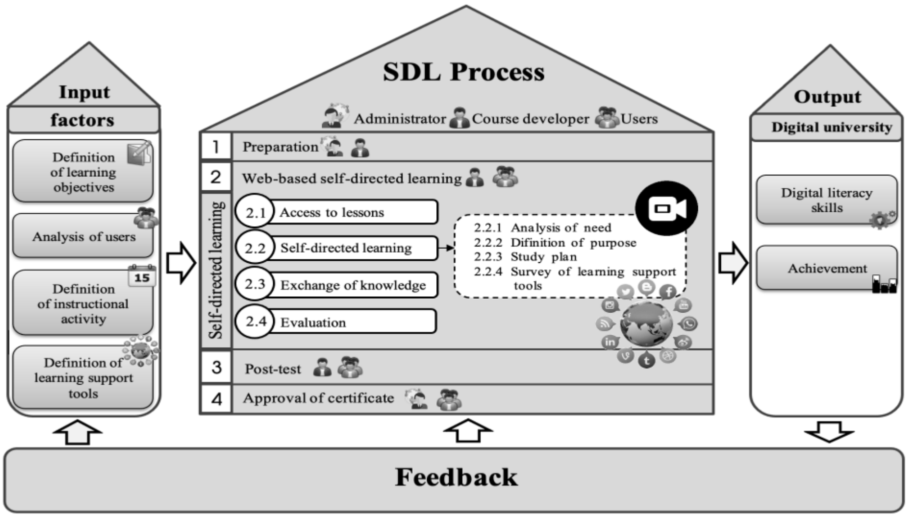

Fig. 3. The SDL MOOCs model to enhance digital literacy skills

According to figure 3, the massive open online courses model with self-directed learning consists of 4 main elements with the following details.

1. Input factors, i.e., definition of learning objectives, analysis of users, definition of instructional activity, and definition of learning support tools, can be summarized as below:

- **Definition of learning objectives:** It is intended to find out the expected learning behaviors by means of evaluation after studying specific contents of the lessons.
- **Analysis of users:** It is a kind of basic data analysis of users, such basic knowledge, basic skills, learning methods, interests, aptitudes, learning objectives, etc. The objective of this section is to design a learning system that is suitable and meets the needs of users.
- **Definition of instructional activity:** The management of suitable activities is an important element that enables users to participate in learning and interact with the developed lessons and systems. Thereby, the said activity can be applied to develop their own learning process.
- **Definition of learning support tools:** Learning support tool is believed to encourage users to achieve their desired learning goals.

2. Instructional processes (SDL Process), i.e., preparation, web-based self-directed learning, post-test, and approval of certificate, can be explained in detail as follows:

- **Preparation:** This stage consists of 3 steps, i.e., system introduction, sign up to the system, and selection of subjects (with/without cost)
- **Web-based self-directed learning:** It is a kind of learning stage that allows the learners to be responsible for setting their own learning plans based on their skills and competencies. Basically, the web-based self-directed learning is on the basis of

learning plans related to the learners' experiences, and the learners shall control this process by themselves. Thereby, this stage includes 4 steps, i.e., (1) access to lessons, in which users are encouraged and motivated to become interested in the courses, starting with introduction to course descriptions, course contents, and the goals to accomplish at the end of the study, (2) self-directed learning, which is concerning the steps of studying the contents of the lessons and conducting instructional activities according to the self-directed learning process. The users shall participate in learning and interacting through a variety of learning support tools such as web forums, social media, etc., (3) exchange of knowledge, which focuses on encouraging the users to have interaction to brainstorm and exchange knowledge in order to bring about new ideas, and (4) evaluation.

- **Post-test:** This stage is concerning a procedure to measure learning achievement of the users after studying all the provided contents and all the activities in the course syllabus. The said learning achievement is measured by taking multiple-choice tests, open-ended exams, or other formats of tests, depending on the discretion of course developers. Also, the evaluation criteria for a certificate are set up by the course developers as well.
- **Approval of certificate:** This is the process of verifying the information by considering whether the users are qualified according to the criteria set by the course developers or not. In case the specified conditions are met, the system will approve that the users are eligible to receive a certificate.

3. Output, i.e., digital literacy skills, achievement, and satisfaction, includes the following details:

- **Digital Literacy Skills:** This refers to the skills of understanding and application of digital technology that encourage learners to achieve lifelong learning, which can lead to learning society by making use of such information technology as Media Literacy, Technology Literacy, Information Literacy, Visual Literacy, Communication Literacy, and Social Literacy.
- **Achievement:** This means the learning achievement that the learners will receive on the condition that they must be qualified as to the criteria provided by the course developers.
- **Satisfaction:** It refers to the satisfaction of users towards the learning through the developed SDL MOOCs model.

4. Feedback: It is the use of data that are derived from the output stage as feedback data. The objective of feedback is to improve the learning process and input factors so that they shall have more suitability and more efficiency.

Table 1. Results of the synthesis of desired characteristics from digital literacy skills [18, 19]

Digital literacy	Digital literacy skills	Desired characteristics
Digital Literacy is considered one of the life skills which are associated with one another. The said skills include Media Literacy, Technology Literacy, Information Literacy, Visual Literacy, Communication Literacy, and Social Literacy.	1. Media literacy	The results reflect the ability of learners in terms of access, analysis, and production of media based on the understanding, and communication of ideas in an effective manner.
	2. Technology literacy	The results represent the expertise of using technology in learning and communication.
	3. Information literacy	The results reflect the ability to search the required information online, to select appropriate information, and to use information for data retrieval.
	4. Visual literacy	It is a reflection of learners' ability to understand and interpret what they view, including analysis, learning, and showing their opinions.
	5. Communication literacy	It reflects the ability to exchange knowledge with others in the society via social media or online learning materials.
	6. Social literacy	It is a reflection of ability to work hand in hand with others in order to achieve the goals.

3.3 Results of the development of instructional processes with self-directed learning to enhance digital literacy skills

In the teaching processes with self-directed learning to improve digital literacy skills (SDL process), the researcher defined the learning stages in the SDL MOOCs model, which was synthesized from the self-directed learning process [6], as shown in Figure 4.

Figure 4 represents the instructional processes with self-directed learning to enhance digital literacy skills (SDL Process). Thereby, the researcher determined the following 4 learning stages within the developed massive open online courses model, including (1) Preparation, which consists of 3 steps, i.e., system introduction, sign up to the system, and selection of subjects (with/without cost), (2) Web-based self-directed learning, in which the researcher applied the theories of self-directed learning to define learning steps in the developed massive open online courses model. The said learning steps include access to lessons, self-directed learning, exchange of knowledge, and evaluation. At this stage, the researcher also performed a contextual analysis to determine the elements of instructional management to be further used to support the web-based self-directed learning, i.e., learning objectives, contents, roles of course developer, roles of users, instructional activity, and learning support tools, (3) Post-test, which is designated to measure learning achievement after the users have completed all of the required course and activities, and (4) Approval of certificate.

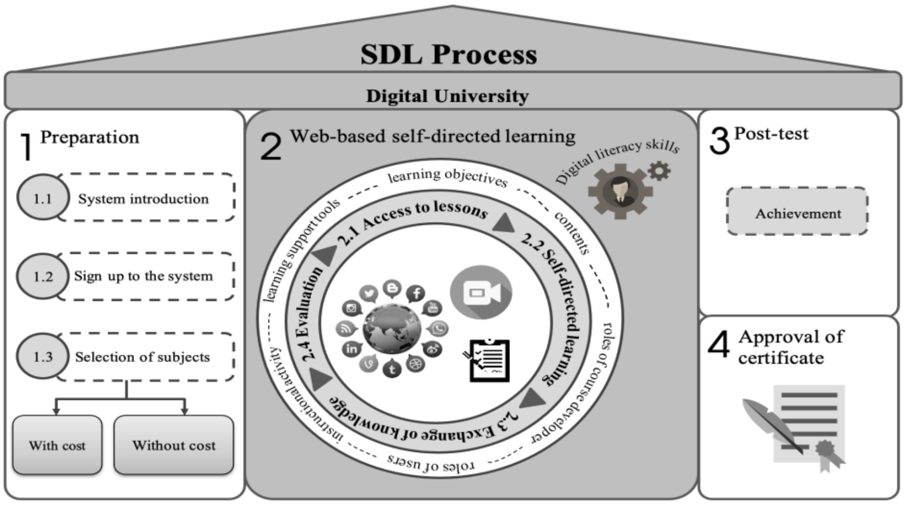

Fig. 4. Instructional processes with self-directed learning to enhance digital literacy skills

3.4 Results of evaluation on the suitability of the development of the massive open online courses model and instructional processes with self-directed learning to enhance digital literacy skills

The study of suitability of the development of the massive open online courses model with self-directed learning to enhance digital literacy skills (SDL MOOCs model). The study of suitability herein was conducted by the 15 experts and the criteria for data analysis (see Table 2) are on the basis of interpretation of Kanasutra [20].

According to the development of the SDL MOOCs model, the results are detailed in Table 3. In reference to Table 3, it is found that the overall suitability of the development of the SDL MOOCs model (overall elements) is at very high level (Mean = 4.93, SD = 0.30). Accordingly, this can probably be concluded that the SDL MOOCs model has all required elements, and it can be employed as a guideline to develop the massive open online courses that can encourage the learners to initiate their self-learning.

Table 2. Range of average scores and interpretation of results

Average score range	Interpretation of results
4.50 - 5.00	Very high level of suitability
3.50 - 4.49	High level of suitability
2.50 - 3.49	Average level of suitability
1.50 - 2.49	Low level of suitability
1.00 - 1.49	Very low level of suitability

Table 3. Results of the SDL MOOCs model development adequacy assessment model (overall elements)

Description	Results		Interpretation
	Mean	***SD***	
1. The massive open online courses model complies with fundamental concepts used to develop the instructional system.	4.93	0.26	Very high
2. The range of coverage of elements in the massive open online courses model conforms to the main elements of the instructional system.	4.80	0.56	Very high
3. The organization of elements in the design of the massive open online courses model is clear with continuity.	4.93	0.26	Very high
4. The organization of elements in the design of the massive open online courses model is suitable and easy to understand.	5.00	0.00	Very high
5. The overall elements in the massive open online courses model are complete, covering all requirements and complying with the objectives of this research.	5.00	0.00	Very high
Overall	4.93	0.30	Very high

Referring to Table 4, it is evident that the overall suitability of the development of the SDL MOOCs model is at very high level (Mean = 4.91, SD = 0.31). It can be summarized the SDL MOOCs model can be applied as a guideline to further develop the massive open online courses, which can be used as an effective tool for learners to promote their self-learning. This is in line with the research of Chatwattana and Nilsook [23], who said that the design of concepts applied the principle of instructional system, and the principle of e-learning design can be support learning in students.

Table 4. Results of evaluation on suitability of the development of the SDL MOOCs model

Description		Results		Interpretation
		Mean	***SD***	
Input factors	Definition of learning objectives	4.93	0.26	Very high
	Analysis of user	4.93	0.26	Very high
	Definition of instructional activity	4.93	0.26	Very high
	Definition of learning support tools	4.87	0.35	Very high
Instructional processes (SDL Process)	Preparation	4.93	0.26	Very high
	Web-based self-directed learning	4.87	0.35	Very high
	Post-test	4.93	0.26	Very high
	Approval of certificate	4.87	0.35	Very high
Output	Digital literacy skills	4.80	0.41	Very high
	Achievement	5.00	0.00	Very high
	Satisfaction	4.93	0.26	Very high
Feedback	Achievement scores	5.00	0.00	Very high
	Opinions from experts	4.80	0.56	Very high
Overall		4.91	0.31	Very high

According to Table 5, it is obvious that the overall suitability of the development of instructional processes with self-directed learning to enhance digital literacy skills is at very high level (Mean = 4.91, SD = 0.29). It can be summarized that the instructional processes with self-directed learning can promote the learners to have more self-learning experiences, more digital literacy skills, and more achievement. This is in line with the research of Kateryna et.al [24], who said that the digital literacy can be used to communicate and solve problems for effective and creative self-realization in education, work, and society. It is also consistent with the research of Gamage et al. [25], saying that the application of interactivity and collaboration in their instructional design can promote skills in learning. In addition, it is in compliance with the research of Wajeesiri [26], saying that the application of self-directed learning process to design an instructional model can promote analytical thinking and meanwhile increase learning achievement.

Table 5. Results of evaluation on suitability of the development of instructional processes with self-directed learning to enhance digital literacy skills

Description		**Results**		**Interpretation**
		Mean	***SD***	
Preparation	System introduction Sign up to the system Selection of subjects	4.93 4.93 4.87	0.26 0.26 0.35	Very high Very high Very high
Web-based self-directed learning	Access to lessons Self-directed learning Exchange of knowledge Evaluation	4.93 4.87 4.93 4.93	0.26 0.35 0.26 0.26	Very high Very high Very high Very high
Post-test		4.93	0.26	Very high
Approval of certificate		4.87	0.35	Very high
Overall		4.91	0.29	Very high

Table 6 shows that the overall suitability of the SDL MOOCs model in terms of practical use is at very high level (Mean = 4.95, SD = 0.22). This can be concluded that the massive open online courses model with self-directed learning has suitable elements, stages, and processes. Also, the model can be applied as a guideline to further develop the massive open online courses with self-directed learning in order to promote the learners to initiate self-learning in digital universities, while enhancing their digital literacy skills and achievement in an efficient manner. According to the summary of results above, this research is compliant with that of Tan, Yu and Gong [27], who mentioned that MOOCs are a new form of education that can lead to the reform of higher education system, initiating the enhancement of instruction quality in universities. It is also consistent with the research of Anisimova, Ganeeva and Sharafeeva [28], who said digital skills are practical and vital to the real life. These skills can promote the development of competency and creativity, and can also generate self-confidence.

Table 6. Results of evaluation on suitability of the SDL MOOCs model in terms of practical use

Description	Results		Interpretation
	Mean	***SD***	
1. Suitability of the massive open online courses model to enhance digital literacy skills.	5.00	0.00	Very high
2. Suitability of stages and processes in self-directed learning to enhance digital literacy skills.	4.93	0.26	Very high
3. Possibility of the massive open online courses model to be used as a guideline to develop the system of massive open online courses (SDL MOOCs System).	5.00	0.00	Very high
4. Possibility of the massive open online courses model for practical use.	4.87	0.35	Very high
Overall	4.95	0.22	Very high

4 Conclusions

The massive open online courses model with self-directed learning to enhance digital literacy skills (SDL MOOCs model) is considered a tool to promote learning outside the classroom for learners in the digital age. The concept is based on the combination of new technologies and teaching methods with the aim of creating new ideas and innovations that can promote learning among modern learners, and meanwhile can respond directly to their learning experiences. The model consists of 4 main elements: (1) Input factors, i.e., definition of learning objectives, analysis of users, definition of instructional activity, and definition of learning support tools, (2) Instructional processes (SDL Process), which consists of 4 steps: preparation, web-based self-directed learning, post-test, and approval of certificate, (3) Output, i.e., digital literacy skills, achievement, and satisfaction, and (4) Feedback, i.e., opinions of experts and achievement scores.

The suitability of the SDL MOOCs model was assessed by 15 experts. The results of this research show that (1) the suitability of the development of the SDL MOOCs model (overall elements) is at very high level (Mean = 4.93, SD = 0.30), (2) the suitability of the development of the SDL MOOCs model is at very high level (Mean = 4.91, SD = 0.31), (3) the suitability of the development of SDL Process is at very high level (Mean = 4.91, SD = 0.29), and (4) the suitability in terms of practical use of the development of the SDL MOOCs model is at very high level (Mean = 4.95, SD = 0.22).

This research can be applied as a guideline to design and develop massive open online courses that can promote learning among learners and generate self-development, satisfying student-centered learning policies and lifelong learning in Education 4.0. In addition, this can lead to a learning society in which the concepts, elements, and processes of self-directed learning are used as guidelines for designing teaching processes in open and massive online courses, encouraging learners to have learning experiences, have skills and abilities to implement their own learning plans, and be able to self-assess. At the same time, teaching activities are provided to promote learning and interaction among learners via social media networks, which can enable learners to have more digital literacy and learning achievements.

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Education of Future Green Engineers for Achieving Sustainable Development in Green Manufacturing Industry

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Abstract—The article is devoted to education of future green engineers for achieving sustainable development in green manufacturing industry. It outlines that green engineering is an important industry which aim is to reduce consumption, to save resources, and to achieve sustainable development in manufacturing. Green manufacturing puts forward new requirements for the training future green engineers. The article reveals the principles of educating future green engineers. Specifical attention is paid to the improvement of the teaching system training of future green engineers, strengthening the teaching staff, changing the teaching mode, strengthening teaching practice and practical training for achieving teaching goals. The authors conclude that it is necessary to clarify the goals of training of future green engineers, and to establish reform the teaching content of green engineering course.

Keywords—students, future green engineers, education, sustainable development, green manufacturing

1 Introduction

The concept of sustainable development is a hot research topic in various countries in the world today. Due to the fact that many industrialized countries have undergone industrial upgrading and transformation, it has become a consensus to embody the concept of sustainable development in the manufacturing sector [1, 6, 12]. There are many ways and measures for achieving it. The focus is development of green manufacturing among them. The specific measures are inseparable from preparing of a team of high-quality professionals [7, 8, 18]. Therefore, it is necessary to explore the issues of educating future green engineers for adapting to the sustainable development.

Green engineering professionals refer to professionals who have a expertise and specialize in green manufacturing. Sustainable development as a clear concept appeared in the Report of the World Commission on Environment and Development in 1987 [20]. Since that time, this concept was put forward, definition has not been formed as a completely unified concept. But most of the documents emphasize that sustainable development is coordination and harmony of nature, society, and economy under conditions of equal importance. Sustainable development of green manufacturing is a concept of harmonious coexistence and order development of society, population and other aspects in the production and manufacturing processes [3, 16, 21].

Sustainable development of green manufacturing and of the entire society are interdependent. So, the main way in achieving sustainable development for green manufacturing is to reflect sustainability of coordination and development in all aspects. At present, the aim is to progress green manufacturing vigorously. Green engineering is based on the original manufacturing model, which is guided by the "3Rs" principle (Reduction, Reuse and Recycling), and comprehensive consideration of resource utilization efficiency and environmental impact. Modern manufacturing mode includes green production activities in the production system and remanufacturing activities in the recycling system, and its goal is to achieve coordination and optimization of enterprise economic, social, and environmental benefits [15, 17, 23].

2 Background

The shift from traditional manufacturing to green manufacturing involves a brand-new employment and education model. Many jobs are changing because of transformation and upgrading of enterprises during the past few years, that results in a shortage of professionals in green manufacturing. Therefore, it is necessary to provide high quality education of future green engineers.

Development of green manufacturing, transformation and upgrading of industrial structure, improvement of quality and efficiency, transformation from a large manufacturing country to a strong manufacturing country put forward new requirements for training future green engineers. However, education of future green engineers faces many challenges, and it cannot meet the requirements of manufacturing transformation and upgrading effectively [2, 5, 11].

Green manufacturing means energy saving, emission reduction and sustainable development. Education of future green engineers should be an all-round process, it should run through the entire process of production considering the inseparable relationship between manufacturing, resources, and environment. Taking China as an example, green manufacturing is in its infancy in many regions nowadays and understanding of its connotation needs to be further improved [4, 9]. Firstly, there are problems in cultivation of green manufacturing, which cannot consider the impact on the environment only and ignore two major aspects of manufacturing process and resources. Secondly, it is necessary to clarify the training objectives to facilitate the teaching and training of future green engineers [10, 14, 26].

The existing university courses for future green engineers cover professional knowledge system according to the requirements of curriculum standards. According to [2, 13, 24] education of future green engineers should be based on the following requirements:

1. Curriculum system should be extremely practical. Introduction to the theoretical course of green engineering in system can only teach green knowledge, and the lack of practical links in green manufacturing has certain limitations.
2. Green engineering course itself should be standardized to facilitate assessment, especially for engineering students, which can be used as an assessment indicator.
3. The level of teaching needs to be improved from the perspective of the academic structure. Faculty should involve industrial partners of green manufacturing into the teaching staff.

These problems must be resolved through acquired learning and training.

3 Materials and methods

3.1 Participants

We conducted experimental work on realization of education of future green engineers in 2020. Students at Southern Federal University, Rostov-on-Don participated in the study. The total number of students was 211 (107 participants were in experimental group, control group included 104 participants). Age range of the students was from 19 to 21 years.

3.2 Principles of education

Education of future green engineers should be based on the following principles:

1. It is necessary to clarify the training goals of green engineering course and to establish a framework for green engineering course throughout the entire process of manufacturing, resources and environment, and product use.
2. It is necessary to establish a framework for green engineering course according to industry characteristics and local economic needs. The training framework should include obtaining knowledge and skills in green manufacturing, green behavior, green attitude, and green values. It should be based on strengthening the teaching practice and internship training.
3. It is necessary to strengthen the concept of green manufacturing, and to understand green manufacturing technology, methods, and feasibility through corporate practice, to implement different green manufacturing technologies for different sections, and to make overall arrangements for energy utilization throughout the enterprise.
4. It is necessary to propose improvement of measures for green manufacturing implementation plans to enterprises through theoretical research, which complements existing technologies [13, 19].

3.3 Program of education of future green engineers

We realized program of education of future green engineers for improving curriculum system and strengthening the practice of green engineering education which was based on the experience of scientists [19, 22, 25] and included:

1. Strengthening of the construction of green engineering practice courses to achieve the teaching effect of doing and learning while experiencing, and at the same time enhancing of the social significance of green engineering.
2. Formation of certain range of standardized operations or design procedures in a certain energy-saving technology field to facilitate the assessment of students.
3. Following of the concept of lifelong learning because it goes beyond formal education and training, including "skills" and "development". Life-long learning helps the students to acquire and to integrate various knowledge and skills. University teaching should cultivate students' life-long learning ability to equip them with this quality, which will be more conducive to the sustainable development and progress of green manufacturing.
4. Advancement of teaching level in green engineering to strengthen cooperation with enterprises, to send teachers to go to factories to learn green manufacturing technology regularly, to understand the needs of enterprises. Experts should be invited to universities to carry out training courses, lectures, and other forms of re-education to improve teachers' green concept and to keep pace with the advanced level.
5. Increasing of teaching content, combining with specific enterprise technical characteristics in order to increase practical teaching content, such as sterilization heat recovery, refrigerant heat exchange, intelligent heat management, simulation system control, etc. It should serve as supplement to the knowledge unit and in-depth integration of bioengineering professional system knowledge using green manufacturing.
6. Reforming of the teaching content is needed so that students can use the knowledge they have learned to design and to demonstrate reasonable process routes, to perform reasonable power and heat exchange calculations and to type selection demonstrations. on equipment, and to perform correct calculations on materials and hydropower balance. Complex knowledge and skills are needed for green engineering projects to solve problems such as high levels of energy consumption, wastewater discharge, and COD emissions.
7. Application of innovative teaching methods based on teaching content, knowledge system settings, construction of relevant cognitive and practical teaching links. Students will deepen their understanding of green manufacturing using virtual laboratories.

4 Results

The purpose of the initial stage of the experiment was to determine the initial level of professional competence of future green engineers. Professional competence of future green engineers involves three components such as activity, informational, and research one. Activity component includes student's ability and willingness for effective planning activities, seeing problems and goals of the expected result in green engineering, searching ways in achieving goals in green engineering, ability for constant personal growth using personal reserves. Informational component is expressed in student's ability and readiness for searching, analyzing, selecting, and transforming necessary information in green engineering independently, ability for carrying out analytical and synthetic processing of information using traditional and new information technologies. Research component is expressed in student's ability and readiness for acquiring and mastering new knowledge in green engineering independently, putting forward ideas and hypotheses, working with various sources of information, conducting observation, proposing the most rational options for realization of research projects in green engineering.

The practical implementation of education of future green engineers was carried out in the form of an analysis based on Likert scale. The results of the study are presented in Table 1 and Table 2.

Table 1. Level of professional competence of future green engineers in the experimental and control groups at the beginning of the experiment

Organizational competence	**Experimental group**			**Control group**		
	Low level, %	***Middle level, %***	***High level, %***	***Low level, %***	***Middle level, %***	***High level, %***
Activity component	40.2	38.3	21.5	40.4	39.4	20.2
Informational component	55.1	29.0	15.9	37.5	39.4	23.1
Research component	43.0	33.6	23.4	41.3	30.7	28.0

Table 2. Level of professional competence of future green engineers in the experimental and control groups at the end of the experiment

Organizational competence	**Experimental group**			**Control group**		
	Low level, %	***Middle level, %***	***High level, %***	***Low level, %***	***Middle level, %***	***High level, %***
Activity component	12.1	37.4	50.5	41.3	38.5	20.2
Informational component	8.4	26.2	65.4	34.6	43.3	22.1
Research component	8.4	23.4	68.2	32.7	37.5	29.8

The results of experimental work on education of future green engineers in control and experimental groups revealed that in the experimental group the level of professional competence of future green engineers is higher than in the control group, that proves the effectiveness of experimental work.

5 Conclusions

Green manufacturing is an important industry which aim is to reduce consumption, to save resources, and to achieve sustainable development in manufacturing. Training of future green engineers puts forward new requirements to cover professional knowledge system such as practical orientation of curriculum system, facilitating of assessment, involving industrial partners of green manufacturing into the teaching staff. Education of future green engineers should be based on principles which include clarifying the training goals of green engineering course and to establish a framework for green engineering course throughout the entire process of manufacturing, resources and environment, and product use; establishing a framework for green engineering course according to industry characteristics and local economic needs; strengthening the concept of green manufacturing; obtaining of green manufacturing technology, methods, and feasibility through corporate practice; proposing improvement of measures for green manufacturing implementation plans to enterprises through theoretical research.

Specifical attention was paid to the improvement of the teaching system of training of future green engineers. The program of education of future green engineers included such items as strengthening of the construction of green engineering practice courses; advancement of teaching level in green engineering; increasing of the teaching content, combining with specific enterprise technical characteristics; application of innovative teaching methods based on teaching content.

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