The Design of a Postgraduate Vocational Training Programme to Enhance Engineering Graduates' Problem-Solving Skills Through PBL

Miliou, Ourania; Ioannou, Andri; Georgiou, Yiannis; Vyrides, Ioannis; Xekoukoulotakis, Nikos; Willert, SØren; Andreou, Andreas; Andreou, Panayiotis; Komnitsas, Konstantinos; Zaphiris, Panayiotis; Yiatros, Stylianos

Published in:
International Journal of Engineering Education

DOI (link to publication from Publisher):
10.5281/zenodo.7589566

Publication date:
2022

Document Version
Publisher's PDF, also known as Version of record

International Journal of Engineering Education Vol. 38, No. 5(A), pp. 1257–1273, 2022
Printed in Great Britain
0949-149X/91 $3.00+0.00

The Design of a Postgraduate Vocational Training Programme to Enhance Engineering Graduates' Problem-Solving Skills Through PBL*

OURANIA MILIOU
CYENS Centre of Excellence, Nicosia, Cyprus. E-mail: o.miliou@cyens.org.cy

ANDRI IOANNOU
Cyprus University of Technology, Department of Multimedia and Graphic Arts, Limassol, Cyprus & CYENS Centre of Excellence, Nicosia, Cyprus. E-mail: andri.i.ioannou@cut.ac.cy

YIANNIS GEORGIOU
Ministry of Education, Culture, Sport & Youth (MOECSY), Nicosia, Cyprus. E-mail: igeorgiou@schools.ac.cy

IOANNIS VYRIDES
Cyprus University of Technology, Department of Chemical Engineering, Limassol, Cyprus. E-mail: ioannis.vyrides@cut.ac.cy

NIKOS XEKOUKOULOTAKIS
Technical University of Crete, School of Chemical and Environmental Engineering, Crete, Greece.
E-mail: nikos.xekoukoulotaki@enveng.tuc

SØREN WILLERT
Aalborg University, Department of Culture and Learning, Aalborg, Denmark. E-mail: swi@agora.as

ANDREAS ANDREOU
CUBEiE L.L.C., Cyprus. E-mail: andreas@cubeie.com

PANAYIOTIS ANDREOU
CUBEiE L.L.C., Cyprus. Email: panos@cubeie.com

KONSTANTINOS KOMNITSAS
Technical University of Crete, School of Mineral Resources Engineering, Crete, Greece. Email: komni@mred.tuc.gr

PANAYIOTIS ZAPHIRIS
Cyprus University of Technology, Department of Multimedia and Graphic Arts, Limassol, Cyprus.
E-mail: pzaphiri@cyprusinteractionlab.com

STYLIANOS YIATROS
Cyprus University of Technology, Department of Civil Engineering and Geomatics, Limassol, Cyprus.
E-mail: stylianos.yiatros@cut.ac.cy

The current rapid technological advancements and the dynamic workplace environments call for engineering graduates to be equipped with a combination of interdisciplinary skills. Among the core skills for the engineering profession is problem-solving. Although industry professionals and academics consider problem-solving an essential attribute of engineers in industry 4.0, research shows that several engineering graduates are not adequately equipped to apply the problem-solving approach in workplace environments. During the past years, the most common approach referred to in the literature for enhancing problem-solving skills in engineering education is Problem-Based Learning (PBL). While research reported that PBL could improve students' skills in the early stage of higher education or within their degree programmes, most engineers generally accept that graduates will "really" learn how to be an engineer at the workplace. This paper reports on the methodological process of designing and developing a postgraduate vocational training programme to enhance engineering graduates' problem-solving skills through PBL. Specifically, it aims to investigate the programme's impact on engineering graduates' problem-solving skills and their perceptions about the PBL experience. A mixed-methods study was applied to answer the research questions. The Problem-Solving Inventory (PSI) was used to collect quantitative data regarding engineering graduates' problem-solving skills and semi-structured interviews were used to gather qualitative data regarding the implementation of the PBL programme. The results showed that the programme was successful in developing engineering graduates' problem-solving skills. Furthermore, engineering graduates reported several additional benefits regarding their learning experience. Examples include gaining a deeper understanding of the problem-solving process, developing professional knowledge, and enhancing employability potential. They also referred to various challenges which emerged during the programme, such as the time allocation for the assimilation of new knowledge, the application of problem-solving processes, and the communication with the technical staff in the workplace settings. We hope that this work can open a platform for discussion regarding the engineering curricula and the use of

* Accepted 5 May 2022.

problem-oriented pedagogies toward improving employability and professional skills through industry-academia collaboration.

Keywords: problem-based learning; problem-solving; vocational training; internship; engineering education

1. Introduction

Engineering is considered a profession that has a considerable impact upon societies and economies [1, 2]. It is by no coincidence that in the current era of the "fourth industrial revolution" or Industry 4.0, which refers to technological breakthroughs, such as artificial intelligence and robotics, there is a fast-growing need for skilled engineers to create and manage advanced and automated production systems [3]. The application of engineering processes covers a range of technical activities, including the "*definition, design, documentation, simulation, and management of products and services, and other related processes along the entire lifecycle*" [4]. From the perspective of technical knowledge, the profession draws upon the disciplines of mathematics, science, and technology, integrated with business and management [5, p. 65]. However, over the last years, the profile of the professional engineer has been enhanced with attributes that refer to non-technical skills [6]. This change was foreseen by the Committee on Engineering Education of the National Academy of Engineering (NAE) (2005), which recognised that "*while certain basics of engineering will not change, the global economy and the way engineers will work will reflect an ongoing evolution that began to gain momentum a decade ago*" [7, p. 4]. Indeed, the current rapid technological advancements, the complex and global technical challenges, and the dynamic workplace environments call for engineering graduates to be equipped with a combination of technical and non-technical skills [8–10]. The latter almost always focus on professional skills that represent "*attitudes, behaviors, skills, and motivation, and not just knowledge*" [9] which can be developed through training [11, p. 4].

Among the most common attributes of the engineering mindset is problem-solving [1, 5, 11–14]. Specifically, the engineering practice involves solving complex, ambiguous, and ill-structured problems [12, 15]. Industry professionals and academics perceive the problem-solving capability as a key attribute of engineers in industry 4.0 [16, 17]. Such perception is also evident among engineering students who view problem-solving as a key skill for their future profession [18, 19].

Despite the importance of problem-solving in the engineering profession, research shows that graduates are not adequately equipped to apply problem-solving in industry environments [20, 21]. The above fact may be attributed to the nature of current educational programmes, which do not sufficiently address the habits of mind required by today's engineers [11]. This challenge is also evident in programmes that focus on Problem-Based Learning (PBL), the most common instructional approach for developing problem-solving skills in engineering education [22]. Specifically, one of the main challenges regarding the implementation of PBL is that the nature of the problem-solving experience in education settings is different from the workplace settings [12, 23]. While research reported that PBL projects could improve students' technical and non-technical skills in the early stage of higher education [24] or within their degree programmes [25], most engineers generally accept that graduates will "really" learn how to become an engineer at the workplace [12, p. 146]. Additional challenges reported in the PBL literature refer to the better preparation of instructors to provide more resources and pedagogical support and training [26]. Considering the above, there is a need to design and develop vital engineering programmes with a balance of engineering theory and practice to transform young engineers' transition to their workplaces [27]. In the era of the Industry 4.0, research on engineering education needs to focus on a modern idea of professionalism which can be based on the design of vocational education and continuous training [17].

This paper reports on the methodological process followed for designing and developing a PBL-based postgraduate vocational training programme called ENGINITE to enhance the professional development of engineering graduates. Specifically, the programme aimed to develop problem-solving skills in graduate engineers through industry-academia collaboration based on the Aalborg model, which is considered one of the most well-established PBL approaches in engineering [22]. The research questions guiding this study are the following:

- RQ1: What is the impact of the ENGINITE programme on enhancing engineering graduates' problem-solving skills?
- RQ2: What are the engineering graduates' perceptions about the learning experience within the ENGINITE programme?

In order to answer the research questions, a mixed-methods study was conducted to collect quantitative and qualitative data regarding engineering graduates' problem-solving skills and their perceptions about the PBL approach. The analysis of the results showed that the programme was successful in developing engineering graduates' problem-solving skills. Additionally, engineering graduates perceived positively their learning experience within the PBL programme.

2. Literature Review

As stated by Miller (2017), "*graduate engineers should be given the opportunity to develop professional skills and mindsets that support them in order to contribute to solving the most complex challenges of our age*" [10, p. 55]. However, many higher education institutions fail to prepare engineering students for practice for various reasons. Namely, the course content does not reflect the real industry requirements [28–30], engineering academics are not equipped with industrial and practical experience of engineering gained prior to their entry into the higher education sector [31], and students are mainly academically but not industry trained [17, 21]. As a result, young engineers graduating from higher education institutions are not industry-ready [17, 30, 32]. This is quite problematic as the demands rising from the technological developments of industry 4.0 keep changing at a very fast pace, and academia fails to match steps with it [29]. Therefore, there is an urgent need to transform young engineers' transition to their workplaces [27] by providing them more opportunities to gain practical experiences and enhance their professional skills in industrial work settings [17, 24].

It is worth noting that the engineering profession is considered among the ones with the highest rates of change, and graduates in engineering work in occupations with much faster rates of job skill change than graduates majoring in other fields. For this reason, early-career engineers need a strong set of skills that will allow them to deal with rapid technological changes [33] but not at the cost of losing a strong theoretical base [28]. Among the core skills for the engineering profession is problem-solving [5, 11–14]. The NAE (2005) in the report *The Engineer of 2020*: *Visions of Engineering in the New Century* stated that "*engineering is problem recognition, formulation, and solution*" and concluded that future engineers "*will be working with diverse teams of engineers and non-engineers to formulate solutions to yet unknown problems*" [7, p. 43]. Nowadays, in the era of Industry 4.0, the above statements are more relevant than ever for enhancing productivity growth and handling forthcoming social and technological challenges [27]. Industry professionals look for graduate engineers who possess more than a strong theoretical knowledge, namely, engineers who are skilful in solving industry-related problems [16, 30, 32, 34]. This perception is also common among engineering students who consider problem-solving skills essential for workplace [18–19, 35].

During the past years, several educational approaches have been applied to enhance problem-solving skills in engineering education. The most common approach is Problem-Based Learning (PBL) which is associated with the development of knowledge as well as higher-order thinking skills, including problem-solving [22, 36, 37]. PBL has been recognised as an approach that supports students to develop essential skills needed for the workplace [38–40]. Specifically, within a PBL programme, students work in small collaborative groups directed by the facilitator [41, 42]. The groups are engaged in a guided learning experience that requires solving complex, authentic problems [43] and building knowledge by interacting with each other [44]. Such problems drive the learning process by triggering students' interest to learn to work through the problems by identifying and researching the concepts and principles they need to know [37]. Through this experience, they are encouraged to take an active role in formulating and analysing problems, generating hypotheses, and presenting possible solutions [41].

It should be noted that PBL is not limited to one common methodology, but it is an instructional approach that can take many forms [45]. Savin-Baden (2014) described nine different formulations of PBL, namely: PBL for knowledge management, PBL through activity, project-led PBL, PBL for practical capability, PBL for design-based learning, PBL for critical understanding, PBL for multimodal reasoning, collaborative distributed PBL, and PBL for transformation and social reform [46]. Barrows (1986) indicated that the common denominator of the different forms of PBL is the use of problems in the instructional sequence and that perfecting problem-solving skills through repeated practise and feedback is considered one of the primary objectives of PBL [47]. In the context of engineering education, research reports positive results from the implementation of PBL programmes regarding students' learning outcomes [48-49] and satisfaction with the learning experience [50]. Other studies highlighted the effectiveness of PBL in enhancing undergraduates' professional skills [24, 51, 52].

Apart from the promising results of the implementation of PBL in engineering education, several challenges have also been reported, especially regarding the application of problem-solving processes. According to Mills and Treagust (2003), "engineers must be able to apply concepts that they learn during their education at university to solve problems outside the experience they had in the course since every problem they encounter in practice will usually be different from those they have encountered at university" [23, p. 8–9]. In other words, in terms of the learning experience, a problem in a classroom setting may be different in nature from a workplace problem [12]. Mainly, students in classroom settings work with well-defined and relatively simplified problems as part of the coursework, such as those found at the end of textbook chapters [12]. These problems are often situated in academic settings [21]; they are structured and not grounded in real-world contexts [32, 53]. As a result, students fail to understand the complexities and ambiguities of workplace problems [21]. This is especially the case for PBL practices that are integrated in an existing single subject or course. In these contexts, the problems in the projects are mostly formulated within the academic (technical) context [54]. While prior knowledge on PBL is important because the application of existing knowledge to new situations through modelling and experimentation is a common engineering practice [36], novice engineers may find themselves unprepared to manage the complexity of real-life projects based on their prior studies [40]. To tackle this challenge, higher education institutions established collaborations with companies in order to introduce a set of authentic problems and engage students in real work problem-solving [55–57]. This trend includes, among others, the provision of internship programmes that are offered by companies as a means to enhance students' understanding of the complex-problem situations they will encounter in real work settings. However, internships are not well-researched from the point of view of learning outcomes [54, 58]. Another challenge refers to the lack of knowledge and skills to transfer from traditional learning methods to PBL methods in higher education [45, 59]. Particularly, instructors should have a clear understanding of the "*wider pedagogical and organizational implications*" of PBL rather than seeing it as "*a means of giving students skills*" [38] or as a "*methodology that consumes scarce resources of the department*" [26]. Additionally, students should also be trained on how to approach learning in a PBL context. For example, they should be able to take responsibility for their own learning and be prepared to follow problem-solving processes [60]. To conclude, more research is needed to shed light on the successful implementation practices of PBL at different levels [45], especially since the design of a PBL programme should be adapted to different settings, cultures, curricula, and circumstances [61].

It must be emphasised that the introduction of PBL to undergraduate courses requires a great deal of coordinated time and effort as "*most universities are not suitably structured for implementing an integrated curriculum*" [62]. For this purpose, higher education institutions need to consider which PBL models could be transferred into their institutions. Additionally, comprehensive considerations should be taken into account from curriculum designers regarding the pedagogical theories and PBL knowledge that underpin the design of a professional curriculum [45].

To address the challenges in PBL implementation outlined above, this paper reports on the design, development, and implementation of ENGINITE, a postgraduate Vocational Education and Training (VET) programme. Drawing from the Aalborg university's experience in implementing PBL in engineering education [22, 63], ENGINITE emphasises Problem-Based Learning (PBL) pedagogy and industry-academia collaboration based on a methodological framework which contextualises PBL implementation to Mediterranean countries.

3. Methodology

3.1 Participants

The participants were recruited via an open call which was disseminated to various social media groups by a university which is based in Cyprus. A total of 12 post-graduate young engineers were recruited to participate in the ENGINITE programme; 67% were females, and 34% were males with a mean age of 25 years (SD = 2.11). Regarding their level of studies, all of them were graduated engineers with different specializations, e.g., Mineral Resources, Environmental, Mechanical, Production & Management, Oil & Hydrocarbon, Chemical, Electrical, Landscape & Geoinformatics, and Civil. Regarding their prior studies, 41% had either a Bachelor's or a Master's degree, and 18% had a 5 year Diploma. The main reasons for expressing interest in the programme, as reported on participants' application forms, were the following: to expand their knowledge, develop new skills, obtain practical experience in their field, receive guidance from academics and industry experts, and increase their employability.

3.2 Methodological Framework

3.2.1 PBL Training

In order to facilitate the design of the ENGINITE training programme, a multidisciplinary team of academics and industry professionals participated in a co-design process to explore the application of

PBL in their particular contexts. This process aimed to equip them with problem-solving skills and prepare them to effectively apply the PBL methodology. The co-design process was carried out in two phases, the reflective pre-work phase and the training phase. Both phases were facilitated by PBL experts from Aalborg University.

The reflective pre-work phase was implemented during a 4-week period. During that time, the participants formed action learning groups that undertook a series of activities that allowed them to experience problem-based learning in their educational and professional settings. The facilitators provided clear processes and structural scaffolding, but at the same time, they gave learners the freedom to choose their challenges and reflect on their own experiences. By doing so, they aimed to promote a sense of personal ownership. The pre-work phase prepared participants for the training phase, which took place in a period of 3 days. The aim of the training phase was to develop participants' confidence in implementing PBL in their contexts. The training was delivered in five consecutive parts by the facilitators. Each part focused on the familiarisation with PBL concepts and processes and followed targeted techniques in order to bring to the surface PBL challenges. The ultimate goal was to facilitate participants' understanding of the PBL process and how it could be utilised to design the ENGINITE programme.

3.2.2 PBL Theory and Guiding Principles

In the context of the ENGINITE programme, the core PBL idea is that *the problem is a driver for the learning process.* In this context:

- 'The problem' is always owned by somebody – PBL requires it to be owned by the learner.
- 'The problem' denotes a specific relation between the learner and certain reality aspects (the problem field) that the learner sees as problematic – in an academically or educationally interesting way.
- Helping the learner to extract 'the problem' from the problem field is one key competence for the PBL supervisor.

In PBL, learning cannot get started unless learners have identified the problem that shall serve as a motor for their learning efforts. A problem can derive from a theory, a person, or a situational context. Specifically, a problem which derives from theory can have a theoretical angle, based on students' reading and course participation. Additionally, a problem which derives from situational contexts may be expressed through a need for intervention or construction or for understanding or theoretically reflected description. Lastly, a problem that derives from a person, e.g., a learner, can be structured as a small-scale research activity with the ultimate aim to drive personal learning processes. Such processes may have a different focus, such as the acquisition of general, scientifically corroborated knowledge, skills acquisition, and competence development. Fig. 1 shows the 'Triangle of learning domains'.

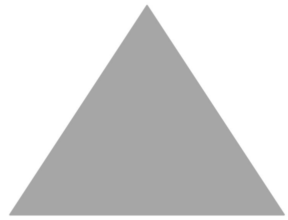

Fig. 1. The triangle of learning domains.

The training phase resulted in the establishment of twelve PBL principles which aimed to guide participants when designing their PBL training. The principles are summarised as follows:

1. Students experiencing ownership to a problem-within-a-context is a prerequisite for learning.
2. Be flexible in defining the learning outcomes.
3. Aim for exemplarity.
4. Let learners arrive at learning outcomes through different routes.
5. Focus on learning through reflection.
6. Let the students be the guide to what they do and don't understand.
7. Be a facilitator, not a teacher.
8. Move facilitation style from 'Follow me' to 'Joint Experimentation'.
9. Focus on learning through social processes.
10. Create the physical learning environment for PBL.
11. Consider assessment.
12. Aim for enhancing learners' skills and attitudes for PBL.

The above guidelines were considered during the design and development of the ENGINITE PBL curriculum and Modules.

3.2.3 ENGINITE PBL Curriculum and Modules

ENGINITE is a postgraduate vocational training programme which aims to graduate engineers with a degree in biochemical, chemical, electrical, electronic, environmental, food, industrial, mechanical, petroleum, safety engineering, chemists, food technicians and/or graduates of a relevant field. The aim of the programme is to support graduate engineers who seek for a job and/or wish to follow a postgraduate vocational training programme; or junior engineers who are partly employed and/or working in a different field and also wish to follow a postgraduate vocational training programme.

The programme is underpinned by the PBL pedagogy, and the guiding principles described above. It is composed of two phases, a training phase (including a set of employability enhancement courses) and an internship phase (including placements in the industry). It was designed at a project level [45, 46] with the aim to promote work-related learning that meets the needs of students, employers, and educators. Specifically, a project-led PBL is organised by universities and companies and focuses on the development of technical knowledge and skills which are clearly described by the facilitator. However, the learning experience is led by the participating students who utilise opportunities, resources, and experiences encountered in the workplace [46].

3.2.3.1 Training Phase

The PBL process was organised in a blended learning environment, and it lasted for 12 weeks. The eight course topics were identified via a literature review and a survey with fifty (50) companies and two hundred (200) engineers, which took place before the implementation of the programme to explore the needs of both companies and graduate engineers in terms of knowledge and skills. Based on the results, the programme combined advanced applied academic topics with practical, contemporary hands-on aspects to endorse the employability skills of graduate engineers. In particular, the technical knowledge was mainly addressed in four of the courses (engineering economics, supply chain, applied process and product optimization, product development) whereas direct development of employability skills was explicitly addressed in another four courses (project management, innovation and entrepreneurial skills, health and safety management, engineering systems thinking). Table 1 presents the ENGINITE training courses per time period and training mode.

The F2F meetings included eight intensive PBL courses, each one with a duration of one week. Each course was organised to resemble a real-world engineering problem or situation as found in industrial settings. That is, an ill-structured problem which promoted hands-on learning in each individual course. Learners had to work in mixed gender and mixed-expertise groups to address those problems and present their solutions. Additionally, each F2F meeting included group reflection sessions which helped trainees assess their level of understanding.

One week before the start of F2F courses, trainees had to access an online training platform which included lists of materials that could be used as background reading and additional case study material. Considering the fact that the trainees needed a broad range of knowledge in order to assimilate and apply the knowledge to solve a problem the online material was organised and developed to ensure that trainees would have a clear understanding of the background concepts prior to embarking on PBL [40]. The purpose was to support trainers to describe the problem context and help trainees familiarise themselves with this area. Particularly, by presenting trainees with possibly problematic contexts and inviting them to search for such problems as will match their learning needs it was expected that they would experience ownership to one or a set of problems. Additionally, the online platform was a space which allowed the facilitator to provide scaffolding and support to students in order to progress as they expected to within the course timeframe.

Finally, within two weeks from the completion of all courses the trainees worked in groups on a larger, complex, multi-dimensional and open-ended problem. Specifically, drawing on knowledge and skills gains during the eight weeks of the training (i.e., a total of 10 weeks learning experience), the trainees had the opportunity to consolidate their knowledge and present their solutions. The course facilitators and several invited speakers from the industrial sector scaffolded the PBL pro-

Table 1. ENGINITE Training Courses

Time period	Training mode	Courses
Week 1	Online	**Employability Enhancement & Managerial Skills** 1. Engineering Systems Thinking: Re-engineering by Simplifying 2. Project Management in Action 3. Innovation, Entrepreneurial and Intrapreneurial skills 4. Applied Efficient Quality and Health & Safety Management Systems
Weeks 2–5	F2F	
Week 6	Online	**Technical Knowledge Enhancement** 1. Engineering Logistics and Supply Chain Analysis in practice 2. Engineering Economics 3. Applied Process and Production Optimization 4. Product Development: From Concept to Market
Weeks 7–10	F2F	
Weeks 11–12	Online	Final projects

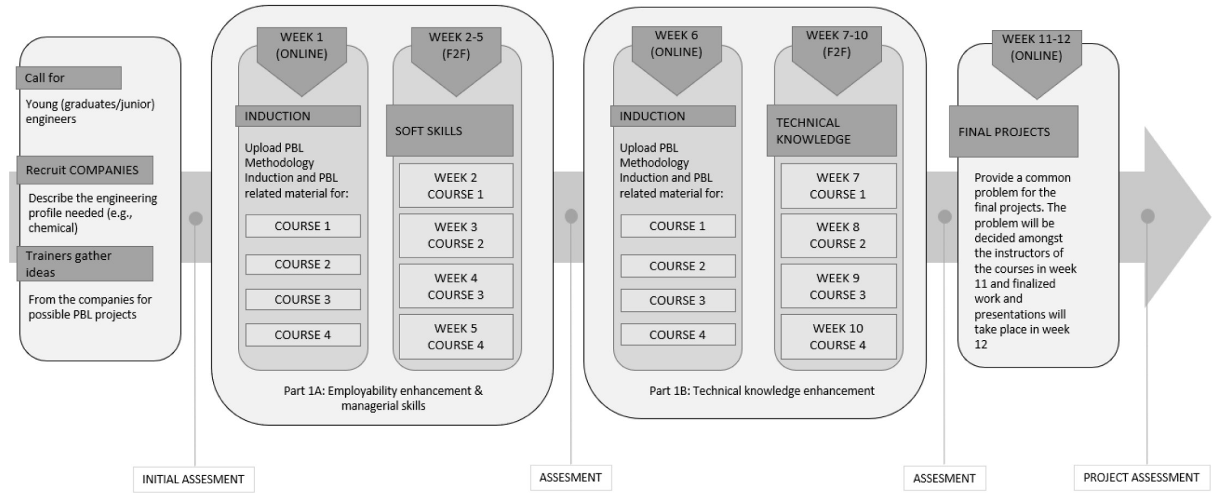

Fig. 2. The Training Phase.

cess. Fig. 2 summarises the activities which took place during the training phase.

3.2.3.2 Internship Phase

Following the training phase, a structured internship offered trainees the chance to apply their problem-solving skills in a professional context and balance engineering theory and practice [27]. In particular, trainees were placed in companies and industrial units in the engineering sector for a 3-month period. The internships were also used as a means to compensate for the limited opportunities that engineering students have for internship placements in the local contexts.

During the internship, the engineering graduates had the opportunity to become familiar with the operations, equipment, and processes of the company (1st month), to work on small scale projects as indicated by their company mentors (2nd month), and lastly, to work on self-initiated projects (3rd month). The projects included PBL activities initiated and designed by the trainees. During these activities, trainees had to conduct an empirical investigation to solve a problem. Overall, the internship phase aimed to offer real-time work exposure, thereby bridging the gap between academia and industry. Fig. 3 shows the activities which took place during the internship phase.

The internship was intended to be an opportunity for participants to spend time in an organization, identify problems that need to be solved and propose solutions that could hopefully be of value to the host company. The internship was, above all, an opportunity for graduates to engage in real

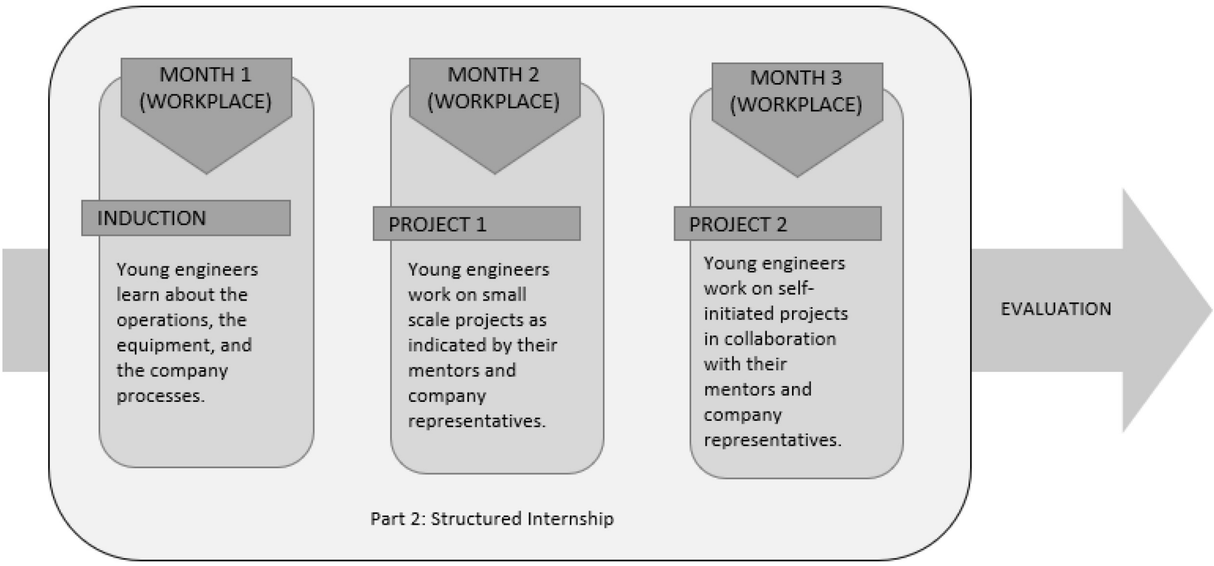

Fig. 3. The Internship Phase.

engineering problem-solving. During the internship phase, each trainee had the support of a mentor, who guided him/her on the learning journey towards problem-solving and how to spend creatively but still professionally his/her time during this interesting process in the organization. Additionally, during weekly meetings, physically or online (e.g., Skype), the mentor helped the trainee to reflect on his/her experiences that week. The mentoring roles were undertaken by PBL trainers in order to supervise the interns. For this reason, they were provided with a guidebook that included instructions regarding the management of the internship placement.

3.3 Data Collection and Analysis

The study adopted a mixed-methods research design. Specifically, quantitative and qualitative data were collected for triangulation and interpretation [64, 65]. This process offers a more complete understanding of the research questions [65]. The quantitative data were collected via a self-assessment questionnaire, the Problem-Solving Inventory, which included close-ended responses regarding problem-solving attributes, and the qualitative data were gathered through semi-structured interviews which aimed to investigate participants' perceptions about the PBL programme.

3.3.1 The Problem-Solving Inventory (PSI)

The problem-solving attitudes were measured using the Problem-Solving Inventory (PSI; Heppner & Petersen, 1982) [66]. The PSI consists of 32 items, measured on a Likert scale (from 1 = Strongly disagree to 6 = Strongly Agree) and organised in three subscales as follows: (a) Problem-Solving Confidence, (b) Approach-Avoidance Style, and (c) Personal Control. Specifically, Problem-Solving Confidence assesses the self-perceived confidence, belief and self-assurance in effectively solving problems and it is composed of 11 items (e.g., "I trust my ability to solve new and difficult problems."). Approach-Avoidance Style assesses whether individuals tend to approach or avoid a problem and it is composed of 16 items (e.g., "When a solution to a problem was unsuccessful, I do not examine why it didn't work."). Lastly, Personal Control assesses elements of self-control on emotions and behavior and it is composed of 5 items (e.g., "When my first efforts to solve a problem fail, I become uneasy about my ability to handle the situation."). Heppner and Petersen (1982) reported reliability coefficient alpha as 0.85 for problem-solving confidence, 0.84 for approach-avoidance style, and 0.72 for personal control. A test-retest reliability reported 0.85 for problem-solving confidence, 0.88 for approach-avoidance style, and 0.83 for personal control [66, p. 71]. The PSI has been used for self-report measures to assess problem-solving attitudes in engineering programmes [67–70] and was found to have satisfactory psychometric properties in different countries and contexts [71–73].

3.3.2 Interviews

When it comes to novel educational interventions, courses, and training programs, the attempt to define their value and impact through the curricular experiences of the participants is important [24]. In order to gather in-depth information about the programme's methodology and identify trends to PBL based on students' perceptions, the researchers developed a semi-structured interview guide. The guide was constructed so that the respondents' answers were directly related to the PBL approach followed during the programme. The interviews were conducted after the completion of the programme, and the average time was approximately 20 minutes. Before the interviews researchers explained the study's goals and informed consent was obtained by the participants. During the interviews, the participants were initially asked to report their general impressions for each phase, and then they were probed to discuss specific aspects of PBL in relation to each phase (e.g., learning process and learning strategies followed per phase, perceived challenges and opportunities, scaffolding and supportive aspects, perceived learning gains). The interview data were recorded and transcribed before the analysis.

4. Results

4.1 The Impact of the PBL Approach on Problem-Solving Attitudes

The PSI data were analysed using a Wilcoxon signed-rank test to assess potential improvements in participants' problem-solving attitudes before and after the programme. Wilcoxon is a non-parametric test suitable for comparisons in small sample sizes [74]. Statistical analyses were conducted using SPSS 25.0. The scores for all the problem-solving dimensions (Problem-Solving Confidence, Approach-Avoidance Style, and Personal Control) were calculated as the sum of ratings for their respective items. The analysis indicated a statistically significant increase in problem-solving attitudes from pre- to post-testing. Specifically, the analysis showed statistically significant differences between the ratings before and after the programme for the Approach-Avoidance Style ($z = -2.49$, $p = 0.01$), the Personal Control ($z = -2.17$, $p = 0.03$), and the Problem-Solving Confidence ($z = -2.09$, $p = 0.04$). In particular, engineering graduates rated their skills higher after the programme.

4.2 Perceptions and Evaluation of the Training Phase

The data from the individual interviews were coded and analysed using a thematic analysis approach. i.e., reporting patterns (themes) within data [75]. Data coding and analysis were cross–checked by two researchers who reached an agreement of over 80%, therefore the coding scheme could be used for reporting the research findings. What follows is a brief presentation of the study's themes.

Course content and delivery: The trainees were satisfied with the course content, although they were unfamiliar with some of the course topics which referred to the Employability Enhancement and Managerial Skills. However, they considered the courses useful for them, and for this reason, they were interested to learn more and expand their background. For instance, one trainee said: "*I was not aware of project management before the program, although it is essential for completing a project*". They also commended that the content in some courses (e.g., supply chain or engineering economics) was demanding to grasp due to time constraints vis-à-vis the complexity of the subject matter. Additional difficulties were reported for the problem-solving process. Specifically, trainees commended that in some courses it was very challenging to deliver the result (a solution to the problem) considering the limited duration of each course (1-week intensive course). According to one trainee: "*It was a tight programme to follow because we had to work daily to the point where we got tired, and it was not easy to assimilate [knowledge]. It would be ideal if the programme was flexible, e.g., three times a week, which would give us a little more time to understand.*" Finally, the trainees positively perceived the presence of invited speakers from the industry during their courses. However, they suggested that these speakers could have been their future mentors/representatives from their internship companies. Such practice would have allowed them to achieve a better connection between the training and the internship phase before the day of their placement. Regarding the training delivery, the trainees found that the online platform was a very useful tool during the PBL process. They perceived its user-friendliness positively, and the easy access to materials. They also mentioned that the reference in tutorials that guided their online research offered a great place to seek guidance and support throughout the courses. Additionally, they stated that access to resources was of paramount significance during the examination of their proposed solutions. As one trainee stated: "*The courses helped me a lot to expand my knowledge. I was asked to do some things that I would not know how to do if I didn't have the knowledge I gained from the programme. I expanded my way of thinking and problem-solving ability*". Lastly, concerning the internship, trainees highlighted that the prior knowledge and the skills gained during the training phase were highly important for their internship experience. They explained, for instance, that because they already had an idea of working within multidisciplinary groups and under specific time frames to solve complex and ill-defined problems, prior knowledge was a great advantage, which scaffolded and accelerated their learning in their companies. Additionally, they stated that induction was a valuable part of the internship programme because it offered them the opportunity to familiarise themselves with the company equipment and infrastructures, as well as with company staff. For instance, one trainee said: "*At the beginning, during the first days, I met the people, I learned about the company, what it does and why, with whom it cooperates, the parts of the factory and the use of the machines.*" Furthermore, they highlighted that during the induction period they were accustomed to the processes and operation of the companies where they were placed.

PBL Approach: The participants perceived the underpinning PBL approach positively. They highlighted that they enjoyed the authentic and real-world problems they were asked to investigate within their projects. They also commended that being responsible for their learning either individually or as members of a team was a very positive aspect of the PBL approach because it allowed them to pursue the depth and width of their learning. For example, one trainee said: "*I was assigned various projects and I had to work with other colleagues, we shared roles to see how to solve the problem. We communicated with external partners from abroad. To prepare the final project, we had to look at the architects' work and then I had to continue my own work, so I saw designs that I did not always have the opportunity to see at the university*". Additionally, they referred positively to the various stages of the PBL process, such as the problem analysis, the exchange and synthesis of ideas, the proposal of various solutions, the investigation of the proposed solutions and their reflection about the pros and cons of each solution. As one trainee said: "*Initially I had to see what information I needed for the solution of the project. . . I had to do a lot of research on the Internet, find articles, look for regulations. I also needed to learn some software, what assumptions they make. I worked with colleagues, with architects, engineers*". Furthermore, some trainees were positively surprised by their proposed solutions to a problem in terms of creativity and feasibility. However, some of them also admitted that the limited duration of each course in some cases affected the quality of their final solutions, explaining that if they had more time at their disposal, they would have achieved much more elaborated solutions. Specifically, one trainee said: "*You apply your theoretical background and you are obligated to work in real-time. You are not given an extension even in cases that you need it*". Another aspect of the PBL that trainees highlighted as positive was the collaboration within multidisciplinary groups. Specifically, they explained that the diversity of their engineering backgrounds enabled the distribution of different roles and tasks during the investigation of each problem based on expertise. They also commended that they felt a sense of complementarity within their groups, which was also beneficial when they provided peer feedback. Reflecting on their internship experience, the trainees reported that, after the induction period, they had the opportunity to work on small-scale projects, as indicated by their company supervisors and subsequently to work on self-initiated projects. According to one trainee: "*After I discussed with the workers and managers, they told me some ideas for developing their company so to choose a project to do for them. . . and I developed [the project] through a programme to enable its construction in the near future*". Another positive aspect that was reported by the trainees refers to the management of their projects. As they explained, they were excited as they had the opportunity to work with real-world problems characterised by high complexity and deliver their work within specific time constraints. They also mentioned that they enjoyed the collaboration with industrial experts. Finally, they positively perceived the problem-solving process, which allowed them to reach creative final solutions and draft reports to successfully accomplish their projects. Generally, the trainees stated that there was an underlying learning process during the induction and the project management stages. According to them, the most beneficial aspects of the learning process were the field observations and the demonstrations by other more experienced people. For instance, one trainee stated: "*I learned to work with people who are different, older, with different knowledge*".

The facilitator's/mentor's role: Trainees highlighted the significant role of facilitators in the PBL approach. They commended that the facilitators' guidance and support were crucial for them before moving autonomously to the problem-solving process. As they explained, the facilitators often prompted them to consider the complexity and the multiple perspectives of the problems they were investigating. In addition, trainees commented that facilitators provided constructive feedback rather than explicit and definitive answers at crucial points during the investigation of possible solutions. This practice allowed them to reflect on their work and revise their action plans as needed. According to one trainee: "*The facilitator provided feedback on what I needed to know and what I did right, what I did wrong and what I needed to improve*." Additionally, trainees were very satisfied with the support and guidance they received during their internships from their mentors (who were also the facilitators during the training phase), explaining that they were sources of valuable feedback, and they supported their professional development.

Perceived Learning Gains: The trainees highlighted that the training phase contributed to the development of general skills (i.e. project management, health and safety management, innovation skills) and the development of engineering knowledge. In particular, they explained that during their internships they were able to gain professional knowledge through a series of activities, such as demonstrations, participation in training seminars/workshops within the companies, interactions with industrial experts, supervision and feedback, recognition, and rewards by the company representatives. They also emphasised how the PBL process helped them develop additional skills. They reported, for instance, that during problem-solving, the teamwork activities and the distribution of several tasks and roles enhanced their skills in working with others or taking up the role of the "group leader". They also explained that they enhanced their critical thinking skills by working in groups where they were called to exchange and negotiate multiple ideas. Additionally, referring to the internship phase, they explained that teamwork unfolded within multidisciplinary groups and contributed to the enhancement of their communication skills while their interactions with their supervisors and other colleagues contributed to the development of professional skills. For instance, one trainee said: "*We gained knowledge in specific fields in the university, however, the engineering profession is broader, and you need to know whom you work with and be open to other perspectives*". Furthermore, the trainees highlighted that their internship enhanced their engineering knowledge and problem-solving skills. They also referred to the process of investigating different solutions as a valuable experience that made them think "out-of-the-box". Also, they stated that they gained work-based experience, they familiarised themselves with the industry culture, and they expanded their professional network. Finally, the trainees mentioned that the whole internship experience enhanced their professional confidence and employability potential. As one trainee said: "*If I did not do the internship, I would not have seen and learned. Another positive aspect was the potential to be employed by the company*".

Challenges: Regarding the training phase, trainees stated that it was challenging to close the projects with a desirable result due to the limited duration of the courses and the complexity of the subject matter. Furthermore, the participants reported on challenges concerning their internship period. Initially, they referred to the relatively short duration of the internship phase and their adaptation period, which covered a significant part of their internship. For example, one trainee said: "*Time management was challenging, i.e. within three months, it was impossible to develop various strategies and fully implement them*". Another confounding challenge was the lack of prior working experience in the field. Regarding the social aspect of the PBL process, the trainees reported two relevant challenges they had to overcome. Firstly, they mentioned that the collaboration with the technical staff was often complicated, as the technicians were using a different mode and code of communication. Specifically, according to one trainee: "*Collaboration with technicians at the factory in the production was challenging. The university does not prepare you about the ways of communicating, how to use a common language. In general, future engineers will experience problems with technicians as soon as they enter the industry or with their supervisors or their colleagues*". Second, some of the female trainees stated that, in some cases, the working environment consisted mostly of males, making them feel uncomfortable. The results of the interviews are summarised in Table 2.

5. Discussion

5.1 Key Findings of the Study

Based on the study's findings we can conclude that the ENGINITE programme contributed to the development of the trainees' problem-solving skills. Specifically, the significantly higher ratings of the trainees' problem-solving skills after the programme indicate that the underpinning PBL pedagogy was a crucial factor in their professional development. Particularly, after the completion of the training phase, the problem-solving confidence, the personal control, and the tendency to approach complex and open-ended problems were significantly improved for the trainees. This finding is very encouraging given that engineering practice is all about dealing with complex, multi-dimensional,

Table 2. Students' Perceptions of their Experience within the PBL Programme

PBL Programme	Benefits/Learning Gains	Difficulties/Challenges
Training Phase	Gaining access to a user-friendly platform that includes tutorials and resources. Attending new courses and topics (e.g., Employability Enhancement & Managerial skills). Gaining knowledge and skills which prepared them for their internship experience. Connecting with invited speakers from the industry. Working on authentic and real-world problems. Taking responsibility for learning. Engaging in deeper learning. Gaining an understanding of the various phases of problem-solving. Working in multidisciplinary groups. Receiving peer feedback. Receiving coaching, support, and constructive feedback from the facilitator. Enhancing engineering knowledge. Developing non-technical skills (e.g., teamwork skills, critical thinking, creativity).	Assimilating new knowledge due to the complexity of the subject matter and the short duration of the courses. Managing the problem-solving process on a tight schedule.
Internship Phase	Familiarising themselves with the company people, equipment, and processes during the induction period. Working in multidisciplinary groups. Working on self-initiated projects. Working on real problems. Developing management skills. Collaborating with industrial experts. Learning from observations and from experienced people. Receiving mentor's feedback for professional development. Enhancing engineering knowledge. Developing non-technical skills (e.g., communication skills, professional skills). Thinking outside of the box. Enhancing employability potential. Developing professional networks.	Managing time due to the short internship duration. Investing a significant amount of internship time into the induction period. Having no prior experience working in the field. Communicating and collaborating with the technical staff. Working in environments with gender imbalance.

and ill-structured problems [12, 15]. Similar results were also reported in previous studies which indicated that instructional approaches such as PBL favour the development of problem-solving skills [51, 52, 68], especially when combined with real-life applications [55]. Specifically, within their internship, the trainees had the opportunity to accelerate their hands-on experiences and consolidated their problem-solving skills. The above finding was confirmed during their interviews as some trainees clearly emphasised the usefulness of their internship placement to the consolidation of the learning benefits derived from the training phase and to their professional development. This finding agrees with previous research which emphasised the value and significance of engineering learning in workplace settings [27]. Also, according to the trainees, additional learning elements that contributed to a positive PBL experience are described as follows. At first, the online platform and the available resources that aimed to prepare trainees for the PBL journey played a significant role in their active engagement in the learning process. In particular, the flexible access to online material, the opportunity to pursue learning aligned to their schedule and the provision of scaffolding from the facilitators contributed to the development of prior theoretical understanding of the subject matter and how the problem-solving process is applied in a particular field. These findings are consistent with prior studies which highlighted the importance of understanding the background concepts prior to embarking on PBL [40, 42]. Another positive element refers to the scaffolding of the problem-solving process by invited speakers-experts in the field. This practice is a modelling technique for realistic expert problem-solving that depicts the way practitioners work in their field [61] and was found to be of value to students, especially for their preparation for industry settings. Prior studies have linked modelling expert problem-solving to positive outcomes regarding the development of problem-solving skills [36, 40]. Some trainees perceived positively the implementation of problem-solving activities within multidisciplinary teams. They mentioned that working in multidisciplinary groups was a beneficial learning experience for the development of both technical and professional skills. Regarding the latter, special reference was made to the development of additional skills related to collaboration and teamwork, such as leadership and communication skills, critical thinking, and creativity. This finding is not surprising, given that studies have revealed that PBL projects which include open-ended and ill-structured problems benefit the development of non-technical skills even when such skills are not directly taught [25, 24, 60, 62]. Additionally, multidisciplinary collaboration is an important aspect of the Industry 4.0 and should be encouraged across disciplines in higher education [54]. Equally important is also self-directed learning which can be developed through the implementation of PBL approaches [52]. Positive results were reported regarding self-directed learning in this study. Specifically, during the programme, trainees had to manage their projects and be responsible for their own learning. As they explained, such processes enhanced their understanding of the subject matter. Overall, the trainees reported that they gained work-based experience and familiarised themselves with the "industry culture", they developed a professional network and enhanced their professional confidence. Another positive aspect of the PBL that emerged from the trainees' responses relates to the facilitation of the PBL process. It appears that the facilitators' training prior to the implementation of the programme prepared them to provide timely and relevant feedback and support. Based on the trainees' commentaries, the facilitators provided effective guidance and support during the learning process and prompted them to gradually move to autonomous learning. The results of previous studies demonstrated that the training of facilitators is of great importance in the implementation of PBL approaches, and it is even more critical when the objective is to guide students to solve complex and open-ended problems [45, 49]. Specifically, the provision of timely feedback and the availability to follow up on inquiries and questions were among the facilitators' qualities that trainees appreciated. Additionally, trainees stated that the support and feedback they received from their mentors were important for the smooth transition from the training phase to the internship phase. This finding is supported by previous research which showed that mentors can support students to bridge the theory-practice gap [55].

An additional interesting finding of the present study relates to the contents of the PBL programme. Specifically, the trainees commended that some of the training courses were completely new to them, especially regarding the Employability Enhancement and Managerial Skills. This finding is aligned with prior research supporting that, while higher education institutions provide a solid theoretical and technical background, they do not adequately address graduates' non-technical skills required by the industry [27]. Based on this finding we can argue that the needs analysis process that took place by the PBL facilitators prior to the development of the ENGINITE programme played a crucial role in the selection of the course content according to the needs derived from the local context.

Apart from the positive results reported previously, there were a few challenges that emerged during the implementation of the programme. Specifically, trainees reported that the period of implementation was relatively short for both the training and the internship phases. In some cases, especially concerning the technical courses, the short timeframes for delivery of project work along with the complexity of the subject matter seemed to have a negative effect on the accomplishment of the project. Similar findings were found in other studies regarding the application of short cycle problem analysis and problem solving which is not representative of the professional work of engineers [36]. Additionally, participants' lack of previous learning experiences within PBL approaches may increase their difficulties to deliver project work [42]. Another challenge refers to trainees' perceived difficulties communicating with the technical staff in the workplace environment. Prior research indicated that the communication skills of the engineering graduates are weak and engineering students are less prepared in this area [27] despite the fact that industry professionals highlight the importance of communication skills in workplace settings [5, 34]. Lastly, another additional challenge refers to the gender representation of engineering staff in workplace settings. Such finding is not surprising given that, female numbers are low in job families such as Manufacturing and Production or Construction and Extraction [3].

5.2 Limitations and Future Directions

The main limitation of this study is the relatively small sample size. While this sample is representative, given the nature of this study, future research should aim for larger samples to allow the generalizability of the results. Second, the findings were reported from the point of view of the participants. It would be interesting for future research to examine the perceptions of the industry experts or the facilitators/mentors to gain a more holistic view of the PBL processes during internship placements. Third, the results are mainly relevant to the specific VET programme, which included a training phase underpinned by PBL, followed by an internship phase. However, this is only one approach for supporting the professional development of graduates in the engineering sector. Future studies could focus on different approaches to VET programmes that would consider their duration and ensure that there is a good balance between the theoretical and practical aspects of the PBL training. This practice would ensure that the problem-solving processes would be understood and successfully implemented. Additionally, future training could focus on communication skills, investigating their impact on the professional development of graduate participants.

6. Conclusion

Nowadays, in the era of Industry 4.0, engineering education requires powerful pedagogical models that can equip engineers with problem-solving skills. This paper makes the case that the success of PBL programmes in engineering education depends on several factors: support from the experts on how to approach PBL, training of educators in terms of pedagogy, prior analysis for the identification of context-specific needs, and a balance between the theoretical and practical applications of problem-solving through industry-academia collaboration. Our findings indicate that the implementation of a postgraduate Vocational Education and Training (VET) programme consisting of a training and an internship phase enabled participants to develop problem-solving skills. The authors highlighted several additional benefits which emerged from both phases. Examples include gaining a deeper understanding of the problem-solving process, developing professional knowledge, and enhancing employability potential. However, various challenges emerged during the programme, raising questions about the quality of the PBL implementation that needs to be further investigated. Such challenges refer to the time allocation for the assimilation of new knowledge and the application of problem-solving, along with challenges in the workplace context, such as communication with the technical staff. We hope that this work can open a platform for discussion regarding the engineering curricula and the use of problem-oriented pedagogies toward improving employability and professional skills through industry-academia collaboration.

Acknowledgements – This work is part of the project 'ENGINITE: ENGineering and INdustry Innovative Training for Engineers via PBL', which is funded under the scheme Erasmus + KA2: Cooperation for innovation and the exchange of good practices (grant agreement no: 2017-1-CY01-KA202-026728), and partially funded by the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 739578 and the Government of the Republic of Cyprus through the Deputy Ministry of Research, Innovation and Digital Policy.

References

1. S. Sheppard, A. Colby, K. Macatangay and W. Sullivan, What is engineering practice?, *International Journal of Engineering Education*, **22**(3), pp. 429–438, 2007.

2. D. Bourn, *Understanding global skills for 21st century professions*, Switzerland, Palgrave Macmillan, pp. 201–219, 2018.
3. World Economic Forum, *The Future of Jobs Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution. Global Challenge Insight Report*, https://www3.weforum.org/docs/WEF_Future_of_Jobs.pdf, Accessed 4 October 2021.
4. M. Abramovici, J. C. Göbel and M. Neges, Smart engineering as enabler for the 4th industrial revolution. In M. Fathi (ed.) *Integrated systems: Innovations and applications*, Springer, Switzerland, pp. 163–170, 2015.
5. D. Q. Nguyen, The essential skills and attributes of an engineer: A comparative study of academics, industry personnel and engineering students, *Global Journal of Engineering Education*, **2**(1), pp. 65–75, 1998.
6. I. Belski, R. Adunka and O. Mayer, Educating a creative engineer: learning from engineering professionals, *Procedia CIRP*, **39**, pp. 79–84, 2016.
7. National Academy of Engineering, *The Engineer of 2020. Visions of Engineering in the New Century*, https://www.nap.edu/read/10999/chapter/1, Accessed 4 October 2021.
8. S. D. Sheppard, J. W. Pellegrino and B. M. Olds, On becoming a 21st century engineer, *Journal of Engineering Education*, **97**(3), pp. 231–234, 2008.
9. R. K. Miller, Why the hard science of engineering is no longer enough to meet the 21st century challenges, *Olin College of Engineering*, pp. 1–15, 2015.
10. R. K. Miller, Building on Math and Science: The New Essential Skills for the 21st-Century Engineer: Solving the problems of the 21st century will require that engineers have a new set of skills and mindsets, *Research-Technology Management*, **60**(1), pp. 53–56, 2017.
11. B. Lucas and J. Hanson, Thinking like an engineer: Using engineering habits of mind and signature pedagogies to redesign engineering education, *International Journal of Engineering Pedagogy*, pp. 4–13, 2016.
12. D. Jonassen, J. Strobel and C. B. Lee, Everyday problem solving in engineering: Lessons for engineering educators, *Journal of Engineering Education*, **95**(2), pp. 139–151, 2006.
13. C. Mitcham, The true grand challenge for engineering: Self-knowledge, *Issues in Science and Technology*, **31**(1), 19, p. 2014.
14. F. M. Kamaruzaman, R. Hamid, A. A. Mutalib and M. S. Rasul, Conceptual framework for the development of 4IR skills for engineering graduates, *Global Journal of Engineering Education*, **21**(1), pp. 54–61, 2019.
15. E. P. Douglas, M. Koro-Ljungberg, N. J. McNeill, Z. T. Malcolm and D. J. Therriault, Moving beyond formulas and fixations: solving open-ended engineering problems, *European Journal of Engineering Education*, **37**(6), pp. 627–651, 2012.
16. N. Fajaryati and M. Akhyar, The employability skills needed to face the demands of work in the future: systematic literature reviews, *Open Engineering*, **10**(1), pp. 595–603, 2020.
17. G. Spöttl, Development of "Industry 4.0"! Are Skilled Workers and Semi-Engineers the Losers?, *7th World Engineering Education Forum (WEEF), Kuala Lumbur*, pp. 851–856, 2017.
18. A. Kirn and L. Benson, Engineering students' perceptions of problem solving and their future, *Journal of Engineering Education*, **107**(1), pp. 87–112, 2018.
19. A. Kolmos and J. E. Holgaard, Employability in engineering education: Are engineering students ready for work?, In S. H. Christensen, B. Delahousse, C. Didier, M. Meganck and M. Murphy (eds.), *The Engineering-Business Nexus*, Springer, Switzerland, pp. 499–520, 2019.
20. J. Liebenberg, M. Huisman and E. Mentz, Industry's perception of the relevance of software development education, *The Journal for Transdisciplinary Research in Southern Africa*, **11**(3), pp. 260–284, 2015.
21. M. Koro-Ljungberg, E. P. Douglas, N. J. McNeill, D. J. Therriault, C. S. Lee and Z. Malcolm, Academic problem-solving and students' identities as engineers, *The Qualitative Report*, **22**(2), pp. 456–478, 2017.
22. K. Edström and A. Kolmos, PBL and CDIO: complementary models for engineering education development, *European Journal of Engineering Education*, **39**(5), pp. 539–555, 2014.
23. J. E. Mills and D. F. Treagust, Engineering education – Is problem-based or project-based learning the answer, *Australasian Journal of Engineering Education*, **3**(2), pp. 2–16, 2003.
24. Ú. Beagon, D. Niall and E. Ní Fhloinn, Problem-based learning: student perceptions of its value in developing professional skills for engineering practice, *European Journal of Engineering Education*, **44**(6), pp. 850–865, 2019.
25. C. A. Sanchez-Gomez, Implementing a joint learning method (PBL and EBL) to innovate the development of mechanical engineering technical and non-technical skills, *International Journal of Mechanical Engineering Education*, pp. 1–21, 2020.
26. A. C. Alves, R. M. Sousa, S. Fernandes, E. Cardoso, M. A. Carvalho, J. Figueiredo and R. M. Pereira, Teacher's experiences in PBL: implications for practice, *European Journal of Engineering Education*, **41**(2), pp. 123–141, 2016.
27. J. Trevelyan, Transitioning to engineering practice, *European Journal of Engineering Education*, **44**(6), pp. 821–837, 2019.
28. C. Reidsema, R. Hadgraft, I. Cameron and R. King, Change strategies for educational transformation, *Australasian Journal of Engineering Education*, **19**(2), pp. 101–108, 2013.
29. B. Motyl, G. Baronio, S. Uberti, D. Speranza and S. Filippi, How will change the future engineers' skills in the Industry 4.0 framework? A questionnaire survey, *Procedia Manufacturing*, **11**, pp. 1501–1509, 2017.
30. D. McGunagle and L. Zizka, Employability skills for 21st-century STEM students: the employers' perspective, *Higher Education, Skills and Work-Based Learning*, **10**(3), pp. 591–606, 2020.
31. I. Cameron, C. Reidsema and R. Hadgraft, Australian engineering academe: a snapshot of demographics and attitudes, *22nd Annual Conference for the Australasian Association for Engineering Education. Developing Engineers for Social Justice: Community Involvement, Ethics & Sustainability*, Fremantle, Western Australia, 5–7 December 2011, pp. 107–113, 2011.
32. L. Büth, V. Bhakar, N. Sihag, G. Posselt, S. Böhme, K. S. Sangwan and C. Herrmann, Bridging the qualification gap between academia and industry in India, *Procedia Manufacturing*, **9**, pp. 275–282, 2017.
33. D. J. Deming and K. Noray, Earnings dynamics, changing job skills, and STEM careers, *The Quarterly Journal of Economics*, **135**(4), pp. 1965–2005, 2020.
34. S. Hawse, Transitioning to professional work: a view from the field. In L. N. Wood and Y. A. Breyer (eds.) *Success in Higher Education*, Springer, Singapore, pp. 229–253, 2017.
35. J. Walther, N. Kellam, N. Sochacka and D. Radcliffe, Engineering competence? An interpretive investigation of engineering students' professional formation, *Journal of Engineering Education*, **100**(4), pp. 703–740, 2011.

36. J. C. Perrenet, P. A. Bouhuijs and J. G. Smits, The suitability of problem-based learning for engineering education: theory and practice, *Teaching in Higher Education*, **5**(3), pp. 345–358, 2000.
37. N. Davidson and C. H. Major, Boundary crossings: Cooperative learning, collaborative learning, and problem-based learning, *Journal on Excellence in College Teaching*, **25** (3&4), pp. 7–55, 2014.
38. M. Savin-Baden, *Problem-based learning in higher education: Untold stories.* SRHE and Open University Press, Philadelphia, 2000.
39. J. Strobel and A. Van Barneveld, When is PBL more effective? A meta-synthesis of meta-analyses comparing PBL to conventional classrooms, *Interdisciplinary Journal of Problem-based Learning*, **3**(1), pp. 44–58, 2009.
40. J. S. Larson, K. Farnsworth, L. S. Folkestad, H. K. Tirkolaei, K. Glazewski and W. Savenye, Using problem-based learning to enable application of foundation engineering knowledge in a real-world problem, *IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE)*, Wollolngong, NSW, Australia, 4–7 December, pp. 500–506, 2018.
41. C. E. Hmelo-Silver, Problem-based learning: What and how do students learn?, *Educational Psychology Review*, **16**(3), pp. 235–266, 2004.
42. W. Hung, All PBL starts here: The problem, *Interdisciplinary Journal of Problem-Based Learning*, **10**(2), 2, 2016.
43. R. Marra, D. H. Jonassen, B. Palmer and S. Luft, Why problem-based learning works: Theoretical Foundations, *Journal on Excellence in College Teaching*, **25**(3&4), pp. 221–238, 2014.
44. W. Hung, Theory to reality: A few issues in implementing problem-based learning, *Educational Technology Research and Development*, **59**(4), pp. 529–552, 2011.
45. J. Chen, A. Kolmos and X. Du, Forms of implementation and challenges of PBL in engineering education: a review of literature, *European Journal of Engineering Education*, **46**(1), 90–115, 2021.
46. M. Savin-Baden, Using Problem-based Learning: New Constellations for the 21st Century, *The Journal on Excellence in College Teaching*, **25**(3&4), pp. 197–219, 2014.
47. H. S. Barrows, A taxonomy of problem-based learning methods, *Medical Education*, **20**(6), pp. 481–486, 1986.
48. G. G. Mitchell and J. D. Delaney, An assessment strategy to determine learning outcomes in a software engineering problem-based learning course, *International Journal of Engineering Education*, **20**(3), pp. 494–502, 2004.
49. A. Mantri, Working towards a scalable model of problem-based learning instruction in undergraduate engineering education, *European Journal of Engineering Education*, **39**(3), pp. 282–299, 2014.
50. V. V. Shinde and S. S. Inamdar, Problem based learning (PBL) for engineering education in India: Need and recommendations, *Wireless Personal Communications*, **69**(3), pp. 1097–1105, 2013.
51. K. M. Yusof, A. N. Sadikin, F. A. Phang and A. A. Aziz, Instilling professional skills and sustainable development through Problem-Based Learning (PBL) among first year engineering students, *International Journal of Engineering Education*, **32**(1), pp. 333–347, 2016.
52. J. N. Warnock and M. J. Mohammadi-Aragh, Case study: use of problem-based learning to develop students' technical and professional skills, *European Journal of Engineering Education*, **41**(2), pp. 142–153, 2016.
53. A. D. Vidic, Impact of problem-based statistics course in engineering on students' problem solving skills, *International Journal of Engineering Education*, **27**(4), pp. 885–896, 2011.
54. R. G. Hadgraft and A. Kolmos, Emerging learning environments in engineering education, *Australasian Journal of Engineering Education*, **25**(1), pp. 3–16, 2020.
55. D. Dunn-Rankin, J. E. Bobrow, K. D. Mease and J. M. McCarthy, Engineering design in industry: Teaching students and faculty to apply engineering science in design, *Journal of Engineering Education*, **87**(3), pp. 219–222, pp. 1998.
56. S. Renganathan, Z. A. B. A. Karim and S. L. Chong, Students' perception of industrial internship programme, *Education + Training*, **54**(2/3), pp. 180–191, 2012.
57. A. Kolmos and J. E. Holgaard, Impact of PBL and company interaction on the transition from engineering education to work, In A. Guerra, F. J., Rodriguez, A. Kolmos and I. P. Reyes (eds.) *6th International Research Symposium on PBL: PBL, Social Progress and Sustainability*, Aalborg University Press, Aalborg, pp. 87–98, 2017.
58. M. Goller, C. Harteis, D. Gijbels and V. Donche, Engineering students' learning during internships: Exploring the explanatory power of the job demands-control-support model, *Journal of Engineering Education*, **109**(2), pp. 307–324, 2020.
59. L. C. Ribeiro, The Pros and Cons of Problem-Based Learning from the Teacher's Standpoint, *Journal of University Teaching & Learning Practice*, **8**(1), pp. 34–51, 2011.
60. A. A. Ahern, A case study: Problem-based learning for civil engineering students in transportation courses, *European Journal of Engineering Education*, **35**(1), pp. 109–116, 2010.
61. M. Christie and E. De Graaff, The philosophical and pedagogical underpinnings of Active Learning in Engineering Education, *European Journal of Engineering Education*, **42**(1), pp. 5–16, 2017.
62. J. J. Kellar, W. Hovey, M. Langerman, S. Howard, L. Simonson, L. Kjerengtroen, L. Stetler, H. Heilhecker, L. Arneson-Meyer and S. D. Kellogg, A problem based learning approach for freshman engineering, *30th Annual Frontiers in Education Conference. Building on A Century of Progress in Engineering Education. Conference Proceedings (IEEE Cat. No. 00CH37135)*, Kansas City, MO, 18–21 October, **2**, F2G-7, 2000.
63. A. Kolmos and F. K. Fink, *The Aalborg PBL model: progress, diversity and challenges*, In A. Kolmos F. K. Fink and L. Krogh (eds.), *The Aalborg PBL model – Progress, Diversity and Challen*ges, Aalborg University Press, Aalborg, 2004.
64. J. W. Creswell, *Research design: Qualitative, quantitative, and mixed methods approaches*, 4th edn, SAGE Publications, Thousand Oaks, California, 2014.
65. J. W. Creswell and V. L. Plano Clark, *Designing and Conducting Mixed Methods Research*, 2nd edn, Thousand Oaks, California, SAGE Publications, 2011.
66. P. P. Heppner and C. H. Petersen, The development and implications of a personal problem-solving inventory, *Journal of Counseling Psychology*, **29**(1), pp. 66–75, 1982.
67. T. F. Wu, R. l. Custer and M. J. Dyrenfurth, Technological and personal problem solving styles: Is there a difference?, *Journal of Technology Education*, **7**(2), pp. 55–71, 1996.
68. D. R. Woods, Problem-based learning for large classes in chemical engineering, *New Directions for Teaching and Learning*, **68**, pp. 91–99, 1996.

69. P. P. Heppner and C. E. Baker, Applications of the problem solving inventory, *Measurement and Evaluation in Counseling and Development*, **29**(4), pp. 229–241, 1997.
70. Ö. Özyurt, Examining the critical thinking dispositions and the problem solving skills of computer engineering students, *Eurasia Journal of Mathematics, Science and Technology Education*, **11**(2), pp. 353–361, 2015.
71. P. P. Heppner, T. B. Pretorius, M. Wei, D. G. Lee and Y. W. Wang, Examining the generalizability of problem solving appraisal in black South Africans, *Journal of Counseling Psychology*, **49**, pp. 484–498, 2002.
72. Y. P. Huang and L. Y. Flores, Exploring the validity of the problem-solving inventory with mexican american high school students, *Journal of Career Assessment*, **19**(4), pp. 431–441, 2011.
73. N. Kourmousi, V. Xythali, M. Theologitou and V. Koutras, Validity and reliability of the problem solving inventory (PSI) in a nationwide sample of Greek educators, *Social Sciences*, **5**(2), 25, 2016.
74. L. Cohen, L. Manion and K. Morrison, *Research Methods in Education*, 8th end., Routledge New York, 2018.
75. M. Q. Patton, *Qualitative Research & Evaluation Methods*, 3rd end, SAGE Publications, Thousand Oaks, CA, 2002.

Ourania Miliou is a Research Associate and a Post-Doctoral Researcher at CYENS Centre of Excellence, Cyprus. She holds a Bachelor's and Master's degree in Education from the Aristotle University of Thessaloniki and a PhD degree in Instructional Technology from the University of Cyprus. Her research interests include instructional design, training delivery, technology-enhanced learning, gamification, e-learning, digital skills, digital competence, and learning design (mostly based on Constructivist Learning approaches) with the use of digital technologies, emerging technologies, and interactive media.

Andri Ioannou is an Associate Professor in the Department of Multimedia and Graphic Arts of the Cyprus University of Technology, Director of the Cyprus Interaction Research Lab (https://www.cyprusinteractionlab.com/), and Team Leader of the "Educational Media for Education and Edutainment" research group of the CYENS Research Centre, Cyprus. Andri has a PhD in Educational Technology and an MA in Education both from the University of Connecticut (USA), and a BSc in Computer Science from the University of Cyprus. Her research contributes to key areas of educational technology, including the (i) design and evaluation of technology-enhanced learning environments, (ii) use of technology to support skills within a 21st century framework including problem-solving, collaboration, metacognition, and "living in the world" skills, (iii) design of embodied, playful and gameful learning using technology, and (iv) technology integration in all levels of education.

Yiannis Georgiou holds a bachelor's degree in Elementary School Teaching as well as a master's degree in Science & Environmental Education from the University of Cyprus, and a PhD in New Technologies for Communication and Learning from the Cyprus University of Technology. His research interests are focused on the design and investigation of immersive learning environments as well as on teachers' professional development regarding novel pedagogies and technologies, using co-design and participatory design approaches. During the preparation of this work, he served as a Post-Doctoral Researcher with the Cyprus Interaction Lab and the CYENS Centre of Excellence.

Ioannis Vyrides is an Assistant Professor at the Department of Chemical Engineering at the Cyprus University of Technology. He has been in the Environmental Engineering Laboratory group leader since 2012. He holds a Diploma in Chemical Engineering from the National Technical University of Athens, Greece (2005). He has a PhD in Chemical Engineering from the Imperial College London. Dr Ioannis Vyrides Research lies in the field of Environmental Engineering and deals with emerging problems that the world needs to tackle in the following decades.

Konstantinos Komnitsas is a Professor in the School of Mineral Resources Engineering of the Technical University of Crete. He holds a PhD degree in Hydrometallurgy and is the director of the Laboratories (i) Ore Beneficiation, (ii) Waste Management and Soil Decontamination, and (iii) Ceramics and Glass Technology of the School of Mineral Resources Engineering of Technical University of Crete. He is expert in the fields of hydro- and bio-hydrometallurgy, waste management and valorization, soil decontamination, environmental risk assessment and Life Cycle Analysis (LCA). He is also member of the Education Council of EURECA-PRO, European University on Sustainable Consumption and Production, which is an alliance of 7 universities located in 6 European countries, https://www.eurecapro.eu/.

Panayiotis Andreou is an experienced Civil Engineer practitioner. He has worked in prestigious international companies and in unique projects. He is a holder of a BSc in Civil and Environmental Engineering from the University of Cyprus, and an MSc in Analysis and Design of Earthquake resistant Structure from the National Technical University of Athens. Panagiotis is also a certified trainer/ facilitator with experience in teaching engineering courses in public and private VET centers. His research interests are focused in Engineering Education, VET sector and applied engineering.

Andreas Andreou graduated from the National Technical University of Athens with the Degree of Chemical Engineer. He holds a Masters in Environment & Development and in Business Administration (MBA). Andreas has a strong background in the dairy sector as well as in the oil & gas sectors. He has also served in multiple positions including but not limited to integrated project management, design and execution, production & operations management, business management and vocational technical training.

Søren Willert is today Professor Emeritus at the Dept. of Culture and Learning, Aalborg University. At Aalborg he has, since 2006, mainly been engaged as PBL-inspired teacher and tutor at master courses for experienced organizational change agents: managers and consultants. During the period 1968–2005 he was attached to Dept. of Psychology, Aarhus University where his academic profile became that of 'university-based practitioner'. Professional practice based on a broad range of psycho-social helper roles: psychotherapist, counsellor, coach, supervisor, process consultant, PBL-inspired teacher, action researcher, gave him access to empirical data on which his research, teaching and professional training activities became based.

Nikolaos Xekoukoulotakis is an Assistant Professor in the School of Chemical and Environmental Engineering of the Technical University of Crete, Chania, Greece, and director of the Laboratory of Environmental Organic Chemistry. He holds a Bachelor's degree in Chemistry (1995) and a PhD degree in Organic Chemistry (2001), both obtained from the Aristotle University of Thessaloniki, Greece. His research interests are in water pollution and environmental clean-up with an emphasis on water and wastewater treatment using several advanced treatment processes. He has participated in several national and international research projects on the degradation of various contaminants of emerging concern employing several advanced treatment technologies. He has supervised 25 undergraduate, 10 Master's, and 1 PhD theses, and he has published 50 articles in peer-reviewed scientific journals (Scopus h-index = 32, over 3400 hetero-citations).

Panayiotis Zaphiris is the Rector of Cyprus University of Technology and a Professor at the Department of Multimedia and Graphic Arts of the Cyprus University of Technology. In the past he served also as Dean of School of Fine and Applied Arts and Head of department of the Department of Multimedia and Graphic Arts. His research interests lie in HCI with an emphasis on inclusive design and social aspects of computing. He is especially interested in HCI issues related to the elderly and people with disabilities. He has also done work in internet related research (web usability, mathematical modelling of browsing behaviour in hierarchical online information systems, online communities, e-learning, web based digital libraries and finally social network analysis of online human-to-human interactions).

Stylianos Yiatros is an Associate Professor in Structural Engineering at the Department of Civil Engineering and Geomatics of the Cyprus University of Technology. His research and innovation work spans from nonlinear structural mechanics to bioinspired design, and circular construction. He has been active in problem-based learning work in engineering education, having been awarded Merit in Excellence in Structural Engineering Education by the Institution of Structural Engineers in 2015. Since 2016 he is the Education Lead for the EIT Climate-KIC Cyprus hub co-designing, coordinating and delivering educational offerings to different target groups associated with Systems thinking, climate innovation and cleantech entrepreneurship.