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New Instructional Approach for Fostering Generic and Professional Competences: Case Study of the Project and Problem Based Learning Engineering Practice Course*

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In this paper, we present a novel instructional approach introduced to the final year engineering students with the aim of developing their generic and professional competences. The proposed approach, based on project and problem based learning and ill-structured problem solving, was analyzed in the context of competence development and implications for engineering educators. The results of our action research indicate that the generic competences that were found to be significantly fostered were: systems thinking, ambiguity tolerance, asking questions, solving ill-structured problems, ability to apply knowledge in practice, presentation and generating new ideas. Professional competences that were found to be significantly fostered all belong to higher order thinking skills, and include the ability to design and evaluate, analyze, interpret and create new engineering solutions. These findings provide empirical support for the use of applied student-centered strategies for developing competences relevant for future work, as well as reflections that can support engineering educators in designing similar teaching and learning environments.

Keywords: engineering students; generic and professional competence development; project-based learning; workplace simulation; implications for engineering educators

1. Introduction

In the 21st century, with rapid knowledge growth, new approaches for preparing students for the workplace are being considered, putting more emphasis on equipping them with the skills and competences in looking for and finding knowledge and dynamically adapting it for different purposes. Today's engineers, in addition to sound technical knowledge, need to understand and appreciate the impact of social and cultural dynamics, develop skills and competences that enable them to deal with ambiguity and solve complex, multi-layered problems. Engineers should also develop the ability to work in multidisciplinary teams, to take initiative, to solve problems creatively, to communicate effectively and to think globally [1]. As it is shown by previous studies, graduates equipped with these essential competences, could have a competitive advantage in finding and preserving their jobs [2, 3]. This increased pressure to equip graduates with competences required for dynamic work environments poses significant challenges for engineering educators in terms of curriculum design which has to overcome traditional educational approaches in order to prepare engineers for the 21st-century careers. In order to fully implement new teaching methods and foster new learning strategies, university teachers, as well as other engineering instructors and mentors, need institutional support, appropriate professional development and examples and exchange of the models of good practice from engineering education research [4].

In order to contribute to the elaboration of the comparable and compatible framework of university qualifications, *The Tuning Educational Structures in Europe* project offered reference points which are expressed in terms of learning outcomes and expected competences after the conclusion of the learning process. In this way, different educational programs across Europe could be adjusted in order to achieve the desired learning outcomes that include generic and subject-related competences. We have adopted Tuning's definition of competence as '*a dynamic combination of knowledge, understanding, skills and abilities*' [5]. In this research, we will analyze the two types of competences—the professional competences (more related to engineering profession) and generic competences that are a combination of learning, analytical and problem-

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solving skills not specifically related to context and transferable across different occupational contexts [6]. The fact that the modern engineering industry needs engineers with competences that include both sound technical understanding applied to practice, and generic competences to work effectively in a business environment is reflected in the recommendations of the professional engineering bodies around the world (Accreditation Board for Engineering and Technology (ABET), USA (a–f) [7], European Federation of National Engineering Associations (FEANI), Europe (g) [8], and the Engineers Australia (h–i) [9]). Engineering programs should demonstrate that their students attain the outcomes linked to some or to all of the skills and abilities summarized below:

(a) an ability to apply knowledge of mathematics, science, and engineering,
(b) an ability to design a system, component, or process to meet desired needs within realistic constraints,
(c) an ability to function on multidisciplinary teams,
(d) an ability to identify, formulate, and solve engineering problems,
(e) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context,
(f) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice,
(g) an awareness of continuous technical change and an attitude to seek innovation and creativity within the engineering profession,
(h) an ability to communicate effectively not only with engineers but also with the community at large,
(i) ability to utilize a systems approach to design and operational performance.

Recent research shows employers' growing concern regarding the competence gap between engineering education and professional practice, identified also in international studies conducted in the UK and the USA [10, 11]. A similar concern was recognized in a study conducted in Austria especially in relation to the following competences: capability to solve problems in a structured and solution-oriented way; project and process/quality management skills; team competences and the ability to handle conflicts; and presentation and written expression [12].

In order to achieve some of the above-mentioned outcomes and close the existing competence gaps, during their formal education students have to be faced with complex, ill-structured real-world problems where learning is set in the learning environments similar to the working one. However, it is difficult to provide this kind of instruction within the conventional engineering curricula, while internships are not always viable or fail to provide a dedicated mentor or a friendly and safe environment that would enhance students' engagement in ill-structured workplace problem solving.

This situation implies that engineering educators need to adjust the instructional approach in order to achieve the desired outcomes. The needed shift in educational approaches that would provide the space for generic and professional competence development includes different student-centered strategies, such as problem-based (PBL) and project-based learning, and ill-structured problems that are found to be highly effective in encouraging the development of the transferable skills [13–15].

The purpose of our action research was to implement the instructional module for professional practice based on project and problem based learning and ill-structured problem-solving in order to explore how effectively this instructional approach would foster engineering students' generic and professional competences. The specific research objectives of the study were to:

- determine the level of success that students perceive regarding their generic competences before and after taking the course,
- determine the level of success that students perceive regarding their professional competences before and after taking the course,
- analyze the contribution of the course to the development of students' generic and professional competences and implications for the practice of engineering educators.

This study was a part of the large four-year research project led by the first author of this article whose aim was to design, implement and evaluate project and problem based internship-like course in the university settings [16, 17].

2. Instructional approach

In order to determine the new instructional approach for designing the project and problem based internship-like course that would foster both generic and professional competences, an innovative conceptual framework was needed, which would encompass different approaches to the learning experience and learning content as well as an approach to defining and evaluating the learning outcomes.

Our framework is based on the constructivist approach to learning and experiential learning inspired by Kolb [18], where student-centered strategies, such as project and problem based learning are introduced in order to allow students to go through the whole learning cycle from concrete experience to active experimentation. The simplified reality of the workplace and its essential functions were represented through a role-play simulation. In the following paragraphs, the basic principles regarding each of the approaches are given, as well as the implications for engineering educators.

In the constructivist learning environment, learning and development, in general, occur through the experiment where learners build and test their hypotheses, evaluate their experience, and review their hypotheses all over again [19]. Therefore, learning environments require that instructors undertake the role of facilitators and not teachers 'per se', thus becoming the guides and not knowledge transmitters while supporting a learner in becoming an effective and reflective practitioner [20]. The instructor's role is to constantly adapt the learning experience by observing the class, reflecting his/her own experience and directing the learning process by setting the goals just a bit further out of the students' comfort zone [21]. Such learning experience is inseparable from dealing with real-life problems that require learning by doing [22].

Project-based learning is a student-centered learning strategy that offers productive ground for the development of competences that are required from future graduate engineers. Such competences include planning and management of work, utilizing practical applications of theoretical learning in real-life situations; working as a part of a team; applying knowledge and skills in industry or other workplace settings; considering technological, environmental and commercial issues [23]. Almost every task undertaken in professional practice by an engineer will be in relation to some project [24]. Projects "require a question or problem that serves to organize and drive activities; and these activities result in a series of artifacts, or products, that culminate in a final product that addresses the driving question" [25]. Instructor's role in project-based learning implies using skills of a project manager such as time management, project management, cooperation and collaboration in addition to planning, monitoring, scaffolding, adjusting and troubleshooting strategies. The topics that instructors select for project and problem based learning need to be carefully chosen, usually integrating a range of disciplines, technical and non-technical, and they should allow the opportunity for problem-solving, collaboration, and cooperation [26, 27].

Problem-based learning (PBL) is conceived as one of the most innovative approaches in the recent educational history as a reaction to the criticism of traditional teaching methods in medicine that was not effective in preparing students for future practice [28]. In this approach, students' learning process is embedded in real-life professional problems that are usually ill-structured. Ill-structured problems have vaguely defined goals and unstated constraints, multiple solutions as well as multiple criteria for evaluating solutions; they require learners to make judgments and defend them [29]. In problem-based learning (PBL) students take ownership of the problem, and the problem-solving process in order to develop their own problem-solving skills, rather than being told how to solve the problem. Problem-based learning requires that instructors develop good facilitation skills, characterized by open-mindedness, the ability to ask stimulating questions, guide students with minimum intervention, and promote students' independence [30]. Instructors should also learn to tolerate the ambiguity during the classes and face the declining motivation that arises when errors occur and when both instructors and students have to accept that errors are necessary in order to learn and to apply acquired knowledge [31].

Workplace simulation can be useful in preparing future engineers since it has been shown that in spite of students' confidence in their knowledge about technical aspects of an engineering job, most of them find it difficult to make the transition from a relatively structured academy environment to an environment where one is given a problem, presented with deadline and then left alone to solve the problem [32].

2.1 Implementation model

The "Project planning and organization in engineering practice" internship-like course was designed for students of the final year of the bachelor studies and/or for the master students of the Telecommunications department and IT department of The School of Electrical Engineering, University of Belgrade. The course was divided into 13 sessions of 3-5 hours, bringing 2 ECTS (European Credit Transfer System). Students worked in small teams on a real project. Each team's task was to create a proposal for the telecommunications system turn-key implementation for an imaginary customer that had to include: the preliminary conceptual design of the system, detailed project plan and final budget for design, supply, installation, and commissioning of the system. The proposal and the complete solution were presented by each team to the "customer board" at the end of the course.

The instructor was an industry expert (the first author) with extensive experience in project management and systems design. She designed and implemented the course so that it would correspond to a real-world engineering project by using the workplace simulation. She took over different roles during the course: the customer, the boss, and the vendor representative. Two professors (one of whom is the second author) from Telecommunications department were in charge of the harmonization of the course with other students' activities, positioning of the course within the engineering curriculum and they formed the part of the "customer board" for the students' final presentations. The simplified reality of the workplace and its essential functions were represented through a role-play simulation. Such course design allowed the shift from the conventional to the more practical approach that is needed in order to provide the space for the development of targeted competences.

3. Research method

This study adopted an action research approach as the most adequate for implementing project and problem based learning in the classroom setting. Action research is a social endeavor that includes broad participation of all relevant parties who are seeking to resolve some important professional or societal issue [33]. Action research is grounded in the practice of those undertaking the research in order to critically reflect upon, and change the practice. Thus, it includes both researchers and professional community that join forces together to find sustainable solutions for broader concerns. In action research projects, researchers define the problem, discuss it in terms of their knowledge and experience, gather the data, plan and design an action, observe the changes and interpret the results. Instructors make documented, systematic improvements in their contexts (e.g., classrooms) as a means of applying new knowledge as it is generated [34]. Action research cycle plan-act-observe-reflect [35] included targeting competences, creating and implementing an adequate method, while students' feedback was an input for further reflection on possible course improvements.

The generic competences that were aimed to foster learning and that were studied in this research were chosen based on their importance for the future engineering profession [7–9], and the gaps reported in the literature [10–12]. These gaps were further discussed and analyzed by the industry practitioner (the first author), who was the instructor in this course, and two university teachers (one of whom is the second author) who work at the university where the course was implemented.

The chosen generic competences were:

S1. Communication—expressing opinion.
S2. Communication—asking questions.
S3. Teamwork—willingness to contribute to a common solution.
S4. Teamwork—accepting differences of opinion.
S5. Presentation.
S6. Finding relevant information on the Internet.
S7. Ability to apply knowledge in practice.
S8. Planning and organization.
S9. Solving ill-structured technical problems.
S10. Generating new ideas in the process of finding a solution.
S11. Ambiguity tolerance.
S12. Systems thinking—technical systems.
S13. Systems thinking—engineering in a social context.

Specific professional competences that are fostered through real project work are based on the competences recommended by professional engineering bodies listed in the first section of this article [7–9]. All of the studied professional competences are domain-specific and belong to higher levels of Bloom's taxonomy [36]. They were:

P1. Apply the basic principles of engineering in telecommunications in the design of simple systems, taking into account the requirements and limitations.
P2. Formulate and solve engineering problems that are insufficiently structured.
P3. Analyze and interpret technical specifications of telecommunication devices and systems.
P4. Use engineering techniques for evaluation and selection of technical solutions.
P5. Find the equipment needed for the technical solution.
P6. Create a realistic implementation plan for the simple project with time and resource constraints.
P7. Perform technical analysis and critical evaluation of the problem, along with the recommendations and conclusions based on technical knowledge.

The data were collected from two generations of students at the beginning and at the end of the 10-week courses that took place in 2013 and 2014. The participants in the study were 33 students of the fourth (final) year of the academic studies of The School of Electrical Engineering of the University of Belgrade, 13 females and 20 males. The contribution of the course to the development of competences was measured through the difference in the perceived levels of competences before and after taking the course, and through the significance of this difference. Therefore, at the beginning and at the end of each course students evaluated each of the above mentioned generic and professional competences on the perceived level of success. Furthermore, instructors noted their reflections about the students' behavior and the course in general which are also presented in the

Table 1. Perceived levels of success for generic competences

		Pre-course		Post-course	
No.	**Generic Competence**	***M***	***SD***	***M***	***SD***
S1.	Communication—expressing opinion	2.94	0.73	3.06	0.63
S2.	Communication—asking questions	2.65	0.71	3.26	0.51
S3.	Teamwork—willingness to contribute to a common solution	3.33	0.61	3.42	0.62
S4.	Teamwork—accepting differences of opinion	3.19	0.70	3.16	0.82
S5.	Presentation	2.35	0.80	2.90	0.70
S6.	Finding relevant information on the Internet	3.03	0.71	3.03	0.66
S7.	Ability to apply knowledge in practice	2.42	0.72	2.81	0.65
S8.	Planning and organization	2.74	0.93	2.97	0.60
S9.	Solving ill-structured technical problems	2.16	0.78	2.61	0.72
S10.	Generating new ideas in the process of finding a solution	2.32	0.70	2.68	0.79
S11.	Ambiguity tolerance	2.50	0.82	2.84	0.58
S12.	Systems thinking—technical systems	2.43	0.82	3.16	0.52
S13.	Systems thinking—engineering in a social context	2.43	0.73	2.84	0.78

result section of this paper. Altogether, these findings could hopefully be implemented in the practice of teachers and instructors who seek to foster students' competences for the workplace and wish to overcome the existing barriers in implementing such an approach [37].

Competences were assessed on the questionnaire that consisted of 13 items related to general competences and 7 items related to professional competences. Each competence was evaluated by the perceived level of success on the scale from $S_{min} = 1$ (the lowest score) to $S_{max} = 4$ (the highest score). This questionnaire was designed relying on the questionnaire from the study of Gerasimovic and Miskeljin [38] in which the importance of some general competences to university students' in Serbia was assessed.

This study relies on self-assessment measures. According to Boud and Falchikov [39] self-assessment is appropriate to be used in the monitoring of competences which need to be developed through practice: learners must develop the capability of monitoring what they do in order to modify their learning strategies appropriately. A comprehensive summary of the relevance of the self-reported level of competences is presented by Lattuca and colleagues [11] concerning particularly ABET outcomes, indicating that the studies over the last decades report correlations of 0.50 to 0.70, on average, between self-report and objective criterion measures. Therefore, our approach was to adopt students' self-assessment as the relevant report of the level of their competence development [39].

The research used descriptive and non-parametric statistics for data analysis due to the size of the data sample (Wilcoxon signed-rank test, based on the difference between scores from the same participants in a different situation) [40]. All the statistical analyses were performed by using IBM SPSS Statistics 21.

4. Results

In this section, we present the analysis of the results obtained for the perceived level of success for the generic and professional competences before and after taking the course (pre-course and post-course), using descriptive and non-parametric statistics. In the final part of the result section, the reflections of the instructor are presented.

4.1 Descriptive statistical indicators for generic and professional competences

The mean values—*M*, and standard deviations—*SD* of the particular level of competence pre-course and post-course are presented in Table 1 (for generic competences) and in Table 2 (for the professional competences). The theoretical mean value for each individual competence, both generic and professional, is given in Equation (1):

$$TM = \frac{S_{min} + S_{max}}{2} = 2.5. \quad (1)$$

The pre-course results of the perceived levels of success for the most of the generic competences are above the theoretical mean (Table 1), while the post-course results of the perceived levels of success show that all the generic competences levels of success are above the theoretical mean. The graphical representation of the differences in perceived levels of success for each generic competence is presented in Fig. 1.

Interestingly, pre-course results show that all of the professional competences are rated at below the theoretical mean (Table 2), while the post-course results show that all of the professional competences are rated well above the theoretical mean. The graphical representation of the differences in perceived levels of success for each professional competence is given in Fig. 2.

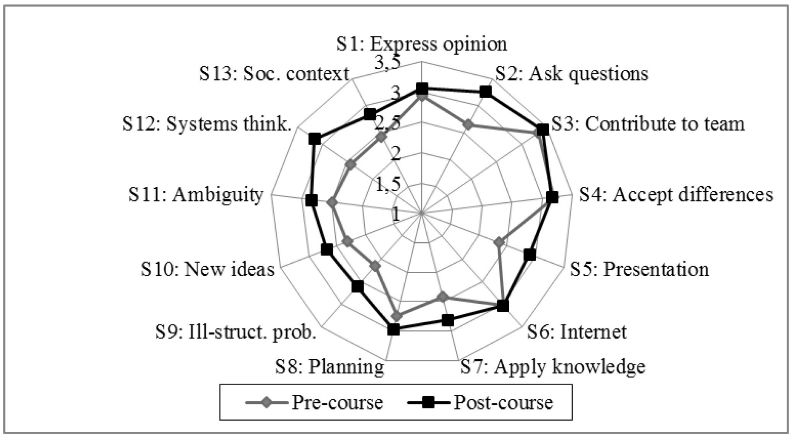

Fig. 1. Generic competences: pre-course and post-course *M* levels difference

Table 2. Perceived levels of success for professional competences

No.	Professional Competence	Pre-course *M*	Pre-course *SD*	Post-course *M*	Post-course *SD*
P1.	Apply the basic principles of engineering in telecommunications in the design of simple systems, taking into account the requirements and limitations	2.30	0.70	2.94	0.70
P2.	Formulate and solve engineering problems that are insufficiently structured	1.63	0.56	2.67	0.65
P3.	Analyze and interpret technical specifications of telecommunication devices and systems	2.37	0.85	3.12	0.78
P4.	Use engineering techniques for evaluation and selection of technical solutions	2.07	0.74	2.97	0.64
P5.	Find the equipment needed for the technical solution	1.87	0.97	3.15	0.76
P6.	Create a realistic implementation plan for the simple project with time and resource constraints	2.37	0.89	3.12	0.70
P7.	Perform technical analysis and critical evaluation of the problem, along with the recommendations and conclusions based on technical knowledge	1.90	0.71	2.97	0.68

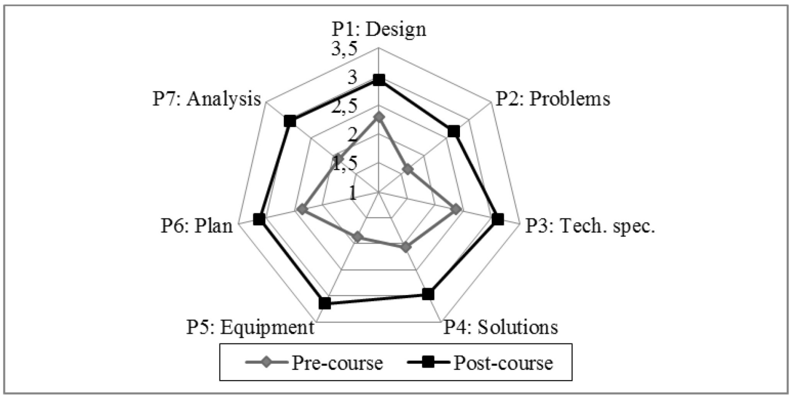

Fig. 2. Professional competences: pre-course and post-course *M* levels difference.

4.2 Analyzing the significance of the differences in the perceived levels of generic and professional competences before and after the course

Further analysis of the pre-course and post-course results of the perceived levels of success for individual generic competences using Wilcoxon signed-rank test revealed the statistically significant increase ($p \leq 0.05$) in the level of perceived success in the following competences:

- Communication—asking questions ($z = -3.82$, $p = 0.00$).
- Presentation ($z = -2.46$, $p = 0.01$).
- Ability to apply knowledge in practice ($z = -2.68$, $p = 0.01$).
- Solving ill-structured technical problems ($z = -2.35$, $p = 0.02$).
- Generating new ideas in the process of finding a solution ($z = -2.40$, $p = 0.02$).

- Ambiguity tolerance ($z = -2.04$, $p = 0.04$).
- Systems thinking-technical systems ($z = -3.92$, $p = 0.00$).
- Systems thinking-engineering in a social context ($z = -2.23$, $p = 0.03$).

Generic competences for which there was no statistically significant difference in the perceived levels of success before and after the course are: 'communication—expressing opinion', 'teamwork—willingness to contribute to a common solution', 'teamwork—accepting differences of opinion', 'finding relevant information on the Internet' and 'planning and organization'.

On the other hand, Wilcoxon signed-rank test showed statistically significant difference ($p \leq 0.05$) in the perceived levels of success before and after the course for all of the professional competences:

- Apply the basic principles of engineering in telecommunications in the design of simple systems, taking into account the requirements and limitations ($z = -3.232$, $p = 0.01$).
- Formulate and solve engineering problems that are insufficiently structured ($z = -4.388$, $p = 0.00$).
- Analyze and interpret technical specifications of telecommunication devices and systems ($z = -3.381$, $p = 0.00$).
- Use engineering techniques for evaluation and selection of technical solutions ($z = -4.508$, $p = 0.00$).
- Find the equipment needed for the technical solution ($z = -4.103$, $p = 0.00$).
- Create a realistic implementation plan for the simple project with time and resource constraints ($z = -3.116$, $p = 0.00$).
- Perform technical analysis and critical evaluation of the problem, along with the recommendations and conclusions based on technical knowledge ($z = -4.439$, $p = 0.00$).

The important finding for the further development of this kind of instructional design is that this course has contributed significantly to the development of precisely those generic competences that are important for the engineering profession and the ones that are probably the least represented in the formal curriculum. These competences include: asking questions, presentation, ability to apply theory in practice, solving ill-structured problems, generating new ideas, ambiguity tolerance and systems thinking in societal and technical contexts. The fact that competences such as communication—expressing opinion, teamwork, finding relevant information on the Internet and planning and organization were not perceived to be significantly developed is contrary to the findings of other studies [13, 14] and may be due to the fact that we applied self-assessment approach. Furthermore, the possible explanation could be in students' overconfidence in the level of these competences before the course [14].

Regarding the professional competences, it is noteworthy that all of the professional competences were rated at below the theoretical mean before the course, while all of the professional competences were rated well above the theoretical mean after the course. The fact that there was a significant difference in perceived levels of success in the results before and after the course for both groups of competences indicates that higher level Bloom taxonomy's elements [36] were implemented in this kind of instructional design. This kind of instructional design can significantly develop students' general ability to solve insufficiently structured problems and thus design, evaluate, analyze, interpret and create new engineering solutions. The development of these competences fully corresponds to the course objectives that were initially set for this course, as well as to the theoretical conclusions of the existing studies e.g., [41], indicating that the project and problem based workplace simulation course has the potential to prepare students for the work environment, supporting the development of professional practice.

4.3 Instructor's reflections

Working in the workplace simulation environment and solving ill-structured problems within project and problem based designed university course is not frequently practiced in the traditional curricula. Therefore, both students and instructor were faced with multiple challenges during the endeavor of fostering generic and professional competences. The constructivist learning environment setting presented one of the greatest challenges for the instructor since consequent class activities have to support and challenge learners' thinking. The most critical teaching activity was reflected in the questions asked by an instructor and the guidance that she provided to students and teams. It is very important that a teacher does not take over the problem-solving for the learner by telling a learner what to do or how to think. This is particularly appreciated by students who, in general, put a great value in finding the solutions on their own, while being supported by the instructor [17]. In the following paragraphs, we present the instructors' reflections on the most salient challenges encountered in the process of specific competence development during the course.

Solving ill-structured problems. The major challenge in fostering this competence was observed to be problem definition. Students need to experientially understand and accept that a problem statement is not clearly defined at the beginning. This may present a special challenge for them, since students are used to working on tasks which contain all the necessary information for solving them. Additionally, the existence of multiple possible solutions and applying different criteria in finding the solution were some of the major challenges that students needed to overcome during this process, which was overwhelming for some of them. The instructor helped by scaffolding and guiding teams with appropriate questions. It is of a paramount importance never to give the answer to the students but to lead them in finding the answer by themselves [17].

Asking questions. The only way of finding the precise definition of the problem and the criteria that are necessary for finding the solutions and serving the customers' needs is by asking questions. The common mistake discovered during the course was that students, instead of asking questions, made assumptions of their own. Once they started working with erroneous assumptions, they were led into undesired directions. The instructor let students make mistakes without interrupting. Only as they became aware of the mistakes after a few hours' work did instructor interfere, so students experientially understood the importance of asking questions [16, 17].

Systems thinking. Systems thinking is the "ability to see the big picture" and understand the system's emergent properties, capabilities, behaviors, and functions" [42]. Students needed some time in order to understand and start applying this skill since they tended to observe the solution through isolated elements without understanding a system in its totality. In order to find a solution for this problem, we found out that block diagrams are a very simple tool that can help in the structuring of the solution [17]. As the course advanced, students were getting more and more skilled in systems thinking and some of them were reporting that they were applying it in a social context as well.

The ability to apply knowledge in practice. Finding a conceptual solution for a system includes connecting the theoretical knowledge obtained through the studies to correspond to the technical solution developed according to the client's requirements. First of all, students have theoretical knowledge on different topics, but almost never have considered actual forms that equipment can have. It was a difficult task for them to connect the black boxes with the real equipment they had to use: antennas, cables, indoor and outdoor units. Secondly, students were mostly reluctant to draw block diagrams, though later they realized that it is a necessary part of looking for a solution. Matching interfaces of different equipment represented the difficult task of putting it all together to fulfill the required purpose [16, 17].

Presentation. Not all students feel comfortable presenting in front of a group of people. In general, students did not have much experience in creating a presentation, so the instructor needed to provide a short introduction with guidelines on both the presentation structure and presenting skills. In order to ensure that all team members practice and use presentation skills, each team member had to present one part of the solution to the audience and the "customer board".

Professional competences. Regarding the development of professional competences, the crucial starting point was to provide a suitable project from real engineering practice. Teams worked on this project in a workplace simulation environment, where they applied the strategies that are accordant with the real work environment. Preliminary design and choice of the best conceptual design solution provide the students with the opportunity to apply different criteria to the proposed solutions. Feasibility, cost, quality, and reliability are all among these criteria. Students have to be instructed to consult regulatory constraints and requirements, interpret and use them as criteria for solution building. Comparison of solutions is an iterative process going on during the whole preliminary design phase. Students thus become aware that both constraints and tradeoffs are necessary and that they have to reflect on them.

Finally, for the competence development, it is necessary to provide a safe environment where students can fail and start again. Higher education generally does not support learning to fail and students show embarrassment when faced with the prospect of failure. The fear of failure was in many cases preventing students from asking questions and experimenting with different solutions since they did not want to appear "unknowledgeable". Teachers' role and guidance, as well as a safe and supporting environment, may be crucial at this point [17].

5. Lessons learned—implications for instructional design

The results of this research indicate that some of the most relevant professional and generic competences for future engineers can be successfully developed through specifically designed project and problem based learning internship-like courses at the universities. Designing and implementing such a course presents both challenges and benefits that we would like to highlight in this section.

The decision to design and hold "Project planning and organization in engineering practice" course was based on the need to present final year engineering students with the opportunity to work on a real-world engineering project and develop generic and professional competences through practice. Designing and implementing a new course, especially one that differs from the usual teacher-centered learning approach, requires time, effort and investment. The instructional model that we constructed combines results from engineering education research and industry practice—therefore we needed approximately 4 months to design the learning environment, learning objectives, activities and assignments, class time, announce and organize the course. Regarding the investment, the course relied on the knowledge students had acquired during their studies and did not teach any new content knowledge. Workplace simulation did not require any additional investments in the course except access to computers and the Internet. The course included one field trip (site survey) to the park/lake where the designed system was to be installed.

Once the course was implemented, course improvements were facilitated by the use of the action research approach, which helped us structure the findings from each course and apply them in consequent course improvements. In the constructivist learning environment setting, it is essential that the instructor respects as well as challenges learners' thinking [43]. This project confirmed the previous findings that by constantly asking questions (instead of giving answers), teachers can support students to approach tasks in a more expert-like manner, to make self-justifications, self-explanations, and self-evaluations, and to acquire a better understanding of the kinds of demands they should be addressing in learning in general as well as problem-solving practice [44]. Students highly valued the way that the instructor conducted the course, particularly the fact that they were guided by questions and never received ready answers, which permitted them to create what they valued the most—the solution on their own. Providing the opportunity for process ownership is what students need since they will be faced with it at the workplace, and gaining confidence in this process is one of the benefits that students valued in this kind of course [17]. In spite of being cognitively more demanding, as the students had little or no previous experience in self-guided real project work, this kind of course challenges their skills and knowledge and students appreciate it, as this approach stimulates their creativity, engineering thinking, and development of competences. With this kind of instruction, students can realize that many of the future workplace problems are not purely engineering and that they have to adopt a broader approach. The opportunity to work on a real project and enhance problem solving as well as other skills has been evaluated by students as professionally and personally important, as well as a significant motivational factor. Students appreciated the opportunity to build competences that are transferable to their future workplace. On the personal level, they felt more self-confident as they actually practiced these competences, but hugely due to the collaborative and social dimensions of learning that they experienced with their peers and colleagues [17].

The introduction of new instructional strategies presents challenges both for school/university and for engineering educators, who need to shift from the traditional teacher-centered to student-centered approach. This implies that the instructor does not lecture, but he or she needs to challenge the learner's assumptions (hypotheses), and, at the same time, provide the necessary guidance and support for each student as well as their teams. This kind of approach can certainly bring some amount of discomfort to instructors, but at the general level, it contributes to their professional development by challenging their established approach as well [45]. Furthermore, teachers and instructors may find the new instructional strategies incompatible with their traditional view of teaching and learning, and they could even make them feel less professionally satisfied since they seem to have reduced responsibility for and control of learning [26]. Nevertheless, this kind of course design can help instructors/teachers/university professors in their professional development by constantly challenging their instructional approach and fostering their collaboration with the industry and thus keeping them up to date with the labor market requirements. This kind of course design experiences have to be further exchanged among the engineering educators in order to deepen their knowledge and understanding of the teaching methods that can encompass both internship-like and traditional learning approach. In this way, these endeavors become life-long learning and development basis for teachers/instructors/university professors as well.

The limitation of our study is that the perceived levels of success for the generic and professional competences are self-assessed and that there are no (more) "objective", third-party measures of achievement. Other elements that could be introduced in the future studies in order to create an even better environment for students' competence development are the in-depth interviews and focus groups with participants that could be focused on particular aspects of the course and its contribution to the development of each competence.

Maybe the major limitation of this approach is that the class size is limited since interactive work with students requires relatively small classes, typically of up to 20 students, which is not always feasible. Nevertheless, with more instructors that would come not only from university but also from the industry, these limitations could be overcome. Partnering companies could also help by providing the equipment that students can use to design the system.

6. Conclusions

In this study we presented a new instructional approach introduced to the final year engineering students with the aim of developing their generic and professional competences. The new student-centered approach was based on the constructivist approach to learning, as well as project-based learning, problem based learning, ill-structured problem solving and workplace simulation. The proposed approach was analyzed in the context of students' competence development and implications for engineering educators.

The students' generic competences that were found to be significantly fostered through this kind of course were: systems thinking, ambiguity tolerance, asking questions, solving ill-structured problems, ability to apply knowledge in practice, presentation and generating new ideas. Professional competences that were found to be significantly fostered all belong to the higher order thinking skills, and comprise the ability to design and evaluate, analyze, interpret and create new engineering solutions.

These results indicate that some of the most important generic and professional competences for future engineers can be successfully developed through specifically designed project and problem based learning internship-like courses at universities.

However, both instructor and students were faced with multiple challenges during the endeavour of fostering generic and professional competences in this new instructional setting. We presented instructors' reflections on these challenges as well as the ways of overcoming the challenges during the course together with implications for engineering educators.

The major importance of this study is that it provides the empirical support for the use of this kind of course design for development of essential generic and professional competences, while its encouraging results could be an inspiration for applying similar teaching strategies. In our case, they were applied in a core engineering course that is thought at the same school.

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