Universitat Autònoma de Barcelona

Competence development in a project and problem based learning professional practice module in engineering education based on ill-structured problem solving: action research and its implications for sustainability education

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Competence development in a project and problem based learning professional practice module in engineering education based on ill-structured problem solving: action research and its implications for sustainability education

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1 INTRODUCTION

This study forms part of the Interuniversity Doctoral Programme in Environmental Education at the Autonomous University of Barcelona. The goal of the research presented is to develop an instructional model based on ill-structured problem solving that would assist engineering students to develop enhanced competences for the workplace by fostering professional and generic skills in the context of sustainable development.

To this end practice-based internship-like course was developed and implemented for the final year engineering students. The course was conducted during 6 semesters in a 4-year action research with the aim of determining competences that students develop with this kind of instruction, as well as of exploring challenges and opportunities that arise during the process of ill-structured problem solving. The findings were used to propose an instructional model in the broader context of education for sustainability.

This study revealed that the proposed model significantly enhanced students' professional skills, and specific generic skills, principally the higher order thinking skills. The predominant issues and challenges that students face during the project based instruction were defined. The final phase of the research revealed that some of the challenges occur periodically while others are more constant throughout the course. Moreover, students' skills development occurs in different patterns, curiously systems thinking being the one that is constantly increasing. Finally, these findings are used to propose professional practice module in the context of sustainable development.

1.1 PROBLEM STATEMENT

In the ever changing work environments engineers need to understand and appreciate the impact of social and cultural dynamics, know how to communicate effectively and think globally, develop skills that enable them to address the unknown and deal with ambiguity and complexity. They should develop the ability to work in the multidisciplinary teams, as well as initiative and creative problem solving (Katehi, 2005). As shown by previous studies, graduates equipped with these essential skills, should have a competitive advantage for the workplace (Scott & Yates, 2002), (S. Male, Bush, & Chapman, 2011).

More than just formal educational approaches are needed to develop the above mentioned skills. The competencies for problem solving, independent and collaborative learning are fostered by using complex ill-structured real world problems, including design problems. The learning is set in the learning environment similar to the work environment where students engage in authentic engineering projects (D. Jonassen, Strobel, & Lee, 2006).

Engineering is about solving problems: engineering practice means solving ill-structured problems, and students should be faced with this kind of problem solving during their studies in order to be adequately prepared for the workplace (Sheppard, Colby, Macatangay, & Sullivan, 2006). In modern engineering contexts, this is emphasized by the additional need to prepare future engineers for understanding and solving complex engineering problems in a multi-layered context of sustainable development.

> *The ever changing working environments and in a scenario-free future, there are no anticipated problems, only anticipated challenges and possible opportunities (…). It seems clear that the future engineering curriculum should be built around developing skills and not around teaching available knowledge.*
>
> *What must be fostered in future engineers is analytic skills, problem-solving skills, and design skills.*
>
> *We must teach methods and not solutions. We must teach future engineers to be creative and flexible, to be curious and imaginative. Future engineers must understand and appreciate the impact of social/cultural dynamics on a team environment. They must appreciate the power of a team relative to the importance of each individual's talent. They must know how to communicate effectively and how to think globally. Engineering curricula must focus on developing skills that enable them to address the unknown.*
>
> *We need engineering curricula that are not overly prescribed, that focus on how to learn and how to apply what has been learned. We need to focus on how to seek and find information. We need curricula that satisfy a few fundamental teaching principles but allow for true variations. Requirements must be flexible to react to change. Future engineers will need design skills, as well as analytical skills. We must also open engineering curricula to non-engineers and teach our students how to solve social problems and how to commoditize technical innovations and processes to erase poverty. We must recreate connections between engineering and the larger society and focus on tools that will improve the quality of life.*
>
> *American engineering schools are facing a great challenge, and we should be looking forward to making it an opportunity for national and global leadership* (Katehi, 2005).

Engineering curricula needs to comprise training in ill- structured problem solving and consequent generic and professional skills development in order to achieve competencies for engineering practice such as ABET, FEANI, IEAust, JABEE. (Grimson, 2002) (Goel, 2006) (D. Jonassen et al., 2006), (Arlett, Lamb, Dales, Willis, & Hurdle, 2010).

However, in a traditional curriculum students are expected to dominate well-structured problems and their encounter with ill-structured problem solving usually occurs for the first time during their internship; if that is not possible they have no option but to leave the university without dealing with this kind of problems.

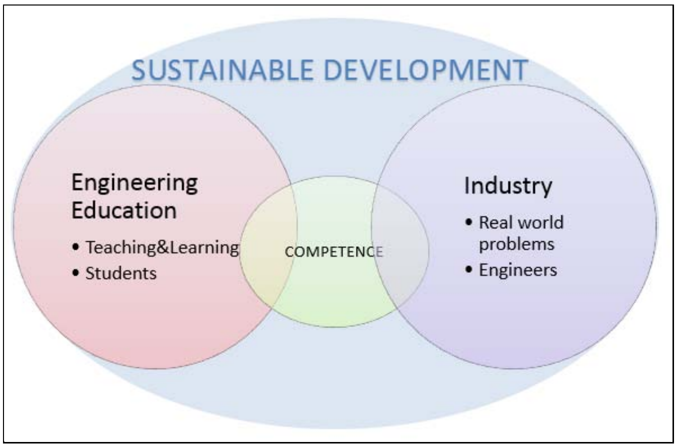


FIGURE 1-1 COMPETENCE DEVELOPMENT: ENGINEERING EDUCATION AND THE INDUSTRY

Most of the students who follow the conventional engineering curriculum get their first opportunity to face ill-structured engineering problem solving during their internship, and if that is not viable students have no other option but to leave university without having dealt with this kind of problems. One of the reasons we find internship experiences difficult to handle is lack of the dedicated person and friendly and safe environment that would enhance students' engagement in ill-defined workplace problem solving. The lack of such approach deprives students of the contact with a real, but friendly work environment before starting to work and thus deprives them of opportunities and preparation they could have gained with a different approach.

On the other hand, the literacy on sustainability and the need for solving sustainability problems is required by the 21st century workplaces. These problems are complex in nature and will require both technical expertise and understanding of societal and environmental issues by future engineers. The importance of understanding and teaching ill-structured problem solving is therefore particularly relevant since it is not only engineering practice that calls for ill-structured problem solving, but also the broader context of sustainability problems, that engineers will be faced with and called upon to solve both in the present and in the future (Steiner & Laws, 2006).

Sustainability themes, as identified by (Cruickshank & Fenner, 2012) include: dealing with complexity, dealing with uncertainty, dealing with change, dealing with other disciplines, dealing with environmental limits, dealing with people, dealing with whole life costs and dealing with trade-offs.

(Steiner & Laws, 2006) inform that the fact that universities have grown more dependent on industry faces them with demands for practically oriented students who are not only theorists but

> "*also capable of solving practically relevant real-world problems has become central in industry and other real-world systems. Real-world problems – especially those with strong social impacts – and their implications for various involved or influenced actors are themselves changing over time. This consequently also requires adaptable styles of problem solving. Since, change is the dominant characteristic of most facets of today's world, we need appropriate educational means to cope with it. Wals and Jickling (2002) stress the critical role of institutions of higher education in cultivating diversity of thought within processes of solving complex real-world problems such as sustainable development".*

The authors conclude that graduates are faced with increasingly complex problems earlier in their careers than this was the case in the previous decades. Therefore, working on problems with strong real-world implications is much more important than analysing systems from a theoretical point of view.

This puts a greater emphasis on combining practical experience with education and practices like internships become more important. Moreover, group (as opposed to individual) problem-solving capabilities become increasingly important in order to provide the required competences needed to work on complex real-world problems.

However, ill structured problem solving skills are often not advanced in current engineering graduates. They also have little or no experience of dealing with uncertainty and ambiguity in problem solving. Too often, engineering curricula place more emphasis on the memorization of facts and well-established procedures than on learning the skills necessary to deal with large, complex problems. As a result, current engineering graduates are entering the market place ill-equipped to deal with the problems society is sure to face.

Recent research shows a growing concern of employers regarding the perceived skills gaps between engineering education and professional practice (Hillmer, Wiedenbrueg, & Bunz, 2012).

Similar conclusion has been reached in international studies conducted in UK and Australia. A survey of industry requirements for engineering education in Britain found evidence of skill deficits and concern that "the grade of degree awarded can be a poor indicator of a graduate's actual abilities" (Spinks, Silburn, & Birchall, 2006). Employers expressed "a need for enhancing courses in terms of their development of practical skills but not at the cost of losing a strong theoretical base". In a longitudinal study of the engineering graduates in Australia (James Trevelyan, 2008) it was shown that the important proportion of the skills and knowledge that students need for their work are learned on the job. While this emphasizes the importance of graduate learning abilities, it also echoes employer concerns that engineering education does not provide students with opportunities to learn skills they will need as graduates.

In Serbia, a study conducted by USAID Competitiveness Project surveyed companies for current workers' skills gaps and identified the biggest skills gaps in ICT industry as generic skills, followed by technology skills, and basic skills such as attitude, appearance etc. (USAID Competitiveness Project, 2008)

Hutzinger, Hutchins, Gierke and Sutherland emphasize the fact that the above mentioned ill-equippness of the engineering graduates for the market place in terms of problems is a result of the educational approach to emphasize the memorization of facts and well-established procedures rather than to learn the skills necessary to deal with large, complex problems (Huntzinger, Hutchins, Gierke, & Sutherland, 2007).

Previous research on education for sustainability as well emphasizes the importance of skilfulness in a discipline as well as systemic thinking competences and an understanding for the complex frame of reference when dealing with sustainable development (Svanström, Lozano-García, & Rowe, 2008), (Wiek, Withycombe, & Redman, 2011).

Due to the undoubtedly complex nature of sustainability problems, engineers will be faced with ill-structured problems that they need to solve, confirmed in recent studies that show the need for the students to leave the University with set of skills for sustainability (Bone & Agombar, 2011). However, if there is no faculty policy on education for sustainability in place and there are no course add-ons in the field of education for sustainable development (ESD), students, especially in Serbia, face the workplace both with significant lack of skills in ill-structured problem solving and with significant lack of understanding of basic sustainability concepts.

How can we attain the capability to solve complex real-world problems through educational means?

It has been shown that by aligning educational practices with workplace realities and including more authentic, complex, ill-structured problems that require the ability to look into the social aspects as well, students' motivation levels can be improved, and their generic competencies enhanced (D. Jonassen et al., 2006), (Andersson & Andersson, 2010b)

Teaching meaningful ill-structured problem solving presents issues and challenges that have been treated in a few studies, such as the studies conducted by (Daniels, Carbone, Hauer, & Moore, 2007a) and (Purzer & Hilpert, 2011). However, the research on when and how to support student engagement and learning during ill-defined problem solving in engineering is still limited and the need has been identified for future research into how the results of the existing studies can be translated into classroom practices, especially in the context of education for sustainability.

This study through action research constructs and refines practice-based instructional model building on workplace problem solving and explores how to support students in ill-structured problem solving and competence development by better understanding both the challenges and opportunities of the students' learning experiences in this context. The findings are used to propose the instructional model of the internship/professional practice that integrates basic principles of education for sustainability.

Two driving forces motivate this research. The first motivating factor is my personal interest in and more than twenty years of work experience with problem solving and decision making as a telecommunications systems engineer and project and program manager in the ICT industry. The second motivating factor is my profound interest in preparing engineering students for engineering practice, and more precisely, preparing them to face sustainable development problems.

When I was faced with work environment shortly after receiving my graduation in engineering in the early 90's I was quite confused as it took me some time to understand that what I was taught at the University had nothing to do with the job that I needed to perform as a junior engineer with a telecom operator. The result is that I had hard time figuring out what it means to work as opposed to study, even though the work environment where I found myself was outstandingly helpful and friendly. During more than twenty years that have passed since I have acquired rich professional experience: I have worked as practicing engineer starting from junior engineer through systems engineer, project manager and CTO, and my job took me to different places, from Latin America to Europe, Africa and Middle East. I have worked mainly in the ICT industry, on mobile and wireless systems; I have maintained and did troubleshooting of big national security communications systems and small scale implementations, even ventured to BSS/OSS and user acceptance testing.

To my mind, the major difference between work and current teaching and learning practices lies in solving ill-structured problems. The lack of teaching of this kind of problem solving in the natural work environment and the utmost necessity of knowing how to solve them, or at least how to start dealing with them, is the major reason why I have undertaken this research, where I intend gain better understanding of the ill-structured problem solving learning experience in order to be able to better support students learning. The other reason is the necessity to incorporate education for sustainable development, which is about solving ill-structured problems; I wanted to use this framework to explore the possibility of creating guidelines for professional practice course in the context of sustainable development building on the results of the ill-structured problem solving research.

It is not easy to provide the meaningful environment for teaching ill-structured problem solving and competence development, even more so in sustainability context. The major hypothesis of this study, based on previous research and personal intuition, is that this professional journey of novice engineers can be facilitated by providing them with industry-like environment where they can start practicing ill-structured problem solving. This is the important first step where novices, once faced with this kind of problems, will feel more comfortable and develop crucial skills needed for the beginning of their engineering profession as well as basic curiosity for applying sustainable development principles, which forms necessary parts of the intrinsic motivation and deep learning.

1.2 PURPOSE OF THE STUDY

The central question of this research is to examine how the specific professional practice instructional module based on ill-structured problem solving assists engineering students to develop enhanced generic and professional skills for the workplace, placing it in the context of sustainable development.

The research objectives are:

1. Develop, implement, evaluate and refine ill-structured problem solving professional practice instructional module in engineering education
2. Explore students' motivation to attend the course and learning styles
3. Determine the module contribution to the generic and professional competence development
4. Explore where and how students could be best supported during the process of ill-structured problem solving and competence development
5. Use the findings to propose the instructional design for teaching ill-structured problem solving in the context of the education for sustainability

As engineering practice is about solving ill-structured problems, and while it is obvious that solving ill-structured problems at the university will not automatically make an experienced engineer (D. Jonassen et al., 2006). Since ill-structured problems need practice to be mastered, the central problem of this study was to understand how we can assist students to develop problem solving skills for the workplace while still in the academic environment. Therefore, this work intends to contribute to the knowledge on the processes of ill-structured problem solving in engineering and to mark the direction where we can support students in the effort. Finally, the objective is to propose an instructional model for sustainability education based on professional practice and on ill-structured problem solving.

1.3 RESEARCH OBJECTIVES AND SUBSEQUENT QUESTIONS

Research objectives and the subsequent research questions are shown in Table 1-1.

TABLE 1-1 RESEARCH OBJECTIVES AND RESEARCH QUESTIONS

Develop, implement, evaluate and refine ill-structured problem solving professional practice instructional module in engineering education	What are the most appropriate pedagogical approaches for teaching ill-structured problem solving
	How do students evaluate the module
	Why do students like/dislke the module
	Why do students perceive the module as important for their personal and professional development
Explore students' motivation and learing styles	What is students' motivation to attend the module
	How are the students' learning styles distributed
Determine the module contribution to the generic and professional competence development	What is the importance students give to generic skills
	What is the students`perception of the level of success of their generic skills
	What is the students`perception of the level of success of their professional skills
	What is the course contribution to specific generic and professional skills development
Explore where the students could be supported during the process of ill-structured problem solving and competence development	What are the major issues and challenges that students experience during ill-structured problem solving
	How are the major issues and challenges distributed over different stages of the ill-structured problem solving process
	How is skills development distributed over different stages of the ill-structured problem solving process
Use the findings to propose the instructional design for teaching ill-structured problem solving in the context of the education for sustainability	What is students' interest in the further formal instruction on sustainable development
	What are the guidelines for the instructional design that would assist students to develop enhanced skills in the context of sustainable development

1.4 RESEARCH DESIGN OVERVIEW

This study adopted an action research strategy, where the researcher-instructor was integrating teaching and research actions in the natural classroom setting.

This type of research is exploratory and was aimed at fulfilling all the research objectives, in order to gain insight into the effectiveness of the implemented educational strategies. The final part or the research includes the proposal of the instructional model to include sustainability education.

With the view of the research objectives, a mixed method approach to data collection and analysis was adopted as the most appropriate for the development of the multiple interpretations required. Approaches associated with field methods such as observations and interviews (qualitative data) were combined with traditional surveys (quantitative data); thus the results from one method can help develop or inform the other method (Creswell, 2003). Qualitative and quantitative data needed to be interceded and interposed with multiple and iterative interpretations. The data from both strands complement each other in order to elaborate, enhance, and illustrate the results from the other strand, as it is beautifully explained by Armarego in an action research presented in her doctoral thesis on educating requirements engineers in Australia as effective learning for professional practice (Armarego, 2007).

The literature review and consultations with teaching staff concurred between June 2010 and April 2011, while the empirical research was conducted during 4 years and consisted in teaching and evaluating 6 professional practice courses between May 2011 and July 2014.

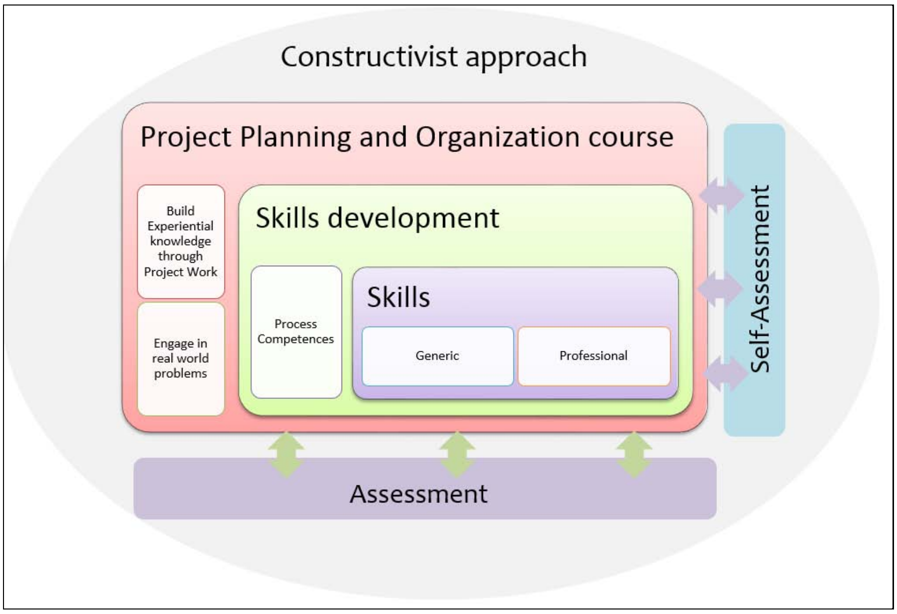


FIGURE 1-2 INSTRUCTIONAL MODEL DESIGN

The first phase of the research began by constructing the instructional model for the purpose of conducting the action research based on the findings from the literature review and researcher`s own 20 year industry experience, and that is how P*i*NG module was created.

After getting the approval for conduction P*i*NG module as professional practice course, that brings 2 ESBP, the course was announced and first group was formed in May 2011. This marked the beginning of the empirical research.

Research instruments were designed for data collection that would be performed during and at the end of the course. The instruments that were used during the course included participant observation and focus groups. At the end of the course students were administered questionnaires with open ended questions and surveys.

Questionnaires were designed to collect students' opinions regarding the course and its contribution to students' personal and professional development.

Surveys that were administered to students at the end of the course were designed to collect the students' evaluation of the P*i*NG course and students' interest in potential future courses that would include sustainable development themes.

Upon the end of the course the analysis of the results was conducted together with research methodology improvements. The results were fed into the next phase.

The second phase of the research included the two courses that were conducted during the autumn semester of the 2011/2012 where the instructional design was stabilized and improved research methodology was applied. The improvements included reducing the number of evaluation questions and creating the final design for the generic skills evaluation survey inspired by (M. Gerasimović & Miškeljin, 2009)

In the reflection and evaluation of this 1st Phase it was concluded that students' attitudes during the course needed to be taken into consideration. However, the way of implementing this approach needed to be tested so the next phase of the research was marked by including the created changes in the course that was conducted in the summer semester of 2011/2012 for a small group of students that marked the pilot research for methodology improvement.

The intended methodology improvement included introduction of student diaries and professional skills survey. The pilot group was closely monitored, which was possible due to the reduced size of the group. Therefore, the close participant observation permitted the posterior thorough reflection on the methodology improvements that resulted in the modification of the students' diaries to include the survey of the phased generic skills and issues and challenges in four points of time during the course. This was inspired by the design applied in (Purzer, Hilpert, & Wertz, 2011).

The improvements were fully introduced in the courses in 2012/2013 and 2013/2014.

Two additional surveys were designed, one for phased issues and challenges, one for phased generic skills evaluation. The content of the surveys aimed to capture data comparable to the data collected in the previous courses since 2010 thus providing insights for the longitudinal research and bringing depth that would explain the phenomena found in the previous results.

The complexity of the research design was thus increased, in all three dimensions. It became matrix design, with three phases and three layers, each layer representing different breadth and depth of the research data. The detailed research design description is given in Chapter 3.

The total of 85 students participated in the study over 4 years during which I held six 10-week courses. The students in their majority were fourth (final) year students of the academic studies of the School of Electrical Engineering of the University of Belgrade, Telecommunications department. A few of the students were Master students and some of them were 3rd year students. A total of two students from the Software Engineering department participated in the course as well.

The design of the research instruments was based on the previous study and questionnaires and surveys available for course evaluation and skills evaluation. All the instruments, both qualitative and quantitative, were constructed by the researcher.

Qualitative data are predominantly those provided by the participants – the students enrolled in the P*i*NG module over the duration of the course, as well as by the researcher/instructor.

Quantitative data are provided by the participants – the students enrolled in the P*i*NG module as responses to diagnostic instruments, formed part of this research.

Data analysis was performed applying qualitative and quantitative methods. Qualitative methods included content analysis and quantitative included descriptive and nonparametric statistics (Wilcoxon signed-rank test) for quantitative data analysis depending on the data and the size of the data sample.

1.5 SIGNIFICANCE OF THE STUDY

With the increasing pressure to equip engineering graduates with skills and competences required by the industry, academy is faced with the necessity of designing and developing effective instructional designs to promote students' preparedness for the workplace. It is essential we gain further understanding on how we can support students during ill-structured workplace problem solving in the safe and friendly academic environment to create practical and powerful pedagogical process knowledge.

Engineering education research has recognized the importance of using real world problems and situations for effective classroom experiences that result in deeper understanding of engineering practice. However, difficulties have been recognized in choosing adequate problems, and applying adequate teaching strategies and professional expertise in order to benefit students preparing them for the workplace. Mainstream research within the field of engineering education needs to move toward exploration into the specific forms of pedagogical and content knowledge that effective engineering practitioners and subject matter experts bring when teaching specific practice-based content to their students.

Hence, this work contributes to the much needed research into the issues and challenges faced by students and teachers in the process of solving workplace problems in an authentic environment that uses teamwork, communication and problem solving. In turn, this understanding is intended to enable instructional designers to gain greater awareness of the ways to support students learning in such environments in order to address the transfer of students' knowledge and competencies from the classroom to the workplace (Kanuka, 2006).

Within the ill-defined problem solving literature, as Purzer and Hilpert describe, studies have focused on comparison of expert and novice behaviours involving short problem solving tasks and case studies that follow few students during a long period of time. The existing studies show students' challenges in certain areas such as problem definition, information gathering, and team collaboration. However, longitudinal studies that examine progressions of student learning and engagement during design and innovative problem solving tasks are scarce (Purzer & Hilpert, 2011).

This study brings the longitudinal empirical research that deepens along the time to explain some of the observed phenomena. The research is focused on evaluation the effectiveness of the project based problem based workplace simulation professional practice course that uses ill-structured problem solving to enhance generic and professional skills development.

The study has confirmed that the development of all the professional skills is significant and that generic skills developed in this course include asking questions, presentation, ability to apply theory in practice, solving ill-structured problems, generating new ideas, ambiguity tolerance and systems thinking, both in technical and social contexts. It has also identified issues and challenges that students face during ill-structured problem solving and its phases, proposing the ways of supporting students in this process.

Furthermore, this study uses the results to propose instructional design for the institutional environments where sustainability education is beginning or is not fully developed, presenting thus the model for its development based on the previous empirical research.

This Thesis is organized under three major phases: literature review of engineering education teaching practices in terms of competence development for engineering practice including the sustainability context, action research over 4 years to examine issues and challenges that students face and competences that they foster during ill-structured problem solving and results with discussion including the guidelines for the professional practice instructional model for the education for sustainability.

2 LITERATURE REVIEW

The major themes presented in the literature review that informed the empirical research include competence development for engineering and for sustainability, ill-structured problem solving as means for competence development, theories of learning and instructional designs that are found suitable for professional practice.

The aim of this literature review is to use existing theories and findings in the area to inform empirical research.

In the first Section the research on competence development for engineering practice and for sustainability is reviewed, revealing the desirable attributes of an engineering graduate in terms of key technical and non-technical competences to solve workplace problems, as well as why those attributes important in terms of sustainability. Skills' gaps are identified as well.

In the second Section the research on ill-structured problem solving is reviewed.

Learning and teaching theories that support the educational shift needed for competence development are reflected in the educational environments that apply constructivist and experiential approach to learning and teaching. Learning by doing is reviewed followed by learning environments that are indicated for this kind of instruction, that include project-based learning, problem based learning, workplace simulation and role play.

2.1 COMPETENCE DEVELOPMENT

The main questions that marked the competence theme were: What are desirable attributes of an engineering graduate in terms of key technical and non-technical competences to solve engineering workplace problems? Why are those attributes important in terms of sustainability?

In the 21st century workplace, with rapid advancement in the pace of knowledge growth new approaches for preparing students for the workplace are being considered, putting more emphasis on equipping them with the skills and capabilities to look for and find knowledge and to dynamically adapt it for different purposes. Rapid knowledge growth rates make it impractical and impossible to impart all the relevant knowledge – therefore more importance should be given to the lifelong learning preparation of today's graduates. The work environments are not static any more – in today's ever changing work environments engineers need to understand and appreciate the impact of social and cultural dynamics, know how to communicate effectively and think globally, develop skills that enable them to address the unknown and deal with ambiguity and complexity. Graduates equipped with these essential skills, as shown by previous studies (Scott & Yates, 2002), (S. Male et al., 2011) should have a competitive advantage for the workplace.

In the next sections the educational model for alignment of workplace and academic interests in terms of competence development is considered, with the goal of determining the best ways to prepare students to acquire skills and competences for entering complex workplace environments. More than just formal educational approaches are needed to develop the above mentioned skills. The competencies for problem solving, independent and collaborative learning are fostered by using complex ill-structured real world problems. The learning is set in the learning environment similar to the work environment where students engage in authentic engineering projects (D. Jonassen et al., 2006).

Students who follow the conventional engineering curriculum often do not have the opportunities to engage in such learning environments during their studies. Therefore it is essential to provide learning environment for fostering students' professional competencies and generic skills as previous research indicates that there are skills' gaps between expected/required skills and actual performance of the engineering graduates recently entering the industry (Desha, Hargroves, Smith, & Stasinopoulos, 2007).

James Trevelyan has conducted a comprehensive research into engineering practice over the last decade, and he argues that there are very few reports of systematic research on engineering practice, the only exception being maybe engineering design (James Trevelyan, 2008). Furthermore, he argues that it is not easy to find "a coherent written account that could provide a comprehensive answer (on what engineers do)". His work includes a list of aspects of engineering practice derived from empirical research based on interviews and observations from all the main engineering disciplines and diverse settings in Australia and South Asia. He concludes that the foundation of engineering practice is distributed expertise enacted through social interactions between people: engineering relies on harnessing the knowledge, expertise and skills carried by many people, much of it implicit and unwritten knowledge.

In the context of education for sustainability, and as an integral part of a global society, engineers are expected to master a combination of disparate capabilities – not only technical competencies concerning problem solving and the production and innovation of technology, but also interdisciplinary skills of cooperation, communication, project management and life-long learning abilities in diverse social, cultural and globalised settings. Thus, new engineering competencies are needed and this may challenge existing and traditional educational lecture-based approaches to teaching and learning (Allan & Chisholm, 2008).

The importance of competence development is therefore recognized to play the central role in the movement to the European Higher Education Area.

2.1.1 Definition of competence

There is a lot of discussion regarding the terms skill, ability and competence. There are also differing views on their importance and levels of achievement, depending whether the source is industry, academy or students themselves.

In order to contribute to the elaboration of a framework with comparable and compatible qualifications in each of European Higher Education Area (EHEA), the Tuning Educational Structures in Europe project was developed (Gonzalez & Wagenaar, 2008). According to Tuning, learning outcomes are expressed in terms of the level of competence to be obtained by the learner, while learning outcomes are statements of what a learner is expected to know, understand and be able to demonstrate after completion of a learning experience. This project defines competence as "*a dynamic combination of cognitive and metacognitive skills, knowledge and understanding, interpersonal, intellectual and practical skills, and ethical values*".

One of the possible classifications of competences is according to their relation to specific domain: some competences are subject-area related (specific to a field of study), others are generic (common to any degree course).

(Winterton, Delamare, & Stringfellow, 2005) argue that in the interests of analytical precision, the terminology of cognitive competence (knowledge), functional competence (skill) and social competence should be adopted.

The taxonomy of Bloom (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956) provides a broader framework for competence definition in the cognitive domain.

For Bloom the development of intellectual abilities and skills is the same as intellectual problem solving. He argues that though the formal instruction may not prepare the students for all the problems they will encounter in the future, it can prepare them to act in new problem solving situations by helping them develop those intellectual abilities and skills which will enable them to adapt that knowledge to the new situations.

As Bloom (Bloom et al., 1956) suggests,

"What is needed is some evidence that the students can do something with their knowledge, that is, that they can apply the information to new situations and problems. It is also expected that students will acquire generalized techniques for dealing with new problems and new materials. Thus, it is expected that when the student encounters a new problem or situation, he will select an appropriate technique for attacking it and will bring to bear the necessary information, both facts and principles. This has been labelled "critical thinking" by some, "reflective thinking" by Dewey and others, and "problem solving" by still others, in the taxonomy we have used the term "intellectual abilities and skills." The most general operational definition of these abilities and skills is that the individual can find appropriate information and techniques in his previous experience to bring to bear on new problems and situations. This requires some analysis or understanding of the new situation; it requires a background of knowledge or methods which can be readily utilized; and it also requires some facility in discerning the appropriate relations between previous experience and the new situation."

Bloom's taxonomy contains six major classes of educational objectives that correspond to lower and higher order thinking skills in the cognitive domain (Bloom et al., 1956):

1. Knowledge
1. Comprehension – intellectual skill and ability
2. Application – intellectual skill and ability
3. Analysis
4. Synthesis
5. Evaluation

Some of the more recent definitions of competence in engineering and sustainability literature include (Edwards, Sanchez-Ruiz, & Sanchez-Diaz, 2009) definition that "*competence means demonstrating the knowledge, skills, experience, and attributes necessary to carry out a defined function effectively".*

According to (Segalàs, Ferrer-Balas, & Mulder, 2009) in a work that examines competences for sustainable development, competence is considered a combination of "Knowing and understanding", "Skills and abilities" and "Attitude".

2.1.2 SKILLS FOR ENGINEERING PROFESSION

Engineering practice is complex integration of problem solving and specialized knowledge, as summarized by Sheppard, Colby, Macatangay, & Sullivan (2006). Engineering work is about solving problems with the intention of affecting change in the world by, for example, modifying processes or procedures or introducing new products, technologies or knowledge.

The modern engineering industry needs engineers with competencies that include both sound technical understanding applied to practice and generic skills to work effectively in a business environment.

Though sometimes dependent on the particular filed of engineering or a specific job, a comprehensive overview of the skills today's engineers should possess was given by (Mills & Teragust, 2003):

> *"The modern engineering profession deals constantly with uncertainty, with incomplete data and competing (often conflicting) demands from clients, governments, environmental groups and the general public. It requires skills in human relations as well as technical competence. Whilst trying to incorporate more "human" skills into their knowledge base and professional practice, today's engineers must also cope with continual technological and organisational change in the workplace. In addition they must cope with the commercial realities of industrial practice in the modern world, as well as the legal consequences of every professional decision they make."*

Professional engineering bodies around the world recommend that engineering programs should demonstrate that their students attain the outcomes linked to some of or all of the skills and abilities summarized below following the recommendations published by:

a) ABET in the USA (Engineering Accreditation Commission, 2011),
b) FEANI in Europe (FEANI, 2013)
c) Engineers Australia (Engineers Australia, 2009):

The criteria defined by Engineering Accreditation Commission (EAC) of Accreditation Board for Engineering and Technology (ABET), United States, is presented in Table 2-1.

The federation of professional engineers that unites national engineering associations from 32 European countries (FEANI) states that engineers aware of their professional responsibilities should strive to achieve competence presented in Table 2-3.

The Engineers Australia Accreditation Board (Engineers Australia, 2009) has identified generic attributes for engineering students that are presented in Table 2-2.

The existing research on engineering skills includes work of Male, Bush and Chapman (S. A. Male, Bush, & Chapman, 2009) (S. A. Male, 2010), who identified important generic engineering competencies in the literature and used them in a study with 300 practising engineers who rated the competence list. The results that were obtained by this study indicate that communication, teamwork and different shapes of management are among the competences rated as most important on the list of technical, non-technical and attitudinal competencies. Self-management, commitment and inter-disciplinary skills are rated high as well, followed by problem solving and the ability to learn.

TABLE 2-1 ABET OUTCOMES (ADAPTED FROM (ENGINEERING ACCREDITATION COMMISSION, 2011))

ABET outcomes
(a) an ability to apply knowledge of mathematics, science, and engineering
(b) an ability to design and conduct experiments, as well as to analyse and interpret data
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
(d) an ability to function on multidisciplinary teams
(e) an ability to identify, formulate, and solve engineering problems
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

TABLE 2-2 ENGINEERS AUSTRALIA GENERIC ATTRIBUTES (ADAPTED FROM (ENGINEERS AUSTRALIA, 2009))

Engineers Australia
a. ability to apply knowledge of basic science and engineering fundamentals;
b. ability to communicate effectively; not only with engineers but also with the community at large;
c. in depth technical competence in at least one engineering discipline;
d. ability to undertake problem identification, formulation and solution;
e. ability to utilize a systems approach to design and operational performance;
f. ability to function effectively as an individual and in multi-disciplinary and multi-cultural teams, with the capacity to be a leader or manager as well as an effective team member;
g. understanding of social, cultural, global and environmental responsibilities of the professional engineers and the need of sustainable development;
h. understanding of the principles of sustainable design and development;
i. understanding of professional and ethical responsibilities and commitment to them; and
j. expectation of the need to undertake lifelong learning, and capacity to do so.

TABLE 2-3 FEANI SKILLS (ADAPTED FROM (FEANI, 2013))

FEANI skills
a. An understanding of the engineering profession and an obligation to serve society, the profession and environment, through commitment to apply the appropriate code of professional conduct.
b. A thorough knowledge of the principles of engineering, based on mathematics and a combination of scientific subjects appropriate to their discipline.
c. A general knowledge of good engineering practice, in their field of engineering and the properties, behaviour, fabrication and use of materials, components and generic ware.
d. An ability to apply appropriate theoretical and practical methods to the analysis and solution of engineering problems.
e. Knowledge of the use of existing and emerging technologies relevant to their field of specialization.
f. An ability in engineering economics, quality assurance, maintainability, and use of technical information and statistics.
g. An ability to work with others on multidisciplinary projects.
h. An ability to provide leadership embracing managerial, technical, financial, and human considerations.
i. Communication skills and an obligation to maintain competence by continuous professional development (CPD).
j. Knowledge of standards and regulations appropriate to their field of specialization.
k. An awareness of continuous technical change and the cultivation of an attitude to seek innovation and creativity within the engineering profession.
l. Fluency in European languages sufficient to facilitate communication when working throughout Europe.

Another study conducted in Australia by Duyen Nguyen back in 1998 included a comparative study of academics, industry and engineering students based on a survey with nearly 200 participants. The results that were obtained indicated that the essential skills and attributes of an engineer are: sound knowledge of fundamental engineering principles and laws, ability to apply the knowledge and convert theory into practice, skilfulness and practice in the chosen field, understanding of the impact on the environment, ability to find environmental solutions to minimise or prevent damage to the environment, knowledge and skilfulness in quality control, broad understanding of economic and political structures (Nguyen, 1998).

In the research project "Aligning Engineering Education with Engineering Practice" conducted at the College of Engineering of the University of Wisconsin-Madison multiple surveys were conducted with over 150 practising engineers to extend the understanding on the skills that are considered essential in engineering work. The results list the following skills: communication, using resources to solve problems, teamwork, application of ethics, lifelong learning, business understanding, as well as defining constraints and creativity (found on the project web-site: http://hplengr.engr.wisc.edu/).

Atman et al. (C.J. Atman et al., 2008) point out that the skills required of modern engineers *"include, among others, and ability to define problems as well as to solve them, a tolerance for ambiguity, design judgment, an understanding of uncertainty and an appreciation of the impact of designed solutions on the people and environment they interact with. Because engineering is situated in real contexts, an ability to consider broad impacts (encompassing technical, social, economic, political, cultural and environmental considerations) is a particularly important aspect of being a successful engineer."*

TABLE 2-4 TUNING PROJECT GENERIC COMPETENCES (ADAPTED FROM (GONZALEZ & WAGENAAR, 2008))

Competence group	***Competence***
Instrumental competences	Ability to analyse and synthesize
	Ability to organize and plan
	Basic general knowledge
	Basic knowledge of the profession
	Oral and written communication in their own language
	Knowledge of a second language
	Basic skills of computer use
	Skills in information management
	Troubleshooting
	Decision making
Interpersonal competences	Capacity and self-criticism
	Capacity for teamwork
	Interpersonal skills
	Ability to work in an interdisciplinary team
	Ability to communicate with experts from other areas
	Appreciation of diversity and multiculturalism
	Ability to work in an intercultural context Ethical commitment
	Ability to apply knowledge in practice
	Research skills
	Ability to learn
	Ability to adapt to new situations Ability to generate new ideas (creativity)
Systemic competences	Leadership
	Ability to work independently
	Design and project management
	Initiative and entrepreneurship
	Concern for quality
	Motivation to improve

Other examples from the literature include an interesting study by (Brumm, Hanneman, & Mickelson, 2006) that was conducted at the Iowa State university with the aim of determining competences that were crucial for achieving ABET outcomes, as well as ways of attaining them. 212 stakeholders from the industry, faculty, students and parents participated in this study in order to identify and validate 14 observable and measurable competencies that were mapped to ABET learning outcomes in a matrix that represents the importance of the competence to achieve the outcome. Furthermore, the stakeholders evaluated the probability of achieving the competence in different learning environments (engineering workplace, internship workplace, capstone course, traditional classroom, etc.). Not surprisingly, the engineering and experiential workplaces were identified as settings most likely to develop and demonstrate the competencies, and the traditional classroom as least likely. These results suggest that experiential education may be critical to students' success.

In a recent comparative study of two higher education institutions in Serbia (Milica Gerasimović & Miškeljin, 2009) the importance and level of achievement of engineering students' competencies was investigated. In this study Gerasimović and Miškeljin used the Tuning project framework of competences, and they found that mechanical engineering students give the highest level of importance to the following competences: "Ability to apply knowledge in practice", "Ability to work independently" and "Knowledge of foreign languages", while their highest self-assessed achievement levels are for "Basic computer skills", "Ability to work independently" and "Decision making". The lowest competences with the lowest levels of importance are "Appreciation of diversity and multiculturalism", "Leadership" and "Design and project management " while the lowest self-assessed achievement levels are for "Leadership", "Research skills" and "Design and project management ".

Tuning project presents comprehensive list of generic competences, as shown in Table 2-4.

In the next section skills for sustainability are considered.

2.1.3 Skills for sustainability

In a well-known definition of sustainability, The Brundtland Commission defines sustainable development as the "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland & World Commission on Environment and Development, 1987). The report points out the importance of eradication of poverty and meeting the basic needs of all; of promoting the principles of intergenerational and intra-generational equity, of recognizing the link between a healthy economy and healthy environment, and of accepting the limitations set by the carrying capacity of the environment.

In the outcome of the 1992 United Nations Conference on Environment and Development in Rio de Janeiro, the role of education is emphasized among the strategies for achieving the goals of sustainable development. With a view to "reorienting education towards sustainable development" it suggests accessibility to environmental and development education in formal and non-formal education for all age groups and using both innovative and traditional pedagogies. (Kagawa, 2007)

As defined by UNESCO, education for sustainable development is *"a process of learning how to make decisions that consider the long-term future of the economy, ecology and equity of all communities"* where interrelations and interactions between these three dimensions need to be determined and considered (UNESCO, 2004).

As future engineers will be required to supply creative solutions to complex sustainability problems the higher education needs to prepare them for these tasks. Fenner (as cited in (Segalàs & Mulder, 2008)) argues that "changes need to be made in the way engineering education is conceived and delivered, so that graduating engineers can become proponents for the implementation of sustainable practices in their organisations."

Engineers will have to solve complex problems facing the ambiguity and often conflicting goals; they will have to manage the uncertainty and ambiguity, evaluate and apply information from non-technical fields, such as economics, public policy, and the environmental and social sciences in order to critically assess the implications of their professional actions, and make judgments about the best course of action based on the available evidence (Huntzinger et al., 2007).

Felder resumes the task that sustainable development problems pose in front of engineering educators in a study that emphasizes the need for creating creative engineers (Felder, 1987):

> *"The toughest problems facing our society—how to provide all our citizens with adequate and affordable food, housing, and medical care, efficient and economical public transportation, clean and safe energy—are not likely to be solved by easy or conventional means. If they could be, they would have been solved by now. To the extent that the problems are technological, creative engineers are needed to solve them. We—engineering professors—are in the business of producing engineers. It would seem our responsibility, and also in our best interest, to produce some creative ones—or least not to extinguish the sparks of creativity our students bring with them"*

One of the key competences that is associated with engineering education for sustainable development is solving complex real world problems. In their work on research and teaching on innovation for sustainable development Posh and Steiner emphasize that this always means handling ill-defined, highly complex problems (Posch & Steiner, 2006). They suggest that it is not possible to capture the complex nature of these problems and their solutions in the traditional single disciplinary approach, and propose that "*a solution that involves a paradigm shift towards a holistic problem solving approach involving systems thinking is needed*." These problems are referred to as "wicked problems" that have no definitive formulation, no clear end, no immediate or ultimate test of their resolution and no possibility of learning by "trial and error". Yet they have consequences to every solution and causes with no unique explanation (Dobson & Tomkinson, 2012).

In a study that describes the introduction of sustainable development at the Cambridge University engineering department, focusing on the underlying skills that engineering students should develop in the sustainability context, Fenner et al. (Fenner, Ainger, Cruickshank, & Guthrie, 2005) argue that though engineers must develop a rigorous understanding of the physical and mathematical principles, engineering design comprises other skills needed in the delivery of projects, products and services. These include a systems view of the world, where the outcomes of engineering work have to meet the clearly defined needs which include non-technical ones, in order to deal with the complexity that needs to be taken into consideration while solutions are being conceived and implemented.

The results of Tomkinson's Delphi study (in (Hopkinson & James, 2010)) where 30 UK experts were asked to express their views on the topic of engineering education for sustainable development indicate:

- Social aspects were seen as the main challenge
- The most important responsibility was raising awareness
- The most highly regarded skill to be fostered by ESD was dealing with complexity
- The best educational approach was case studies and role play

Competencies can be categorized as key competencies - those which are relevant across different spheres of life and for all individuals - and domain-specific competencies which are necessary for successful action in certain situations and contexts (Barth, Godemann, Rieckmann, & Stoltenberg, 2007). The results of their explorative study based on focus groups from formal and informal learning settings suggest that higher education should clearly focus on the development of the knowledge, skills, perspectives and values related to sustainability, developing skills for creative and critical thinking, oral and written communication, collaboration and cooperation, conflict management, decision-making, problem-solving and planning, using appropriate ICTs, and practical citizenship.

The concept of competences for sustainability has been defined more recently by Cortés, Segalàs, Cebrian and Junyent (Cortés, Segalas, Cebrian, & Junyent, 2010) as the "*complex and integrated set of knowledge, skills, abilities, attitudes and values that people put into play in different contexts (social, educational, employment, family etc.) to resolve issues related to development issues, as well as operate and transform reality with sustainability criteria.*"

The study conducted by Cebrián and Junyent in Spain (Cebrián & Junyent, 2015) summarizes that integrative and interdisciplinary teaching and learning approaches such as problem solving, critical thinking and systems thinking can foster sustainability skills. The emphasize the role of systems thinking as crucial for the ability to see the interconnections between different dimensions (environmental, development, social, economic, cultural) and the complexity of systems and situations that can contribute to the effective problem-solving of sustainability issues.

Engineers need to be equipped with skills and competences in order to meet the challenges of the work environments in the context of complex sustainability problems.

These skills have been studied and proposed by different engineering accreditation bodies.

In the guiding principles of Engineering for Sustainable Development issued by The Royal Academy of Engineering, UK, (Dodds & Venables, 2005) recommending that engineers should have the ability to:

- *operate and act responsibly, taking account of the need to progress environmental, social and economic issues simultaneously;*
- *use imagination, creativity and innovation to produce products and services which maintain and enhance the quality of the environment and community' and meet financial obligations, and*
- *understand and encourage stakeholder involvement.*

In these guiding principles there are four steps suggested as one way of generating the capability to be achieved by engineering graduates. First is demonstration that the student is aware of and understands the concept of sustainable development; secondly, an analysis of the life-cycle of a product, industry or process extended to identifying areas for improvement where role-play can be used; thirdly, the content on or relationship to the concept and practice of sustainable development of the course content; fourthly, undertaking the significant projects where the resulting product, process or system should be framed in a sustainable development context (Dodds & Venables, 2005)

(Steiner & Laws, 2006) argue that in order to solve complex problems university graduates need to possess a broad set of sophisticated competences that include:

- *field-related knowledge;*

- *the capability to design and understand a complex system;*
- *the social competence needed to actively participate in group work together with the stakeholders including the ability to analyse potential stakeholders and their specific competences and set up a "participation road map" for different stakeholder groups*
- *the capability to responsibly choose and apply the appropriate problem-solving methods including variants for a consistent future development together with their evaluation and the design of an "implementation action plan".*

In the already mentioned study of introducing sustainable development in the Engineering Department of the Cambridge University, Fenner et al. (Fenner et al., 2005) have also added the following competences that are required form modern engineers:

- *The need to engage in problem definition through careful dialogue with all stakeholder groups and a proper recognition of context.*
- *An understanding of mechanisms for initiating and managing change in organisations so future engineers are equipped to play a leadership role.*
- *An acknowledgement that technical innovation and business skills also must be understood, nurtured and combined as precursors to the successful implementation of sustainable solutions.*

In the recent work Segalàs, Ferrer-Balas, Svanström, Lundqvist and Mulder classify the competences for sustainability based on the research of three European universities. These include (Segalàs, Ferrer-Balas, Svanström, Lundqvist, & Mulder, 2009):

In the knowledge domain:

- *World current situation*
- *Causes of unsustainability*
- *Sustainability fundamentals*
- *Science, technology and society*
- *Instruments for sustainable technologies*

In the skills and attitudes domain:

- *Self-learning*
- *Cooperation and transdisciplinarity*
- *SD Problem solving*
- *Systemic thinking*

- *Critical thinking*
- *Social participation*

In the affective domain:

- *Responsibility/ commitment/SD challenge acknowledge*
- *Respect/ethical sense/peace culture*
- *Concern/risk awareness*

The affective domain and sustainability values were the themes of the research we conducted with general population (Božić & Tramullas, 2009)(Božić, 2010).

Queis argues that (Queis, 2007) education for sustainable development calls for a particular kind of educational practice where the learner is an active processor of information. Theoretical research studies have shown that knowledge will not be transferred from teachers to students, but will be constructed and built up in concrete situations based on the foundations of their own experiences. This is a constructivist notion of learning: learners construct meaning, which is the knowledge that they will use in their life.

2.1.4 Skills gap analysis

The research that presents skills gaps can be divided in two broad categories: reports by engineering professional societies and reports originating from individual studies conducted by researchers in the field of engineering education either through literature review or industry surveys.

An example of engineering professional society report is the report of the Royal Academy of Engineering in the UK ("Educating Engineers for the 21st Century," 2007) which identifies shortage of suitable engineering graduates and skill gaps, based on the study of industry views:

> *"Over one-third of companies responding indicate that shortages and skill deficiencies are impeding new product development and business growth, as well as increasing recruitment costs. Specific gaps exist in problem solving and application of theory to real problems, breadth and ability in maths"*

In a comprehensive review of competency gaps in engineering graduates Sally Male (S. A. Male, 2010) discusses the gaps that were originated by different classes of reasons: a) firstly, the changes in the professional context of engineering such as rapid technological change, globalization and increased concern for environmental issues have influenced changing demands of engineers and engineering education; b) Male recognizes persistent gaps that include communication skills and have been called for in the last century; c) gaps in communication, leadership, and social skills; d) gaps in creativity, problem solving, innovation, design, ethics, reflection, and complex systems, as required for engineering practice

The example of individual study that included industry survey is a recent study by Hillmer et al. in Austria (Hillmer et al., 2012) that conducted a competencies' gap analysis. Major deviations were revealed between expected/required skills and the actual performance of the engineering graduates who have a maximum of three years' industry experience. The analysis was performed based on the survey conducted with the participants from the industry and concerning graduates from Bachelor's and Master's engineering programs. The results of this study suggest that the major gaps exist in the:

- capability to solve problems in a structured and solution-oriented way
- project and process/quality management skills
- leadership in projects
- development of ideas
- work skills, time management and self-organization
- team competence and the ability to handle conflicts and
- a huge gap between required and actual competence related to rhetoric & presentation and written expression.

The research based on the industry survey in Valencia that was carried out at Universidad Politecnica de Valencia (UPV), Spain during 2010 analysed the competences gap according to the employers as well as their satisfaction with the employed graduates coming from the UPV. The sample was composed by 339 companies. The study addressed 23 competences that belonged to technical competences, personal skills and teamwork skills. The results of this study indicate that there are skills gaps in the first five competences as listed by the industry: teamwork, working under pressure, motivating others, generating new ideas and problem solving and analytical thought.

The skills gap analysis conducted in Serbia by USAID Competitiveness Project (USAID Competitiveness Project, 2008) surveyed companies for current workers' skills gaps and identified following types of skills gaps: 64% are generic skills, 24% technology skills, and 12% of basic skills such as attitude, appearance etc. In the generic skills category, those mostly mentioned are:

- Communication skills
- Problem solving skills
- Time management skills
- Negotiation skills.

The surveyed companies revealed that they would undertake the following future generic skill training (ordered by stated importance): Project Management Skills; Problem solving skills; Communication skills; Conflict management; Change management; Teamwork skills

In the previously mentioned study conducted at the College of Engineering of the University of Wisconsin-Madison (K. Anderson, Courter, Nicometo, Nathans-Kelly, & McGlamery, 2009) a survey data from 113 practising engineers indicates that skills where undergraduate education could do better are:

- hands-on real world problems and business training
- technical communication
- disciplinary breadth
- project management experience.

The initial implications for engineering education derived from this study would be to:

- Apply concepts and skills to real-world problems
- Focus on communication skills
- Work with clients, with monetary implications
- Work through realistic constraints (beyond the classroom)

Finally, in an exploratory case study by Hanning, Abelsson, Lundqvist and Svanström in Sweden (Hanning, Abelsson, Lundqvist, & Svanström, 2012) it was found that industry demands a broader range of competences in sustainable development amongst engineers in general than what is currently provided. The analysis benchmarked the exiting sustainable development education to industry's needs concluding that the alumni identify a need for more competences related to economic issues, sustainable business management, social issues and green technologies, than what they were provided in their education. However, large differences exist between different sectors of industry, which needs a more focused investigation related to specific sectors.

Preparing students to acquire skills and competences for complex workplace problem solving is challenging and the importance of continuous exploration of how different educational methods support and foster the development of generic and professional skills is evident. Engineering educators and instructional designers propose a diversity of approaches to support efficient learning in a context of practice with real life problems and situations, such as problem based learning, project based learning, etc. Some of them are presented in the next Chapter, while next section centres on the pedagogical role of ill-structured problem solving as crucial for competence development for the workplace.

2.2 ILL-STRUCTURED PROBLEM SOLVING

Developing expertise in problem solving is critical to the success of a wide range of human activities. Problems differ in their scope and range, from simple to complex, from those that have only one solution to those that have multiple solutions.

Newell and Simon define a problem in a following way*: "A person is confronted with a problem when he wants something and does not know immediately what series of actions he can perform to get it."* (Newell & Simon, 1972).

Definitions of problem include a gap between the current or initial state and the desired or goal state; therefore there is a starting point, the goal, and unknown set of actions to reach the goal. The motivation for solving the problem is some social, cultural or intellectual value to finding or solving the unknown, and there may exist rules that specify allowable operations, generally called constraints (David H Jonassen, 2000) (Chi & Glaser, 1985).

Problems that are used most commonly in schools and universities are well-defined or well-structured problems (David H Jonassen, 1997). These problems require the application of a finite number of concepts, rules, and principles to a constrained problem situation. These problems consist of a well-defined initial state, a known goal state, and constrained set of logical operators for arriving at a solution based on the materials presented in the text.

Most of the real-world problems encountered in everyday life belong to a different kind of problems, ill-structured or ill-defined problems. The information required to solve the problem is not all available in the problem statement (David H Jonassen, 1997)(David H Jonassen, 2000).

The characteristics of the ill-structured problems, according to Jonassen (David H Jonassen, 1997) are shown in Table 2-5.

Ill-structured problems are also inherently interdisciplinary, requiring the integration of several domains. They include important social, political, economic, and scientific problems. Design is well known as an ill-structured and pernicious problem (Simon, 1973).

Problems found or given to engineers and designers do not often contain all of the information required to solve the problem in the problem statement; in many cases even the statement itself may not be clear, and multiple solutions might exist.

It is important to differentiate between well-structured problems and ill-structured problems since well-structured problem solving that occurs in traditional school setting has shown to have limited relevance and transferability to authentic problems in everyday life. Therefore, students should be exposed to ill-structured problems, and instructional strategies should be developed to support students’ skills in solving ill-structured problems. (Ge, 2001)

TABLE 2-5 CHARACTERISTICS OF ILL-STRUCTURED PROBLEMS (ADAPTED FROM (David H Jonassen, 1997)**)**

Characteristics of ill-structured problems
Appear ill-defined because one or more of the problem elements are unknown or not known with any degree of confidence
Have vaguely defined or unclear goals and unstated constraints
Possess multiple solutions, solution paths, or no solutions at all – there is no consensual agreement on the appropriate solution
Possess multiple criteria for evaluating solutions
Possess less manipulable parameters
Present uncertainty about which concepts, rules, and principles are necessary for the solution or how they are organized,
Possess relationships between concepts, rules, and principles that are inconsistent between cases
Offer no general rules or principles for describing or predicting most of the cases
Have no explicit means for determining appropriate action
Require learners to express personal opinions or beliefs about the problem
Require learners to make judgments about the problem and defend them

Different kind of skills is employed for solving ill-defined problems, that include skills such as goal monitoring and reflection, (Shin, Jonassen, & McGee, 2003) compared to solving well-defined problems where all elements and processes required for the solution are knowable and known and where the solutions require using logical, algorithmic processes.

According to (Gagné, 1975) problem solving is the most sophisticated form of learning.

Pedagogical role of ill-structured problems is therefore to train students in processes that can be transferred to real world situations, giving them an opportunity to practice their skills in an authentic way. For engineering education, this means a challenge to integrate workplace real-world problems into the curriculum and while keeping up with new challenges and changing roles of engineers in the workplace.

In the following sections, the literature on both engineering and sustainability problems is reviewed.

2.2.1 ENGINEERING AND SUSTAINABILITY PROBLEMS

Engineering is characterized by ill-defined problems, where a practitioner deals with ambiguity, and in some cases exploits the ambiguity to develop creative solutions.

Jonassen and et al. have conducted a qualitative study of workplace engineering problems in order to identify their main attributes (D. Jonassen et al., 2006). According to this study, workplace engineering problems are ill-structured and complex because they possess conflicting goals, multiple solution methods, non-engineering success standards, non-engineering constraints, unanticipated problems, distributed knowledge, collaborative activity systems, the importance of experience in solving them, and multiple forms of problem representation. Furthermore, problems are made even more ill-structured because engineers work and communicate with people from different backgrounds, deal with constraints coming from different areas (engineering, environmental, legal, financial, management or other), deal with incomplete or missing information and face unanticipated problems. As a result they may make critical assumptions.

The most common kind of problems that practicing engineers solve are design problems (products, processes, systems, and methods design); however, engineers need to solve a variety of decision-making, troubleshooting, and systems analysis problems.

In order to function effectively at the workplace, engineers need to apply higher order thinking skills such as inquiry, investigation, organization, reflection, reasoning, analysis, and problem solving. If the goal of the engineering education programs is to better prepare engineers for the workplace, students should be engaged in resolving the complexities and ambiguities of those kinds of problems that make use of these skills (D. Jonassen et al., 2006).

In the same study, Jonassen et al. suggest that engineering students should "*Experience directly or vicariously the complexities of work-place problems as often as possible ("they should have some classes or something where you could have got to go out in the field a little bit and see some of this stuff")"* (D. Jonassen et al., 2006)

(Hadgraft, 2005) states that sustainable development concept with its interrelationships between society, the environment, and economic/industrial development brings additional complexity to engineering problems, which implies evaluating and applying information from multiple disciplines, such as economics, public policy, and the environmental and social sciences, while surrounded by uncertainty and ambiguity, in order to design more eco-efficient systems and technologies in both a national and global setting. Innovation is required, as is up-to-the-minute research.

Other challenges identified in the literature include the sustainability themes defined by Cruickshank and Fenner in the Engineering for Sustainable Development master programme at Cambridge University, conveyed as key challenges, in which engineers must respond to new societal expectation by (Cruickshank & Fenner, 2012):

- *Dealing with complexity – through adopting a systems approach*
- *Dealing with uncertainty – when decision making in the absence of complete information or evidence*

- *Dealing with change – by challenging orthodoxy and envisioning the future*
- *Dealing with other disciplines – through building multi-disciplinary teams.*
- *Dealing with environmental limits – through resource efficiency, pollution control and maintaining ecosystem services.*
- *Dealing with people – through consultation processes and negotiation to meet society's and individual's needs*
- *Dealing with whole life costs – by considering project externalities and life cycle management*
- *Dealing with trade-offs – by avoiding optimisation around a single variable to create solutions acceptable for all.*

(Cruickshank & Fenner, 2012)

When dealing with complex problems, students not only need the knowledge base to make sound engineering decisions, they need the intellectual development (e.g. higher-level cognitive and critical thinking skills) to supply effective solutions to complex technical problems.

Sustainability problems require flexible, integrative, multidisciplinary problem-solving approaches, rather than singular solutions. In addition, students learn that problem solving is often more than the product of an intellectual exercise.

(Huntzinger et al., 2007) note that students should be presented with complex, ill-defined problems in order to develop problem-solving skills and stimulate learning; these problems should be like those found in the real world in order to make transfer from the classroom likely (D. Jonassen et al., 2006).

2.2.2 The process: Ill-structured problem solving

Albert Einstein was once asked if he had one hour to save the world, how he would spend the hour. He is reputed to have said, "I would spend 55 minutes defining the problem and then only five minutes solving it."

Ill-structured problem solving in general involves:

a) problem representation,
b) develop solutions,
c) make justifications and construct arguments,
d) monitor and evaluate problem-solving plans and solutions.

Jonassen defined following steps for ill-structured problem- solving (David H Jonassen, 1997):

Articulating Problem Space and Contextual Constraints includes processes to determine what the nature of the problem is and examine the context, where the knowledge is organized around the problem once the type of problem is recognized.

Identifying and Clarifying Alternative Opinions, Positions, and Perspectives of Stakeholders includes identification of alternative views or perspectives, and reconciliation of different interpretations of phenomena involved.

Generating Possible Problem Solutions includes creation of the solution alternatives and selection of the viable alternative

Assessing the Viability of Alternative Solutions includes making claims about the probable effects of events, objects, or phenomena on others and justifying the claims while iteratively restricting alternatives before selecting a solution. The "best" solution is the one that is most viable, that is, most defensible.

Monitoring the Problem Space and Solution Options includes deciding on the possibility of solving the problem

Implementing and Monitoring the Solution (if this is viable) once the solution is implemented the performance of the elements in the problem is monitored in order to determine the effectiveness of the solution

Adapting the Solution by adjusting and adapting the implemented solution based on feedback

The framework presented by Dougherty and Fantaske highlights the abilities college students should possess to identify, choose and implement solutions (Dougherty & Fantaske, 1996):

***Understanding the Problem*.** Problem solving is frequently initiated by the recognition that a problem exists. At some point, problem solvers must define the problem, search their memories for previous experiences solving similar problems, and understand the goals associated with solving the problem

Background Knowledge and Information Needed. In addition to searching memory and understanding goals for a specific problem, an individual must begin to gather the information needed to arrive at a well-considered solution. The knowledge needed to solve different types of problems varies considerably. Some problems require domain-specific knowledge in which information about the subject matter of the problem becomes necessary. Conceptual knowledge includes knowledge of the theories and principles associated with a given domain. Procedural knowledge, on the other hand, represents the capacity to execute problem-solving operations. Other problems may require practical know-how acquired through informal learning, personal experience, or the guidance of a mentor or colleague

Generating Possible Solutions. Solutions are generated by using thinking skills and an appropriate knowledge base. The generation of solutions often calls for creativity while preserving a sense of direction and keeping in mind that more than one acceptable approach often exists.

Choosing a Solution. Before choosing a solution from multiple alternatives, constraints are to be used to evaluate possible solutions. Evaluative criteria is based on a wide range of expertise, and in addition to evaluating, it should be used to rank possible solutions based on the probability and desirability of expected outcomes. Finally, the solver should combine the factors identified by their analysis to produce a detailed solution.

Evaluation of Solution and Making Recommendations. Effective problem solvers should determine a means for evaluating alternatives to ensure the achievement of specified goals. This evaluation may include a review of the process that leads to further refinement and, eventually, a recommendation of an appropriate course of action (Dougherty & Fantaske, 1996).

Successful problem-solving among other factors relies on the motivation and social skills of the problem-solver as well as their ability to effectively transfer knowledge/strategies gained through experience from one situation to another. Another strong predictor of problem-solving skills is the solver's level of domain knowledge. How much someone knows about a domain is important to understanding the problem and generating solutions (David H Jonassen, 2000).

A compilation of the problem solving steps is given by Bulu in a dissertation on scaffolding students' content knowledge and ill-structured problem solving (Bulu, 2008):

- *The first step of problem solving, representation of the problem and the mental construction of the problem space, is the most significant part of problem solving according to (Bransford & Stein, 1993; Jonassen, 2000).*
- *When learners are faced with a problem, they first begin with representation, which includes the solvers' interpretation and understanding of the problem. Incorrect representation makes it impossible to solve the problem since solvers do not know what to search for (Chi & Glaser, 1985).*
- *Since most of the ill-structured problems are pseudo problems, the first step in ill-structured problem solving is deciding whether there is a problem (Jonassen, 1997).*
- *Next, to understand the problem, solvers should identify what is known and what is unknown. Ill-structured problem solving requires extensive knowledge from memory (Voss & Post, 1988).*

- *After representing the problem, solvers start generating solutions. However, for ill-structured problems there are conflicting assumptions, evidence, and opinions that lead to multiple solutions (Kitchener, 1983).*
- *Therefore, solvers should select one among the multiple solutions that they think is suitable to the problem essence and that is reachable based on the problem and its constraints (Sinnott, 1989).*
- *After generating solutions, solvers need to justify them by indicating why they will work, as well as consider the possible difficulties of the proposed solution and how these difficulties may be resolved (Voss & Post, 1988).*
- *Since ill-defined problems do not have a definite single solution and each solution may have some validity and contain some error, solvers should make epistemic assumptions. By assessing the truth-value of possible solutions, solvers develop a strategy to select one solution (Kitchener, 1983).*
- *During solution search and justification, problem solvers continuously engage in monitoring and evaluating activities (Voss & Post, 1988). These activities assist solvers to control their own processes, apply appropriate strategies, deal with their limitations, and stay on track (Kluwe & Friedrichsen, 1985).*

2.2.3 CHALLENGES DURING ILL-STRUCTURED PROBLEM SOLVING

Challenges that learners face during ill-structured problem solving are based on the difficulties of novice learners to meet the complex requirements of the problem solving process. Problem solving is a complex process that requires domain-specific knowledge, structural knowledge, metacognitive processes to plan, monitor, evaluate, and revise investigation plans, and justification skills (Bulu, 2008).

Felder and Brent in a study of understanding student differences (Felder & Brent, 2005) suggest that students have different levels of motivation, different attitudes about teaching and learning, and different responses to specific classroom environments and instructional practices. They found that the more thoroughly instructors understand the differences, the better chance they have of meeting the diverse learning needs of all of their students. Three categories of diversity that have been shown to have important implications for teaching and learning are differences in students' learning styles (characteristic ways of taking in and processing information), approaches to learning (surface, deep, and strategic), and intellectual development levels (attitudes about the nature of knowledge and how it should be acquired and evaluated).

The above may affect students' approach to ill-structured problems as well, and consequently to the challenges they face during ill-structured problem solving.

The research on how to support students during ill-structured problem solving is still limited, and among the calls for support to students' learning in solving ill-structured problems stand out those at the Frontiers in Education (FIE) Conferences in 2007 and 2011.

In a 2007 panel, Mats Daniels et al. had the intention of inspiring the audience to look into how to integrate solving ill-structured problems and of providing examples of how it can be and has been done (Daniels et al., 2007a).

In 2011, another special session was proposed by Purzer and Hilpert with the goal of engaging participants in cognitive processes critical for ill-defined problem solving (Purzer & Hilpert, 2011). The authors suggested to link theory, research, and classroom implications for educators interested in researching ill-defined problem solving and related ways to support student learning in their classrooms. Cognitive dissonance was a theory the authors proposed to introduce and apply it to classroom tasks. One of the goals proposed for the panel was the discussion on challenges students face and methods to help them overcome these challenges without sacrificing novelty, suggesting the right balance of instructor support so as not to eliminate novelty and maintain fidelity to the ill-defined problem as essential to student learning.

Purzer et al. examined changes in engineering students' perceived challenges during a semester-long design project to identify the most salient challenges they experienced and when they occurred (Purzer et al., 2011). The hypothesis they started with was that patterns in students' perceived challenges in key areas would take the form of multiple, overlapping waves. Based on existing problem solving theory, these authors hypothesized six different types of challenges students could face during the project:

1. problem definition,
2. information gathering,
3. analysis
4. project management
5. solution generation
6. solution detailing

A longitudinal data from about 130 first-year engineering students was collected on-line at five points of time during a semester, with some variation in sample size between time points. A series of Chisquare difference tests were conducted to examine changes in students' perceived challenges during the course of the project. The most salient out of the set of 6 pre-defined challenges experienced by students were identified. Fluctuations in reported skills suggest that students engage and reengage with certain dimensions of innovative problem solving tasks. There is a need for future research into how the results of the existing studies can be translated into classroom practices, as the research on when and how to support student engagement and learning during ill-defined problem solving in engineering is still limited (Purzer & Hilpert, 2011).

One of the studies that investigated students' difficulties in solving ill-structured problems was described by Mendonca, Oliveira, Guerrero, & Costa (2009). The study was conducted on a sample of 10 students in first-year computer programming course and it suggests that students present difficulties in the interpretation of the problem, formulating questions to enlighten the problem, analysing the problem constrains and registering effectively the new problem information.

Understanding the issues and challenges during ill-structured problem solving and the pedagogical strategies to deal with them is crucial to producing effective instructional designs for teaching and learning in the context of preparing students for the workplace.

2.3 LEARNING THEORIES

A major goal of higher education is to prepare students for flexible adaptation to new problems and settings in their future work environments.

As emphasized in previous chapters, traditional education is based on solving well-structured problems that have convergent solutions, and engage the application of a limited number of rules and principles within well-defined parameters. Typically, students become proficient in solving narrowly defined textbook problems, but have relatively little experience in solving ill-structured, open-ended problems—the type often faced in practice.

Biggs and Tang argue that the focus on declarative knowledge, which is encouraged by university accreditation and assessment procedures, is actually not the one that is professionally relevant (Biggs & Tang, 2007). On the other hand, functioning knowledge is within the experience of the learner, who can put declarative knowledge to work by solving problems, designing buildings, planning teaching or performing surgery. Functioning knowledge requires a solid foundation of declarative knowledge. Biggs and Tang suggest that the academic knowledge learned at the university in a traditional academic lecture does not transfer to practice in the workplace in a straightforward or uncomplicated way.

This transfer according to (Kerka, 1997) is facilitated by having someone model how to understand and deal with the situations that included ill-defined, complex, or risky situations and guide their attempts to do so. Research on how people learn in the workplace demonstrates that what is taking place is constructivist, situated learning, often through cognitive apprenticeship.

In the constructivist theory the goal for learning is the creation and transfer of context-dependent, flexible and adaptive learning and complex problem solving, in contrast to the behaviourist and cognitive (information processing) theories of learning where the goal of learning is to adopt a pre-specified knowledge base (Ge, 2004).

The central question is how ill-structured real world engineering practice problems can be connected to an engineering course. Preparing students to acquire skills and competences for complex workplace problem solving is challenging; engineering educators and instructional designers propose a diversity of approaches, some of which are presented below.

Pedagogical role of ill-defined problems is unquestionably important: it is to train students in the problem solving processes, giving them an opportunity to practice their skills in an authentic way and take increasing responsibility for constructing and defending their own judgments. It has been found that students need practice to develop adequate conceptual frameworks (make meaning) and apply those frameworks while solving complex ill-structured problems (D. Jonassen et al., 2006).

Jonassen (1997, as cited in (Jonassen & Land, 2000)) describes the instructional designs for ill-structured problems that share assumptions with constructivism, recommending to embed instruction in an authentic context.

This requires a shift from traditional to more student-centred learning. New demands from business and accrediting agencies who have put an increasing pressure on engineering programs to integrate job-related skills into the undergraduate curriculum call for this shift as well.

In the following Sections major approaches to learning for practice are reviewed: student centred learning, constructivist approach to learning, learning by doing and learning for transfer.

2.3.1 Student centred learning

Student centred learning environments present learners with the responsibility for his/her own learning and the freedom of choice: the learning environment is supportive for students to develop their potential.

It has been shown that this approach to learning promotes a deeper approach to learning and lifelong learning. Feedback is primarily concerned with helping students to improve, as opposed to teacher centred where it is primarily concerned with telling students whether they have fulfilled the assessment criteria.

TABLE 2-6 STUDENT-CENTRED VERSUS TEACHER-CENTRED CHARACTERISTICS (SOURCE: (Brown, 2004)**)**

Student-centred	*Teacher-centred*
Focuses on what the student does to learn	Focuses on what the teacher does to teach and what the student should do
Students' experience as well as their knowledge is considered	Focuses primarily on increasing students' knowledge
Students take key decisions on what to study and how	Teacher takes key decisions on what to study and how
Students take key decisions on choice of assessment task and criteria	Teacher takes key decisions on assessment task and criteria
Feedback is primarily concerned with helping students to improve	Feedback is primarily concerned with telling students whether they have fulfilled the assessment criteria
Assessment and feedback include self-, peer and collaborative assessment	Assessment and feedback do not include these approaches
Active learning	Passive learning
Deep learning	Surface learning
Problem-based	Discipline-based
Emphasises development of understanding and constructions of meaning	Emphasises transmission of knowledge
Concerned with meta-cognition – with learning how to learn	Not concerned with meta-cognition
Uses enquiry-based methods such as projects, dissertations and portfolios	Does not use enquiry-based methods
Emphasises reflective learning	Emphasises reproductive learning
Develops autonomy	Develops conformity

The traditional theories of learning include behaviourist and cognitive theories that focus on the design of content that is intended for processing and repeating (Biggs & Tang, 2007).

Putting student in the centre of learning shifts the focus to the goals and activities of the learner rather than to the presentation of content. This is reflective of constructivist and situated theories of learning, which focus on learners actively constructing knowledge in context of the situations in which they are participating.

According to (Barrows, 1996) "The ability of the tutor to use facilitory teaching skills during the small group learning process is the major determinant of the quality and the success of any educational method aimed at 1) developing students' thinking or reasoning skills (problem solving, metacognition, critical thinking) as they learn, and 2) helping them to become independent, self-directed learners (learning to learn, learning management). Tutoring is a teaching skill central to problem-based, self-directed learning."

Though the research on how people learn in the workplace demonstrates that what is taking place is constructivist, situated learning (Kerka, 1997), we shall examine contemporary theories of teaching and learning for a broader context, including the theories developed by John Dewey, whose vision is that “School should be less about preparation for life and more like life itself.”

2.3.2 CONSTRUCTIVIST APPROACH

Principles applied to these new learning environments are described by (J. R. Savery & Duffy, 2001). These seven principles can greatly inform the design of a constructivist learning environment that supports learners in developing complex problem solving skills as well as domain expertise:

1. Anchor all learning activities to a larger problem.
2. Design an authentic task.
3. Design the learning environment to reflect the complexity of the environment in which the learner should be able to function at the end of learning.
4. Support the learner in developing ownership for the overall problem.
5. Design the learning environment to support and challenge the learner’s thinking.
6. Encourage testing ideas against alternative views and alternative contexts.
7. Provide opportunity for and support reflection on both the content learned and the learning process.

Savery and Duffy propose to design the learning environment to support and challenge the learner's thinking. With the critical goal of supporting the learner in becoming an effective worker/thinker in the particular domain, the teacher must assume the roles of consultant and coach. The most critical teaching activity is in the questions the teacher asks the learner in that consulting and coaching activity. It is essential that the teacher value as well as challenge the learner's thinking. (J. R. Savery & Duffy, 2001)

Bruner (1966) promoted discovery learning in the exercise of problem solving, emphasizing feedback as both meaningful and within the information-processing capacity of the learner, promoting a sense of self-reward in the process of constructing knowledge from experience, which makes it unique to each individual.

From a constructivist perspective, learning is a process in which learners actively construct knowledge by integrating new information and experiences into what they have previously come to understand, revising and reinterpreting old knowledge in order to reconcile it with the new. Instead of absorbing or passively receiving objective knowledge that is "out there," this is an active self-regulatory process that constructs new models of understanding. In addition, learning must be useful to the learner; intrinsic motivation emerges from the desire to understand, to construct meaning. Using a constructivist approach, teachers facilitate learning by encouraging active inquiry, guiding learners to question their assumptions, and coaching them in the construction process (Kerka, 1997).

Constructivist instructors have to adapt to the role of facilitators and not teachers thus becoming the cognitive guides of learner's learning and not a knowledge transmitters. Duffy and Cunningham in their work "Constructivism: Implications for the Design and Delivery of Instruction" present an overview of the historical and philosophical context of constructivism in educational setting emphasizing the critical goal to support the learner in becoming an effective thinker (Duffy & Cunningham, 1996)

(Bonk & Cunningham, 1998) argue that when it comes to employing constructivism, practicing educators are not provided with guidelines for implementing and assessing it in order to reconstitute and embed constructivist ideas within their personal philosophies and teaching practices, discovering on the way that "tools fostering social interaction and learner-centred instructional practices are transforming learning from silent, solitary acts to lively, meaning-making events rich in discussion and interchange".

Constructivist designers avoid the breaking down of context into component parts as traditional instructional designers do, but are in favour of environments in which knowledge, skills, and complexity exist naturally. Therefore, designers develop procedures where the instructional goals evolve as learning progresses. The goal, for instance, is not to teach a particular version of history, but to teach someone how to think like a historian (Karagiorgi & Symeou, 2005)

The constructivist approach implies that a facilitator needs to display a different set of skills than a teacher.

> *"A teacher tells, a facilitator asks; a teacher lectures from the front, a facilitator supports from the back; a teacher gives answers according to a set curriculum, a facilitator provides guidelines and creates the environment for the learner to arrive at his or her own conclusions; a teacher mostly gives a monologue, a facilitator is in continuous dialogue with the learners" (anonymus)*

Dougherty and Fantaske have discussed evidence from research (Dougherty & Fantaske, 1996) to suggest different ways for educators in helping students to refine their approach to problem solving: 1) instructors should encourage discussion in the classroom as students work through problems in order to encourage students to think critically about their problem solving, 2) professors should place students in a decision-making role, working together to move through each phase of the problem-solving process. 3) As professors challenge their students to search for information through individual efforts rather than by taking notes, students become more likely to realize the importance of effective and efficient information gathering and its impact on problem solving in ill-structured domains.

The facilitator therefore should be able to adapt the learning experience by observing the class and taking the initiative to steer the learning experience to where the learners want to create value. This skill of the instructor underlines the importance of guidance for the development of problem-solving skills that is receiving increased attention in the field of instructional design. This is influenced by Vygostsky's theory (Vygotsky, 1978) of the "zone of proximal development" which denominates the zone in which students achieve the best learning. This zone is defined with "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers". The goals should be set just a bit further out of the student's comfort zone, but achievable with the help of knowledgeable other.

Regarding the characteristic of the instructor, it is interesting that back in 1965 Mathews and Bailey (Mathews & Bailey, 1965) specified qualifications of instructor for a creative engineering course, which corresponds to the student centred learning environments of today. They included following specifications for the teacher, that represent a difficulty of its own when it comes to choosing faculty staff that can take a role of facilitator:

> 1*) An engineering degree.*
>
> *2) Five or more years of experience as an engineer in his discipline or equivalent research experience at a university. This experience preferably would be in a wide variety of engineering activities.*
>
> *3) A dominant interest in creating new and improved ideas and products.*
>
> *4) A set of positive attitudes, i.e., attitudes which go beyond the critical approach to propose improvements. A deep-seated belief that a difficult task can be successfully completed is implied here.*
>
> *5) A proven record of having himself created new workable ideas and products, i.e., his problem solving approach has yielded positive results.*
>
> *6) A genuine interest in sharing his thought processes with others.*
>
> *7) A proven capability to teach.*

8) Capacity to transmit some of his enthusiasm for his subject area to students.

9) Capacity to blend analysis and synthesis techniques as required by the engineering problem.

10) Having experienced failure of some of his engineering ideas.

(Mathews & Bailey, 1965)

2.3.3 Learning by doing

One of the first educational theorists who believed that people learn by doing, and that all genuine education is achieved through experience was John Dewey.

In his work "Experience and Education" Dewey argues that genuine education comes about through experience, but not any experience – in order to be educative experience has to promote the growth of further experience (Dewey, 1938). Therefore, the quality of the experience is of paramount importance which makes *"the central problem of an education based upon experience … to select the kind of present experiences that live fruitfully and creatively in subsequent experiences."* This presents the principle of continuity.

The other principle brought out by Dewey is interaction, which in other words is an interplay between objective and internal conditions that form experience; these factors and their interaction form a situation. As Dewey beautifully describes it (Dewey, 1938):

> *"The two principles of continuity and interaction are not separate from each other. They intercept and unite. They are, so to speak, the longitudinal and lateral aspects of experience. Different situations succeed one another. But because of the principle of continuity something is carried over from the earlier to the later ones. As an individual passes from one situation to another, his world, his environment, expands or contracts. He does not find himself living in another world but in a different part or aspect of one and the same world. What he has learned in the way of knowledge and skill in one situation becomes an instrument of understanding and dealing effectively with the situations which follow."*

According to Dewey, the responsibility of the teacher is to select the objective condition for learning based on the students who are learning at a particular time. The more difficult part of is, as Dewey argues, that:

> *"It is not enough that certain materials and methods have proved effective with other individuals at other times. There must be a reason for thinking that they will function in generating an experience that has educative quality with particular*

individuals at a particular time., Responsibility for selecting objective conditions carries with it, then, the responsibility for understanding the needs and capacities of the individuals who are learning at a given time"

Experiential learning theories situate experience at the core of the learning process. Learning is about meaningful experiences – in everyday life – that lead to a change in an individual's knowledge and behaviours.

Subsequent theorists, such as Kolb have similarly pointed out that while experience is a part of learning, it is not, on its own, a sufficient condition for learning (D.A. Kolb, 1984). Kolb developed the argument that learning is the process of transforming experience into knowledge, and he suggested that learning is more effective if it is based on the learner's own experience. He proposed that when people reflect on their learning, they can develop a theoretical understanding of it, apply it to new situations and repeat the cycle. Different approaches to learning are associated with the phases of the learning cycle. Kolb's experiential learning model has four phases: concrete experience (CE), reflective observation (RO), abstract conceptualisation (AC), and active experimentation (AE). The model provided the basis of his Learning Style Inventory, which measures a learner's preference for specific phases of learning. This model is described more into detail in Section 5.1.4

Another point to this debate is brought by Osterman in an article that reviews the work of Donald Schön and Chris Argyris (K. Osterman, 1990). Osterman points out the importance of reflection and reflective practice in the education of professionals, elaborating on the reflective practitioner introduced by Schön and Argyris.

Biggs and Tang claim that effective learning in the higher education context requires: a knowledge base, a motivational context, learning activities and interaction. For learning to occur, students need to observe and reflect on experience, develop concepts to make sense of the experience and then apply and test out these concepts through new experiences (Biggs & Tang, 2007). These autorhs argue that learning for transfer implies the deep approach to learning, which is associated with intrinsic motivation.

Deeper learning occurs when the learner is able to transfer what was learned to new situations. Research on teaching for transfer indicates that learning for transfer requires knowledge, understanding and skills for using this knowledge to solve problems. Intrapersonal skills and dispositions, such as motivation and self-regulation, support deeper learning. Pellegrino and Hilton argue that the process of deeper learning is essential for the development of 21st century competencies (including both skills and knowledge); simultaneously, the application of transferable competencies supports the process of deeper learning thus forming a recursive, mutually reinforcing cycle (Pellegrino & Hilton, 2012).

Eraut defines transfer as “the learning process involved when a person learns to use previously acquired knowledge/skills/competence/expertise in a new situation” (Eraut, 2004). This may be easy if the new situation is similar to some of the previous situations; however, if the new situation is unfamiliar and complex as well this task becomes challenging. Eraut numbers the following factors that influence the transfer:

- The nature of what is being transferred
- Differences between the contexts
- The disposition of the transferee
- The time and effort devoted to facilitating the transfer process.

The student with a deep approach to learning would try “to understand the underlying purpose and meaning of the information encountered, to make a critical assessment of it and to reach a personal viewpoint”; one with a surface approach would demonstrate acquaintance with and understanding of the information “without actively seeking to restructure it or develop any personal perspective” (Eraut, 2004).

2.4 LEARNING ENVIRONMENTS

The existing literature on teaching workplace problem solving in engineering education is as rich and complex as engineering practice itself. As summarized by Sheppard, Colby, Macatangay, & Sullivan (2006), engineering practice is a complex integration of specialized knowledge, problem solving skills and good judgement for the service of society. Engineering education should ideally integrate these domains, serving as an apprenticeship to the profession.

One solution for preparing engineering graduates to become better workplace problem solvers is converting their curricula to problem based learning or project based learning.

Jonassen, Strobel, & Lee (2006) argue that preparation for future engineering work should include the ability to solve problems and to learn independently and collaboratively. In order to prepare students to solve workplace problems different and complex ill-structured problems should be used in a problem based learning setting that fosters meaningful collaboration and use of real world problems. Jonassen (1997) articulated a problem-solving process and a series of pedagogical recommendations and supporting the construction of knowledge bases that reflect real-world knowledge.

For (Dym, Agogino, Eris, & Frey, 2005) specific aspects of systems thinking that should be experienced by engineering students are related to project-based learning.

Trevelyan (2009) on the other hand argues that engineering is a much broader human social performance, and that not only design and technical problem solving need to be emphasized in teaching engineering practice, but also social interaction skills with emphasis on communication and distributed expertise through social interactions between people. In a previous study (James Trevelyan, 2008) argues that students need the opportunity to build a rigorous intellectual framework in which to think about human behaviour issues, alongside existing rigorous treatment of scientific, mathematical and technical issues. Beyond this, students require exposure to the complexities of engineering practice that is necessary in order to overcome currently perceived weaknesses in engineering education as perceived by industry employers and graduates alike.

Atman et al. (2010) invite engineering educators to help students prepare for the challenges of the work world, by preparing them to solve more complex and ambiguous problems, participate in larger and more diverse teams and apply new communication skills.

When identifying learning experiences that best support the development of expert professional practice, Litzinger, Lattuca, Hadgraft, & Newstetter (2011) emphasize that students should engage in a number of authentic engineering projects, and that feedback on the learning processes is crucial for students to understand what they can do well, and what they need to improve.

(Frank, 2000) suggests thirty “engineering systems thinking” laws. Based on these laws, a curriculum for constructing “engineering systems thinking” could be designed while connecting underlying learning theories as a base of the created learning environment.

Educational approaches that apply the above principles are problem-based and project based learning, experiential and collaborative learning (Savin-Baden, 2008).

Multiple studies on the problem based and project based learning offer rich theoretical discussions (e.g. Savin-Baden, 2008; Perrenet, Bouhuijs, & Smits, 2000), different implementation experiences (e.g. Du & Kolmos, 2006; Mitchell & Smith, 2008; Hadgraft, 2005) and relate them to the work world (e.g. Poikela & Poikela, 2005).

2.4.1 Project based learning

Graaf and Kolmos argue that the difference between problem based and project based learning is that problem-based learning is defined by open-ended and ill-structured problems that provide a context for learning while project based learning is based on an assignment or task that the students have to perform (Graaf & Kolmos, 2007).

Project based learning is a student centred approach to learning.

One of the first proponents of project based learning in education were Blumenfeld et al. (Blumenfeld et al., 1991). They argue that project based learning is focused on teaching by engaging students in investigation.

> *"Within this framework, students pursue solutions to nontrivial problems by asking and refining questions, debating ideas, making predictions, designing plans and/or experiments, collecting and analysing data, drawing conclusion, communicating their ideas and finding to others, asking new questions and creating artifacts.*
>
> *There are two essential components of projects: They require a question or problem that serves to organize and drive activities; and these activities result in a series of artefact, or products, that culminate in a final product that addresses the driving question".*

Project based learning "begins with an assignment to carry out one or more tasks that lead to the production of a final product—a design, a model, a device or a computer simulation. The expected result of the project is a written and/or oral report presenting the outcome" (Prince & Felder, 2006).

According to (Crawford, Tennant, & Wilson, 2003), project based learning in engineering is an important tool for the development of the skills needed by the graduate engineer, which include:

- *planning and management of work over an extended period of time; meeting deadlines and working within other externally defined constraints;*
- *tackling work which lacks a well-defined outcome or has a wide range of possible answers;*
- *utilising practical applications of theoretical learning in real-life situations;*
- *thinking about different aspects of engineering – design, materials, manufacturing – as parts of an integrated process;*
- *presenting and interpreting technical information in various ways;*
- *working across discipline boundaries, often as part of a team, drawing on engineering, science, business, computer science etc. as required;*
- *applying knowledge and skills in industry or other workplace settings, considering technological, environmental and commercial issues.*

The effective learning model for project based learning according to (Gibson, 2005) should contain the following elements:

1) Identify a suitable project

2) Describe the project in the context of the students' world

3) Organise course content and facilities around the project

4) Encourage students to take responsibility for defining their learning experience and planning project activities

5) Encourage collaboration via learning teams

6) Demand all students demonstrate the results of their learning through a product and/or performance

(T. Anderson, Torrens, Lay, & Duke, 2007) present some of the practical project based opportunities at the University of Waikato and examine the role these have played in a developing engineering program. They suggest that the use of practical learning experience in undergraduate degree programs offers students the opportunity to apply their knowledge and receive feedback in a supportive environment before entering the workplace or undertaking further study.

(Moor & Drake, 2001) investigate the question of how to structure the process of using projects to teach engineering design in order to insure an effective learning environment without compromising the independence and open-ended nature of the student's experience. Project management tools are suggested as a solution to the problems that are faced in this process, namely: a milestone schedule, regular project review meetings and memos and design memos which document each design task as the project progresses.

On the other hand, there are arguments that the key to engineering employability are project management skills, since most of the engineering work is organized around projects This implies that in many organisations engineers perform project management work as well. In the module described by Clark (Clark, 2007) and developed at the Aston University, UK, the key driver has been a focus on employability, while the module has become a catalyst for the development of the overall programme and a driver towards professional accreditation.

Other studies on project based learning in engineering education include studies on different approaches to teaching diverse engineering subjects (microprocessors, telecommunications, etc.) which use project based learning and ill-structured problems. These studies indicate that students respond favourably to this kind of instruction without offering detailed descriptions of the research methodology used to evaluate the learning environment (Kim, 2012), (Aliakbarian et al., 2014).

One exception is a recent study by Hosseinzadeh and Hesamzadeh with the aim of investigating the advantages and drawbacks of using the project based learning in teaching specialized subjects in electrical power engineering. The study is based on the authors' reflections and student feedback in the PBL-based course in power system modelling and analysis. However, before taking these specialized courses students attend other project based learning courses in their first year. In these courses, named Engineering Skills 1 and 2, students carry out a few projects in teams and develop generic skills such as the ability to collaborate in teams, as well as project management, time management, and presentation skills. The results indicate that it is possible to deliver both technical content and professional skills (Hosseinzadeh & Hesamzadeh, 2012).

New teaching and learning approaches need to be applied with care; problems need to be carefully constructed while difficulties that arise are described as anxiety in students that is triggered by the uncertainty introduced by problems with no single solution (Mitchell, Canavan, & Smith, 2009) and the declining motivation that arises when errors occur, when instructors and students have to accept that errors are necessary in order to learn and to apply acquired knowledge (Lamar et al., 2012).

(Jollands & Parthasarathy, 2013) in "Developing Engineering Students' Understanding of Sustainability Using Project Based Learning" describe the experience of RMIT University where students go through a stream of project based learning subjects from first to final year. The results of the study indicate that the students' understanding of sustainability increased substantially from 2nd to final year, and this was attributed to undertaking multiple projects and use of spread-sheeting tools while concept maps are a useful way to evaluate innovations in teaching sustainable engineering.

(Du & Kolmos, 2006) argue that students develop process competencies going through the experience and process of real project. Students learn to work both independently and collaboratively, as would many professionals. They regularly convene to share, evaluate, and critique each other's work. In addition, students perform activities that are regarded as components of professional practice. They deal with multiple and often conflicting goals and values, work with constraints, and determine the most appropriate action to take, often in the absence of complete information or certainty. Students learn to employ initiative, resourcefulness, and personal accountability as they develop solutions to the problem.

The body of research regarding the student centred educational approaches has grown importantly in the last decade. In the following paragraphs some of the relevant research regarding skills development as well as basic principles regarding each approach are given; the examples of more detailed descriptions can be found in the work of Mills and Treagust (Mills & Treagust, 2003) in their article “Engineering Education: Is Problem-Based or Project-Based Learning the Answer?”, of Graff and Kolmos on characteristics of problem based learning (Graaff & Kolmos, 2003) and in the work of Felder and Brent (Felder & Brent, 2004) who present an overview of active and cooperative learning as well as problem and project based learning.

2.4.2 Problem Based learning

Problem based learning (PBL) was developed as a general model in medical education in the early 1970's and since that time it has been refined and implemented in an increasing number of other areas including engineering. PBL was first introduced in the Chemical Engineering at McMaster University in Canada, followed by other universities in the U.S., Europe and Australia. Some of the examples described in the literature include: Aalborg University (Du & Kolmos, 2006), RMIT University (Hadgraft, 2005), University of Leuven in Belgium (Heylen, Smet, Buelens, & Vander Sloten, 2007), University College London in UK (Mitchell & Smith, 2008).

According to Barrows (Barrows, 1996), problem based learning is student centred, where students take responsibility of their own learning and the teacher’s role is that of a facilitator, guide, co-learner, tutor or professional consultant. Learning occurs in small groups and the knowledge constructed and the skills and attitudes developed as the students try to solve the problems are more relevant than the solution per se. New information is acquired through self-directed learning. Barrows also identified some PBL instructional goals that can be transferred to other disciplines as well: the acquisition of an integrated knowledge base structured around real-life problems and the

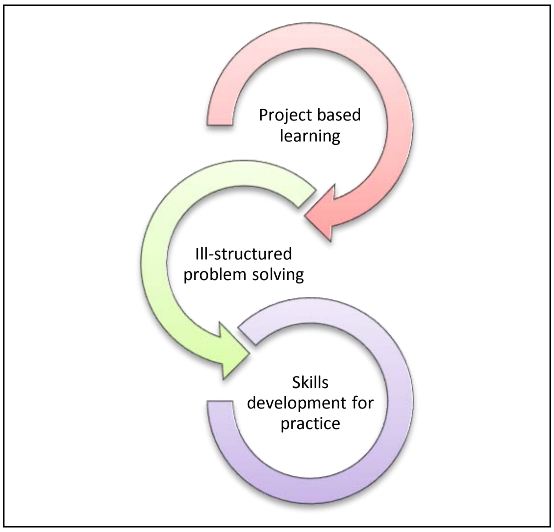


Figure 2-1 Skills development for practice: project and problem based learning

development of an effective and efficient problem-solving process as well as self-directed learning and teamwork skills.

As PBL requires that students take responsibility for their own learning, they should be provided adequate time for self-directed learning. Collaboration (with peers, tutors and facilitators) is essential in PBL. Before completing their work on a problem, the students should reflect on what has been learned and determine if there are concepts missing in their overall understanding, or whether additional skills are required.

de Camargo Ribiero (de Camargo Ribeiro, 2008) conducted a qualitative study of student evaluation of the PBL approach in an administration theory module of an electrical engineering programme at a university in Brazil. The class was composed of 38 students, majority of which were fifth year students. The PBL format implemented implied the work of self-tutored groups of 4 to 5 students – facilitated by the teacher – with paper problems. The development of communications, teamwork, problem-solving, research and leadership skills and were reported by students. Additionally, the reported advantages of PBL include: Self-directed learning, Integration Theory/practice, Teamwork, Enjoyable Learning Environment, and Enhanced Communications. The challenges PBL poses to students and teachers, such as increased time/workload, coverage versus depth of content knowledge and balanced teacher direction, should be dealt with in accordance with PBL's principles. Students reported that the PBL approach was more engaging and interesting as it allowed them to construct their own knowledge instead of absorbing teachers' words and they were able to seek information on their own to solve problems. Students also reported that they developed specific work skills such as, ability to research, produce syntheses, express ideas, communicate, and effectively work in teams to develop solutions to problems

Polanco (Polanco, Calderón, & Delgado, 2004) conducted a three-year evaluation of a problem-based learning integrated curriculum in a second-year engineering program at a Mexican university. The longitudinal data suggested that students taught with PBL achieved higher grades and performed better than students who received traditional instruction in advanced engineering courses. However, differences were significant only in Probability and Statistics and Oral communications scores, while they were not significant in other three core engineering subjects.

Similarly, Woods (Woods, 2006a) was the first to introduce the PBL curriculum in a chemical engineering program at McMaster University in Canada. A comprehensive research suggests that PBL students' confidence in problem-solving skills and their willingness to solve challenging problems also increased substantially compared to traditional students, suggesting that PBL students' attitudes aligned with open-ended problem solving and self-directed learning.

Canavan (Canavan, 2008) summarized the experience of the problem-based learning applied to electronic and electrical engineering at three universities in the United Kingdom with around 200 students as participants over a three-year period. The evaluation included expert reviews, studying achievement of objectives, quantitative and qualitative investigations, face-to-face discussions with individuals and groups, focus groups and semi-structured interviews. The results indicate that the introduction of PBL generally promoted autonomous learning, development of deep thinking skills and a greater responsibility for learning. Generic skills developed during the PBL activities, such as communication skills, group work, critical appraisal of information and task management were considered as beneficial by students regarding their future employability. A degree of resistance to PBL was evident from some students, while negative perceptions were generally related to the impact that a PBL approach had on student workload and their need to manage their learning more effectively than for traditionally taught courses.

In presenting one of these universities where PBL was introduced and evaluated, Mitchell, Canavan and Smith (Mitchell, Canavan, & Smith, 2010) point out one of the aspects that emerged over the course of the evaluation "that potential employers were rather well-disposed to the skills developed through PBL, as recounted by a number of students who had participated in interviews for work placements with various employers during which their experiences of PBL had been discussed. It was clear from these discussions that employers placed significant value on the generic skills developed by PBL, such as teamwork, problem solving, and communication skills. This recognition acted as an important validation factor for the students, allowing them to reflect upon the relationships between what they were learning and the methods employed and how these related to their future employability."

Yadav, Subedi, Lundberg and Bunting conducted a study that investigated the influence of PBL on undergraduate electrical engineering students' conceptual understanding. Participants included 55 students in the experimental phase of the study. Participants completed pre-post tests surrounding the four topics covered in the study to examine the impact of PBL on students' learning and conceptual understanding. The results from this study suggest that students gained more during the problem-based learning approach as compared to traditional lecture approach. Specifically, student gains from PBL were almost twice than learning gains from traditional lecture. (Yadav, Subedi, Lundberg, & Bunting, 2011)

Some of the concerns regarding the introduction of the PBL were argued by Ribeiro and Mizukami (Ribeiro & Mizukami, 2005). The results of their investigation of the PBL introduction in the post graduate course indicated that the concerns might include: more requiring regarding workload (also noticed by (Mitchell et al., 2010)), the pressure for participation placed on more introverted students, and in some cases not equal contribution of all team members.

2.4.3 Internship and workplace simulation

For students who enter the work world after graduating the structures of their new work environments are unfamiliar and multi-faceted, and it can be difficult for newly hired engineers to find the information they need. They find that the problems that they are solving are more complex and ambiguous than the problems that they solved in school. Sometimes, they feel that they are not allowed sufficient exposure to the —big picture of where they and their work activities fit into the goals of the work group or company. (Cynthia J Atman et al., 2010)

As summarized by Kerka (Kerka, 1997), activity is a key factor in knowledge construction, and participation in everyday work activities "forces" learners to access higher-order procedural knowledge. Kerka numbers some of the strengths of the workplace as a learning environment:

(1) authentic, goal-directed activities;

(2) access to guidance--both close assistance from experts and "distant" observing and listening to other workers and the physical environment;

(3) everyday engagement in problem solving and

(4) intrinsic reinforcement.

Savery and Duffy suggest that if domain specific problem-solving skill should be learned then a simulation which confronts the learner with problem situations within that domain might be appropriate. (J. R. Savery & Duffy, 2001)

Jonassen et al. in a work Everyday problem solving in engineering argue that learning to solve classroom problems does not necessarily prepare engineering students to solve workplace problems. By identifying the attributes of workplace problems through an ample qualitative study that offers comprehensive examples suggest implications for designing engineering curricula and experiences that better prepare students for solving workplace problems. When it comes to internship experiences Jonassen et al. argue that they are *“generally deemed invaluable to the intellectual and professional development of engineering students”.* However, internship experiences, even if viable may be subject to the limitations of all apprenticeship experiences: for safety or productivity reasons, apprentices are often relegated to non-essential, inauthentic tasks; they rarely have the opportunity to encounter a substantial range of engineering problems or take risks that are an inherent part of real problem solving (D. Jonassen et al., 2006)

(Göl, Nafalski, & Mcdermott, 2001) elaborate on the practice of using industry-inspired final year projects in the programs offered in the School of Electrical and Information Engineering at the University of South Australia. In many schools, senior-level capstone courses have been developed in an effort to bring the practical side of engineering design back into the engineering curriculum. Such courses provide an experiential learning activity in which the analytical knowledge gained from previous courses is joined with the practice of engineering in a final, hands-on project and direct industry involvement are rich experiences where either industry or academia have vital interest in providing practice to engineering graduates. Several examples of current projects are discussed.

Dutson, Todd, Magleby and Sorensen present a review of literature on teaching engineering design through project oriented capstone courses as part of an effort to better prepare graduates for engineering practice. They revise over 100 papers to describe standard practices, and group them by major topics that include the development of capstone design courses, course descriptions, project information, industry involvement, student design teams and evaluation criteria. They point out that many courses take form of an imaginary engineering company, where students assume the roles of chief engineer, senior engineers and staff engineers; in other courses they have job-type interviews of the students before the start of the project. Students in the course have vacation days, a holiday, and a company picnic during the course. Dutson et al. conclude that such attempts at simulating an actual working environment may increase the realism of the projects and help educators provide students with a more real-life engineering experience (Dutson, Todd, Magleby, & Sorensen, 1997)

Sullivan and Barren argue that many engineering schools have incorporated practices such as memo writing, group work, problem solving, and case studies into existing courses. There is a general concern that the technical content of these courses is being squeezed because of adding these innovations. The results of their work indicate that it is possible to develop a module that synthesizes the above separate practices so as to address the concerns of business while keeping technical content at the centre of the curriculum (Sullivan & Baren, 1997).

Göl et al. describe successful practice of using industry-inspired final year projects in the programs offered in the School of Electrical and Information Engineering at the University of South Australia (Göl et al., 2001). Several examples of current projects are discussed. Industry has a vital interest in engineering education since the quality of graduates is of critical importance to the success of its endeavours.

Transferring a particular concept or idea from an education setting to a workplace setting is particularly difficult, because of the considerable differences in context, culture and modes of learning. According to Eraut, transfer depends on the students' orientation regarding learning – whether it is deep or surface (Eraut, 2004).

Entwistle, in the broader discussion on the ELT project that was undertaken in the UK (N. J. Entwistle, 2005) argues that the three aspects that are linked most closely to a deep approach are the accessibility and thoroughness of explanations, the enthusiasm shown for the subject, and the empathy that is shown for students' difficulties and the quality of support that follows. The key difference between these approaches is the students' intention – whether to understand the material for themselves or to pass the course with limited effort or engagement. Each intention then brings into play differing processes of learning that inevitably lead to different learning outcomes and levels of understanding. Subsequent research found that students also differed in terms of the extent to which they had adopted a strategic approach to studying which can be sub-divided into monitoring studying, study organisation and time management, and effort and concentration.

Work-based learning is used to describe learning through work so that learning occurs through engaging in a work role. It is located at the work place with support from the employer and university. Savin-Baden views work-based learning as the opportunity for partnership which may occur at different levels: between founders of work-based learning and higher education institutions, or between university and learner. Initiatives such as work-based learning have promoted professional development and lifelong learning. Work-based learning is not usually perceived as a problem-based approach to learning because it centres on learning through work and tends to be individually guided and focussed on solving problems in the immediate work environment (Savin-Baden, 2006)

In a comprehensive practice guide for work integrated learning, it is highlighted that students need to be adequately prepared in order to learn in a work environment. Students need to be introduced to the placement environment, they need instruction and guidance. (*Work-Integrated Learning : Good Practice Guide*, 2011)

2.4.4 Role play

The concept of role playing as a teaching method has a long tradition and has been widely used in higher education.

According to Andersson and Andersson (Andersson & Andersson, 2010a):

> *Role playing for teaching purposes is part of a wider group of teaching and learning methods known as simulation and gaming which provide a learning mechanism that involves and activates the participants embracing their roles, guided only by implicit rules and instructions [12]. Role play constitutes a case-based learning method in*

which the participants assume the roles of different characters and interact in the contextual settings of a given scenario (Andersson & Andersson, 2010a)

Herremans and Murch view the role play as the tool of experiential learning that can enhance multidisciplinary decision making (Herremans & Murch, 2003). Their argument is built on the similarity of characteristics of the adult learner (motivated by needs and interests; life-centred orientation; Experience-sourced; self-directing; range of differences) and experiential learning. They present a comprehensive list of principles for preparing the experiential sessions and role play scenarios, the approach that they used successfully in MBA programs to challenge students to resolve some of the complex, multi-dimensional issues facing today's organizations. They have found this approach to be transferable to other learning situations.

Chou and Hsiao present a case study of role play as an alternative learning strategy and evaluate its effectiveness to support engineering students' programming skills (Chou & Hsiao, 2011). The study was conducted with forty-two undergraduate students, majoring in computer sciences and information engineering, using mixed methods research. The results of the study indicate that students who studied in the game-based approach performed better than those who studied in a non game-based activity. As a conclusion of the study, a six-stage learning framework was created to illustrate how students cognitively engage in the role-play activity.

An important point is given by Felder, Woods, Stice and Rugarcia in an article where they offer alternative instructional methods that engineering professors could use in the 21st century engineering education, based on different criteria one of which is that "*Most engineering professors should feel reasonably comfortable with them after a little practice: It is conceivable, for example, that getting students to role-play molecules in a reactive gas would teach them more about the dynamic behaviour of a given system than would a standard lecture. Some instructors find methods like this useful and can manage to pull them off; still, it is safe to say that most engineering professors would never contemplate doing anything like that in their classes. Such methods will not be included in our list of recommendations."* (Felder, Woods, Stice, & Rugarcia, 2000)

Other examples for using role-play in engineering education include (Surendran & Ehie, 2005) who describe the implementation and evaluation of the Systems Analysis and Design course arguing that the objective of these courses is to prepare the students for engineering practice. They argue that the use of role-play is justified as an effective teaching pedagogy in information systems courses that enhances communication skills.

In a case study of (Conwell, Catalano, & Beard, 1993) role-play was used to help students understand the client needs before designing a product.

Anderson and Anderson inform of the role play simulation in which students play the role of engineers who interact with professionals from the industry in an industrial environment that was introduced in the two engineering courses at Lund University in Sweden and at the Technical University of Denmark (Andersson & Andersson, 2010b). The results indicate that the students engage in the role play and express an increased understanding of the requirements and the implicit rules of real-life engineering. The study concludes that role play with participation of representatives from the industry can facilitate the teaching of professional skills in engineering education.

Druckman and Ebner present a case study of applying role play simulation for learning negotiation skills. In their study they provide a thorough literature review on the experiences and evaluation of simulation role play learning, pointing out the findings from previous research that simulations are more effective as aids to retaining the learned material and in instilling a positive attitude toward the subject matter (Druckman & Ebner, 2008).

3 RESEARCH DESIGN

3.1 RESEARCH CONTEXT

Engineering education in Serbia dates from the 19th century when the first university level lecture in the field of electrical engineering was held in 1894. The School of Electrical Engineering of the University of Belgrade is the oldest institution where engineering is taught in Serbia. Professor Stevan Marković was the first lecturer and founder of Electrical Engineering Chair within the Engineering department of the Belgrade Higher School. In 1898, Marković also founded the first electrical engineering laboratory in Serbia.

Electrical and telecommunications engineering today is studied at 5 faculties that belong to state universities: School of Electrical Engineering, University of Belgrade; Faculty of Technical Sciences, University of Novi Sad; Faculty of Technical Sciences Čačak, University of Kragujevac; Faculty of Electronic Engineering, University of Niš; Faculty of Technical Sciences Bor, University of Belgrade. Privately funded universities have engineering management programs, and do not teach technically based curricula.

Serbia joined the Bologna Process in 2003 and thus initiated a gradual reform process, which received its legal support in 2005 by the adoption of a new Law on Higher Education. This law formally introduced the European Credit Transfer System, three-cycle system of study and diploma supplement. From 2007/08 the new reformed study programmes at all higher education institutions apply to all new students.

Higher education system has two types of studies: academic studies organised at universities, and vocational profession-oriented studies organised either at colleges of applied studies or at universities. Serbia currently has 17 accredited universities - 8 state universities, and 9 private universities. The three-cycle system of academic studies includes: basic academic studies lasting 3-4 years, carrying 180 to 240 ECTS, master studies lasting 1-2 years with 60 to 120 ECTS, and doctoral studies with a minimum of three years of study or 180 ECTS.

The School of Electrical Engineering today comprises a number of departments: Generic ware Engineering, Basic Electrical Engineering, Computer Science and Informatics, Telecommunications and

Information Technology, Signal Processing and Automation, Power Engineering, Electronics Engineering and Physical Electronics. 500 new students are enrolled each year.

At the School, a traditional lecture based engineering curriculum is taught with problem based courses at graduate level studies. In general students have little or no contact with engineering practice during their undergraduate studies. Though fourth-year students of all the departments have obligatory internship of a minimum of two weeks that brings two ECTS points, meaningful internship experiences are hard to find.

Regarding engineering students' preparation for the complex tasks of sustainable development, according to recent research by Djukic (2011), in Serbia hardly anyone opts to adventure into the interdisciplinary considerations of sustainable development and sustainability programs incorporated in the university teaching. In addition to this, each profession, discipline or program, as well as their interpreters at the university have their own rigid stance on sustainability. It is hard for them to recognize that things are changing, both in theory and even faster in practice, and that this requires a change in attitudes, prejudices, and new understanding of determinants and processes that influence both development and sustainability.

In the absence of a formal agenda for the introduction of sustainable development education in engineering, each of the engineering faculties is introducing the subject according to its own, with strong technical focus, such as renewable energy, but without considering sustainable development concepts in terms of environmental, societal and economic aspects of sustainable development.

3.2 METHODOLOGICAL FOUNDATION

The research presented in this study is action research conducted from the interpretative and critical perspectives. Action research is grounded in the practice of those undertaking the research, where the researcher is a participant, and undertakes the research in order to critically reflect upon, and change his or her practice- action research is a type of inquiry in which instructors make documented, systematic improvements in their classrooms as a means of applying new knowledge as it is generated (Biggs & Tang, 2007) (Borrego, Douglas, & Amelink, 2009). Koro-Ljungberg and Douglas (2008, as cited in (Borrego et al., 2009)) note that in contrast to the hypothesis-driven perspectives, situational perspectives such as interpretivism and critical theory are focused on delivering understandings of particular situations or experiences. They are generally inductive in approach and allow for insights and findings to emerge throughout the data collection and analysis process. Participant selection is purposive, since statistical generalizability is not the aim of this research.

3.2.1 ACTION RESEARCH

The term "action research" was first used by Kurt Lewin with a special focus on social action (Case & Light, 2011).

Action research is an active investigative method where participants take part in a dynamic and discursive educational process.

This form of research is part of a worldview that "sees human beings as co-creating their reality through participation, experience, and action" (Denzin & Lincoln, 2000). Inclusion of the students in the process of generating knowledge about their own understanding of learning, the subject, and their use of their education for work is an important step in changing the usual power relationships in the classroom. (Reid & Petocz, 2003).

It is flexible, open to change necessitated by experience and circumstance, and it is subject to the practitioner's critical and rational practical judgments. It is about trying to understand professional action from the inside; as a result, it is research that is carried out by practitioners on their own practice, not (as in other forms of research), done by someone on somebody else's practice. (Waters-Adams, 2006). The aims and benefits of action research are strategic improvement of practice. In its design, methods, and realization, it consciously and deliberately sets out to improve, enhance, and realize practice through actions informed, but not constrained, by research and theory.

Lewin characterized Action Research as "a comparative research on the conditions and effects of various forms of social action and research leading to social action", using a process of "a spiral of steps, each of which is composed of a circle of planning, action, and fact-finding about the result of the action". In common with contemporaries who began to apply action research to education Lewin advocated a tightly controlled systematic methodology, based on evidence and evaluation. The aim was social or curriculum improvement, with the process driven by a goal determined at the outset which could be redefined so that it remained appropriate. (Waters-Adams, 2006) (Brien, 2001a)

According to Brien (Brien, 2001b) much of the researcher's time is spent on refining the methodological tools to suit the exigencies of the situation, and on collecting, analysing, and presenting data on an ongoing, cyclical basis.

The purpose of this practice is to engage with one's own action and with others in a self-reflective

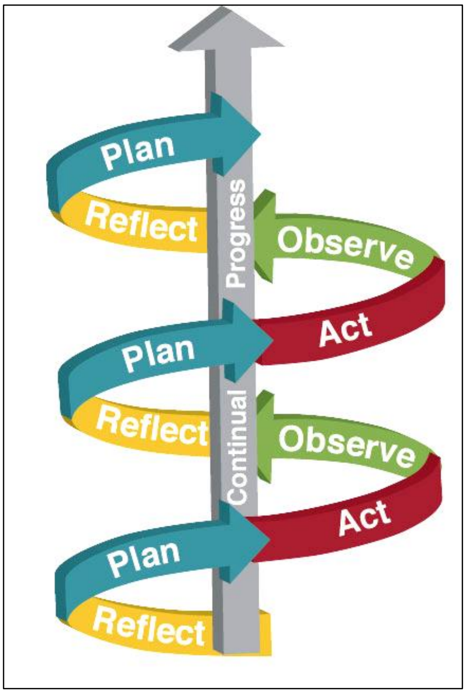


FIGURE 3-1 ACTION RESEARCH (SOURCE: VALENCIA COLLEGE WEB PAGE)

way, so that all become more aware of their behaviour and of its underlying theories. It is based on the "raw" data of accounts and recordings of practice (usually in the form of "talk") gathered by the actors themselves, encouraging public testing of one's own perceptions and the use of action-experiments to test new theories of action and to develop new skills (Reason, 1994)

Elliott considers that action research is a reflective practice with the aim of improving realization of process values *“The fundamental aim of action research is to improve practice rather than to produce knowledge. The production and utilisation of knowledge is subordinate to, and conditioned by, this fundamental aim.”* (Elliott, 1991)

Kemmis and McTaggart (Kemmis & McTaggart, 2007) describe the implementation of this strategic action as a continuous cycle of four moments:

- Plan: planning is undertaken to improve what is already happening. It is forward looking and based on the evidence already collected. Intended outcomes serve as the rationale for the changes.
- Act: deliberate and controlled changes in the activities in practice
- Observe: practical judgement of the effects of action in the implementation of the plan
- Reflect: reflect on the effects of action as a basis for next cycle of research.

According to (O’Hanlon, 1996),

> *"reflection on practice in an action research process leads to a willingness to examine and re-examine teaching or professional practice from a variety of perspectives and theoretical viewpoints. It challenges accepted orthodoxies, which are unexamined and repeated in contexts that are differentiated and complex. The action research process requires professionals to differentiate their methods and activities in contextually appropriate ways"*

According to (Case & Light, 2011), action research of this kind can be a particularly effective methodology for engineering faculty who are not only interested in systematically researching their own educational practices but also in implementing substantial personal and social change in their practice. However, the use of action research is still relatively rare in engineering education research.

Reflection is part of action research since the action of the research can only be understood by an ongoing act of interpretation according to Schön (1983, as cited in (K. F. Osterman & Kottkamp, 1993).

3.2.2 Mixed-method research

The approach of this research was to explore how students experienced ill-structured problem solving in a workplace simulation environment, in particular what is their perception on personal and professional implications of the approach and why, and how did it affect their skills development. The means of the research were qualitative methods with posterior quantitative queries where necessary: open ended questions, talk groups, participant observation, surveys. In this way, different understandings of the concept emerge.

Mixing quantitative and qualitative approaches has been found to be purposeful in terms of participant enrichment, instrument fidelity, treatment integrity, and significance enhancement (Onwuegbuzie & Leech, 2006).

There are occasions where qualitative and quantitative research are brought together in the study of the same phenomenon but then divide in terms of what is explored (Ritchie & Lewis, 2003).

(Jick, 1979) argues that the two approaches can be reconciled in integrating fieldwork and survey methods, claiming that the viability and necessity of such linkages have been advocated by various social scientists. Researchers using qualitative methodology are encouraged to systematize observations, to utilize sampling techniques, and to develop quantifiable schemes for coding complex data sets. Though survey research may contribute to greater confidence in the generalizability of results, qualitative data and analysis function as the glue that cements the interpretation of multimethod results.

Qualitative research seeks to understand phenomena in depth and within specific contexts, with an in-depth focus on only a few individuals or situations, a focus on the context of the study, and recognition of the researcher as an instrument of the study. The goal of qualitative research is to gain an understanding of why or how phenomena occur in terms of context-specific descriptions. (Denzin & Lincoln, 2000). Other characteristics of the qualitative study are that the activities of collecting and analysing data, developing and modifying theory, elaborating or refocusing the research question, and identifying and dealing with validity threats are usually going on more or less simultaneously, each influencing all of the others. In addition, the researcher may need to reconsider or modify any design decision during the study in response to new developments or to changes in some other aspect of the design.

Qualitative data collection methods include observation, interviews, focus groups, collection of texts, and the creation or collection of images.

Data management methods include recording, transcription, transcript checking, and the use of computer- assisted analysis generic ware.

Data analysis methods include constant comparison, memo writing, and theory building, narrative analysis techniques and microlinguistic analysis techniques. It is commonly recognized that writing and reporting in qualitative research are part of the analytic process, in that a researcher's thinking and interpretation generally develops via the writing process.

(Carter & Little, 2007) argue that qualitative research questions are "open-ended, evolving, and non-directional" that tend to seek, to discover, to explore a process, or describe experiences. They typically attempt to obtain insights into particular educational, familial, and social processes and experiences that exist within a specific location and context. As such, qualitative research questions typically describe, rather than relate variables or compare groups, avoiding the use of words such as "affect," "influence," "compare," and "relate." More specifically, qualitative research questions tend to address "what" and "how" questions. (Onwuegbuzie & Leech, 2006)

The results of a qualitative study take the form of a number of qualitatively distinct categories which together capture the essential experience at the collective level. (Booth, 2001)

The first step in this process is pooling the data in order to gain the collective context of it and temporarily losing the individual voices of all who have contributed to the data. After that the "data reduction" step has to take place, deciding what data are most pertinent to the study, which is not always straightforward and requires the judgment of the researcher. The researcher engages with this pool of data and seeks categories that can represent the whole of the data, reviewing it for common ideas or "themes" that they contain. Themes are not always stated explicitly, but labelling the main idea or ideas in a text segment helps the researcher organize and capture the sense of the data. The themes generated during analysis form the basis of the findings of the study.

After an iterative process of analysis, that end in a small number of categories, each of which are distinctly different from one another.

As Miles and Huberman (Miles & Huberman, 1994) illustrate, making grids and charts can be helpful at this point.

Then, the categories can be juxtaposed with the original data to illuminate the research question in various ways. This involves "triangulation" (testing data against each other), building a logical chain of evidence, and "structural corroboration" (making sure that the picture of the whole that is portrayed makes sense, is supported by the pieces of evidence that constitute the finding).

Whenever possible, the researcher should check his or her interpretations with the original respondents or colleagues for support or disconfirmation.

The results are communicated as descriptions of the essential aspects of each category, illustrated by pertinent extracts from the data. As each topic is discussed, the arrays of the particular category or theme being treated can be used to supply examples, quotations, or frequencies to add detail to the report (Chism, Douglas, & Hilson, 2008)

Quantitative methods are a good fit for deductive approaches, while the phrasing of the research questions govern how data will be collected as well as the method of statistical analysis used to examine the data (Creswell, 2003).

Descriptive statistics such as percentages, means and standard deviations are used to describe a situation.

Quantitative studies within engineering education rely heavily on descriptive statistics derived from surveys. However, quantitative research designs using statistical analyses to examine whether there are significant differences between groups on various indicators are present as well. The third type of studies are those that more explicitly utilize theory and advanced statistical methods to test hypotheses that concern relationships between and among various indicators. In a comprehensive review of the research in engineering education focused on quantitative, qualitative, and mixed research methods Borrego et al. present an overview of the approaches used while offering a broader picture of the methods with respect to definition, aims, appropriate research questions, evaluation criteria, and examples from the Journal of Engineering Education. They argue that descriptive statistics refers to reporting of frequencies, in order to examine the status the educational experiences of students enrolled in engineering programs. While descriptive studies describe the situation without addressing any relationships between variables or groups, other methods such as Pearson's correlation, t-tests, ANOVAs, or MANOVAs can be used to analyse the results to determine whether there is a significant relationship between indicators or whether the mean score of one group differs significantly from another (Borrego et al., 2009).

3.2.3 VALIDITY

Validity of the mixed method research is argued to be reached through triangulation.

Denzin developed the concept of triangulation which in addition to the use of diverse data, involves combining different methods and theories, identifying different types of triangulation (Denzin & Lincoln, 2000):

- Data triangulation - the use of variety of data sources and data sets in a study. Data may be both qualitative and quantitative, gathered by different methods or by the same method from different sources or at different times.
- Methodological triangulation - the use of multiple methods to study a single problem or phenomenon. It may also include the use of the same method on different occasions and situations.

It is often stressed out that different methods have different weaknesses and strengths and therefore the main effect triangulation can offer is to overcome the weaknesses of any single method. Within this context, quantitative and qualitative approaches are usually seen as different ways of studying the same phenomenon and able to answer the same research questions.

In order to achieve credible findings, Lincoln and Guba advocate to: thoroughly get to understand the phenomenon of interest by prolonged engagement; triangulate different methods, sources, and theories; triangulate researcher perspective; triangulate participants; use structural corroboration in order to assure that the arguments *"hang together and make sense, that they are logical and describe the data well"* (1985, as cited in (Hadzililas, 2010)).

Generalizability or external validity is substituted by the term "transferability" by Lincoln and Guba (1985, as cited in (Armarego, 2007)). The goal of a particular study is not to provide generalized findings that apply in all contexts, but to provide a description that applies within the context being studied.

(Jick, 1979) argues that multiple and independent measures, if they reach the same conclusions, provide a more certain portrayal of the course contribution to competence development. Furthermore, triangulation can also capture a more complete, holistic, picture of the phenomena under study. According to (Ritchie & Lewis, 2003) the 'security' that triangulation provides is through giving a fuller picture of phenomena, not necessarily a more certain one. Research designs that extensively integrate both fieldwork (e.g., participant observation) and survey research are not common.

3.3 RESEARCH OBJECTIVES RELATED TO RESEARCH QUESTIONS

The central question of this research is how the specific practice-based instructional model based on ill-structured problem solving can assist engineering students to develop enhanced generic and professional skills for the workplace, placing it in the context of sustainable development.

To this end the researcher through action research constructs and refines practice-based instructional model building on workplace problem solving and explores how to support students in ill-structured problem solving and competence development by better understanding both the challenges and opportunities of the students' learning experiences in this context. The findings are used to propose the characteristics of the professional practice instructional model that would integrate basic principles of sustainable development

The research objectives, shown in the with corresponding research questions:

1. Develop, implement, evaluate and refine ill-structured problem solving professional practice instructional module in engineering education
2. Explore students' motivation to attend the course and learning styles
3. Determine the module contribution to the generic and professional competence development
4. Explore where and how students could be best supported during the process of ill-structured problem solving and competence development
5. Use the findings to propose the instructional design for teaching ill-structured problem solving in the context of the education for sustainability

TABLE 3-1 RESEARCH OBJECTIVES AND RESEARCH QUESTIONS

Develop, implement, evaluate and refine ill-structured problem solving professional practice instructional module in engineering education	What are the most appropriate pedagogical approaches for teaching ill-structured problem solving
	How do students evaluate the module
	Why do students like/dislke the module
	Why do students perceive the module as important for their personal and professional development
Explore students' motivation and learing styles	What is students' motivation to attend the module
	How are the students' learning styles distributed
Determine the module contribution to the generic and professional competence development	What is the importance students give to generic skills
	What is the students`perception of the level of success of their generic skills
	What is the students`perception of the level of success of their professional skills
	What is the course contribution to specific generic and professional skills development
Explore where the students could be supported during the process of ill-structured problem solving and competence development	What are the major issues and challenges that students experience during ill-structured problem solving
	How are the major issues and challenges distributed over different stages of the ill-structured problem solving process
	How is skills development distributed over different stages of the ill-structured problem solving process
Use the findings to propose the instructional design for teaching ill-structured problem solving in the context of the education for sustainability	What is students' interest in the further formal instruction on sustainable development
	What are the guidelines for the instructional design that would assist students to develop enhanced skills in the context of sustainable development

3.4 COMPLEX RESEARCH STRATEGY: PHASES AND LAYERS

The research was realized in multiple consecutive phases, where each phase ended with reflection and planning of the subsequent phase, introducing enhancements as a result of this reflection.

In the beginning of the process of action research in this work the educational concern which needed further investigation was selected. The original decision was to focus on creative problem solving in engineering studies, after which we investigated this issue, collected data and conducted preliminary information on the courses that could include creative problem solving during engineering studies at the School of Electrical Engineering of the University of Belgrade.

The research timeline is presented in the following Section.

3.4.1 Research timeline & Phases

The action research was performed in the period of four years, from 2010 to 2014 in the phases as described in Chapter 3.3: preliminary phase, 1st, 2nd, 3rd phase and post phase.

May – September 2010: The researcher conducted literature review

September - November 2010: The researcher conducted preliminary interviews with faculty staff to understand the research context and undertook a reflective process through numerous discussions and evaluation of existing courses structure, instructional methods and learning outcomes. These early interviews suggested that there was a significant lack of practice and consequently competence in real engineering problem solving, as well as important lack of problem and project based learning experience.

December 2010: Decision to design the course.

After concluding that no such courses existed in the undergraduate studies, the researcher decided to redefine the focus of the research, according to the findings of this initial investigation, as what was identified as more crucial issue that necessitated further study: competence development through ill-structured problem solving. The approach of the research was to develop the instructional module that would improve the practical situation, by giving students the opportunity to foster competences and to gain knowledge in the sustainable development basics.

The first step in action research therefore began with reflection on an issue or research question, which defines the focus of the subsequent investigation. The decision that was reached by the researcher was to design such a course, starting by determining the comprehensive instructional design.

January- March 2011: Course design and preliminary model testing.

The researcher developed the instructional design after performing a comprehensive literature review on the instructional models that support the desired learning outcomes. The module design was presented to the School of Electrical Engineering in the form of the Engineering Practice course for senior year students. The improvement aimed at introducing appropriate methods for teaching ill-structured problem solving in engineering practice in terms of competence development as well as the students' understanding of the basics of sustainable development. The research instruments were designed and tested on the sample of five volunteer students.

May- June 2011: 1st Course implementation.

A systemic inquiry was undertaken involving multiple forms of evidence (questionnaires, surveys, observation of classes and class discussions).

October to December 2011: 2nd and 3rd course implementation

After finishing the initial phase reflected in implementing the instructional design and beginning to explore relevant issues, the researcher reached the conclusion that the identified issues needed to be understood with more detail. In order to develop new instruments the in-depth research of a small group was conducted.

The goal of this small group research was to allow intensive study of particular issues, to reflect characteristics which emerge from the first stage of analysis.

May-June 2012: 4th course implementation. In-depth study of the small group.

New ideas evolved aimed at bringing more detailed understanding regarding phased issues and challenges and skills development. To this end, surveys in form of learning diaries were developed to measure issues and challenges and skills development periodically, in the four determined times during the course.

April - May 2013: 5th course implementation

Additional instruments designed and partially tested during the fourth course were applied to this group. The additional instruments included periodic surveys measuring major challenges that students face during the ill-structured problem solving process as well as their competence development. One major change was introduced in the competence development survey, including indirect measurement of the course contribution by determining PRE and POST course levels.

May – July 2014: 6th course implementation
The stable design from the previous course was applied

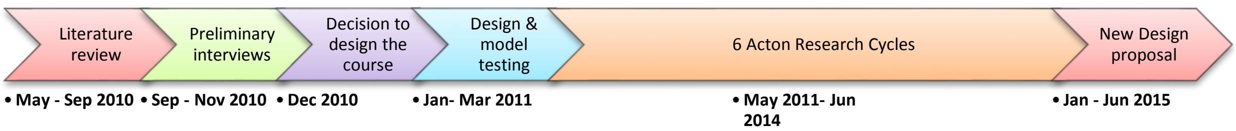


FIGURE 3-2 RESEARCH TIMELINE

Summary of the research timeline:

Preparatory Phase:

- **May – September 2010:** Literature review
- **September - November 2010:** Preliminary interviews

- **December 2010:** Decision to design the course.
- **January- March 2011:** Course design and preliminary model testing.

1st Phase:

5th May- 15th June 2011: 1st Course implementation.

2nd Phase:

08th October – 13th December 2011: 2nd and 3rd course implementation

18th May – 07th July 2012: 4th course implementation. In-depth study of the small group.

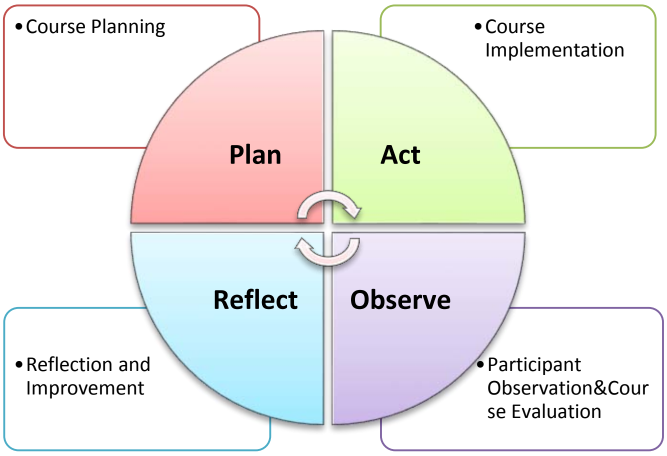


FIGURE 3-3 ACTION RESEARCH CYCLES 1 TO 6

3rd Phase:

04th April – 20th June 2013: 5th course implementation

08th May – 04th July 2014: 6th course implementation

Post Phase:

September 2014 – January 2015: New course design proposal

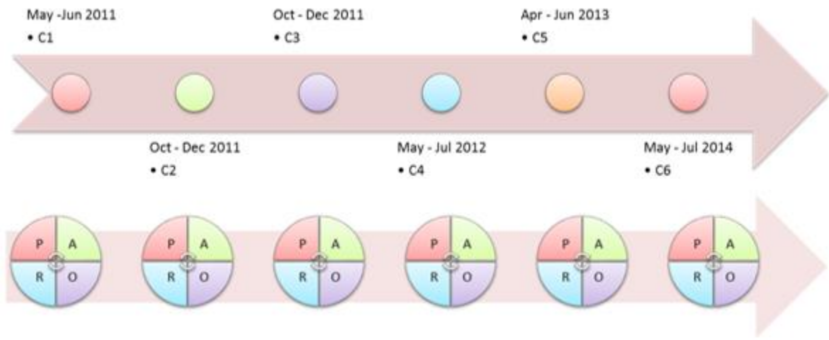


FIGURE 3-4 FIELD WORK: ACTION RESEARCH 4-YEAR TIMELINE FOR SIX COURSES CONDUCTED FROM 2010/2011 TO 2013/2014

The phased action research and methodology enhancement through action research phases, created the need to differentiate various layers of data.

As a consequence of the phased action research and methodology enhancement through action research phases, the researcher considered appropriate to differentiate layers of data.

3.4.2 RESEARCH LAYERS

Specific research objectives that were derived from the research questions were explored in each of the three research layers.

The objectives of the Layer 1 were to provide the basic understanding of the issues and challenges that students face during ill-structured problem solving, explore students' perception of the course importance for their personal and professional development, as well as their evaluation of the course and of the learning experience. Additionally, this research layer aimed at exploring students' motivation to attend the course and determining students' learning styles.

After the 1st Phase Layer 1 results were obtained, it became evident that deeper insight was necessary in order to determine students' skills development. This was the reason why Layer 2 research was designed, with the aim of providing understanding regarding competence importance and development.

Layer 2 research was conducted during 2nd and 3rd Phase of the action research. The Layer 2 research started in the 2nd Phase of the research, where the course contribution to skills development was measured directly, by asking students to asses this contribution. However, after the results were obtained it was evident that some more depth needed to be added to the research by indirect skills measurements: the contribution of the course to the skills' development was measured indirectly, through the difference in the perceived skills' level of success PRE course and POST course, and the significance of this difference. Therefore, in the 3rd Phase the data regarding skills importance and development was collected both before and after the course. In this phase the self-assessment of the professional skills levels was added. The Layer 2 research was thus deepened in the 3rd Phase by determining the level of success in generic and professional skills before and after the course, in order to gain insight into the effectiveness of the implemented educational strategies.

TABLE 3-2 SPECIFIC RESEARCH OBJECTIVES

Specific research objectives
○ Determine the most appropriate pedagogical approaches for teaching ill-structured problem solving (from literature review)
○ Determine how students evaluate the module
○ Explore the reasons why students like/dislike the module
○ Explore the importance of the learning experience for students' personal and professional development
○ Explore students' motivation to attend the module
○ Determine how the students' learning styles are distributed
○ Determine the importance that students perceive for generic skills
○ Determine the level of success that students perceive regarding their generic skills achievement
○ Determine the level of success that students perceive regarding their professional skills achievement
○ Determine the contribution of the practice-based module to specific generic and professional skills development
○ Explore the major issues and challenges that students experience during ill-structured problem solving practice-based course
○ Determine how the major issues and challenges are distributed over different stages of the ill-structured problem solving
○ Determine how the skills development is distributed over different stages of the ill-structured problem solving
○
○ Propose how the instructional module could be adapted to assist students to develop enhanced generic and professional skills in the context of sustainable development

After the 2nd Phase results were obtained, I needed to organize deeper research into issues and challenges and skills developed during ill-structured problem solving, in order to get insight how they are distributed along the course duration because it was evident that challenges that students face depend on where in the process of ill-structured problem solving they find themselves. Somehow at that time I came across the research by Purzer et al. (Purzer et al., 2011) that offered an adequate framework for designing the challenges investigation: measuring challenges at certain points of time during the course. I decided to use the results from Layer 1 challenges, adding some challenges that I knew novice engineers were facing when performing design and project management tasks.

Layer 3 research was conducted during the 3rd Phase of the research, and it was aimed at bringing more depth and providing insights for the phasing of the issues and challenges and skills development during ill-structured problem solving that would explain in more depth the phenomena found in the results of Layers 1 and 2 of the research.

The list of the specific research objectives derived from the research questions is provided in Table 3-2, while the links between research objectives and research questions per research Layers are presented in Figure 3-5 and the complex multi-level research design is presented in Figure 3-6 and Figure 3-7.

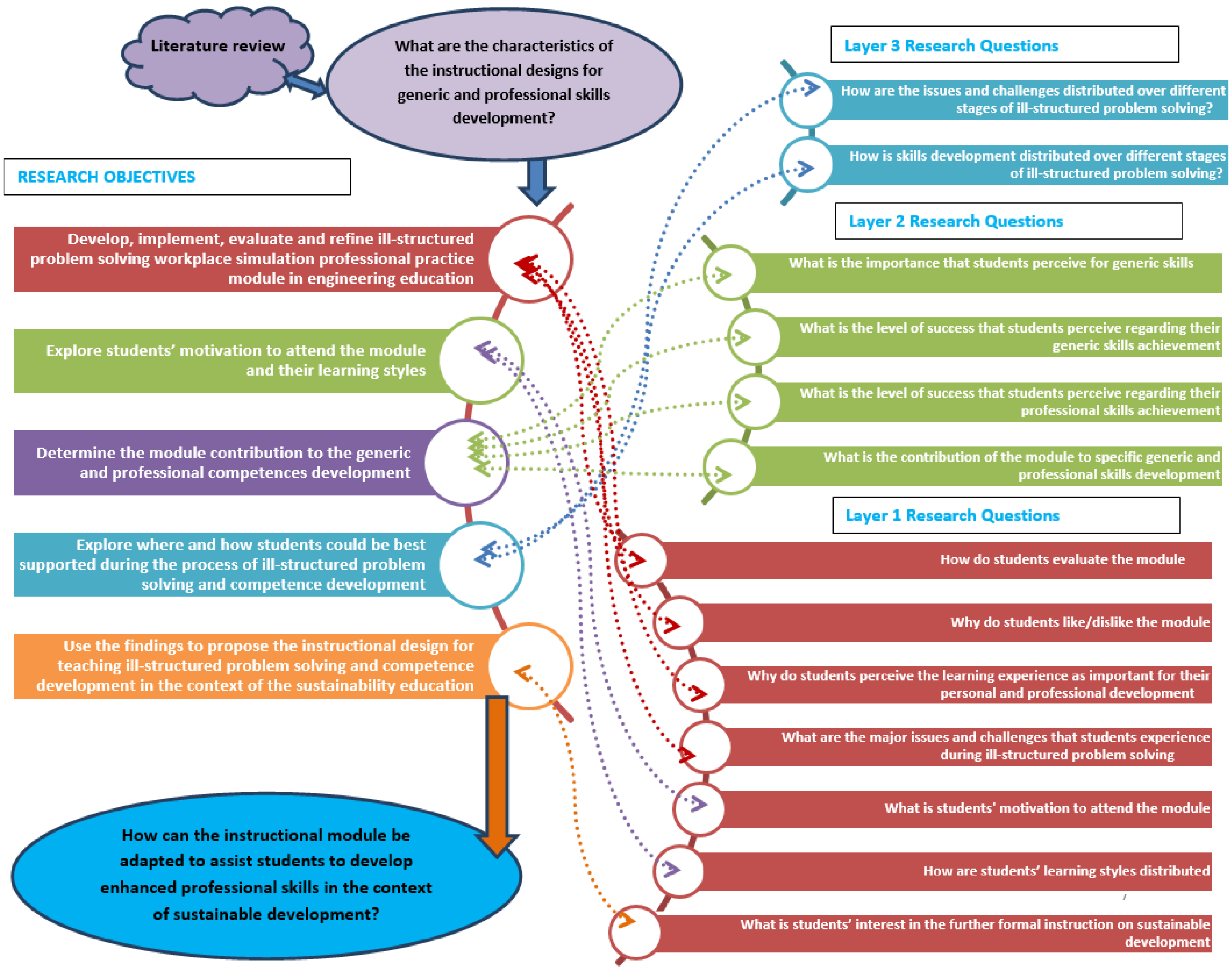


FIGURE 3-5 COMPLEX MULTI-LEVEL RESEARCH STRUCTURE: RESEARCH OBJECTIVES AND RESEARCH QUESTIONS PER RESEARCH LAYERS

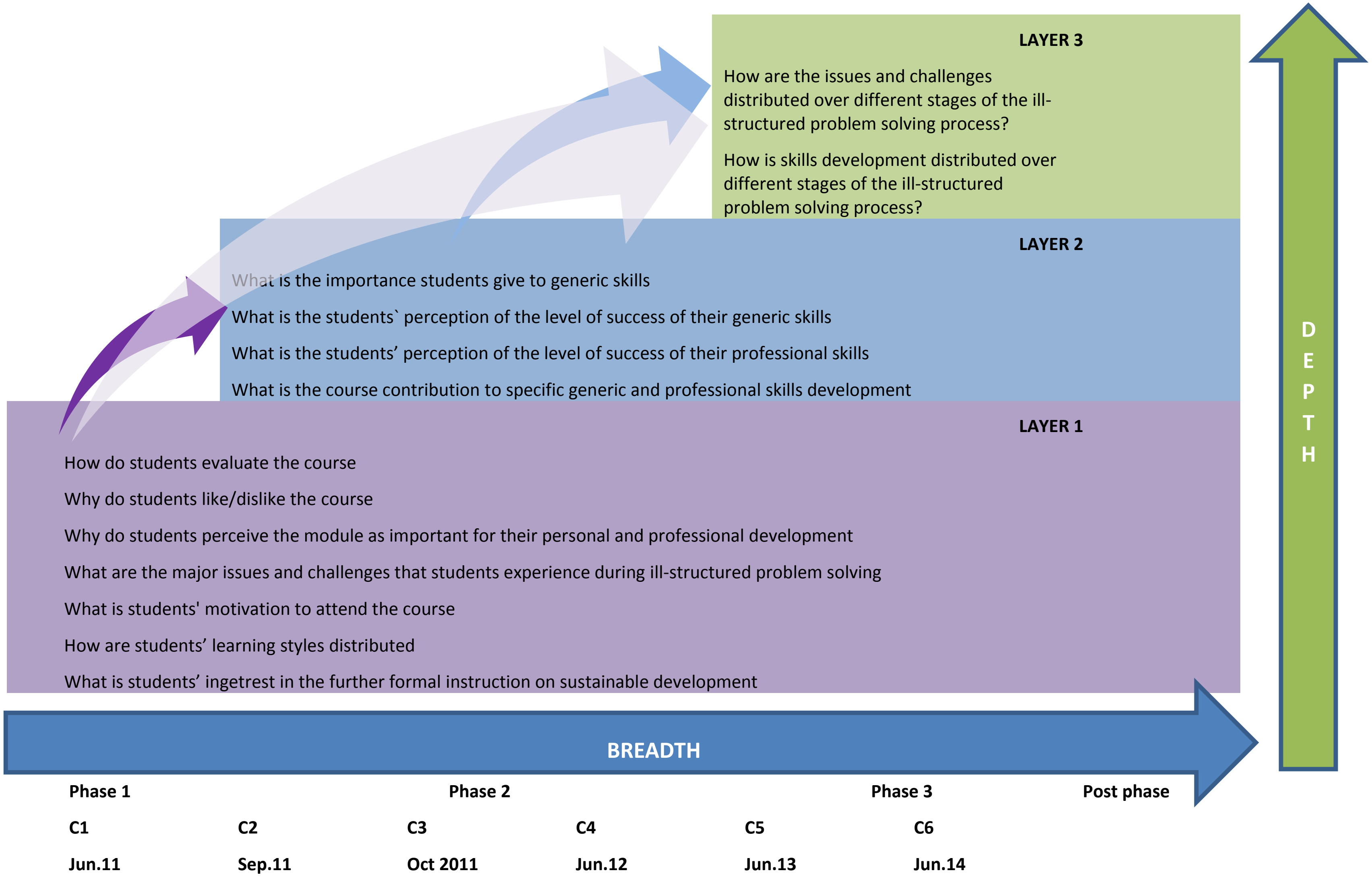


FIGURE 3-6 COMPLEX MULTI-LEVEL RESEARCH DESIGN AND TIMELINE

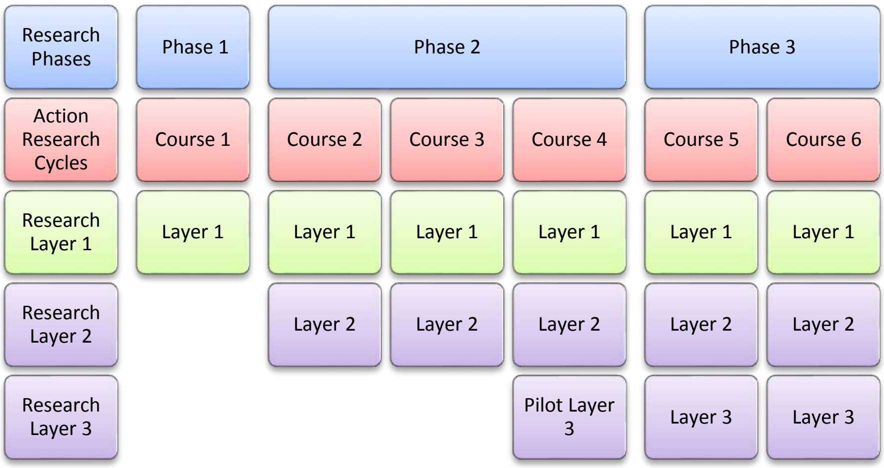


FIGURE 3-7 COMPLEX RESEARCH STRUCTURE MATRIX

3.5 DATA COLLECTION INSTRUMENTS

Mixed method research included gathering, analysing and interpreting data from various sources and using various research instruments.

The aspects of the issues and challenges evolved during the course as researcher was immersed in the natural classroom settings at the beginning of the first course, and were consequently derived from the field notes and participant observation, as well as from the classroom discussions.

The aspects of the course evaluation were easier to measure as there are plenty of examples in previous research and practice, e.g. Berkeley Center for Teaching and Learning, (https://teaching.berkeley.edu) and Evaluation forms for Problem Based Learning at the University of Delaware (http://www.udel.edu/pbl/forms/) with standard evaluation surveys that were adapted to this particular course.

Regarding competence development, there is no one generally agreed way of measuring skills development.

On the basis of past research, there are several alternative techniques one could use: (a) Ask the person directly, (b) Ask the person indirectly (e.g., projective tests), (c) Ask someone who interacts with the person, and (d) Observe systematically the person's behaviour or (e) Measure particular skills development. Predictably, each of these strategies has both strengths and weaknesses.

Decisions that needed to be made included choosing skills self-assessment and direct and indirect measurements regarding course contribution to skills development. Furthermore, empowering students with the assessment process improves their learning.

Given the potential pitfalls in each method, the most appropriate research strategy was deemed to be mixed method with triangulation. No single method was sufficient and thus a design evolved that utilized a combination of methods (Jick, 1979).

Methods were wide-ranging enough to cover all the dimensions of the research questions.

As mentioned previously, research instruments were developed during the research emerging from one research phase to the other. Data were collected over a period of 4 years which incorporated multiple approaches. Surveys were distributed to all the students attending the courses from 2010/2011 to 2013/2014.

They contained a combination of standard measures related to the evaluation of the learning experience, using open ended questions to determine students' like and dislike of the course, as well as their perception of the course contribution to their personal and professional development and their motivation to attend the course.

The survey also contained items related to the course evaluation in terms of project and problem based learning as well as preparedness for sustainable development basics. In addition to end-course self-reports, participant observation was conducted during the entire course, as well as three class discussions.

By the end of the second phase of the research, the idea emerged to illuminate phased skills and challenges perception at 4 different points in time during the course. It was hypothesized that challenge and skill development levels may coincide during the course.

Scaled type surveys were used representing at the same time reflective diaries in a basic form to measures skills development and challenges appearance and level.

The surveys became more meaningful when interpreted in light of qualitative information or open ended questions results by applying triangulation.

In the following Chapters research instruments that were used in the study are briefly described, while their exact form is given in the Appendices.

3.5.1 Participant observation and field notes

(Patton, 2002a) describes participant observation as "an omnibus field strategy in that it combines document analysis, interviewing of respondents and informants, direct participation and observation, and introspection".

Fieldworkers combine in their field notes data from personal, eyewitness observation with information gained from informal, natural interviews and informants' descriptions thus employing multiple and overlapping data collection strategies: being fully engaged in experiencing the setting. Observer is not neutral, but rather acts as a participant-observer.

Observation can be classified as structured or unstructured.

In structured observation specific categories of behaviour are identified ahead of time, and the observation protocol involves identifying whether or not these behaviours occur.

In contrast, an unstructured observation occurs by recording in some fashion everything that occurs. Subsequent analysis of the data is used to create meaning from what occurred.

Unstructured observation in the form of field notes can record (adapted from (Mulhall, 2003)):

- Structural and organizational features – what the actual buildings and environment look like and how they are used
- Students – how they behave, interact, communicate
- The process of activities in class
- Special events – an expert visit of class discussions
- Dialogue
- An everyday diary of events as they occur chronologically – the learning experience process that evolves in the classroom settings
- A reflective diary – this includes both data obtained in the field and reflections on the data after being in the field

Biases come from both the observer and those being observed. However, this bias is a necessary part of the phenomenographic action research, where different perceptions are examined and we made a "shift from a concentration on observation as a 'method' per se to a perspective that emphasizes observation as a context for interaction among those involved in the research collaboration" as Angrosino suggests (as cited in (Chism et al., 2008))

Structured observation was conducted only during the pilot course that marked the transition from the 2nd Phase to the 3rd Phase of the research.

3.5.2 Open ended questionnaire

Open ended questionnaire in form of brief, open-ended survey responses can be selected to gather qualitative information about the learning experience and to further explore different dimensions of respondents' experiences as argued by (Chism et al., 2008) . This type of data can provide a rich description of respondent reality that in comparison to interviews or focus groups, can offer greater anonymity to respondents and often elicit more honest responses. It can also capture diversity in responses and provide alternative explanations to those that closed-ended survey questions are able to capture (Miles & Huberman, 1994)

The drawbacks are that open-ended survey data are often time-consuming to analyse, some respondents do not answer the questions, and coding decisions made by researchers can pose threats to the reliably and validity of the results.

The limited response length of the survey format forces respondents to express themselves in more of a concise "list" format while at the same time giving them the opportunity to explain themselves in a short narrative form.

The analysis of this type of text poses several challenges. The "free list in context" nature of the data can make it difficult to choose an appropriate methodology. Furthermore, open-ended survey responses are challenging because brief responses (as compared to interview transcripts or journals) are typically sparse, and the removal of context from concepts is problematic for coder understanding.

Also, some respondents are more willing or able to express their answers, respondents typically produce many different kinds of responses, and responses can generate frequent or infrequent mention of topics that may have different importance to the respondents. This type of data makes standardization and reduction into codes very difficult, can make the reporting of frequencies or co-occurrences less meaningful, and requires careful justification of analysis decisions.

3.5.3 Class discussions

Class discussions were conducted to illuminate the students' view of the questions such as: "What is the work environment like?" "What do engineers do at work?" "What kind of engineering jobs exist?" "Do you think some of the teaching strategies should change to get closer to real work environment?"

The three class discussions, one at the start of the course and two towards the completion of the course, highlighted any changes that had taken place in the students' understanding and perceptions of the engineering profession, their opportunities in the world of work and obstacles that they foresee. Two class discussions were held only with the instructor and one was with subject matter expert or manager of a telecommunications company.

The main points and issues that were mentioned by the students were recorded in the form of unstructured participant observation and field notes.

3.5.4 Scaled type surveys

Scaled type surveys provide the quantifiable results as they pertain to opinions, attitudes, or trends (Creswell, 2002).

Different types of scaled type surveys were used in this research:

1. Likert type scale
2. Level/order list
3. Simple scale

Likert-type scales are designed to measure attitudes or opinions. These ordinal scales measure levels of agreement/disagreement. A Likert-type scale offers the respondents the choice of five pre-coded responses from strongly agree to strongly disagree with the neutral point being neither agree nor disagree. This scale allows the individual to express how much they agree or disagree with a particular statement.

Rank order list gives the respondent a set of items and asks them to first choose a certain number of items ant then put the items in some form of order.

Simple scale survey gives the respondent a set of items and asks them to evaluate the items by the level of success.

3.5.5 Kolb LSI

Learning Style Inventory (LSI) is a 12-item survey (kindly facilitated by Hay group for our research)) developed by David Kolb, a cognitive theorist, to assess students' learning styles. Different people learn in different ways. The aim of this survey is to describe how each individual learns. Each item has four different words/choices. These words/choices are used to describe one's style and students are asked to grade them for each question. Based upon their choices, each student's learning style is determined as one of the following: Diverger, Assimilator, Accommodator and Converger.

More detailed description of the Kolb LSI Is given in Section 5.1.4

TABLE 3-3 OVERALL RESEARCH INSTRUMENT LIST PER TASK DERIVED FROM RESEARCH QUESTIONS, PHASE, TYPE AND TIME

No	Tasks derived from Research Questions	What is measured	Instrument	Type	Time
1	✶ Explore the reasons why students like/dislike the module ✶ Explore the significance of the module for students' personal and professional development ✶ Explore students' motivation to attend the module	Personal and professional benefit. Motivation. Like and dislike of the course.	Questionnaire 1 (QUEST1)	Open-ended questions	End
2	✶ Determine how students evaluate the module ✶ Determine the students' interest in further instruction on sustainable development	Overall course evaluation Interest in SD	Survey 1 (SURV1)	Likert type scale	End
3	✶ Determine how the students' learning styles are distributed	Learning styles	Kolb LSI 3.1 (KOLBLSI)	12 question survey	Start
4	✶ Explore the major issues and challenges that students experience during ill-structured problem solving practice-based course	Issues and challenges arising during the learning experience	Participant observation (PROBS 1)	Unstructured focused observation	During
5	✶ Explore the major issues and challenges that students experience during ill-structured problem solving practice-based course	Issues and challenges arising during the learning experience	Class discussion 1 (CDISC1)	Field notes	During
7	✶ Determine the importance students give to generic skills ✶ Determine the level of success that students perceive regarding their generic skills achievement ✶ Determine the contribution of the practice-based module to the generic and professional skills development	Generic skills importance, level and course contribution (self-assessed)	Survey 2 (SURV2)	Scaled survey	End
8	✶ Determine the importance students give to generic skills PRE and POST course ✶ Determine the level of success that students perceive regarding their generic skills achievement PRE and POST course	Generic skills importance and level (self-assessed)	Survey 3 (SURV3)	Scaled survey	Start End
9	✶ Determine the level of success that students perceive regarding their professional skills achievement PRE and POST course	Professional skills importance and level (self-assessed)	Survey 4 (SURV4)	Scaled survey	Start End
10	✶ Determine how the major issues and challenges are distributed over different stages of the ill-structured problem solving	Challenges in different phases of the learning experience.	Challenges list (CHALLPH)	Order/level	T1, T2, T3, T4
11	✶ Determine how the skills development is distributed over different stages of the ill-structured problem solving	Skills in different phases of the learning experience.	Skills list (SKILLPH)	Scaled survey	T1, T2, T3, T4

3.6 PARTICIPANTS

Participants are purposively selected, following the objectives of the research to investigate final year engineering students with respect to ill-structured problem solving phenomena and competence development. This is argued to be characteristic of qualitative research where samples are selected to serve an investigative purpose rather than to be statistically representative of a population (Ritchie, Lewis, & Elam, 2003). The sampling was place- based.

The choice of participants reflects diversity with respect to different gender, background and academic success issues.

Total student sample included 85 student participants, final year undergraduate and Master students from the School of Electrical Engineering of the University of Belgrade

TABLE 3-4 PARTICIPANTS

Group/Semester	*C1: IV year 2010/2011*	*C2: IV year 2011/2012*	*C3: Master 2011/2012*	*C4: IV year 2011/2012*	*C5: IV year 2012/2013*	*C6: IV year 2013/2014*	*Total*
Number of students	15	23	8	6	13	20	85
Male	4	13	7	4	8	12	48
Female	11	10	1	2	5	8	37

4 ACTION RESEARCH

Based on the results of the Layer 1 in 1st Phase the research was expanded in 2nd Phase to explore the skills and abilities that students perceive that they develop during the course. These results were the basis for further research in the 3rd Phase with respect to challenges that students perceive as the most important during different phases of the ill-structured problem solving process, as well as the skills that they develop in different phases of the learning experience.

The final goal is to re-define the teaching strategies to be more effective based on the results.

Based on the 1st and 2nd Phase of the research, following research objectives were identified for the 3rd Phase of this study: (1) to explore what are the challenges that students perceive as the most important during different phases of the ill-structured problem solving process; (2) to examine students' perceptions on the skills that they develop in different phases of the learning experience; (3) to re-define teaching strategies based on the results (1-3).

With this study we hope to contribute to the research on how to support students during ill-structured problem solving process, that has been called for in the literature.(Daniels, Carbone, Hauer, & Moore, 2007b) (Purzer & Hilpert, 2011)

4.1 P*I*NG INSTRUCTIONAL MODULE DESIGN

PiNG module was designed with the main goal of providing engineering students with the opportunity to experience the ill-structured problems and the work environment as closely as possible while still in the academic environment, thus creating the opportunity to investigate the implications of this instructional module for teaching and learning.

The idea was to create the supportive learning environment, where students would develop skills and abilities in a meaningful context relevant for professional practice.

The researcher decided to use workplace simulation where she as instructor would have multiple roles and at the same time be facilitator of the learning experience. This is the setting where the students would be able to experience engineering practice and perceive the course as an introduction to the working world of the telecommunications engineer. It is also intended to lead the students in the development of different generic and professional skills while finding ways of problem solving, project organizing, collaborating with their colleagues through teamwork and inter-teamwork and exploring different modes of communication.

The focus on the use of real, not sufficiently defined project work in order to experience the processes involved stresses the relevance of the techniques and tools to the professional engineer's work environment, as emphasized by (Woods, Felder, Rugarcia, & Stice, 2000) and (Du & Kolmos, 2006)

The module was designed following problem based and project based learning principles that were found to be adequate for professional skills development, as described in more detail in Section 2.4. The approach to leaning adopted for this course is based on the constructivist approach to learning and experiential learning inspired by Kolb (D.A. Kolb, 1984). Simplified reality of the workplace and its essential functions were represented through workplace simulation and role-play.

The module is organized in such a way to resemble the real-world situations that are particularly found in small and medium enterprises (SME) where an engineer is often required to combine the roles of a system designer and project manager in different phases of the product or service development. The course objective is to provide students with the opportunity to work on a real project from engineering practice, to experience all the phases of project planning and organization and to foster problem solving skills that will help them solve problems during project work. Generic skills development includes: communication, team work, critical thinking, creative problem solving and presentation.

Course design is represented in Figure 4-1.

Teamwork

Students work independently in small teams where they practice skills of teamwork, communication, negotiation of ideas and knowledge, information finding, idea generation, and others (Witt et al., 2002). Students develop process competencies going through the experience and process of real project planning and organization according to the client's requirements (Du & Kolmos, 2006).

The control of learning is intended to be distributed among the participants including the instructor. Participants generate and share new knowledge through dialogue, interaction, and collaboration. Team members engage in self-directed learning and reflective activities such as self-directed research, journaling, and self-assessment (Barrows, 1996) (Duffy & Cunningham, 1996) (J. Savery, 2006).

Instructor's role

The instructor is just a facilitator of learning, not a transmitter of knowledge – she works with students on the creation and development of knowledge and skills, guides and stimulates discussion and monitors group processes. The students' learning process consists of finding solutions by themselves with minimal help but with an always present and supportive instructor (T. a. Litzinger, Lattuca, Hadgraft, & Newstetter, 2011). The emphasis is not on teaching content, but on guiding students in their experience of 'how to work'.

(Billett, 2002) has referred to the opportunities to engage in work, as well as the guidance provided, as crucial in shaping *"how individuals elect to engage in goal-directed activities and secure direct (close or proximal) and more indirect (distal) kinds of guidance (e.g. opportunities to observe and listen)".*

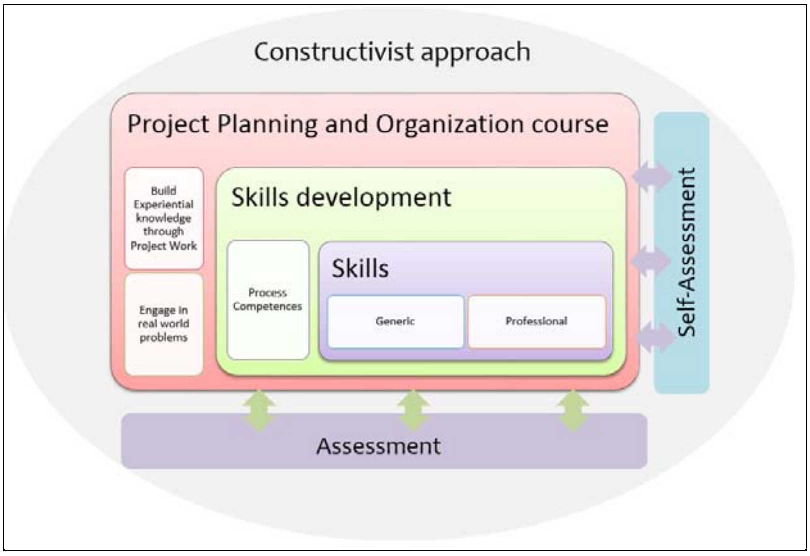


FIGURE 4-1 MODULE DESIGN

The problem

The problem that is in the centre of the project work is taken from everyday engineering practice and therefore authentic and relevant to students, it is ill-structured and it has no obvious right answer. The information available is incomplete or ambiguous on purpose. The problem presentation is such that it is unclear which concepts, rules, and principles are necessary for the solution. It allows alternative solutions instead of one correct answer.

It is a design problem, and these are the most complex and ill-structured of all kinds of problems, where the apparent goal is to find an optimal solution within determined constraints; however, design problems usually have vaguely defined or unclear goals with unstated constraints, they possess multiple solutions with multiple solution paths, and they possess multiple or unknown criteria for evaluating solutions, among other characteristics determined by Jonasson and stated in Section 2.2.1. Although design problems are the most common kind of problem that practicing engineers solve, a variety of decision making, planning, organizing, systems analysis and regulatory problems, where students need to engage different set of cognitive skills are also part of the project work. (D. Jonassen et al., 2006).

Sustainable development concepts are introduced as well, with the idea to organize future courses in order to work on projects that have direct impact on the environment, such as sensor systems in agriculture or smart grids.

Sample problem

Conceptual design of a telecommunications system including a proposal for a turn-key solution. The system consists of a wireless system for Internet access at different points of Kalemegdan Fortress Park in Belgrade, and microwave link connection to the Client's Master Site where Internet connection is available.

Assessment

In order to pass the course students are expected to: attend more than 95% of the classes; actively participate in teamwork; communicate effectively with team members, other teams and the instructor; solve problems; work independently; participate in preparing and giving a final presentation. Though the assessment is informal during the course we continuously assess the students' progress in problem solving and project processes through questionnaires and class observation; at the end of the course each team's presentation is assessed. The assessments conducted during the course on the individual and on the team levels are "assessments for learning".

On the individual level, students are continuously assessed during the course on: active participation in teamwork; effective communication with team members; active approach to solution finding; independent idea generation; formulating and asking questions.

On the team level, each teams' wireless communications system conceptual design is reviewed and assessed before elaborating the final solution. It is assessed on: functional description, block diagram, equipment specification, and proposed installation correctness. The feedback from the instructor is aimed at improving designs and submitting improved versions for the final proposal.

At the end of the course each team presents its wireless communications system solution as part of the turn-key system proposal that the client has requested. The presentation includes conceptual design, wireless access and microwave equipment specifications, installation overview, project plan and financial offer. The presentation is assessed on the team level on: communications system conceptual design adequacy in response to the client's request; design supported by sufficient detail and clear drawings; adequate project budget; realistic and clearly presented project plan. Each student is assessed on the individual level for the use of voice and vocabulary and professional position during his/her part of the team's presentation.

4.2 1ST PHASE: MODULE IMPLEMENTATION AND EVALUATION

4.2.1 MODULE IMPLEMENTATION

The course lasts 80 hours over a half semester.

The course is organized in three- and four-hour classes. Students are expected to: attend classes; actively participate in teamwork; communicate effectively with team members, other teams and the instructor; solve problems; work independently; participate in preparing and giving a final presentation.

The course is divided in three phases. After the introduction on problem solving, students begin with project work and finalize the course with the presentation of their solution. The course structure is shown in Figure 4-2.

In the introductory phase, after being given a brief overview of the course and a presentation of the objectives and expected outcomes of the course, students are asked to create their own problem solving model. They are encouraged to participate in the model creation as this will be their own model, and they will be able to modify it as they construct knowledge through the course (J. R. Savery & Duffy, 2001).

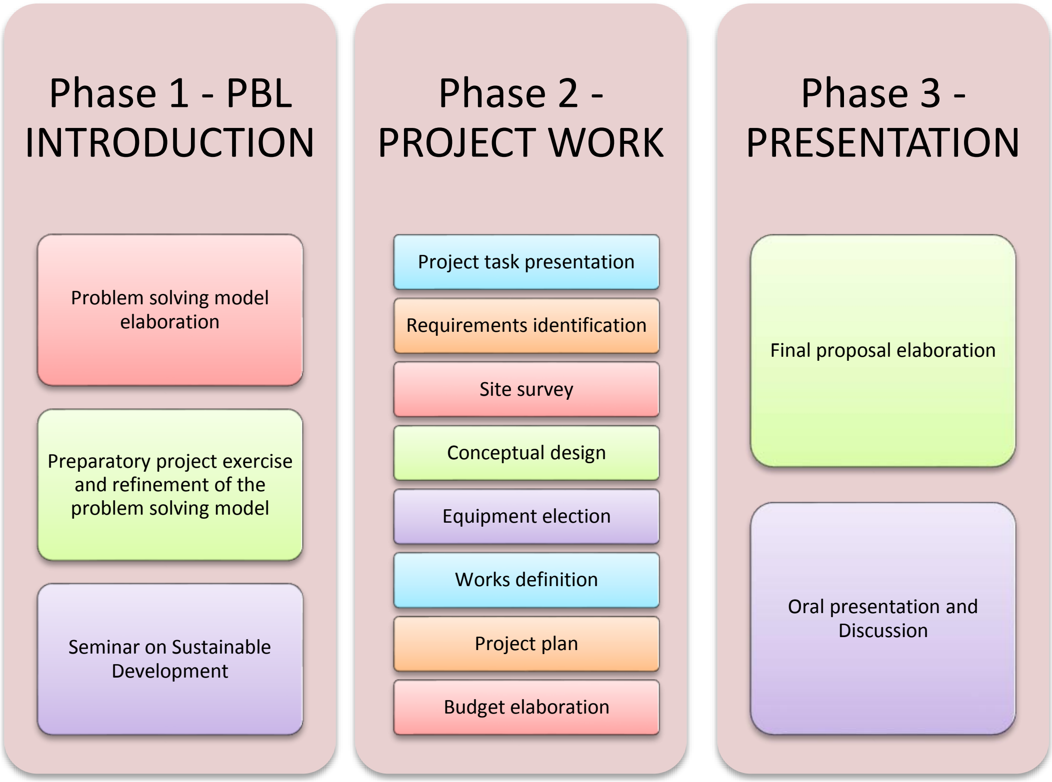


FIGURE 4-2 PROJECT PLANNING AND ORGANIZATION IN ENGINEERING PRACTICE: P/NG COURSE STRUCTURE

This is the starting point of the problem solving process and the next step is completing the first exercise: solve the problem, create basic engineering solution design and organize work on a simple project – from concept to implementation, with an analysis of the process through which the solution is obtained. After this exercise, the group's problem solving model is revised and modified if needed.

Project work is the central part of the course with the main task being presented in a form of an ill-structured request for quotation (RFQ). At this stage the teams are formed, varying from three to five students. Students have to identify a problem, investigate alternatives, perform analyses, work with stakeholders (role played by the instructor), and develop an implementation plan. Teams take ownership of their project and the problem-solving process, as would a professional.

The task is to create a wireless system proposal in response to a tender issued by an imaginary customer. The proposed system must provide wireless Internet coverage for two spots of the Belgrade Ada Lake Sports Resort and an ISP Internet connection via point-to-point link. The proposal must include preliminary design of the system, detailed project plan and final budget for design, supply, installation and commissioning of the system.

In other courses during their studies, students have already obtained theoretical knowledge on wireless systems. No theory is exposed by the instructor and the project planning and organization model is constructed by students themselves in the course of the project. This is not easy, but a pedagogical goal of this course is to learn how to identify and overcome barriers, to create necessary incentives and support, and to adapt the implementation strategy to be effective.

Upon understanding clients' requirements, researching the equipment that can be used and undertaking the site survey, the preliminary design of the system is created. Bill of materials is prepared, containing a more detailed specification of the equipment and installation materials. As the course is focused on project planning and organization, the systems engineering part of the course is limited to creating a correct conceptual solution of the system. Licenses and logistics issues (such as transport, customs, delivery dates) are discussed and determined.

A Gantt chart is introduced in order to provide the final project plan. Planning of human resources includes details for the engagement of engineers, technicians and subcontractors. The project plan is elaborated at the end of the solving process, where students reflect on all the phases of the works done. This is the way that reflects their future professional work, where most likely they will be in charge of organization of works and will have to reflect upon it.

Project budget elaboration is based on all the above parameters.

A formal written report is prepared together with a formal oral presentation to the client, academic tutors and the peer group." The students benefit by developing an understanding of working in industry, gain context to their degree programme and improving their process and communication

TABLE 4-1 COURSE OUTLINE

Class No.	*Class theme*	*Class description*
1.	Overview of the course	Introduction to the goals and expected outcomes of the course. Filling in the questionnaire (self-evaluation of generic and professional skills level).
2.	Introduction to the model of structured problem solving	Creation of the group`s problem solving model Exercise: solve the problem and organize works on a simple project - from concept to implementation.
3.	Sustainable development principles	Basics of sustainable development and the implications for engineering projects in the field of telecommunications
4.	Project task	Students are presented with the ill-structured task to create a response to a tender that should contain conceptual system design with detailed description of all the equipment and works, as well as project schedule and final price for system delivery, installation and commissioning. Each team presents its solution for evaluation to the client in a Power Point presentation at the end of the course. Groups formation Analysis of the process through which a solution is reached and necessary changes and add-ons to the group's problem solving model Problem analysis and analysis and definition of user requirements
5.	Generate possible solutions and preliminary specifications	Generate possible solutions and check equipment available on the Internet. Site survey Query of prices and conditions Analysis of the responses
6.	Comparison and selection of the most acceptable conceptual design	Comparison of the criteria of feasibility, cost, quality, reliability. Necessary permits and regulatory issues. Installation requirements. Additional questions to the investor
7.	Specification of equipment and works	After the analysis each team creates a more detailed specification of equipment and works.
8.	The structure of the works and resources on the project	Planning logistics. Planning works on the installation and commissioning. The duration of the works on the project. Human Resource Planning
9.	Detailed project plan	Gantt chart Detailed project plan
10.	Final specification	Final specification is elaborated with corresponding prices based on all the above parameters
11.	Offer elaboration	Each team elaborates the offer for the turn-key project
12.	Guidelines for Power Point presentations. Consultations	Teams work to elaborate the presentation of their solution. This is independent work and does not happen during the class.
13.	Power Point presentations.	Each team presents its solution in a Power Point presentation with the most significant elements of the solution and offer to the client.

skills. Projects can also highlight the limitations of theoretical treatments and the simplifications that need to be made to adapt theory to practice. This gives practice in creating satisfactory theoretical models of complex practical systems and an appreciation of how to apply theory to real situations (Crawford et al., 2003).

Presentation of the final proposal to the customer is held at the end of the course. It is not enough to come up with a good proposal; each team needs to ''sell'' their solution to the customer represented by the instructor and two professors from the telecommunications department. Each team's proposal presentation is assessed for: solution accuracy and answer to the client's request; solution support with sufficient details and clear drawings; adequate project budget; realistic project plan; professional position, use of voice and vocabulary.

Though each team creates its own solution, the course is not competitive. Biggs claims that more students are turned off and work less well under competitive conditions than those who are turned on and work better. Although competition is often touted as the way the 'real' world works, it does not follow that universities should make learning competitive for the general run of students, as happens when using norm-referenced assessments such as 'grading on the curve.' (Biggs, 1996).

The aim of the course is to provide learning environment for students to:

1. Apply principles of basic systems engineering to real-life engineering projects to develop conceptual design of a simple system
2. Evaluate and optimize conceptual design of a simple system by using different criteria that comprises basic sustainability principles, price, time, feasibility
3. Plan and organize activities in a real-life engineering project to develop, simple project plan
4. Evaluate and optimize project plan
5. Elaborate the complete solution that includes conceptual design, cost and project plan
6. Present and justify the proposed solution
7. Develop problem solving strategies for solving ill-structured problems by using structured and creative ways to solve problems that arise during project execution
8. Recognize relevant details during site surveys
9. Understand and accept that there is not one solution to practice problems
10. Understand complexities of engineering practice
11. Demonstrate awareness of regulatory, environmental and sustainability contexts of engineering practice
12. Communicate as a professional with clients and colleagues in real-life engineering situations
13. Operate effectively and ethically as a team member in real-life engineering situations

The above objectives are reflected in the work of (Cynthia J Atman et al., 2010) that through a comprehensive research summarizes that students should be presented with an opportunity to experience significant learning opportunities that help them with the transition to professional engineering world:

a) practice how to react when presented with a challenge

b) excel in self-directed study

c) find their way towards a solution when faced with owing a real-world engineering problem

d) solve the ill-structured problem in a workplace simulation environment

e) extend their understanding of engineering through working in the field

f) develop confidence in their abilities as engineers

g) work in teams

h) learn to ask questions

i) understand that in engineering practice there are perspectives and constraints other than pure engineering

j) understand that decisions can often incorporate more factors than those that pertain only to the engineering aspects

k) listen to others, effectively incorporate input, express their own ideas and communicate their ideas to multiple audiences in the many modes they need to

4.2.2 Module evaluation & Methods overview

In the 1st Phase of this research data was collected using qualitative and quantitative methods. The items that were investigated were:

- ✓ The importance of the learning experience for students' personal and professional development
- ✓ Like and dislike of the course.
- ✓ Overall course evaluation
- ✓ Learning styles
- ✓ Issues arising during the learning experience
- ✓ Generic skills importance, level and improvement (pilot version)

The objectives of the Layer 1 research introduced in this phase were:

- ✶ Determine how students evaluate the module

- ✶ Explore the reasons why students like/dislike the module
- ✶ Explore the significance of the module for students' personal and professional development
- ✶ Explore the major issues and challenges that students experience during ill-structured problem solving practice-based course
- ✶ Determine how the students' learning styles are distributed
- ✶ Determine the students’ interest in further instruction on sustainable development

The qualitative methods used included unstructured participant observation and field notes in form of research diary, as well as open ended questionnaire.

The questionnaire (QUEST1, presented in Appendix 1 – Research instruments used in the study) consisted of five open-ended questions, and addressed the perceived importance of the P*i*NG course for professional and personal development and what was it that students liked or disliked the most about the course as well as their recommendation on what should be changed for the course to be better. The open ended questions included the following questions:

Q1. “The experience gained at this course is important for my future profession because”

Q2. “The experience gained at this course is important for me personally because”

Q3. “My motivation to attend this course was”

Q4. “On this course I liked the most”

Q5. “On this course I would change the following for the course to be better”

Quantitative methods included scaled type surveys for course evaluation and learning styles.

The survey (SURV1, presented in Appendix 1 – Research instruments used in the study) included 13 items for course evaluation as follows:

ST1. The content of the course is such that I understand the learning objectives

ST2. I adopted the project planning and organization techniques enough to be able to apply them to simple projects in the future

ST3. I adopted the process of solving technical problems enough to be able to apply it in the future

ST4. It is difficult to perform the course work without previous theoretical lectures

ST5. I like problem based learning

ST6. I like learning based on real projects

ST7. I enjoy working in a team

ST8. The lecturer used good judgment to provide information when necessary during the project work

ST9. The lecturer has conducted this course very well

ST10. The course has fulfilled my expectations

ST11. I would like to attend another course based on the real problems

ST12. I would recommend this course to others

ST13. I am interested in learning more about the concept of sustainable development in some of the courses in the future

Upon the end of the 1st Phase the evaluation of the results was conducted together with research methodology improvements. The reflection took place in order to plan for the next phase and to feed the results into the next phase.

The improvements included reducing the number of evaluation questions for overall course evaluation and creating the final design for the generic skills evaluation survey.

The instrument that was partially applied in the 1st course is Generic skills importance, level and course contribution, described in the next Section.

4.2.3 REFLECTION

Motivation is key for engaging student in deep learning.

The importance of motivation is evident for performing any task and in this study it was important to reveal why students engage in learning, in order to understand. According to (Biggs & Tang, 2007) students engage in learning because they are interested: a) in the outcome, with view of reward or punishment that would follow the outcome (extrinsic motivation); b) in what the outer world thinks, e.g. the “audience”, with view of pleasing the “model” that is admired and identified with (social motivation); c) in competition, when students perform the task in order to enhance the ego, beat their colleagues and create the feeling of satisfaction about themselves (achievement motivation); d) in the task itself, where students perform the task because they are interested in the task or activity itself, with view of the process itself and intellectual pleasure coming from exercising the skill in solving the task, independently of any rewards that might be involved (intrinsic motivation).

Intrinsic motivation drives deep learning and the best academic work, where the central role is occupied by the task and the process of learning itself.

In addition to the question about motivation, 2nd Phase introduced the self-assessment of students’ generic skills.

The skills that were aimed to foster and to measure were chosen based on the studies on their importance for the future engineering profession and on the reported gap in their development as pointed out in Section 2.1.

4.3 2ND PHASE: METHODLOLOGY IMPROVEMENTS

The second phase of the research included the three courses that were conducted during the winter and summer semesters of the 2011/2012 where the instructional design was stabilized and improved research methodology was applied.

In the 2nd Phase of this research data was collected using qualitative and quantitative methods. The items that were preserved compared to the 1st phase are:

- ✓ The importance of the learning experience for students' personal and professional development
- ✓ Like and dislike of the course.
- ✓ Overall course evaluation
- ✓ Learning styles
- ✓ Issues arising during the learning experience

The items that were added compared to the 1st phase are:

- ✓ Motivation.
- ✓ Generic skills importance, level and improvement (self-assessed)

The main objectives of the Layer 2 research introduced in this phase were:

- ✶ Determine students' motivation to attend the course
- ✶ Determine the importance that students perceive that different skills have for their future profession
- ✶ Determine the level of success that students perceive for these skills
- ✶ Determine the perceived contribution of the course for the skills development
- ✶ Analyse how these three variables are related and which are the specific skills where students could be more supported

4.3.1 METHODS OVERVIEW

The design of the skills survey was based on the survey presented in the study of the importance and the level of achievement of the undergraduate students competencies, based on the Tuning project framework of competencies assess the importance of generic competencies for their future professions, and whether the teaching/learning methods used have any impact on their assessments (M. Gerasimović & Miškeljin, 2009).

The choice of the generic skills was made based on the findings in engineering and sustainability skills.

It can be concluded that the skills for sustainability and for engineering coincide in the skills and abilities part:

- Systems thinking in technical and social aspects
- Ambiguity tolerance
- Trade-offs
- Creativity
- Communication, teamwork and people skills

The skills chosen to be further investigated and used in the survey include:

S1. Communication -expressing opinion
S2. Communication-asking questions
S3. Teamwork-willingness to contribute to a common solution
S4. Teamwork-accept 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

At the end of each course students evaluated each of the above mentioned generic competences on these three levels. The goal was to analyse the overall difference of assessment of these three broader dimensions as well as the specific assessment of different competences on these dimensions in order to gain insight into the effectiveness of the implemented educational strategies.

In continuation short justification for measuring each of the selected skills is given.

Communication (S1-S2). The ability to communicate is about expressing complex ideas and information clearly, precisely and accurately in spoken and written communication. The inclusion of speaking and writing in public fora requires the skill to tailor communication to the audience and to the purpose of the communication. The ability to communicate also includes an ability to use appropriate information communication technologies to support communication. High level communication skills are regularly cited as the most important skill demanded by employers. Communication skills are frequently identified as one of the two main factors contributing to job success, the other being the ability to work in teams.

Teamwork (S3-S4). Employers have identified the ability to work effectively in a team environment as one of the most important graduate attributes in a global business environment. Students with good teamwork skills respect and value their own contribution as well as the views and contributions of others. They exhibit highly developed skills in listening, questioning, persuading, respecting, helping, sharing and participating, and are adept at applying conflict resolution strategies to ensure team effectiveness. (“ECU Curriculum Framework : Examples for Teachers,” 2012)

Presentation (S5). With oral presentations, as with written reports, learners need to be clear about the purpose of the exercise and the needs of the audience as this will affect how the presentation is best structured and delivered. A presentation designed to provide a detailed explanation to an assessment panel of how the project was conducted would need to be very different in style as well as content to one aimed at a more general audience interested primarily in the project’s findings.

Finding relevant information on the Internet (S6). Cognitive activities related to searching, gathering, deducing, and using information are critical elements of work tasks in the engineering problem solving domain. In order to solve a problem, a student must be able to reason effectively about information, whether that information is readily available or the student has to search for more information. Real world problem solving occurs in information-rich environments, making it difficult to acquire the relevant information because the relevant information must be filtered from the irrelevant information. (KUMSAIKAEW, JACKMAN, & DARK, 2006) (Bowden, 1985)

Ability to apply knowledge in practice (S7). It has been shown that industry regards the ability to apply theoretical knowledge in practice as the single most desirable attribute in new recruits, though this ability has become rarer in recent years (Spinks et al., 2006) (Shuman, Besterfield-Sacre, & McGourty, 2005). This implies the use of previously acquired knowledge/skills/competence/expertise in a new situation which becomes challenging if the new situation is unfamiliar and complex (Eraut, 2004).

Planning and organisational skills (S8). Whilst students will need to utilise planning and organisational skills within any formal programme of study, it is important to recognise that learning through projects introduces a different level of demand on these skills. Project based learning provides an excellent environment for developing abilities in project planning and project management, both key skills for the professional engineer. Added to that, it is not uncommon within engineering programmes for skills in planning and organising to be formally assessed.

Solving ill-structured engineering problems (S9). Skills required to solve problems are different – usually taught well-structured problems require different skills than ill structured problems. Students are taught to solve well-structured problems, but at the workplace they are faced almost exclusively with ill structured problems. Therefore it is important to prepare them for ill structured problem solving by fostering appropriate skills. (Lynch, Ashley, Pinkwart, & Aleven, 2009). The ability to identify the nature and relevant context of the problem, what knowledge is needed to address it, and what methods are best suited to solve the problem can only come with practice in solving complex problems. (T. A. Litzinger et al., 2011a)

Generating new ideas in the problem solving process (S10). The ability to generate ideas is one of the aspects of creative thinking, and creative problem solving in engineering (Maiden et al., 2010), (Stouffer, Russell, & Oliva, 2004). This skill can involve playing around with ideas, but goes beyond that to developing new or original ideas that have purpose or value.

Ambiguity tolerance – existence of more than one solution (S11). In the category personality traits (Kobe & Goller, 2009) list tolerance of ambiguity as one of the crucial personal traits that employers look for in new employees, especially if they are looking for engineers that are needed for creative solutions, as ambiguity tolerance is one of the divergent thinking characteristics. As Sternberg writes in (Robert Sternberg, 2007) *"creative idea tends to come in bits and pieces and develops over time. However, the period in which the idea is developing tends to be uncomfortable. Without time or the ability to tolerate ambiguity, many may jump to a less than optimal solution."* Additionally in a study conducted by Moti Frank (Frank, 2006) with leading industry engineers, ambiguity tolerance was ranked as 6th on the list of important cognitive characteristics of systems engineers. On the other hand, it can be considered as one of the vital capacities for sustainability science (Sprain & Timpson, 2012).

Systems thinking – technical systems (S12). The above mentioned study by Moti Frank (Frank, 2006) is dedicated to Engineering Systems Thinking, *a "high-order thinking skill that enables engineers to successfully perform systems engineering tasks".* The main characteristic of this skill is the ability to see the "big picture" while avoiding to get stuck in the details*," to be able to identify the system's* *emergent properties, capabilities, behaviours, and functions without looking inside the system and its parts/components/details."* This is a vital skill for systems engineers in the fields of systems and product design.

Systems thinking – technical systems in societal context* (*S13). The experiential learning in the internship-like environment provides a unique setting where the actions that define performance and competences can be assessed while the student is actually engaged in the practice of engineering at the professional level. Therefore these competences for problem solving, independent and collaborative learning are fostered by using complex ill-structured real world problems in the learning setting similar to the work environment, while understanding the importance of developing workplace competences in students provides an opportunity to enhance the engineering education process as competencies provide students with a clear map and the navigational tools needed to become successful engineers and have a strong impact on student learning.

Assessing skills and abilities is not an easy task nor is it straightforward. According to Boud and Falchikov (Boud & Falchikov, 2006), self-assessment is appropriate to be used in the monitoring of skills which need to be developed through practice, as a learning activity designed to improve professional practice. It relates to "enabling students to become effective and responsible learners who can continue their education without the intervention of teachers or courses". In this context, students also need to form the opinion and determine the skills that are important for their professional practice. Self-assessment is necessary skill for lifelong learning; it needs to be developed in university courses and it is necessary for effective learning since learners must develop the capability of monitoring what they do and modifying their learning strategies appropriately. Self-directed study encourages learners towards evaluation which is at the highest end of Blooms' cognitive domain. Therefore, our approach was to adopt students' self-assessment as the relevant measure of their skills development. Other assessment is carried out by the instructor during the course on the individual and on the team level, in the "assessment for learning" context as it does not lead to formal grades.

4.3.2 Reflection

In the reflection and evaluation during the 2nd Phase the researcher concluded that students' skills development and issues and challenges during the course needed to be taken into consideration. However, the way of implementing this approach was not straightforward and the researcher decided to conduct a course for a small group of students in the summer semester of 2011/2012. The goal was to conduct structured participant observation of the students' behaviour that would mark the pilot study for methodology improvement in the 3rd phase.

The initial methodology improvement that was introduced to the pilot group included student diaries and professional skills survey.

The pilot group was closely monitored, which was possible due to the reduced size of the group. Therefore, the close participant observation permitted the posterior thorough reflection on the methodology improvements that resulted in the modification of the students' diaries to include the survey of the phased generic skills and issues and challenges in four points of time during the course.

The survey of the phased generic skills and issues and challenges in four points of time during the course was inspired by the design applied in (Purzer et al., 2011).

The improvements were fully introduced in the 3rd Phase courses in 2012/2013 and 2013/2014. Two additional surveys were designed for the 3rd phase, one for phased issues and challenges, and one for phased generic skills evaluation.

The complexity of the research design was thus increased, in all three dimensions. It became matrix design, with 3 phases and 3 layers, each layer representing different breadth and depth of the research data. The detailed research design description is given in Chapter 3.

4.4 3RD PHASE: FINAL IMPROVEMENTS

The P*i*NG module design followed the same structure from the beginning of the course.

The methodology improvements were fully introduced in this phase with the novel approach to collecting data in the courses in 2012/2013 and 2013/2014.

In the 3rd Phase of this research data was collected using qualitative and quantitative methods. The items that were preserved compared to the 1st and 2nd Phases are:

- ✓ Personal and professional benefit.
- ✓ Like and dislike of the course.
- ✓ Overall course evaluation
- ✓ Learning styles
- ✓ Issues arising during the learning experience
- ✓ Issues arising during the learning experience. Course issues
- ✓ Motivation.
- ✓ Generic skills importance, level and improvement (self-assessed)

The main objectives of the Layer 3 research introduced in the 3rd Phase are:

- ✶ Determine the importance and the level of success that students perceive for generic skills PRE and POST course
- ✶ Determine the level of success that students perceive for professional skills PRE and POST course
- ✶ Determine the phased issues and challenges in 4 points of time (T1, T2, T3 and T4)
- ✶ Determine the phased skills development in 4 points in time (T1, T2, T3 and T4)

4.4.1 Methods overview

The course was designed to foster specific professional skills through real project work, based on the skills and abilities recommended by professional engineering bodies. All of the studied professional skills are domain specific and belong to higher order thinking skills according to Bloom´s taxonomy of learning (Felder & Brent, 2004). They refer to:

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. Analyse 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

Each skill was evaluated by their level of success before and after the course on the scale from 1 to 4, with 1 being the lowest score and 4 the highest score.

The contribution of the course to the skills' development was measured indirectly, through the difference in the perceived skills' level of success before (PRE) and after (POST) the course.

Challenges list T1, T2, T3, T4 (CHALLPH) was aimed at capturing data comparable to the data collected in the previous courses since 2010/2011 thus providing insights for the longitudinal research and bringing depth that would explain the phenomena found in the previous results. The challenges list is formed of the challenges found in the 1st and 2nd Phases. Students were offered to choose 5 out of 18 proposed challenges listed in continuation and then order them from 1 to 5, giving the order of 1 to the most difficult one and the order of 5 to the least difficult of the five chosen challenges:

CH1. _____understand where to start from in order to solve the problem
CH2. _____define the problem that should to be solved
CH3. _____learn to ask questions
CH4. _____understand and take into account the requirements of the client
CH5. _____connect theory and practice
CH6. _____independently decide on how to collect and use information
CH7. _____accept uncertainty final decision (there is not only one correct solution)
CH8. _____accept that there are limitations and compromises
CH9. _____clearly express my demands in communication with other stakeholders
CH10. _____visually present the problem (block diagram, sketch)
CH11. _____face the failure and move on in search of solutions
CH12. _____face the reality during the site survey
CH13. _____define criteria for evaluating solutions
CH14. _____compare solutions and decide which one is the best
CH15. _____plan and organize the project work
CH16. _____describe the technical solution of the system
CH17. _____justify the offer of the system
CH18. _____present the offer of the system

Skills list T1, T2, T3, T4 (SKILLPH) was aimed at fine tuning the skills development over the duration of the course and different challenges that students found along the way. This list was composed of 12 skills whose development levels were rated from 1 to 10. Therefore, the researcher aimed at providing data comparable to the data collected in the previous courses and bringing depth that would explain the phenomena found in the previous skills measurements results.

PH-S1. Expressing opinion
PH-S2. Asking questions
PH-S3. Willingness to contribute to a common solution
PH-S4. Accept differences of opinion
PH-S5. Finding relevant information on the Internet

PH-S6. Ability to apply knowledge in practice

PH-S7. Planning and organization

PH-S8. Solving ill-structured technical problems

PH-S9. Generating new ideas in the process of finding a solution

PH-S10. Ambiguity tolerance

PH-S11. Systems thinking

PH-S12. Presentation

Layer 3 data was collected and analysed only in the Phase 3.

Quantitative methods were used for data collection and descriptive and non-parametric statistics for data analysis.

5 DATA COLLECTION AND ANALYSIS

5.1 LAYER 1

Issues and challenges were determined through the analysis of the instructor's participant observation protocols and field notes from class discussions.

Students' perception of the learning experience and their motivation to attend the course was explored through the answers to the open-ended questionnaire.

The course was evaluated through a Likert type survey.

Students' learning styles were determined by using the Kolb LSI scaled survey.

Data for the Layer 1 was collected over the six 10-week courses, over 4 years, from 2011 to 2014.

The participants were all the 85 students that attended the courses, as shown in the Table 5-1.

In the Table 5-2 the tasks derived from Research Questions together with the corresponding data instruments are presented.

The qualitative data that included responses to open-ended questions, observation protocols and field notes was analysed following the phenomenographic data analysis which typically reflected the process of identifying the themes and patterns of data/responses in relation to the research questions (Patton, 2002b)

TABLE 5-1 LAYER 1 PARTICIPANTS

Group/ Semester	*C1: IV year 2010/2011*	*C2: IV year 2011/2012*	*C3: Master 2011/2012*	*C4: IV year 2011/2012*	*C5: IV year 2012/2013*	*C6: IV year 2013/2014*	*Total*
Number of students	15	23	8	6	13	20	85
Male	4	13	7	4	8	12	48
Female	11	10	1	2	5	8	37

This included the areas including student perception of the personal and professional benefits of the course, student learning experiences, issues and challenges associated with the learning experience and strategies for improvement. Such responses were also examined to enable interpretation of the complexity and variety of student perception and practice of utilising ill-structured problem solving problem and project based course for competence development.

The quantitative data that included responses to course evaluation surveys and Kolb LSI were analysed using descriptive statistics and Kolb LSI key.

5.1.1 Participant observation and field notes

The participant observation protocols were filled in for each of the six courses (Course 1, Course 2, Course 3, Course 4, Course 5 and Course 6) from 2010/2011 to 2013/2014.

The instruments that were used for structured and unstructured observation are, as described in Section 4.2.2:

- Participant observation. Unstructured focused observation: Field notes and research diary (PROBS1)
- Participant observation. Structured observation (PROBS2)

The approach the researcher adopted was to record only those activities that were relevant to the research that had to do with the issues arising during the problem solving process or skills development.

Collection of data was done by field notes that included observations of interactions between students in teams, interactions between teams, activities that occur in the classroom, as well as some of the questions that students asked. As field notes taken on site cannot capture as much detail as is being seen, I expanded them as soon as possible off-site.

The analysis of the data collected through participant observation protocols and field notes was performed for each of the three research phases, while preserving the identification of the semester and year in which the data was collected.

The researcher first read the aggregated notes and observations and analysed them by identifying themes that emerged from the data. The iterative process thus started by developing an initial understanding of the perspectives of the students who are being studied. That understanding was then tested and modified through cycles of additional data collection and analysis until coherent interpretation was reached, as described in (Creswell, 2003), (Patton, 2002b). The iterative process included going back to the themes that first evolved from the notes, representing main issues and challenges that were observed during the classes and discussed by the students during the class discussions: (1) difficulty in starting to solve the problem, (2) difficulty in asking questions (3) connecting theory and practice, (4) insecurity originating in the lack of any practical experience in project work and ill-structured problem solving throughout the previous years of academic studies.

When observations were re-grouped in the iterative process, the final list of the issues and challenges that were developed from the observations reflected the themes very similar to those found in the field notes data.

Findings from the participant observation protocols and class discussion field notes were discussed with the two professors from the Department of Telecommunications and triangulated with the observations of the researcher who observed all the class sessions from the first to the last module. The refinements were negotiated where it was necessary leading to the congruence of themes which strengthened confidence in their validity.

As additional data emerged in the 2nd and the 3rd Phase the findings from the 1st Phase were re-checked and modified if needed. The modifications proved to be scarce, resulting in adding only one challenge in the 2nd Phase that was not recognized during the 1st Phase data analysis.

TABLE 5-2 LAYER 1 RESEARCH INSTRUMENTS

No		What is measured	Instrument	Type	Time
1	✶ Explore the importance of the module for students' personal and professional development ✶ Explore the reasons why students like/dislike the module ✶ Explore students' motivation to attend the module	Personal and professional benefit. Motivation. Like and dislike of the course.	Questionnaire 1 (QUEST1)	Open-ended questions	End
2	✶ Determine how students evaluate the module ✶ Determine the students' interest in further instruction on sustainable development	Overall course evaluation Interest in SD	Survey 1 (SURV1)	Likert type scale	End
3	✶ Determine how the students' learning styles are distributed	Learning styles	Kolb LSI 3.1 (KOLBLSI)	12 question survey	Start
4	✶ Explore the major issues and challenges that students experience during ill-structured problem solving practice-based course	Issues and challenges arising during the learning experience	Participant observation (PROBS 1)	Unstructured focused observation	During
5	✶ Explore the major issues and challenges that students experience during ill-structured problem solving practice-based course	Issues and challenges arising during the learning experience	Class discussion 1 (CDISC1)	Field notes	During
6-10	Layer 2 and Layer 3 data				

5.1.2 OPEN ENDED QUESTIONNAIRE

The instrument that was used for open ended questionnaire is, as described in Section 4.2.2 :

- Open-ended Questionnaire 1 (QUEST1)

This is a five open ended question questionnaire (Appendix 1 – Research instruments used in the study) that was used to explore students' perceptions of the instructional module significance for their personal and professional development. In Phase 2 one item was changed in this questionnaire introducing the question on Motivation.

A conceptual content, or thematic, analysis was performed on the open-ended questionnaire answers to transform and organize the data ((Maxwell, 2005); (Miles & Huberman, 1994)).

The analysis of the data collected through open ended questionnaire was performed for each of the three research phases, while preserving the identification of the student, semester and year in which the data was collected.

All the answers were transcribed to a data analysis matrix that contained 4 columns and variable number of rows. The first column contained the data transcribed from the questionnaire, together with the student ID number at the top of each student's row and the question number for each of the corresponding question rows. The second and the third column contained the student ID number. The fourth column was filled in during the analysis with the categorization codes of the student answers.

Care was taken to be able to trace text excerpts back to their original context. The table rows contained first the row with student ID, followed by the rows containing data from the questions 1 to 5. Each question number was clearly marked which enabled tracing the data to its original context as analysis proceeds. Each question row with corresponding transcript was printed in different colour representing different question. Therefore, Q1 was yellow, Q2 green, Q3 light blue, Q4 purple and Q5 white.

On the total, we had 85 questionnaire forms that were filled in over 4 years, each containing 5 rows with questions Q1-Q5, which makes a total of 425 answers that were examined.

Firstly, the researcher read the transcripts for each question and analysed them all together by identifying patterns or regularities in the thoughts and ideas. This was an iterative process that was repeated in order to deduce the main emerging themes from the data. These generated explicit themes for each of the questions Q1 to Q5 inductively. The only difference in the data structure was that the Course 1 did not contain the question regarding Motivation and all the following courses did.

In the course 1, there were two questions regarding what the student did not like in the course and how they would make it better, which was merged to one question in posterior courses.

Once the emerging themes were identified, they were coded and the data was labelled in the 4th table column with the initial set of theme codes from that process. Then the tables were cut by rows for each of the questions and folded forming thus data notes where the facing part contained question number, student answer student ID, and the folded part contained student ID and coded categories.

The researcher developed a data analysis panel to help her analyse the open ended questions data, where all the data notes were arranged under previously identified main themes for each question. The data panel was inspired by (Escalas & Güell, 2005). In Figure 5-1 the data panel for Q1 to Q3 is presented. Differently coloured data notes were pinned to a data analysis panel that contained question area as multiple rows and themes as columns.

FIGURE 5-1 DATA ANALYSIS PANEL

Data analysis panel thus consisted of a table representing the 5 questions and variable number of rows where identified themes were marked at the top of the row followed by the transcribed answers that represented the theme.

Further content analysis was performed to re-check the answer's categorization by themes, where in cases when more themes emerged in one answer these were written with student ID on a separate note and pinned to a corresponding theme. The visual representation was easy to manage due to different colours of data notes per question.

The purpose of this process was to perform the second cycle of the data analysis by comparing the notes from the first coding and the second categorization of the data on the panel table. The organizing of the data according to the new independent categorization with no view of the initial categorization, allowed the researcher to look at all the text segments that have been placed into each question category together. Through looking at the assembled segments, the researcher could decide to change the category label in the field, to move some segments to other categories where they fit better, to split one category into more than one and recode the segments accordingly, or to rename to category or readjust its boundaries to better accommodate the data. The researcher compared the data notes new categorization with the initial one at the back of the data notes to identify any mismatches.

Thus the data was further refined into a final categorization by themes by re-checking how well the initial codes did or did not fit the responses, and introducing the refinements. This was the way to provide convergence on the data as described by (Miles & Huberman, 1994). Once the codes were checked to fit the sample responses sufficiently, and re-arranging the data by final themes, the final version of the themes and corresponding answers was created. (Henry, Tawfik, Jonassen, Winholtz, & Khanna, 2012)

Data panel thus helped in visually sorting the data into themes, and cross checking the accuracy of the analysis (Patton, 2002b). It has several notable strengths or advantages as it retains the context of the original concepts present in the answers to each of the questions. It also enables estimation of the similarity between concepts and clusters of concept categories that are representative of a combination of human judgment/respondent experience and statistical analysis (Jackson & Trochim, 2002).

In this research the content analysis combined with multi-colour data panel proved as a useful method particularly well suited to the type of data generated by open-ended questions as well as to the exploratory nature of these types of questions. The result is a visual representation of thematic clusters representing accumulations of open-ended survey responses.

Throughout the analysis process, the researcher was careful in the ways she organized and interpreted the data to ensure the transferability, dependability, and reliability of the results. This was accomplished through methodological and investigator triangulation in order to ensure the credibility of the study ((Denzin & Lincoln, 2000); (Patton, 2002b)).

5.1.3 LIKERT TYPE SCALE SURVEY

The instrument that was used for course evaluation was the extended version of the:

- Course evaluation Survey 1 (SURV1)

This is a 13-item survey (Appendix 1 – Research instruments used in the study) that was used to measure students' assessment of the learning environment, as described in Section 4.2.2. All items used the 5-level Likert-scale, which ranged from 1 (Strongly Disagree) to 5 (Strongly Agree).

Likert type scale survey for course evaluation was analysed using descriptive statistics.

5.1.4 KOLB LSI

The basis for Kolb's Learning Style Inventory (LSI) is the experiential learning model described in Section 2.3.3.

Kolb, Boyatzis and Mainemelis explain the concept of learning styles as patterned ways in which we choose to perceive and process the new information. Some people perceive new information

> "*through experiencing the concrete, tangible, felt qualities of the world, relying on our senses and immersing ourselves in concrete reality. Others tend to perceive, grasp, or take hold of new information through symbolic representation or abstract conceptualization – thinking about, analysing, or systematically planning, rather than using sensation as a guide. Similarly, in transforming or processing experience some of us tend to carefully watch others who are involved in the experience and reflect on what happens, while others choose to jump right in and start doing things."* (David A. Kolb, Boyatzis, & Mainemelis, 2000)

The dimensions that we choose from are reflective observation (preferred by watchers), or active experimentation (preferred by doers). Other two dimensions are concrete experience (feelers) and abstract conceptualization (thinkers). We need to resolve the conflict between concrete or abstract and between active or reflective in some patterned, characteristic ways, depending on different factors that include our past experience and present condition (David A. Kolb et al., 2000).

An important premise of this learning style model is that everyone, regardless of their preferred learning style, uses all four learning style types at some point during the learning process. (Larkin-Hein & Budny, 2000)

Though the predictive validity of a LSI instrument is critical, there appears to remain support for the learning model itself. Its inclusion in popular experiential texts and its widespread dissemination as a tool in management education support this assertion (Hunsaker, 1981)

Applications of the Kolb Model in engineering have been described in (Sharp, 1998), (Álvarez & Domínguez, 2001), (Armarego, 2007), (Agudelo-Romero, Salinas-Urbina, & Jorge-Fernando Mortera-Gutiérrez, 2010).

Kolb's Learning Style Inventory (LSI) classifies students into one of four learning styles based on how the rank-order of twelve sets of four words. Scores from the LSI place the learner into a quadrant based on two learning modes. The quadrants represent the four learning styles: Diverger (CE-RO), Assimilator (RO-AC), Converger (AE-AC), and Accommodator (AE-CE) (Fox & Bartholomae, 1999):

1. Diverger. A student classified as a diverger perceives information through concrete experience and processes it through reflective observation. A diverger may best process information by their feeling and by observation. Divergers do well with viewing a concept or idea from many perspectives and combining relationships into a meaningful whole. Divergers are characterized as being emotional, people– oriented, and imaginative – they can easily generate ideas. They are good at working in a group and at blending many different experiences or pieces of information into a whole (Kolb, 1981).
2. Assimilator. An assimilator perceives information through abstract conceptualization and processes information through reflective observation. The assimilator may be good at synthesizing separate pieces of information, analysing them, organizing them, and assimilating them into a whole. Assimilators are more systematic in their approach to ideas and theories and do well when information is detailed, logical, and orderly. An assimilator prefers to digest and think about the information (Kolb, 1981).
3. Converger. A converger perceives information through abstract conceptualization and processes it by active experimentation. A converger approaches ideas and theories systematically, and ideally transforms information by applying the ideas and information to practical situations. Convergers are less people oriented and more technically minded. They tend to converge or move quickly to make decisions, and to quickly cut through to the essentials of the matter at hand (Kolb, 1981).
4. Accommodator. Students classified into the accommodator learning style perceive information through concrete experience and process it through active experimentation. Accommodators may learn most effectively through a hands-on experience, may prefer to engage in an activity related to the topic, or use the information in trial and error exercises. They like applying course material in new situations to solve real problems. Accommodators learn from interactions with others, and can be characterized as being risk takers, and enjoying new challenges and experiences (Kolb, 1981).

5.2 LAYER 2

Layer 2 of this study, building on the findings during the 1st Phase of the action research, aimed to gain a different perspective and insight of the students' competence development during the professional practice problem and project based learning course.

The competence development was assessed by students' perception of their skills level of success, importance and course contribution of the skills development.

Layer 2 data was collected and analysed during the 2nd and the 3rd Phase of the research.

The research used quantitative research methods for data collection and different statistical methods for data analysis due to different data in the 2nd and the 3rd Phase.

The goal was to analyse the overall difference of assessment of these three broader dimensions as well as the specific assessment of different skills on these dimensions in order to gain insight into the possibilities of the further development and improvement of the course.

In the 2nd Phase the data regarding competence importance and development was collected only after the course. The course contribution to skills development was measured directly, by asking student to asses this contribution on the scale from 1 to 4.

In the 3rd Phase, the data regarding competence importance and development was collected both before and after the course. In this phase the professional skills levels assessment was added. The research was aimed at determining the level of success in generic and professional skills before and after the course, in order to gain insight into the effectiveness of the implemented educational strategies. The contribution of the course to the skills' development was measured indirectly, through the difference in the perceived skills' level of success PRE course and POST course, and the significance of this difference.

2nd Phase data was analysed using descriptive statistics for data analysis.

3rd Phase data was analysed using descriptive and nonparametric statistics (Wilcoxon signed-rank test) for data analysis due to the size of the data sample in 3rd Phase data.

All the statistical analysis are performed by using IBM SPSS Statistics 21.

TABLE 5-3 LAYER 2 PARTICIPANTS

Group/Semester	*C1: IV year 2010/2011*	*C2: IV year 2011/2012*	*C3: Master 2011/2012*	*C4: IV year 2011/2012*	*C5: IV year 2012/2013*	*C6: IV year 2013/2014*	*Total*
Number of participants in Layer 2	8	22	8	5	13	20	76
Generic competence importance, level of success, course contribution POST	8	22	8	5	x	x	43
Generic competence importance, level of success PRE/POST	x	x	x	x	13	20	33
Professional competence level of success PRE/POST	x	x	x	x	13	20	33

TABLE 5-4 LAYER 2 RESEARCH INSTRUMENTS

No		*What is measured*	*Instrument*	*Type*	*Time*
1-5	Layer 1				
6	✶ Determine the importance students give to generic skills ✶ Determine the level of success that students perceive regarding their generic skills achievement ✶ Determine the contribution of the practice-based module for the generic and professional skills development	Generic skills importance, level and course contribution (self-assessed)	Survey 2 (SURV2)	Scaled survey	End
7	✶ Determine the importance students give to generic skills PRE and POST course ✶ Determine the level of success that students perceive regarding their generic skills achievement PRE and POST course	Generic skills importance and level (self-assessed)	Survey 3 (SURV3)	Scaled survey	Start End
8	✶ Determine the level of success that students perceive regarding their professional skills achievement PRE and POST course	Professional skills importance and level (self-assessed)	Survey 4 (SURV4)	Scaled survey	Start End
9-10	Layer 3				

5.2.1 SCALED SURVEY 2ND PHASE

The data in the 2nd Phase was collected at the end of each of four 10-week courses in the period from 2011 to 2013 (Course 1, Course 2, Course 3 and Course 4). The data was collected form 43 fourth (final) year of the academic studies of the School of Electrical Engineering in Belgrade (

Table 5-3)

Layer 2 data in this Phase was collected through:

- Generic skills importance, level and course contribution Survey 2 (SURV2)

Survey 2 was aimed at determining various aspects of student generic competences assessments: the level of success, the importance of competences for the future work and the contribution of the course to the development of competences.

At the end of each course students evaluated each of the above mentioned 13 generic skills on three dimensions: the perceived level of success, the perceived importance of the skill for their future profession and the contribution of the course to the skills' development.

Each skill was evaluated by the level of success on the scale from S_{min}=1 to S_{max}=4, with 1 being the lowest score and 4 the highest score. Thus, there were three overall scores: the overall level of success in performing different skills, the overall importance of different skills for the future profession and the overall contribution of the course to the development of different skills. Evaluation of these dimensions was performed for each of the N_{SS}=13 generic skills.

The design of the questionnaires was based on the questionnaire presented in the study of the importance and the level of achievement of the undergraduate students competencies, based on the Tuning project framework of competencies assess the importance of generic competencies for their future professions. (Milica Gerasimović & Miškeljin, 2008)

5.2.2 SCALED SURVEY 3RD PHASE

The data in the 3rd Phase was collected at the beginning and at the end of the two 10-week courses in the period from 2013 to 2014 (Course 5 and Course 6). The participants in the study were 33 students of the fourth (final) year of the academic studies of the School of Electrical Engineering in Belgrade, 13 female and 20 male (

Table 5-3)

For the items in this Layer data were collected through:

- Generic skills importance and level PRE and POST Survey 3 (SURV3)
- Professional skills level PRE and POST Survey 4 (SURV4)

Generic skills importance and level PRE and POST Survey 3 (SURV3) contains the same items as SURV2 described in Section 4.3. The only difference is that skills are not assessed for the course contribution.

Professional skills level PRE and POST Survey 4 (SURV4) was aimed at determining the level of success of student professional competences assessment. This is a 7-item survey (Appendix 1 – Research instruments used in the study) created to measure students' self-perceptions of their current level of success in professional skills and competences and indirectly the course contribution to these skills development.

At the beginning and at the end of each course students evaluated each of the 13 generic skills on two dimensions: the perceived level of success and the perceived importance of the skill for their future profession.

At the beginning and at the end of each course students evaluated each of the above mentioned 7 professional skills on the perceived level of success.

Each dimension was evaluated on the scale from 1 to 4, with 1 being the lowest score and 4 the highest score. Thus, we had three overall scores: the overall level of success in performing different skills, the overall importance of different skills for the future profession and the overall contribution of the course to the development of different skills. Also, we had the evaluation of these dimensions for each of the 13 skills.

The design of the questionnaires was based on the questionnaire presented in the study of the importance and the level of achievement of the undergraduate students competencies, based on the Tuning project framework of competencies assess the importance of generic competencies for their future professions. (Milica Gerasimović & Miškeljin, 2008)

Each skill was evaluated by the level of success on the scale from S_{min}=1 to S_{max}=4, with 1 being the lowest score and 4 the highest score. Thus, there were four overall scores: generic and professional skills success before and after the course. Evaluation of these dimensions was performed for each of the N_{SS}=13 generic skills and for each of the N_{PS}=7 professional skills.

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 two scores from the same participants in different situation) (Field, 2013). All the statistical analysis was performed by using IBM SPSS Statistics 21.

5.3 LAYER 3

Layer 3 data was collected only in the 3rd Phase. Data was collected at the beginning and at the end of the two 10-week courses in the period from 2013 to 2014 (Course 5 and Course 6). The participants in the study were 33 students of the fourth (final) year of the academic studies of the School of Electrical Engineering in Belgrade, 13 female and 20 male.

At four different moments during each course (T1, T2, T3, T4) students filled in a two lists.

For the items in this Layer data were collected through:

- ✶ Challenges list T1, T2, T3, T4 (CHALLPH)
- ✶ Skills list T1, T2, T3, T4 (SKILLPH)

TABLE 5-5 LAYER 3 PARTICIPANTS

Group/Semester	*C1: IV year 2010/2011*	*C2: IV year 2011/2012*	*C3: Master 2011/2012*	*C4: IV year 2011/2012*	*C5: IV year 2012/2013*	*C6: IV year 2013/2014*	*Total*
Number of participants in Layer 3	x	x	x	x	13	20	33
Phased Challenges	x	x	x	x	13	20	33
Phased skills	x	x	x	x	13	20	33

TABLE 5-6 LAYER 3 RESEARCH INSTRUMENTS

No		*What is measured*	*Instrument*	*Type*	*Time*
1-5	Layer 1				
6-8	Layer 2				
9	✶ Determine how the major issues and challenges are distributed over different stages of the ill-structured problem solving	Challenges in different phases of the learning experience.	Challenges list (CHALLPH)	Order/level	T1, T2, T3, T4
10	✶ Determine how the skills development is distributed over different stages of the ill-structured problem solving	Skills in different phases of the learning experience.	Skills list (SKILLPH)	Scaled survey	T1, T2, T3, T4

The Challenges list was aimed at determining their greatest challenges at that particular moment during the course, while the Skills list was aimed at determining the skills that students perceived that they developed till that particular moment during the course.

5.3.1 ORDER/LEVEL LIST AND SCALED LIST

Challenges list is an order/level list in which students they were asked to choose 5 out of 18 proposed challenges and then order them from 1 to 5, giving the order of 1 to the most difficult one and the order of 5 to the least difficult of the five chosen challenges.

The design of the Challenges list was inspired by (Purzer et al., 2011).

However, the challenges that I chose for this list originated in the research form Layer 1 where main challenges that students encounter during the course were found, as presented in Section 6.2

The list of challenges is presented in Section 4.4

Consequently, the surveys were carried out in 4 points in time, with the timing as follows:

TABLE 5-7 LAYER 3 INSTRUMENT TIMELINE AND DESCRIPTION

Class	*Instrument submission time*	*Instrument Description*
4th class	T1	Students selected and ranked 5 challenges and assessed the development of each of generic skills in the previous 2 classes (CHALLPH and SKILLPH)
6th class	T2	Students selected and ranked 5 challenges and assessed the development of each of generic skills in the previous 2 classes (CHALLPH and SKILLPH)
8th class	T3	Students selected and ranked 5 challenges and assessed the development of each of generic skills in the previous 2 classes (CHALLPH and SKILLPH)
10th class	T4	Students selected and ranked 5 challenges and assessed the development of each of generic skills in the previous 2 classes (CHALLPH and SKILLPH)

The Skills list was composed of 12 skills. Each skill was evaluated by the level of success on the scale from S_{min}=1 to S_{max}=10, with 1 being the lowest score and 10 the highest score. Thus, there were four overall scores: generic skills success at moments T1, T2, T3 and T4. Evaluation of these dimensions was performed for each of the N_{SS}=12 generic skills.

Each issue and challenge that was ranked from 1 to 5 was coded by the powers of 10 to 2, 10 corresponding to the greatest challenge rank of 1, 8 to the rank of 4, 6 to the rank of 3, 4 to the rank of 4 and 2 to the lowest rank of 5.

Descriptive statistics was used for data analysis of the Survey 3.

6 LAYER 1 RESULTS: ISSUES, CHALLENGES AND EVALUATION OF THE LEARNING EXPERIENCE

In this Chapter the results of the Layer 1 of the research and discussion of the findings are presented.

The objectives of the Layer 1 were to provide the basic understanding of the issues and challenges that students face during ill-structured problem solving, explore students' perception of the course importance for their personal and professional development, as well as their evaluation of the course and of the learning experience. Additionally, this research layer aimed at exploring students' motivation to attend the course and determining students' learning styles.

Layer 1 research extended over four years, from 2011 to 2014 and comprised all the three phases (1st, 2nd and 3rd Phase) of the research, with data from all the six courses that I held as instructor during these four years.

6.1 FINDINGS RELATED TO THE PROBLEM SOLVING MODEL

In the beginning of each course students were presented with problem solving models, and instructed to create a model of their own, that should be the group's problem solving model.

Problem solving models are presented for each course:

1st course

- Precisely define and analyse given parameters and conditions and for them
- Find the algorithm
- Optimize
- Do the best we can with what we have
- Find the most efficient solution

2nd and 3rd Course

- What the system should do (Problem analysis)
- Plan
- Prototyping
- Prototype testing
- Technical realization

- Testing

4th Course

- Determination of requirements
- Theory studying
- Getting to know past experiences
- Project
- Planning the devices and materials
- Implementation (connect everything according to the project)
- Testing
- Comparison with the initial problem (request)

5th Course

- Analysis
- Acquire the Team
- Preliminary conceptual design
- Work assignments
- Constraints (technical, financial)
- Conceptual Design
- Procurement of the system components
- System implementation
- Testing
- Elaboration of system documentation
- User training
- Maintenance

6th Course

- Investigate the cause of the problem, and the consequences
- Consider ways of solving it
- Find the optimum solution
- Testing
- Repeat the procedure

6.2 FINDINGS RELATED TO ISSUES AND CHALLENGES OF THE LEARNING EXPERIENCE

This section includes description of the findings and discussion about the issues and challenges of the learning experience that students went through during the course.

Research question:

- What are the major issues and challenges that students experience during ill-structured problem solving?

6.2.1 ISSUES AND CHALLENGES

6.2.1.1 WHERE DO I START? DEFINE THE ILL-STRUCTURED PROBLEM.

Problem analysis and definition of client requirements is the crucial starting point of the project work as students are encouraged to deal with the definition of an ill-structured problem. The task at hand is not given in sufficient detail, and some of the main inputs are omitted on purpose. Teams have to struggle to get to the definition of the problem before starting to solve it. For this purpose, the instructor is the client in question and makes all the necessary clarifications on the required system that students ask for. Dividing the task into smaller parts and analysing each one of them helped. This phase was critical for learning to ask questions.

6.2.1.2 LEARNING TO ASK QUESTIONS

Obviously, asking questions is the only way of finding out what the client really wants. Questioning is clearly an integral part of a design (Dym et al., 2005) but it has to be learnt and practiced. The common mistake discovered was that students, instead of asking questions, made assumptions of their own. Once they started working with erroneous assumptions, they were lead into undesired directions – because they never asked questions. This is closely related to defining the ill-structured problem, where students learn to ask the client about his requirements. This is also where the instructor can help. After letting students fail in their endeavour, after a few hours' work, either they themselves or with the help of the instructor posed questions they understand that they have made a mistake and go back to the starting point to try again, but this time including asking questions.

6.2.1.3 CONNECTING THEORY AND PRACTICE

Students mostly have theoretical knowledge on different topics such as radio systems, path analysis and wireless access systems, but have never considered actual forms that equipment takes. At first, students are reluctant to draw block diagrams though later they realize that it is a necessary part of the solution. They are also instructed to consult Regulatory constraints and requirements, to look for

Regulatory body's frequency usage plans and are encouraged to interpret and use them as criteria for solution building. 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. Matching interfaces of different equipment represented the tough task of putting it all together to fulfil the required purpose.

6.2.1.4 SELF-GUIDED STUDY AND INFORMATION GATHERING

The client's requirements were translated to the technical language but they contained black boxes that had to be filled with corresponding equipment. Checking the available equipment and possible system configurations is based on the Internet search. This is the task that most students are not familiar with and in the beginning they have a hard time interpreting equipment data sheets and matching them to fit black boxes. The tasks are divided within teams, each member dealing with one part of the problem. This is the second key phase of the project, crucial for the conceptual design of the system.(T. A. Litzinger et al., 2011a)

6.2.1.5 FACING THE REALITY: SITE SURVEY

A visit to the sites where the system is to be installed is an obligatory part of the project work. All teams visit the sites with the instructor. During the site survey, each team modifies its own solution according to the actual site conditions. This part of the project work is when the students face reality for the first time during their project work as they are asked to determine installation conditions. Power supply possibilities are sought for as well as masts or other support for wireless and point-to-point equipment installation. Sketches and photos of the terrain and equipment location are made, including relevant power supply distances.

6.2.1.6 DEALING WITH AMBIGUITY AND TRADE-OFFS

Dealing with ambiguity was found to be especially hard for some of the students. It seems difficult for them to grasp the idea that there is not one correct and right solution, but that there are more solutions that fit. They insisted on knowing the "correct" answer, and not being able to find one brought disappointment to some of them. 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. Comparison of solutions is an iterative process going on during the whole preliminary design phase. At this stage, students find it difficult at first to work with feasibility criteria and this is where they need more instructor guidance.

Our results support previous research that problem based learning causes some discomfort and frustration among students as the necessary information is not readily available like traditional lecture.

Simon argues that there is initially no definite criterion to test a proposed solution to an ill-structured problem, much less a mechanizable process to apply the criterion. The problem space is not defined in any meaningful way, for a definition would have to encompass all kinds of structures that architect might at some point consider, all considerable materials, all design processes and organizations of design processes. The hopelessness of even trying to sketch the congeries of elements that might have to be included in the specification of a problem space proves the greater hopelessness of defining in reasonable compass a problem space that could not, at any time during the problem solving process, find its boundaries breached by the intrusion of new alternatives.

6.2.1.7 CLEAR COMMUNICATION

Communicating with suppliers and learning to define well what one is looking for are skills developed through inquiring about prices and terms of delivery of the equipment. These are obtained on the Internet, but in case they were unavailable, a team was required to send an e-mail to the instructor who then had the role of equipment/material provider. This task teaches students to define well what they are looking for. That is, instead of asking for a quote for "a cable we need for the radio link", the student is instructed to define the cable type, connectors, length, etc. if s/he wants to get the appropriate answer. Communication with the instructor was in most cases a part of the role play where instructor was a client or a supplier. Otherwise it implied a direct request for help on different issues. However, the instructor's answers always served as guidance – students were at all times left to find answers on their own. Communication with other teams was found to be surprisingly collaborative – in general, all queries by other teams were considered and handled friendly and helpfully which fostered the development of collaborative atmosphere of the course.

6.2.1.8 DEALING WITH FAILURE

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, since they did not want to appear "unknowledgeable". Teachers' role and guidance may be crucial at this point, as well as safe and supporting environment. *S16:"We learned not to desist even if solving (the problem) seemed impossible".* It is important that students are allowed the opportunity and time to fail and try again since in practice the failure is a mechanism for learning to do better. The attitude that failure isn't failure should be promoted.

6.3 OVERALL COURSE EVALUATION

This section includes the findings on the overall course evaluation.

Research question:

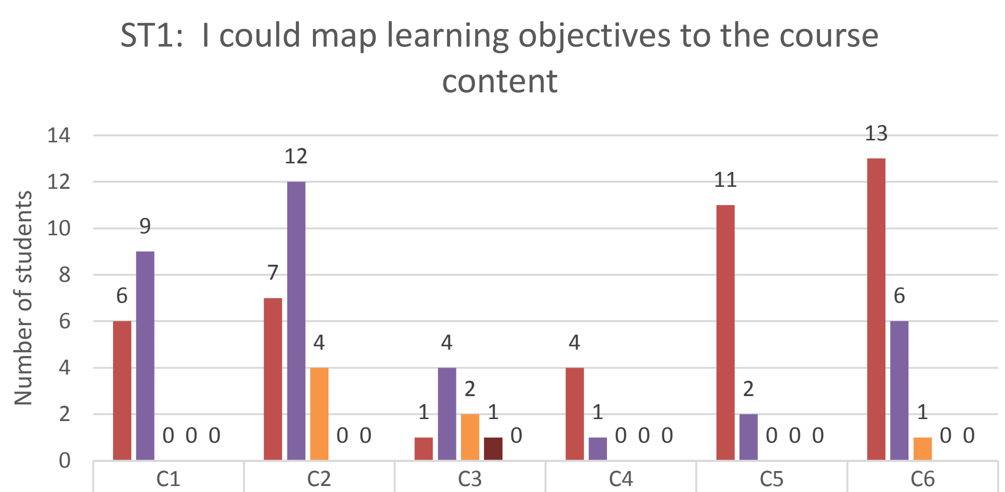
- How do students evaluate the professional practice module?

The course was evaluated on 13 different items on Likert type 5-level scale which ranged from 1 (Strongly Disagree) to 5 (Strongly Agree).

The last, 13th item regarding Sustainable development interest is presented in the next section.

Students filled in the survey at the end of the course. The only exception was that not all the questions were present in the 1st Course, which is clearly marked on the graphs.

The results are presented for each of the statements of the survey, where separate results are presented for each of the six courses (C1: 1st Course to C6: 6th Course) showing the number of students per course that selected each of the scores from Likert scale (1 - Strongly Disagree, 2 – Disagree, 3- Neither Agree nor Disagree, 4 – Agree, 5 - Strongly Agree).



	C1	C2	C3	C4	C5	C6
5	6	7	1	4	11	13
4	9	12	4	1	2	6
3	0	4	2	0	0	1
2	0	0	1	0	0	0
1	0	0	0	0	0	0

FIGURE 6-1 MAPPING THE LEARNING OBJECTIVES TO THE COURSE CONTENT

The results (Figure 6-1) demonstrate that the vast majority of students consider that they could map the learning objectives to the course content (51% of students “Strongly Agree”, 40% “Agree”, 8% is “Neither Agree nor Disagree” and 1% “Disagree”), which indicates that objectives are set clearly and that students understand them. However, in the case of bigger groups (such as C2 or C6) more attention should be put into linking the course objectives with course content.

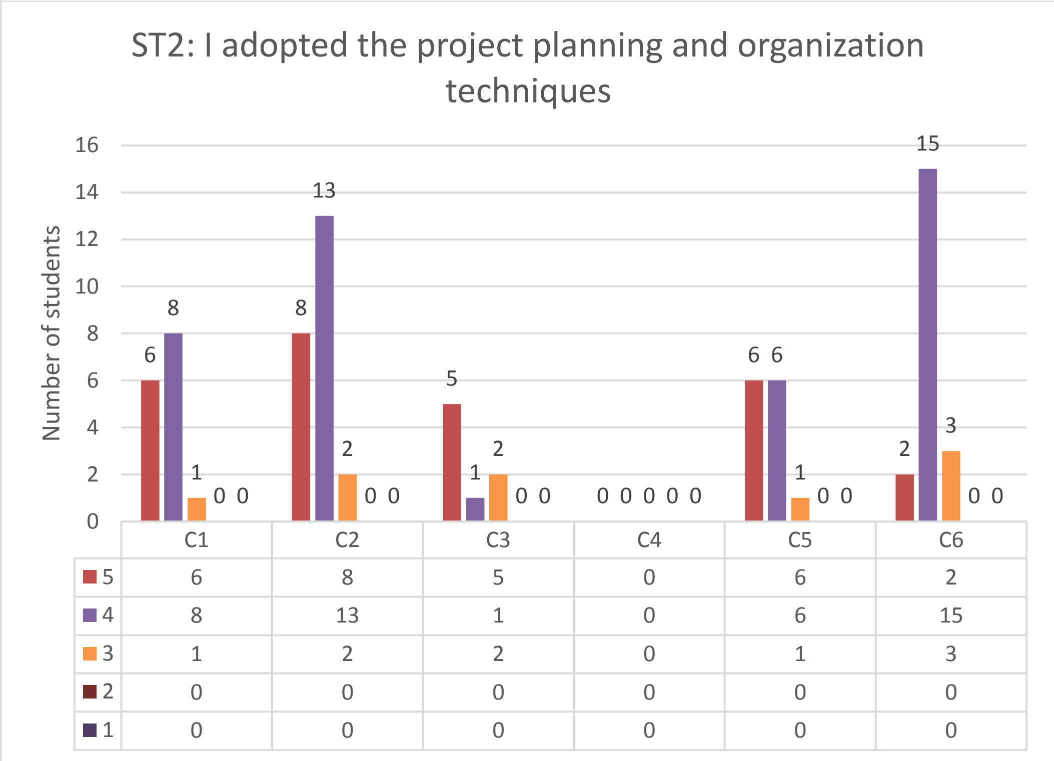
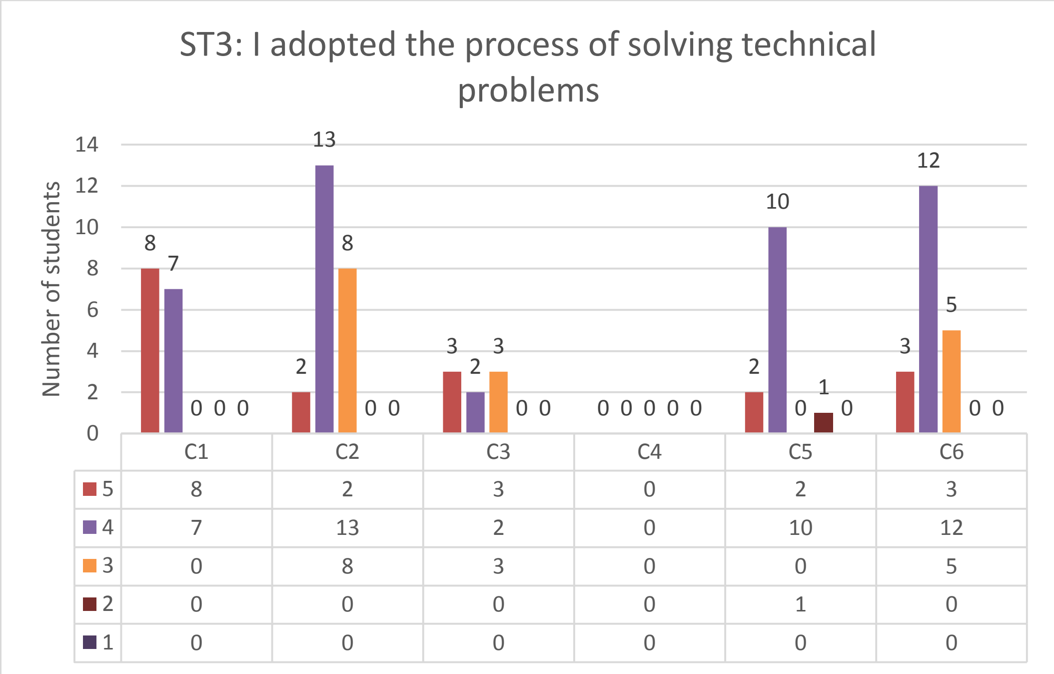


FIGURE 6-2 ADOPTING THE PROJECT PLANNING AND ORGANIZATION TECHNIQUES

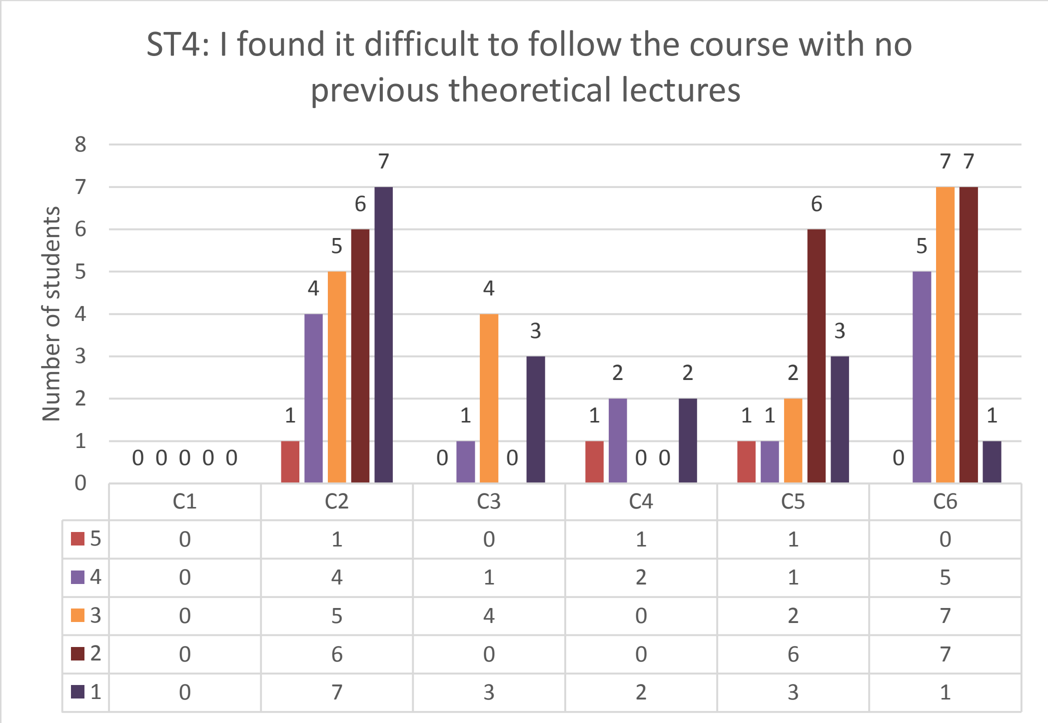
Regarding the adoption of the project planning and organization techniques, the results (Figure 6-2) demonstrate that though less than half of the students “strongly agree”, vast majority considers that they have adopted these techniques, and none of the students marked any level of disagreement with this statement (32% “Strongly Agree”, 51% “Agree”, 11% “Neither Agree nor Disagree”). It can be concluded that a very high percentage of the total number of students considers that they have adopted project planning and organization techniques (84%) thus demonstrating that the course has fulfilled one of its stated objectives.



	C1	C2	C3	C4	C5	C6
5	8	2	3	0	2	3
4	7	13	2	0	10	12
3	0	8	3	0	0	5
2	0	0	0	0	1	0
1	0	0	0	0	0	0

FIGURE 6-3 ADOPTING THE PROCESS OF SOLVING TECHNICAL PROBLEMS

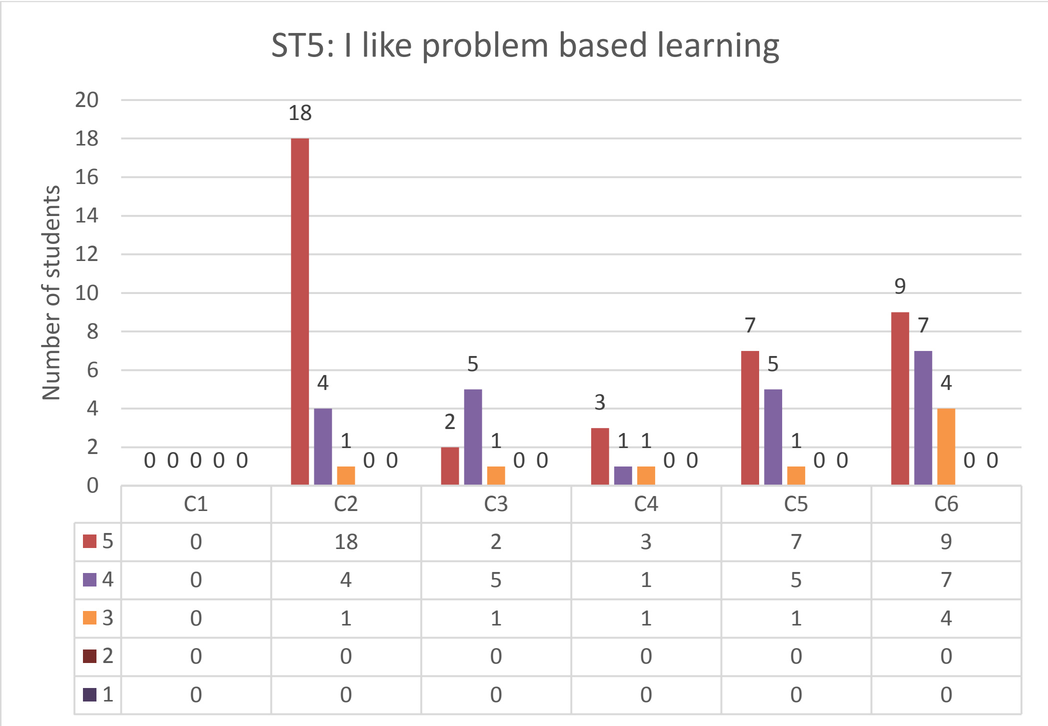
The results (Figure 6-3) demonstrate that more than half of the total number of students consider that they adopted the process of solving technical problems (55,70% “Agree”), while slightly less than a quarter “Strongly agree“ (22,78%) with the statement, making for a total of around 78% of students that are positive about adopting this process. Considerable percentage is neutral (20, 25% “Neither Agree nor Disagree”) while a small percentage of 1, 27% “Disagree”. The results indicate that more effort should be put in the technical problem solving guidance.



	C1	C2	C3	C4	C5	C6
5	0	1	0	1	1	0
4	0	4	1	2	1	5
3	0	5	4	0	2	7
2	0	6	0	0	6	7
1	0	7	3	2	3	1

FIGURE 6-4 DIFFICULTY IN FOLLOWING THE COURSE WITHOUT PREVIOUS THEORY

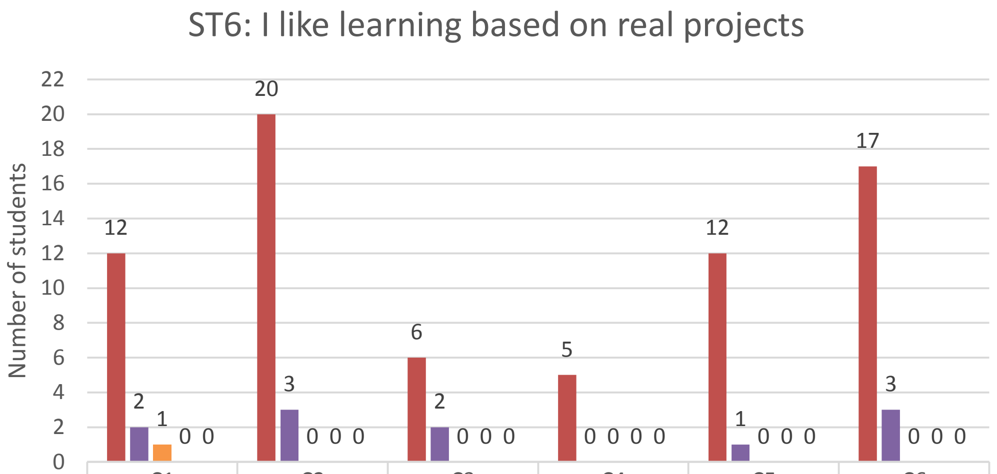
Q4 was a “reverse” question to test the student consistency and integrity in filling in the survey. The results (Figure 6-4) demonstrate that no students “Strongly Agree” with the claim, 23,19% of the students found it difficult to follow the course with no previous lectures (“Agree”), 26,09% were neutral, while a total of 50,73% “Disagree” or “Strongly Disagree” with this claim. These results indicate that considerable number of students perceives that they need theoretical lectures on some of the topics that they will be faced with once they enter work environment, and on which they will be offered no theory once they start working. This indicates that more effort is needed in raising students’ awareness of the lifelong learning and self-guided learning. Q4 was not part of the survey for the 1st Course.



	C1	C2	C3	C4	C5	C6
5	0	18	2	3	7	9
4	0	4	5	1	5	7
3	0	1	1	1	1	4
2	0	0	0	0	0	0
1	0	0	0	0	0	0

FIGURE 6-5 INCLINATION FOR PROBLEM BASED LEARNING

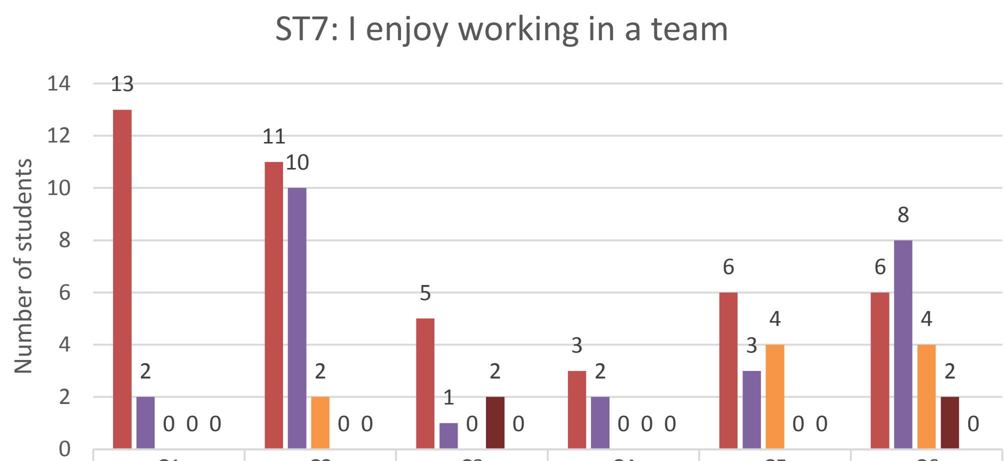
The results (Figure 6-5) demonstrate that the vast majority (88,54%) of students like problem based learning: 56,52% students “Strongly agree” and 31,88% “Agree”, while 11,59% are neutral. No students marked “Disagree” or “Strongly Disagree” options which indicates that students are very much in favour of learning in and accepting problem based learning environments. Q5 was not part of the survey for the 1st Course.



	C1	C2	C3	C4	C5	C6
5	12	20	6	5	12	17
4	2	3	2	0	1	3
3	1	0	0	0	0	0
2	0	0	0	0	0	0
1	0	0	0	0	0	0

FIGURE 6-6 INCLINATION FOR LEARNING BASED ON REAL PROJECTS

The results (Figure 6-6) are strongly in favour of learning based on real projects: 98,81% of students like learning based on real projects: 85,71% “Strongly Agree” and 13,10% “Agree”, only 1,19% are neutral and no students marked “Disagree” or “Strongly Disagree” options. The results demonstrate that students are by important majority more certain that they like project based learning than problem based learning, which should be considered in designing future instructional modules.



	C1	C2	C3	C4	C5	C6
5	13	11	5	3	6	6
4	2	10	1	2	3	8
3	0	2	0	0	4	4
2	0	0	2	0	0	2
1	0	0	0	0	0	0

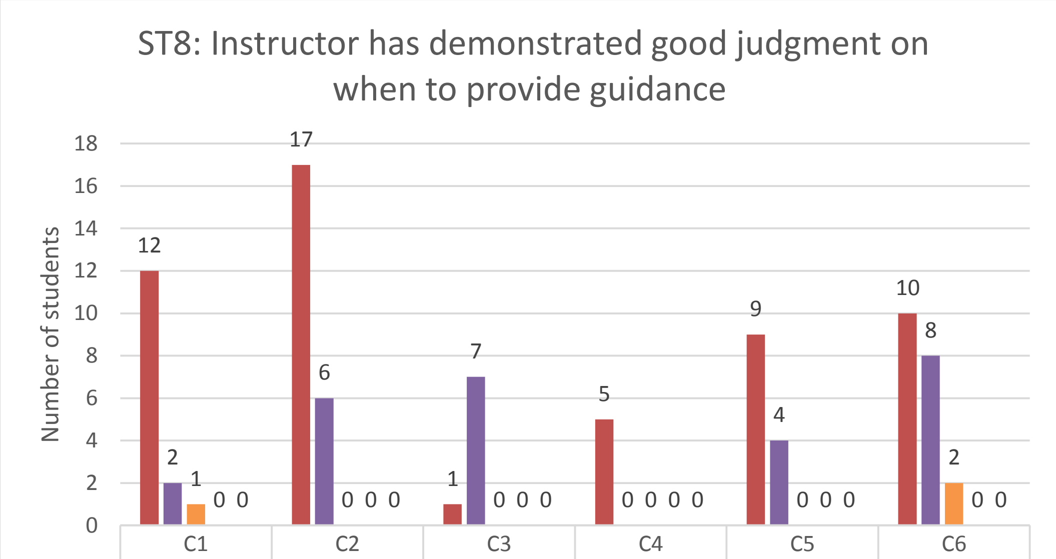
FIGURE 6-7 ENJOYING TEAMWORK

As for the teamwork, more than half of the students “Strongly Agree” that they enjoy it (52,38%), 30,95% “Agree” 11,90% is neutral but there are 4,76% of students that do not enjoy it (“Disagree”). This issue could be further investigated in the future by finding the reasons for this dislike - however, this percentage is very low and no students marked “Strongly Disagree” which indicates a very balanced approach to learning when teamwork is concerned. (Figure 6-7)

Q8 and Q9 evaluated the instructor:

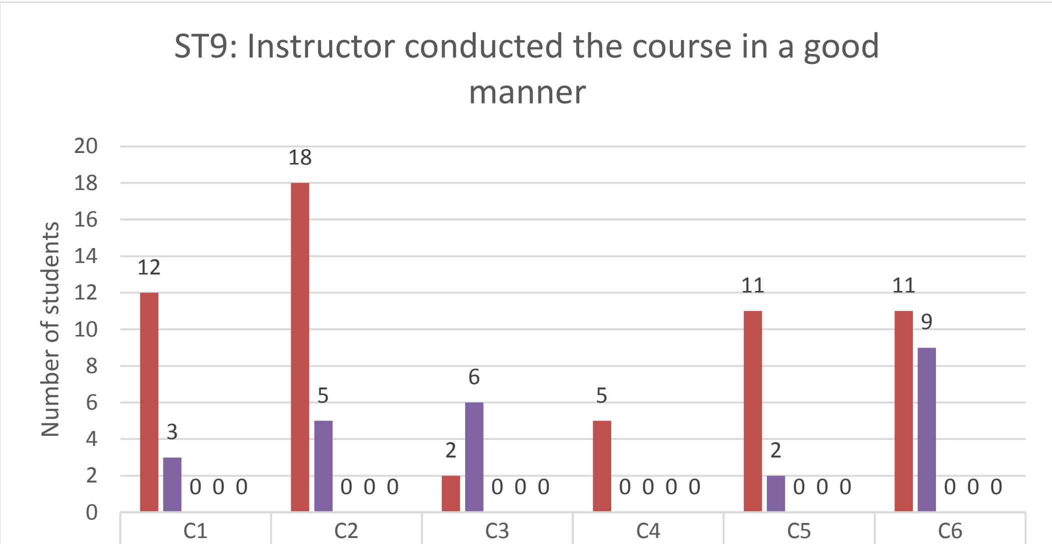
The evaluation of the instructor’s good judgement on when to provide guidance shows that vast majority (96,43%) of the students consider this true: 64,29% “Strongly Agree”, 32,14% “Agree” and there are 3,57% neutral answers. None of the students disagree with this statement. These results indicate that by vast majority the students perceive that the instructor’s approach is satisfactory (Figure 6-8).

Similar results are shown for the overall evaluation on how the instructor conducted the course (Figure 6-9), though in this case 100% of the students gave positive answers: 70,24% of the students “Strongly Agree” that the instructor conducted the course in a good manner, 29,76% “Agree” with this statement and there are none neutral or disagree options selected. These results confirm the previous conclusion, that the instructor’s overall approach was excellently accepted by the students, though they indicate that the judgement on when to provide guidance could be improved.



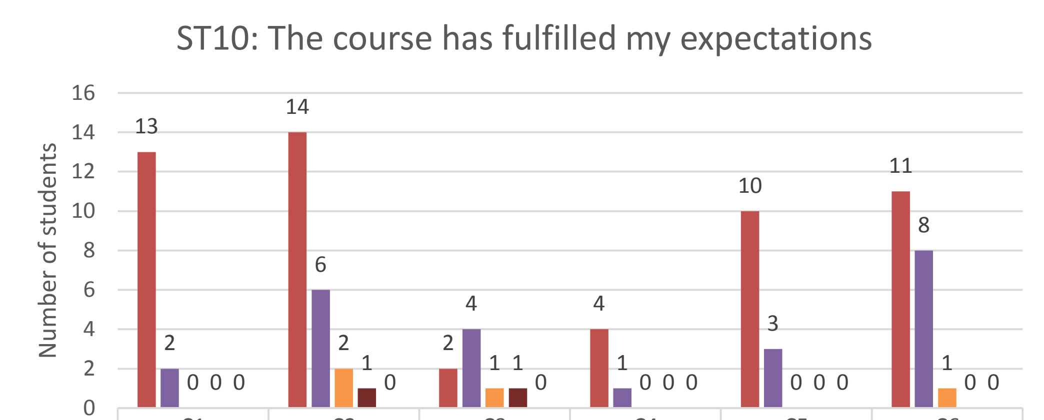
	C1	C2	C3	C4	C5	C6
5	12	17	1	5	9	10
4	2	6	7	0	4	8
3	1	0	0	0	0	2
2	0	0	0	0	0	0
1	0	0	0	0	0	0

FIGURE 6-8 INSTRUCTOR GUIDANCE



	C1	C2	C3	C4	C5	C6
5	12	18	2	5	11	11
4	3	5	6	0	2	9
3	0	0	0	0	0	0
2	0	0	0	0	0	0
1	0	0	0	0	0	0

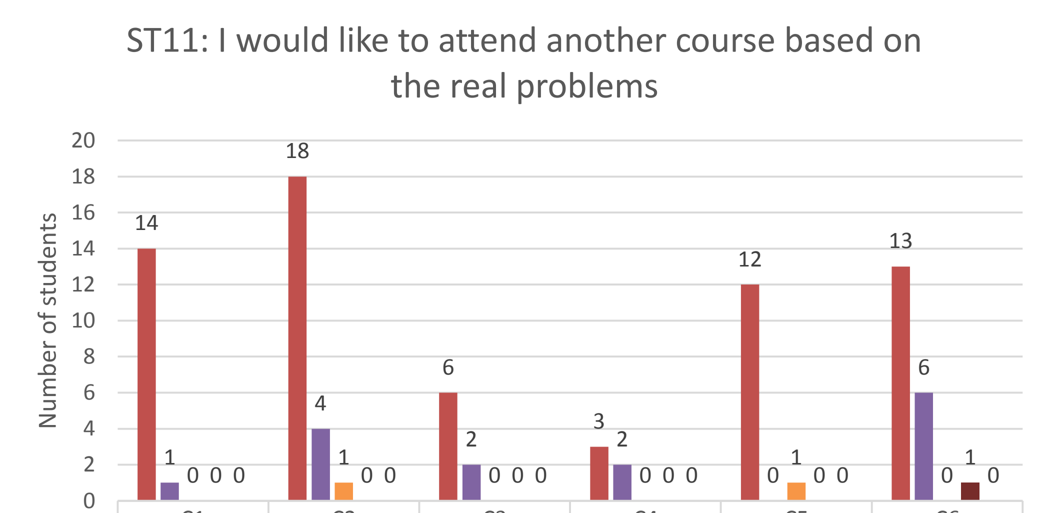
FIGURE 6-9 OVERALL INSTRUCTOR EVALUATION



	C1	C2	C3	C4	C5	C6
5	13	14	2	4	10	11
4	2	6	4	1	3	8
3	0	2	1	0	0	1
2	0	1	1	0	0	0
1	0	0	0	0	0	0

FIGURE 6-10 FULFILLED EXPECTATIONS

The results (Figure 6-10) indicate that 64,29% of the students “Strongly Agree” that the course has fulfilled their expectations, 28,57% “Agree”, 4,76% are neutral, and 2,38% “Disagree”. These results indicate that more effort could be put into prior information to the students so that they would have even more realistic expectations from the course.



	C1	C2	C3	C4	C5	C6
5	14	18	6	3	12	13
4	1	4	2	2	0	6
3	0	1	0	0	1	0
2	0	0	0	0	0	1
1	0	0	0	0	0	0

FIGURE 6-11 PREPAREDNESS TO ATTEND ANOTHER COURSE BASED ON REAL PROBLEMS

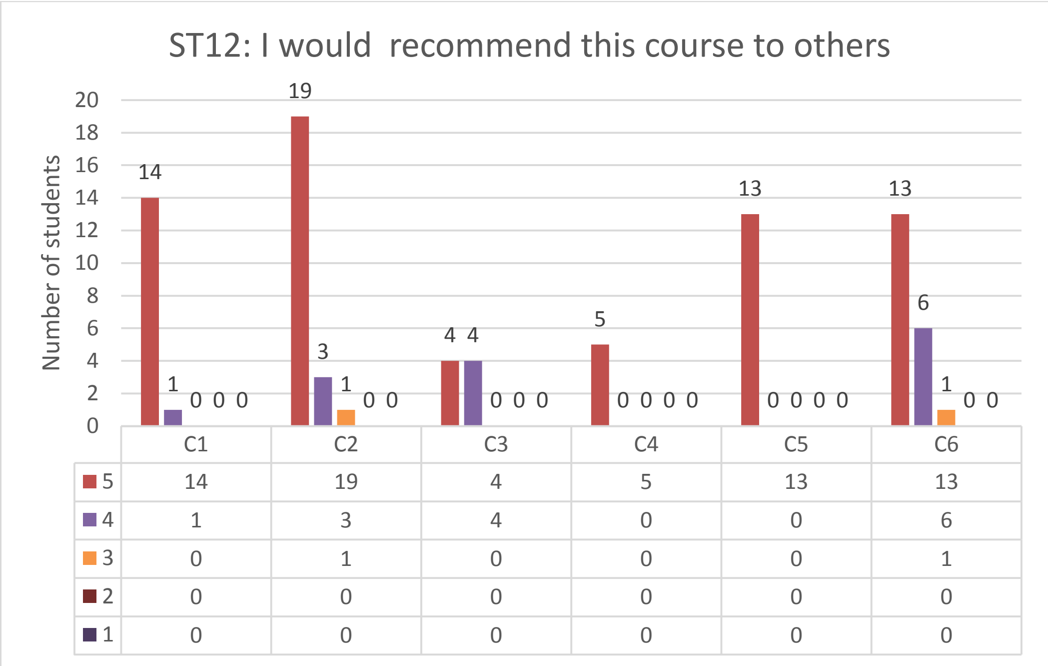
Based on the results (Figure 6-11), a total of 96,43% of the students would like to attend another course based on real problems (78,57% “Strongly Agree” and 17,86% “Agree”). There are 2,38% of neutral answers and 1,19% of the students would not be eager to attend another similar course (“Disagree”). These results indicate that nearly 100% of the students would attend another similar course, thus indirectly confirming their preparedness to further engage in problem and project based learning based on real world ill-structured problems.

TABLE 6-1 OVERALL RESULTS OF THE COURSE EVALUATION SURVEY (IN % OF THE ANSWERS)

Stat. No.	*Statement item*	*Percentage per Likert scale answer*				
		Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
ST1	I could map the learning objectives to the course content	50,00%	40,48%	8,33%	1,19%	0,00%
ST2	I adopted the project planning and organization techniques	34,18%	54,43%	11,39%	0,00%	0,00%
ST3	I adopted the process of solving technical problems	22,78%	55,70%	20,25%	1,27%	0,00%
ST4	I found it difficult to follow the course with no previous theoretical lectures	4,35%	18,84%	26,09%	27,54%	23,19%
ST5	I like problem based learning	56,52%	31,88%	11,59%	0,00%	0,00%
ST6	I like learning based on real projects	85,71%	13,10%	1,19%	0,00%	0,00%
ST7	I enjoy working in a team	52,38%	30,95%	11,90%	4,76%	0,00%
ST8	Instructor has demonstrated good judgment on when to provide guidance	64,29%	32,14%	3,57%	0,00%	0,00%
ST9	Instructor conducted the course in a good manner	70,24%	29,76%	0,00%	0,00%	0,00%
ST10	The course has fulfilled my expectations	64,29%	28,57%	4,76%	2,38%	0,00%
ST11	I would like to attend another course based on the real problems	78,57%	17,86%	2,38%	1,19%	0,00%
ST12	I would recommend this course to others	80,95%	16,67%	2,38%	0,00%	0,00%
ST13	I am interested in learning more about the concept of sustainable development in some other course	48,10%	32,91%	16,46%	2,53%	0,00%

Students have stated that they would be very eager to recommend this course to others: 80,95% “Strongly agree”, 16,67% “Agree”, there are 2,38% neutral answers and none disagrees (Figure 6-12). These results indicate that nearly 100% of the students would recommend this course to others, thus indirectly confirming their satisfaction with the course.

The summary of the results from the course evaluation survey are shown in Table 6-1



	C1	C2	C3	C4	C5	C6
5	14	19	4	5	13	13
4	1	3	4	0	0	6
3	0	1	0	0	0	1
2	0	0	0	0	0	0
1	0	0	0	0	0	0

FIGURE 6-12 PREPAREDNESS TO RECOMMEND THIS COURSE TO OTHERS

6.4 FINDINGS RELATED TO STUDENTS' PERCEPTION OF THE LEARNING EXPERIENCE

In this Section the results related to the students' perception of the importance of the learning experience for their personal and professional development as well as their like/dislike for the course are presented.

Research questions:

- Why do students perceive the module as important for their personal and professional development?
- Why do students like/dislike the module?

6.4.1 IMPORTANCE FOR STUDENTS' PERSONAL AND PROFESSIONAL DEVELOPMENT

Results on the students' perception of the importance of the learning experience for their professional and personal development are shown in Table 6-2 . The grade of importance in Q1 and Q2 represents the mean obtained by grading the importance on the scale from 1 to 5 (1 – not important and 5 - very important). It is presented for every course separately as well as a total value.

Answers to open ended questions Q1 and Q2 are grouped by categories, taking into account all the answers, where one student may have stated more than one category in his/her answer. These answers are presented by categories in the Table 6-2.

Students evaluate the course importance for their professional development with the mean grade of importance from 4,17 to 4,8, with the total mean value of 4,56.

Regarding the categories of answers regarding the importance for their future profession, the category that was stated by the vast majority of students was the opportunity to work on a real project and solve real engineering problems.

Actually for the majority this was the first course of this kind during their studies. As one of the students stated: "*I got an idea how it actually looks like in practice, I realized the way to connect it all, and I found out about some problems that I never thought of."(S1)*

TABLE 6-2 STUDENTS' PERCEPTION OF THE IMPORTANCE OF THE COURSE EXPERIENCE FOR THEIR PROFESSIONAL (Q1) AND PERSONAL DEVELOPMENT (Q2)

Group/Semester	*C1*	*C2*	*C3*	*C4*	*C5*	*C6*	*Total*
Answers by categories							
Q1: The experience gained at this course is important for my future profession because							
for the first time I experienced the work on a real project	5	9	1	1	4	9	29
I did practical work on project organization and execution	3	10	2	0	2	3	20
I gained the experience that will help me at work	3	5	3	0	3	5	19
I enhanced my problem solving process	3	6	1	0	3	5	18
I worked in a team	2	7	0	0	0	6	15
I connected the theory studied at the university with practice	5	2	1	0	1	3	12
Mean Grade of importance for future profession	4,8	4,17	4,63	5	4,38	4,4	4,56
Q2: The experience gained at this course is important for me personally because							
it brought me valuable teamwork experience	5	12	3	0	6	10	20
I feel more self-confident	6	4	3	0	1	3	13
I approach problem solving from the practice point of view	4	6	2	1	2	2	12
I communicate better with my colleagues	5	6	0	0	1	4	11
it enhanced my organizational skills	0	5	0	0	0	2	7
It enhanced my presentation skills	1	3	1	0	2	6	13
Mean Grade of importance for personal development	4,53	3,82	4	4,6	4	4,15	4,18

Some of the sample students' answers regarding the professional importance:

- *Because the professional practice gave me an insight into how my future profession could look like, and we acquired the knowledge on how to get to the information we need, how to design a system, how to ask questions (S55)*
- *For the first time I was able to think as an engineer, to view the system as a whole (S62)*

- *Because now I begin to understand what actual implementation of the project looks like, how to find the equipment, where to look for the solution, what kind of questions we need to ask, site survey…. (S67)*
- *for the first time we were faced with a completely undefined problem, as most of them in the future will be (S68)*
- *I have never paid attention to the soft skills, and now I can see how big is the difference*

Students evaluate the course importance for their personal development with the mean grade of importance per course ranging from 3,82 to 4,6, with the total mean value of 4,18.

FIGURE 6-13 STUDENTS' PERCEPTION OF THE IMPORTANCE OF THE LEARNING EXPERIENCE FOR P DEVELOPMENT

Regarding the importance for their personal development, the categories of answers are presented in Table 6-2 and Figure 6-14. The category that appeared as most frequently stated by the students was teamwork. (*S3: "I realized what my qualities were and I managed to improve some segments in my teamwork"*). Some of the sample students' answers of the personal importance:

- *I got the insight of what it means to work in a team and what kind of person I am for collaboration (S58)*
- *Augmenting the levels of tolerance. Accepting the differences, Work on self-confidence. Palpable work results. (S69)*
- *The course contributed to be more extrovert in the communication with team members, and to better express my ideas (S73)*

- *because I feel more self-confident about my knowledge and presentation to the group of people (S85)*
- *it is totally different from anything that I have done and seen before and it is a step forward in my development S46)*
- *I presented the conceptual design for the first time (S57)*
- *Now I see how much I still have to broaden my knowledge and skills (S36)*
- *I learned that it is not a shame to ask anything and that it is important to communicate (S31)*
- *At the first place working in a team, the necessity of communication, research on different ideas and systems (S28)*
- *Dealing with opposing views and finding compromise (S16)*

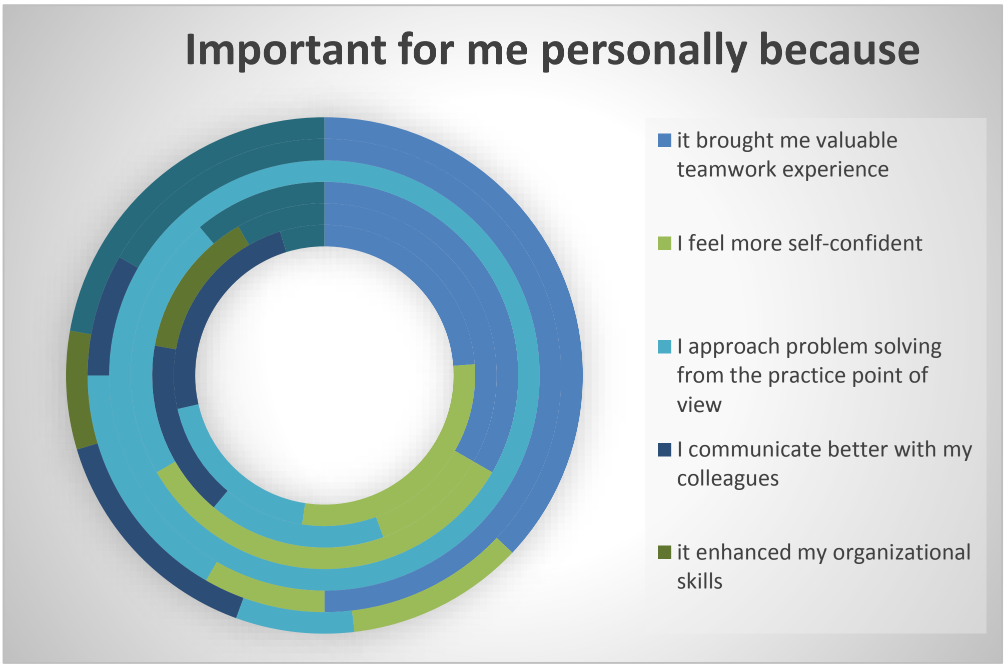


FIGURE 6-14 STUDENTS' PERCEPTION OF THE IMPORTANCE OF THE LEARNING EXPERIENCE FOR PERSONAL DEVELOPMENT

6.4.2 LIKE AND DISLIKE FOR THE COURSE

The open-ended questionnaire revealed what students liked the most about this course. The answers are ranked by the number of times stated in all of the courses.

Students stated few issues that they disliked about the course, mostly related to the schedule, classes being too early or too late, etc. Some of the suggestions for improvement were related to the fact that students would like to work on real world equipment, to be able to touch the equipment and install the designed system.

TABLE 6-3 WHY DO STUDENTS LIKE THE COURSE?

Theme No.	Sample students' answers
The approach to teaching and learning; process ownership and Instructor guidance	'I liked it all! The way of learning, without theory, getting the problem and working directly on a solution.' (S8);
	'Creativity and stimulation of engineering thinking.' (S9)
	'Each one of us was encouraged to perform our work – not even once did we get a ready answer from the instructor. We had to come up with a solution on our own.'(S10)
	'Putting the problem in front of us and from our part investing all our effort and knowledge into solving it' (S37)
	'I liked that I reached the solution on my own, and that I had the opportunity to ask all I wanted a person with extensive experience in telecommunications' (S35)
	'the methods, interactivity with the teacher, finding solutions to problems on our own' (S12)
	'I liked the fact that each team had different ideas, which is why we were able to appreciate different approaches to solving problems. Also, one of the most important things is the openness of the instructor and the way we worked at the course'(S13)
	'Instructor's guidance on how to get on the right track.'(S12)
Positive atmosphere	'What I liked the most is the atmosphere during the course, because we learned to work on a serious project in a more relaxed atmosphere.'(S14).
	'This is something that we did not do before and we need it for our further education and for the work that we will perform in the future' (S18)
	'We did not have the pressure of 'you must do this' and this is why it was easy to do it all' (S43)
	'Positive atmosphere and a very good approach of the instructor' (S2)
	'Atmosphere is what I liked the most. It was working and relaxed at the same time'
	'The atmosphere , which was great, and the flexibility in the work (we had all the necessary breaks, but we stayed as long as it was necessary to finish the work) ' (S33)
Teamwork	'I liked that each team had different ideas, so we could see different approaches to solving problems.' (S11).
Real project work	'Work on ill-defined problems, team work, being able to manage real problem solutions, conversations about what is actually in store for us at the workplace.'(S13) 'The work on the real problem and the entire process of problem solving, from analysis to implementation' (S16) 'Site visit, and solving real problems related to the system Implementation' (S18)
	'Problem solving, research, communication, engagement' (S22)
	'Getting to know all the phases of elaboration of the conceptual design of the project, as well as the atmosphere and the teacher - student relationship' (S34) Field visit and the search of the best solutions in the real location conditions (S45)
Diversity	Creativity and encouraging engineering thinking (S42)
	A change compared to the pure theory of the previous studies (S36)
	Finally I did something that can be applied (S27)

6.5 FINDINGS ON MOTIVATION AND LEARNING STYLE

The results regarding students' motivation to attend the course and their learning styles are presented in this Section.

Research questions:

- What is students' motivation to attend the module?
- How are the students' learning styles distributed?

6.5.1 MOTIVATION

Students' motivation to attend the course was assessed through their answers to the open-ended question in order to determine why they decided to pursue the course that is not obligatory and requires substantial effort on their part to attend the course lasting 80 hours.

We introduced this question only for the last two courses; therefore there are no answers for the 2010/2011 semester. The results are shown in Q3 (Table 6-4 and Figure 6-15).

As a motivation for attendance, most of the students mentioned work on a real project because it was extremely interesting and appealing; another motive was gaining new and practical experience, and fostering skills.

TABLE 6-4 STUDENTS' MOTIVATION TO ATTEND THE COURSE (Q3)

Group/Semester	*C1*	*C2*	*C3*	*C4*	*C5*	*C6*	*Total*
Answers by categories							
Q3: My motivation to attend this course was							
to work on a real project from practice because it is extremely interesting and appealing	n/a	15	1	2	2	1	21
to gain new and practical experience	n/a	10	4	1	1	1	17
to foster my skills	n/a	5	4	0	2	8	19
to complete the project task	n/a	1	1	3	1	7	13
to work in a team	n/a	3	1	1	1	4	10
to connect theory and practice	n/a	2	1	0	2	4	9

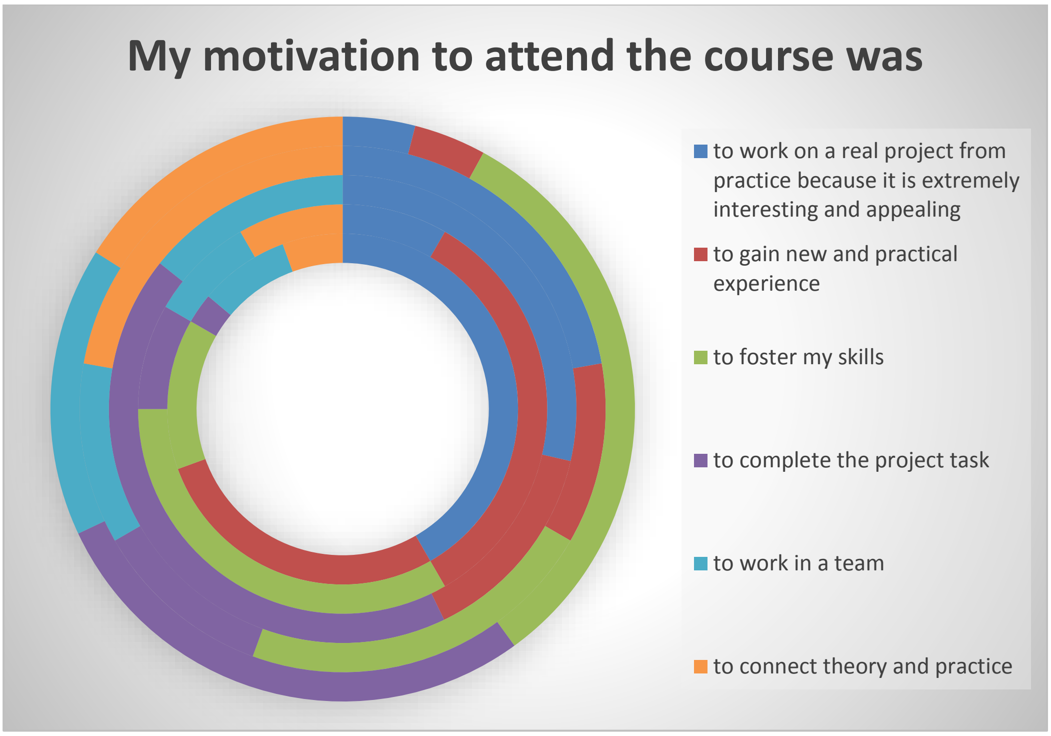


FIGURE 6-15 STUDENTS' MOTIVATION TO ATTEND THE COURSE

Some of the sample students' answers on the motivation to attend the course:

- *to learn all that was offered by the course, as well as working with my colleagues (S67)*
- *gaining practical experience and giving my contribution to the team (s68)*
- *the motivation to do all the work that needed to be done on time came from the team spirit and from the wish to succeed as a team, it was out of the question that someone could just sit and not do the work S76*
- *my main motivation was to get to know the problems from the practice , to develop my skills and to participate in team work (S29)*
- *my main motivation was that I saw that I would learn something , because the project is very well organized and helpful (S17)*
- *Unknown terrain. We did not get ready answers about everything as during our studies. (S8)*
- *My main motivation was to learn as much as I can about planning and organization (S40)*

6.5.2 LEARNING STYLES

The students' learning styles are nearly evenly between assimilating (47,5%) and converging (39%) learning styles, whereas accommodating (6%) and diverging (7,3%) are present in a minority of students.

TABLE 6-5 STUDENTS' LEARNING STYLES

Group/Semester	*C1*	*C2*	*C3*	*C4*	*C5*	*C6*	*Total*
Distribution of the learning styles							
Diverger	1	1	1	1	1	1	6
Assimilator	7	16	2	5	4	5	39
Converger	5	5	4	0	8	10	32
Accommodator	1	1	0	0	0	3	5

6.6 FINDINGS ON STUDENTS' INTEREST IN LEARNING MORE ABOUT SUSTAINABLE DEVELOPMENT

In this sections the results regarding the students' interest in learning more about sustainable development are presented.

Research question:

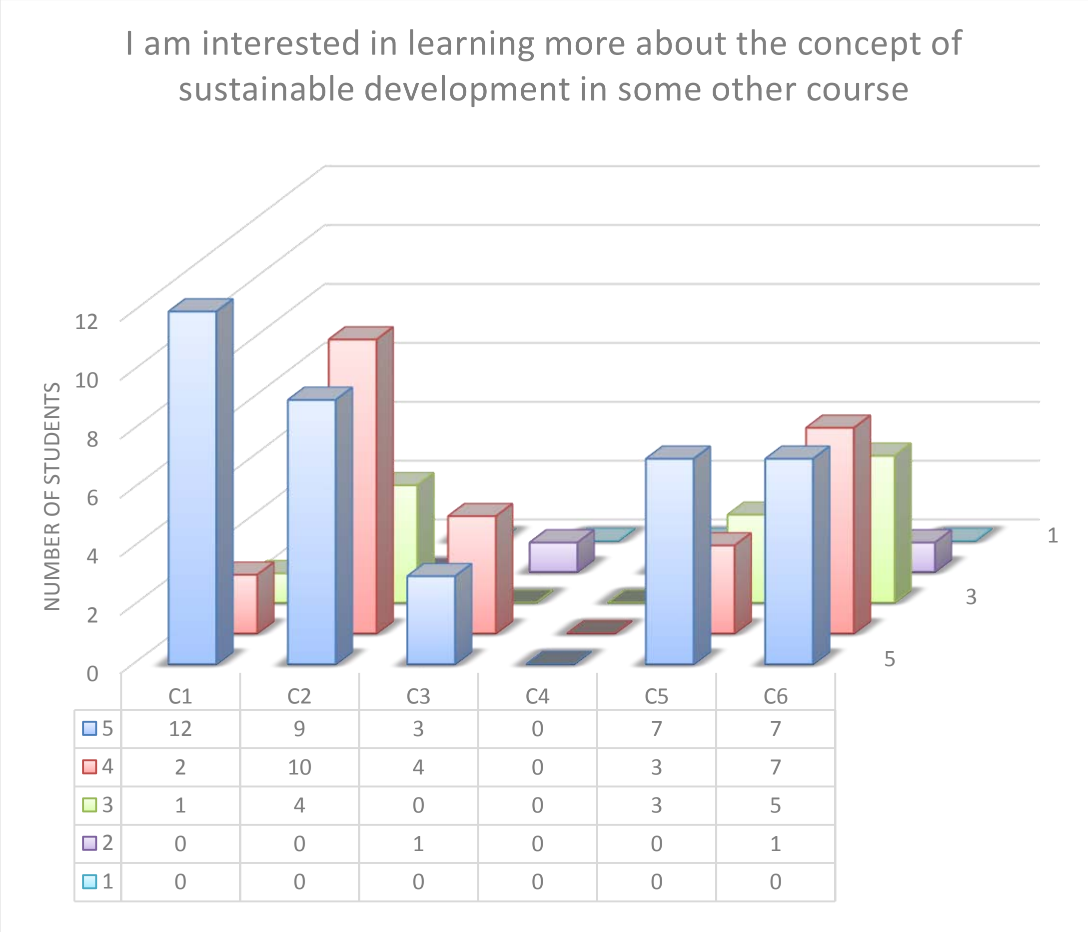
- What is students' interest in further formal instruction on sustainable development?

At the beginning of the session, the instructor always asked about their previous knowledge of the term and its meaning. Most of the students had never heard of it, and very few knew the meaning of the word.

The results indicate that students have significant interest (81,01%) in learning more about the concept of sustainable development in the future, where almost half of the students "Strongly Agree" (48,10%), 32,91% "Agree", 16,46% are neutral and 2,53% "Disagree".

The very low percentage of the students that disagree and no students that strongly disagree indicate that a future course that would include learning about sustainable development principles would not be rejected by students – on the contrary, the fact that almost half of the students "strongly agree" indicates that such a course would be very welcome.

The distribution of the answers per course is given on the Figure 6-16.



	C1	C2	C3	C4	C5	C6
5	12	9	3	0	7	7
4	2	10	4	0	3	7
3	1	4	0	0	3	5
2	0	0	1	0	0	1
1	0	0	0	0	0	0

FIGURE 6-16 INTEREST FOR LEARNING MORE ABOUT THE CONCEPT OF SUSTAINABLE DEVELOPMENT IN THE FUTURE COURSES

7 LAYER 2 RESULTS: COMPETENCE DEVELOPMENT

In this section results of the Layer 2 research are presented, which are aimed towards gaining insight into the students' competence development during the professional practice problem and project based learning course.

The competence development was assessed by students' perception of their skills' level of success, importance and course contribution of the skills development.

Layer 2 data was collected and analysed during the 2nd and the 3rd Phase of the research.

The empirical results of the 2nd Phase were obtained by the analysis of the POST course data and included only generic skills with direct course contribution measurement through a survey where students were asked to directly assess the level of course contribution to each of the generic skills development.

The empirical results of the 3rd Phase were obtained by the analysis of both PRE and POST course data and included both generic and professional skills, with indirect course contribution measurement by comparing PRE and POST data.

The research used quantitative research methods for data collection and different methods for data analysis due to different data in the 2nd and the 3rd Phase.

The goal of the research was to analyse the overall difference of assessment of these dimensions as well as the specific assessment of different skills in order to gain insight into the possibilities of the further development and improvement of the instructional design.

7.1 FINDINGS ON GENERIC SKILLS IMPORTANCE, LEVELS OF SUCCESS AND P*I*NG MODULE CONTRIBUTION – 2ND PHASE

The results on the generic skills importance, level of success and course contribution from 2nd Phase are presented in this Section. Skills' levels were self-assessed by students after the Course 2, Course 3 and Course 4 in the 2nd Phase.

The mean values and standard deviations of the particular skills' levels POST course are presented for generic skills. The theoretical mean value for each individual skill is:

$$TM = \frac{S_{\min} + S_{\max}}{2} = 2.5.$$

7.1.1 IMPORTANCE

The mean values and standard deviations of the particular skills' importance levels POST course are presented for generic skills in Table 7-1.

When it comes to rating the importance of individual skills, the results of the descriptive statistics as presented in indicate that they are relatively uniform, none of them falls below the value of 3.

At the end of the course the students evaluate following generic skills as more important in their future profession (above the median value):

- Teamwork - willingness to contribute to a common solution (M=3,81, SD=0,39)
- Communication - expressing opinion (M=3,77, SD=0,43)
- Ability to apply knowledge in practice (M=3,77, SD=0,48)
- Communication - asking questions (M=3,72, SD=0,55)
- Teamwork - willingness to accept differences of opinion (M=3,72, SD=0,45)

TABLE 7-1 DESCRIPTIVE STATISTICS FOR THE SKILLS IMPORTANCE LEVELS 2ND PHASE (ONLY POST)

Descriptive Statistics

	Generic skill	Mean	Std. Deviation
		Statistic	Statistic
S1.	Communication - expressing opinion	3,77	0,43
S2.	Communication - asking questions	3,72	0,55
S3.	Teamwork - willingness to contribute to a common solution	3,81	0,39
S4.	Teamwork - willingness to accept differences of opinion	3,72	0,45
S5.	Presentation	3,53	0,55
S6.	Finding relevant information on the Internet	3,47	0,63
S7.	Ability to apply knowledge in practice	3,77	0,48
S8.	Planning and organization	3,70	0,51
S9.	Solving ill-structured technical problems	3,23	0,68
S10.	Generating new ideas in the process of finding a solution	3,51	0,63
S11.	Ambiguity tolerance	3,09	0,75
S12.	Systems thinking - technical systems	3,38	0,62
S13.	Systems thinking - engineering in a social context	3,29	0,81

and the following generic skills as less important in their future profession (below the median value):

- Generating new ideas in the process of finding a solution (M=3,51, SD=0,63)
- Finding relevant information on the Internet (M=3,47; SD=0,63)

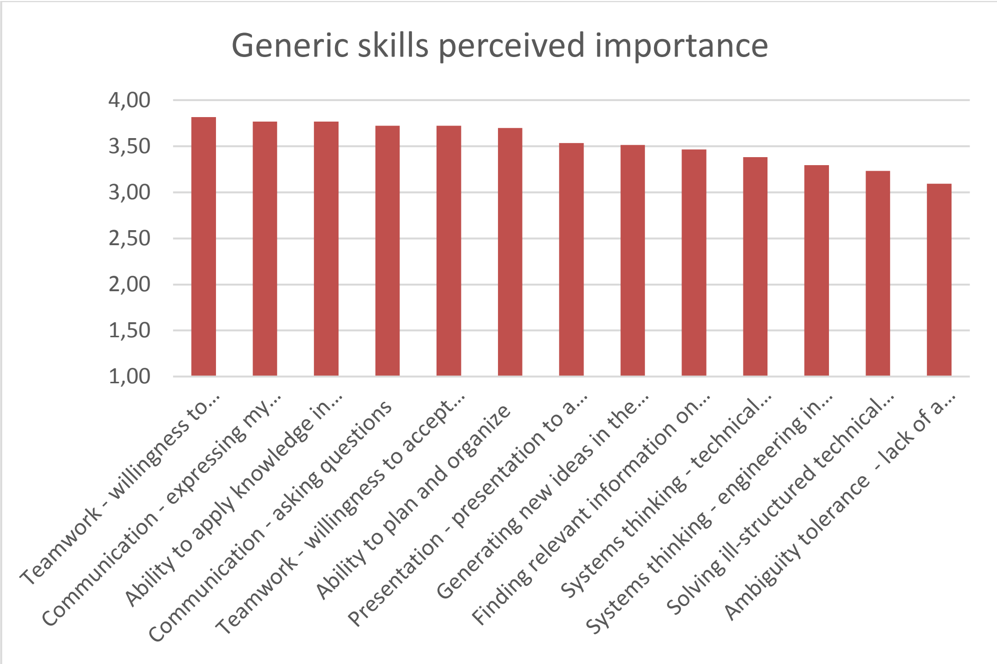


FIGURE 7-1 LEVELS OF GENERIC SKILLS IMPORTANCE IN 2ND PHASE ORDERED FROM HIGHEST TO LOWEST BY MEAN VALUE (ONLY POST)

- ❖ Systems thinking - technical systems (M=3,38; SD=0,62)
- ❖ Systems thinking - engineering in a social context (M=3,29; SD=0,81)
- ❖ Solving ill-structured technical problems (M=3,23; SD=0,68)
- ❖ Ambiguity tolerance (M=3,09; SD=0,75)

7.1.2 LEVEL OF SUCCESS

The results of the self-assessment of the levels of success of individual skills indicate that they have more diversified values than the levels of importance, which is expected. The results are shown in

Table 7-2 and Figure 7-2.

At the end of the course, students perceived to have the highest level of success in terms of the following generic skills as more important in their future profession (above the median value):

- ❖ Finding relevant information on the Internet (M=3,53; SD=0,55)
- ❖ Teamwork - willingness to contribute to a common solution (M=3,45; SD=0,71)
- ❖ Teamwork - willingness to accept differences of opinion (M=3,23; SD=0,78)
- ❖ Communication - expressing opinion (M=3,02; SD=0,56)
- ❖ Planning and organization (M=3,00; SD=0,69)
- ❖ Communication - asking questions (M=2,88; SD=0,85)

TABLE 7-2 DESCRIPTIVE STATISTICS FOR THE SKILLS LEVEL OF SUCCESS 2ND PHASE (ONLY POST)

Descriptive Statistics

	Generic skill	Mean	Std. Deviation
		Statistic	Statistic
S1.	Communication - expressing opinion	3,02	0,56
S2.	Communication - asking questions	2,88	0,85
S3.	Teamwork - a willingness to contribute to a common solution	3,45	0,71
S4.	Teamwork - the willingness to accept differences of opinion	3,23	0,78
S5.	Presentation - presentation to a group of people	2,77	0,84
S6.	Finding relevant information on the Internet	3,53	0,55
S7.	Ability to apply knowledge in practice	2,77	0,90
S8.	Planning and organization	3,00	0,69
S9.	Solving ill-structured technical problems	2,56	0,73
S10.	Generating new ideas in the process of finding a solution	2,84	0,78
S11.	Ambiguity tolerance - the lack of a single correct solution	2,79	0,67
S12.	Systems thinking - technical systems	2,88	0,81
S13.	Systems thinking - engineering in a social context	2,83	0,87

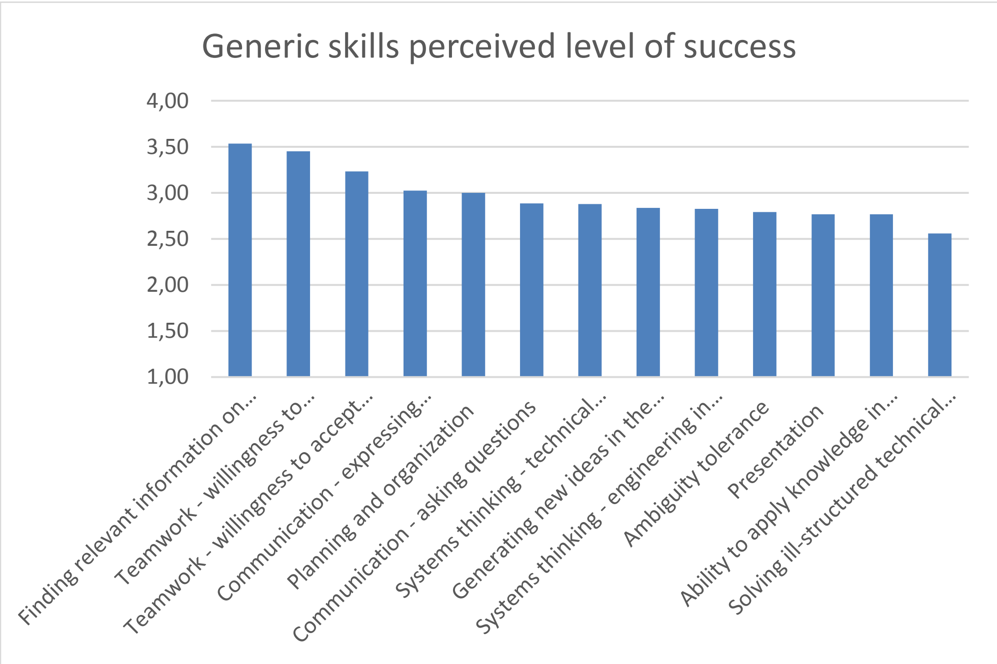


FIGURE 7-2 GENERIC SKILLS LEVEL OF SUCCESS IN 2ND PHASE ORDERED FROM HIGHEST TO LOWEST BY MEAN VALUE (ONLY POST)

and the following generic skills as less important in their future profession (below the median value):

- Generating new ideas in the process of finding a solution (M=2,84; SD=0,78)

- ❖ Systems thinking - engineering in a social context (M=2,83; SD=0,87)
- ❖ Ambiguity tolerance - lack of a single correct solution (M=2,79; SD=0,67)
- ❖ Presentation - presentation to a group of people (M=2,77; SD=0,84)
- ❖ Ability to apply knowledge in practice (M=2,77; SD=0,90)
- ❖ Solving ill-structured technical problems (M=2,56; SD=0,73)

The results indicate that the students' perception of the level of success that they possess for individual skills in general is inclined towards generic skills such as teamwork and communication, and Planning and organization. Finding relevant information on the internet is considered to be the skill with highest level of success, though as can be seen from the previous section, it is not perceived as very important.

On the contrary, "Ability to apply knowledge in practice", though considered very important, is perceived as one of the skills with lowest level of success.

Consequently, the ability to apply knowledge in practice, solving ill-structured problems, ambiguity tolerance and presentation need to be emphasized in this kind of instruction and practiced in order to reach higher levels of success of these skills.

7.1.3 COURSE CONTRIBUTION

At the end of the course, students evaluated to what extent the course contributed to the development of individual generic skills. The results are shown in Table 7-3 and Figure 7-3.

The results indicate that students perceive that the course has contributed more to the following generic skills (above the median value):

- ❖ Teamwork - willingness to contribute to a common solution (M=3,77; SD=0,48)
- ❖ Teamwork - willingness to accept differences of opinion (M=3,50; SD=0,63)
- ❖ Planning and organization (M=3,37; SD=0,69)
- ❖ Finding relevant information on the Internet (M=3,35; SD=0,87)
- ❖ Communication - asking questions (M=3,33; SD=0,71)
- ❖ Communication - expressing opinion (M=3,30; SD=0,71)
- ❖ Systems thinking - technical systems – median (M=3,21; SD=0,78)

and less to the following generic skills (below the median value):

- ❖ Ability to apply knowledge in practice (M=3,14; SD=0,74)
- ❖ Solving ill-structured technical problems (M=3,14; SD=0,74)
- ❖ Systems thinking - engineering in a social context (M=3,05; SD=0,80)
- ❖ Generating new ideas in the process of finding a solution (M=2,98; SD=0,71)

- Ambiguity tolerance - lack of a single correct solution (M=2,93; SD=0,74)
- Presentation - presentation to a group of people (M=2,88; SD=0,73)

TABLE 7-3 DESCRIPTIVE STATISTICS FOR THE COURSE CONTRIBUTION LEVELS 2ND PHASE (POST COURSE)

Descriptive Statistics

	Generic skill	Mean	Std. Deviation
		Statistic	Statistic
S1.	Communication - expressing opinion	3,30	0,71
S2.	Communication - asking questions	3,33	0,71
S3.	Teamwork - a willingness to contribute to a common solution	3,77	0,48
S4.	Teamwork - the willingness to accept differences of opinion	3,50	0,63
S5.	Presentation - presentation to a group of people	2,88	0,73
S6.	Finding relevant information on the Internet	3,35	0,87
S7.	Ability to apply knowledge in practice	3,14	0,74
S8.	Planning and organization	3,37	0,69
S9.	Solving ill-structured technical problems	3,14	0,74
S10.	Generating new ideas in the process of finding a solution	2,98	0,71
S11.	Ambiguity tolerance - the lack of a single correct solution	2,93	0,74
S12.	Systems thinking - technical systems	3,21	0,78
S13.	Systems thinking - engineering in a social context	3,05	0,80

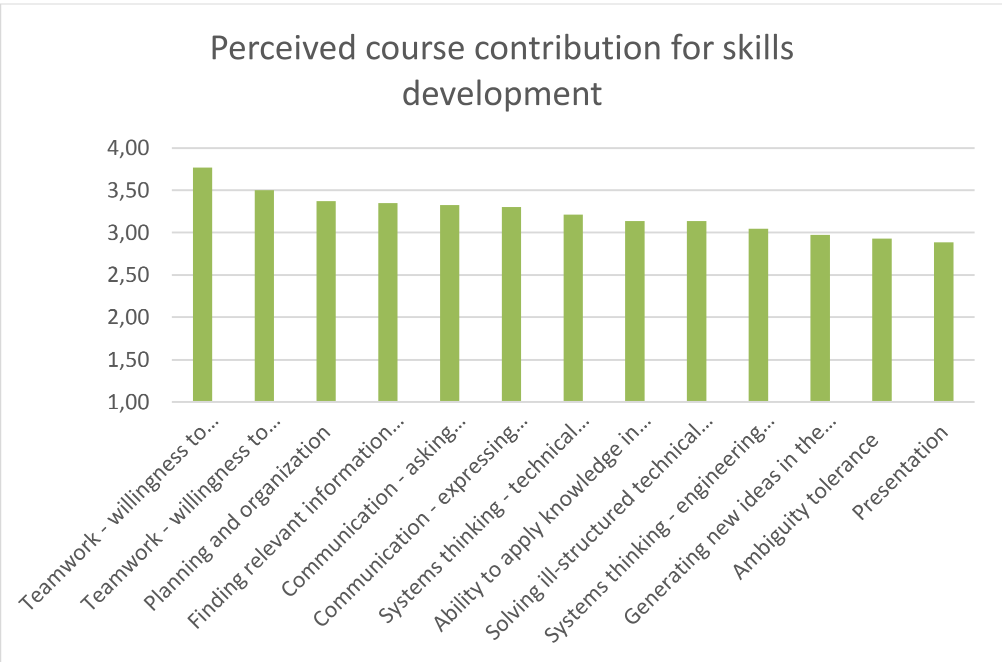


FIGURE 7-3 LEVELS OF COURSE CONTRIBUTION TO SKILLS DEVELOPMENT IN 2ND PHASE ORDERED FROM HIGHEST TO LOWEST BY MEAN VALUE (ONLY POST)

In the final comparison of the perceived levels of importance, level of success and course contribution for individual skills (Figure 7-4) it can be observed that considerable gaps exist between importance and level of success for *Ability to apply knowledge in practice*, *Communication – asking questions* and *Presentation*. Likewise, there are considerable gaps between importance and course contribution for *Presentation*, *Ability to apply knowledge in practice*, and *Generating new ideas in the process of finding a solution*, which confirms the discussion presented in Sections 7.1.1, 7.1.2 and 7.1.3.

The overall results of the skills measurements in the 2nd Phase indicate that the students were highly aware of the importance of the different skills for their future profession, that they did not feel fully able to perform them, and that their perception of the course contribution in developing the different skills is above the expected average so we could conclude that the course recorded the expected success.

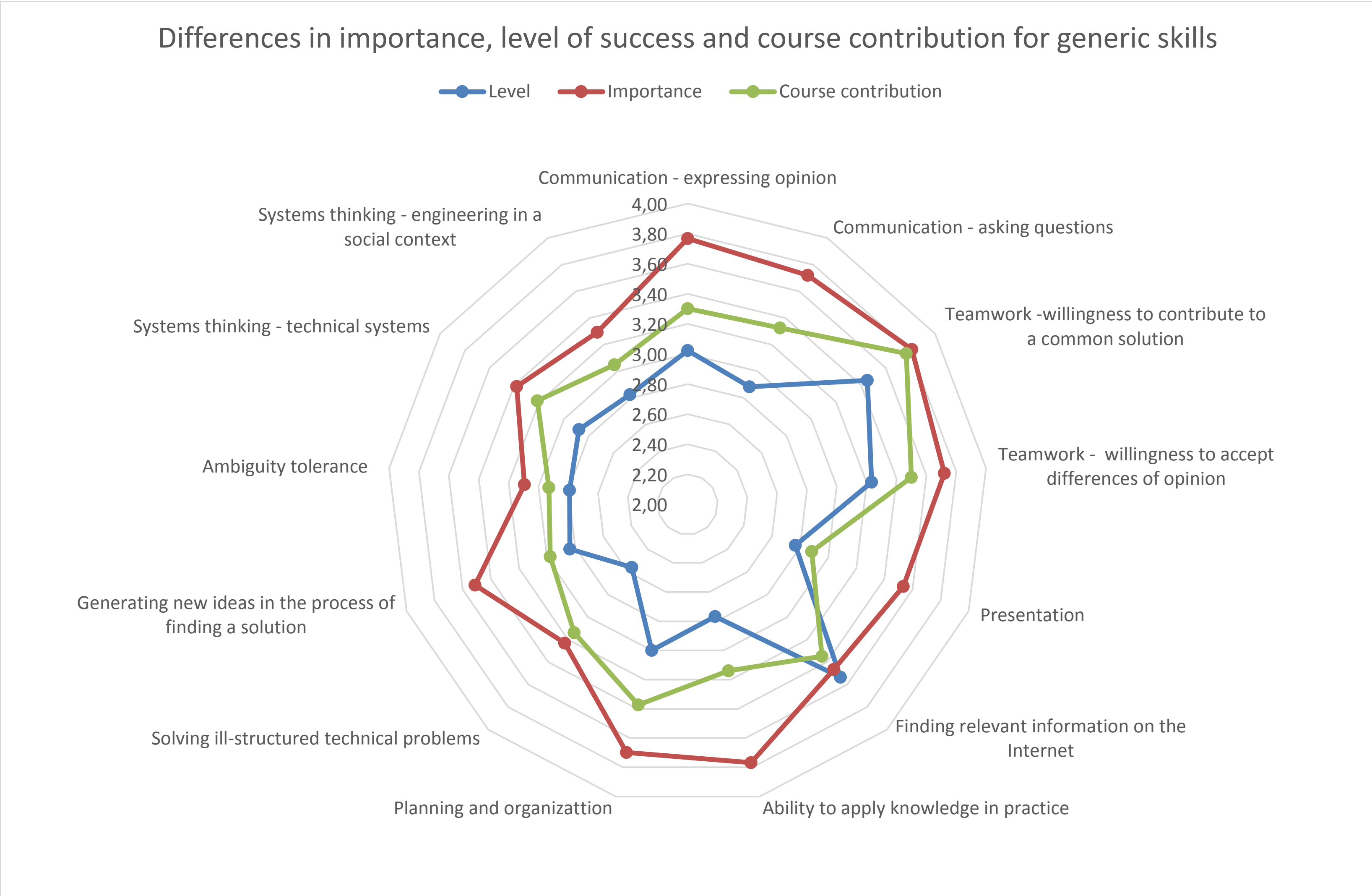


Figure 7-4 Differences in the perceived Mean levels of Importance, Level of Success and Course Contribution for the generic skills in 2nd Phase (only POST)

7.2 FINDINGS ON GENERIC SKILLS IMPORTANCE AND LEVELS OF SUCCESS – 3RD PHASE

The results on the generic skills importance and level of success from the 3rd Phase are presented in this Section. Skills' levels were self-assessed PRE and POST course for all the courses in the 3rd Phase, and the results presented include descriptive statistics and non-parametric analysis.

Descriptive statistics

The mean values - M and standard deviations - SD of the particular skills' importance and levels of success PRE course and POST course are presented both for generic skills and for professional skills. The theoretical mean value for each individual skill, both generic and professional, is:

$$TM = \frac{S_{\min} + S_{\max}}{2} = 2.5.$$

7.2.1 IMPORTANCE

Descriptive statistics

When it comes to rating the importance of individual skills, they are relatively uniform both before and after the course; they are all above the theoretical mean value, none of them falls below the value of 3, as presented in Table 7-4. This confirms the results of the 2nd Phase.

Both at the beginning and at the end of the course the students evaluate following generic skills as more important in their future profession (above the median value):

- Ability to apply knowledge in practice (M=3,84; SD=0,37)
- Teamwork - willingness to contribute to a common solution (M=3,70; SD=0,53)
- Teamwork - willingness to accept differences of opinion (M=3,61; SD=0,50)
- Communication - asking questions (M=3,55; SD=0,51)
- Generating new ideas in the process of finding a solution (M=3,55; SD=0,57)

and the following generic skills as less important in their future profession, both before and after the course (below the median value):

- Systems thinking - technical systems (M=3,55; SD=0,62)
- Presentation (M=3,52; SD=0,57)
- Solving ill-structured technical problems (M=3,36; SD=0,65)
- Ambiguity tolerance (M=3,12; SD=0,60)
- Systems thinking - engineering in a social context (M=3,00; SD=0,71)

Planning and organization (M=3,55; SD=0,57) is one of the skills whose level did not change PRE and POST course. Mean and standard deviation for every skill on the scale of importance before and after the course are shown in Table 7-4.

TABLE 7-4 DESCRIPTIVE STATISTICS FOR 3RD PHASE GENERIC SKILLS IMPORTANCE (PRE AND POST)

Descriptive Statistics

	Generic skill	PRE		POST	
		Mean	Std. Deviation	Mean	Std. Deviation
S1.	Communication -expressing opinion	3,39	0,61	3,59	0,56
S2.	Communication-asking questions	3,55	0,51	3,76	0,44
S3.	Teamwork - willingness to contribute to a common solution	3,70	0,53	3,82	0,39
S4.	Teamwork-accept differences of opinion	3,61	0,50	3,61	0,66
S5.	Presentation	3,35	0,71	3,52	0,57
S6.	Finding relevant information on the Internet	3,45	0,57	3,61	0,56
S7.	Ability to apply knowledge in practice	3,84	0,37	3,73	0,45
S8.	Planning and organization	3,55	0,57	3,55	0,56
S9.	Solving ill-structured technical problems	3,35	0,75	3,36	0,65
S10.	Generating new ideas in the process of finding a solution	3,55	0,57	3,64	0,49
S11.	Ambiguity tolerance	3,10	0,75	3,12	0,60
S12.	Systems thinking-technical systems	3,42	0,67	3,55	0,62
S13.	Systems thinking-engineering in a social context	3,06	0,81	3,00	0,71

TABLE 7-5 WILCOXON SIGNED RANKS TEST FOR IMPORTANCE (POST – PRE)

Test Statistics[a]

	S1pos - S1pre	S2pos - S2pre	S3pos - S3pre	S4pos - S4pre	S5pos - S5pre	S6pos - S6pre	S7pos - S7pre	S8pos - S8pre	S9pos - S9pre	S10pos - S10pre	S11pos - S11pre	S12pos - S12pre	S13pos - S13pre
Z	-1,147[b]	-2,111[b]	-1,265[b]	-,243[c]	-,943[b]	-1,508[b]	-,832[c]	,000[d]	-,206[c]	-,632[b]	-,188[c]	-,832[b]	-,347[c]
Asymp. Sig. (2-tailed)	,251	,035	,206	,808	,346	,132	,405	1,000	,837	,527	,851	,405	,729

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

c. Based on positive ranks.

d. The sum of negative ranks equals the sum of positive ranks.

Non-parametric statistics

Wilcoxon signed-rank test did not show a statistically significant increase in the overall level of importance for generic skills at the end of the course.

Further analysis of the level of importance PRE course and POST course for individual generic skills revealed the statistically significant increase only in the level of importance of the Communicaton – asking questions, as shown in the Table 7-5.

7.2.2 LEVEL OF SUCCESS

Descriptive statistics

The mean values - M and standard deviations - SD of the particular skills' levels PRE course and POST course are presented for generic skills in Table 7-6. Levels of success for most of the generic skills PRE course are perceived to be above the theoretical mean, while POST course all the generic skills' levels of success are perceived to be above the theoretical mean. Differences in perceived levels of success for each generic skill are given in Figure 7-5.

Non-parametric statistics

Wilcoxon signed-rank test showed a statistically significant increase in the overall level of success for generic skills at the end of the course.

Further analysis of the level of success PRE course and POST course for individual generic skills revealed the statistically significant increase in the level of success of the following skills, as shown in the

Generating new ideas in the process of finding a solution (z=-2,400, p=0,016)

- Ambiguity tolerance (z=-2,045, p=0,041)
- Systems thinking-technical systems (z=-3,660, p=0,000)
- Systems thinking-engineering in a social context (z=-2,233, p=0,026)

Generic skills 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-accept differences of opinion, finding relevant information on the Internet and planning and organization*.

Table 7-7:

- Communication-asking questions (z=-3,819, p=0,003)
- Presentation (z=-3,019, p=0,003)
- Ability to apply knowledge in practice (z=-2,683, p=0,007)
- Solving ill-structured technical problems (z=-2,349, p=0,019)

TABLE 7-6 DESCRIPTIVE STATISTICS FOR 3RD PHASE LEVELS OF SUCCESS FOR GENERIC SKILLS (PRE AND POST)

Descriptive Statistics

		PRE		POST	
	Generic skill	Mean	Std. Deviation	Mean	Std. Deviation

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 common solution	3,33	0,61	3,42	0,62
S4.	Teamwork-accept 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

- Generating new ideas in the process of finding a solution (z=-2,400, p=0,016)
- Ambiguity tolerance (z=-2,045, p=0,041)
- Systems thinking-technical systems (z=-3,660, p=0,000)
- Systems thinking-engineering in a social context (z=-2,233, p=0,026)

Generic skills 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-accept differences of opinion, finding relevant information on the Internet and planning and organization*.

TABLE 7-7 WILCOXON SIGNED RANKS TEST FOR LEVEL OF SUCCESS (POST – PRE)

Test Statistics[a]

	S1pos - S1pre	S2pos - S2pre	S3pos - S3pre	S4pos - S4pre	S5pos - S5pre	S6pos - S6pre	S7pos - S7pre	S8pos - S8pre	S9pos - S9pre	S10pos - S10pre	S11pos - S11pre	S12pos - S12pre	S13pos - S13pre
Z	-,894[b]	-3,819[b]	-,535[b]	-,131[c]	-3,019[b]	,000[d]	-2,683[b]	-1,301[b]	-2,349[b]	-2,400[b]	-2,045[b]	-3,660[b]	-2,233[b]
Asymp. Sig. (2-tailed)	,371	,000	,593	,896	,003	1,000	,007	,193	,019	,016	,041	,000	,026

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

c. Based on positive ranks.

d. The sum of negative ranks equals the sum of positive ranks.

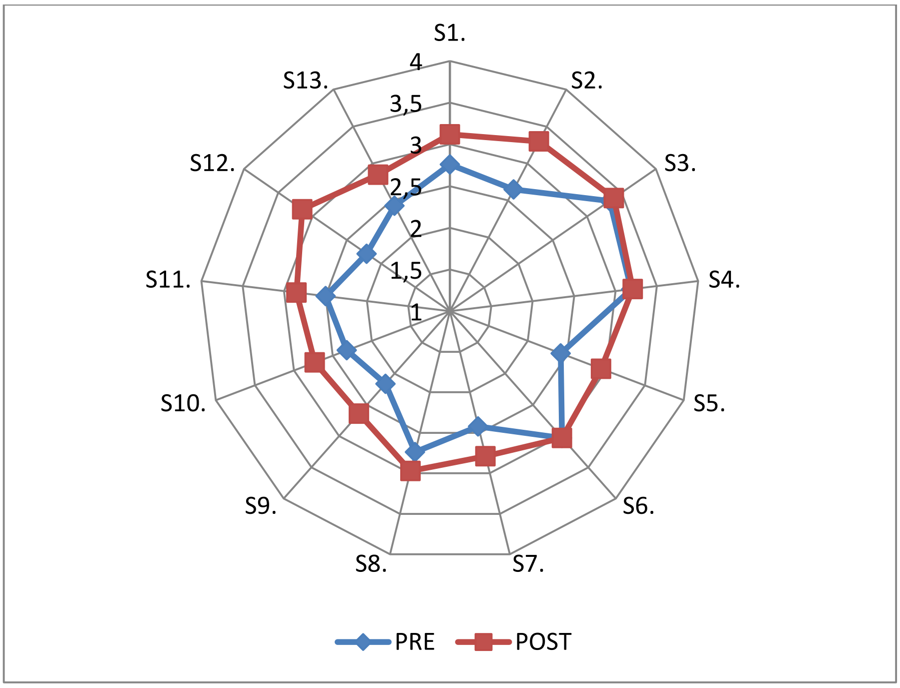


FIGURE 7-5 DIFFERENCES IN THE PERCEIVED MEAN LEVEL OF SUCCESS FOR GENERIC SKILLS PRE AND POST (3RD PHASE)

7.3 FINDINGS ON PROFESSIONAL SKILLS LEVEL OF SUCCESS

Descriptive statistics

The mean values - M and standard deviations - SD of the particular skills' levels PRE course and POST course are presented for professional skills in Table 7-8.

Differences in perceived levels of success for each professional skill are given in Figure 7-6. It can be observed that all of the professional skills are rated as below the theoretical mean PRE course, while all of the professional skills are rated well above the theoretical mean POST course.

TABLE 7-8 DESCRIPTIVE STATISTICS FOR 3RD PHASE LEVELS OF SUCCESS FOR PROFESSIONAL SKILLS (PRE AND POST)

Descriptive Statistics

		PRE		POST	
		Mean	Std. Deviation	Mean	Std. Deviation
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.	Analyse 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

Non-parametric statistics

On the other hand, Wilcoxon signed-rank test showed statistically significant difference in the perceived levels of success before and after the course for all of the professional skills (

Table 7-9):

- P1. 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=0,001)
- P2. Formulate and solve engineering problems that are insufficiently structured (z=-4,388, p=0,000)
- P3. Analyse and interpret technical specifications of telecommunication devices and systems (z=-3,381, p=0,001)
- P4. Use engineering techniques for evaluation and selection of technical solutions (z=-4,508, p=0,000)
- P5. Find the equipment needed for the technical solution (z=-4,103, p=0,000)
- P6. Create a realistic implementation plan for the simple project with time and resource constraints (z=-3,116, p=0,002)
- P7. Perform technical analysis and critical evaluation of the problem, along with the recommendations and conclusions based on technical knowledge (z=- 4,439, p=0,000)

TABLE 7-9 WILCOXON SIGNED RANKS TEST FOR LEVEL OF SUCCESS PROFESSIONAL SKILLS (POST – PRE)

Test Statistics[a]

	P1post - P1pre	P2post - P2pre	P3post - P3pre	P4post - P4pre	P5post - P5pre	P6post - P6pre	P7post - P7pre
Z	-3,232[b]	-4,388[b]	-3,381[b]	-4,508[b]	-4,103[b]	-3,116[b]	-4,439[b]
Asymp. Sig. (2-tailed)	,001	,000	,001	,000	,000	,002	,000

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

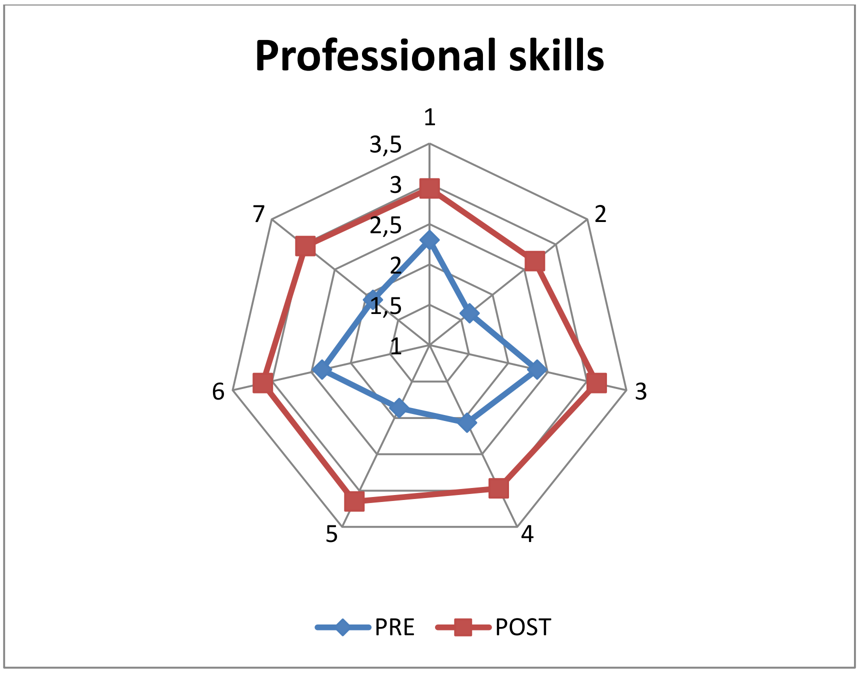


FIGURE 7-6 DIFFERENCES IN THE PERCEIVED MEAN LEVEL OF SUCCESS FOR PROFESSIONAL SKILLS PRE AND POST (3RD PHASE)

8 LAYER 3 RESULTS: PHASED CHALLENGES AND SKILLS DEVELOPED

Layer 3 data was collected and analysed only in the 3rd Phase.

Quantitative methods were used for data collection and descriptive statistics for data analysis.

Challenges list T1, T2, T3, T4 (CHALLPH) was aimed at capturing data comparable to the data collected in the previous courses since 2010/2011 thus providing insights for the longitudinal research and bringing depth that would explain the phenomena found in the previous results. The challenges list is formed of the challenges found in the 1st and 2nd Phases.

Skills list T1, T2, T3, and T4 (SKILLPH) was aimed at fine tuning the skills development over the duration of the course and different challenges that students found along the way. This list was composed of 13 skills whose development levels were rated from 1 to 10. Therefore, the researcher aimed at providing data comparable to the data collected in the previous courses and bringing depth that would explain the phenomena found in the previous skills measurements' results.

8.1 FINDINGS ON PHASED ISSUES AND CHALLENGES

In this Section the results on the phased issues and challenges are presented.

Research question:

- How are the major issues and challenges distributed over different stages of the ill-structured problem solving process?

The results of the Course 5 and 6 Challenges list are shown in Table 8-1.

In order to determine how issues and challenges were distributed over different stages of the ill-structured problem solving two different approaches were applied for data analysis.

Firstly, in order to represent both the frequency and order of the challenges selected in each of the periods T1, T2, T3 and T4, each challenge was rated by order/level, as well as per frequency of selections in each of the periods T1, T2, T3 and T4. Then, the mean rated value was calculated taking into account the number of students that participated in the rating for each of the periods T1, T2, T3 and T4.

The resulting rated challenges list is shown in the In order to analyse challenges that have more variation and those that are more stable throughout the course, I made a decision to separate them in two groups: challenges with the variation of the rated values higher than 1,5 over T1, T2, T3 and T4 and those with the variation of the rated values lower than 1,5.

Table 8-1.

In order to analyse challenges that have more variation and those that are more stable throughout the course, I made a decision to separate them in two groups: challenges with the variation of the rated values higher than 1,5 over T1, T2, T3 and T4 and those with the variation of the rated values lower than 1,5.

TABLE 8-1 OVERALL CHALLENGES RATED T1, T2, T3, T4

Code	Challenge	T1	T2	T3	T4
CH1	understand where to start to solve the problem	6,29	2,00	1,20	1,11
CH2	define the problem to be solved	1,86	1,60	1,13	0,52
CH3	learn to ask questions	2,00	0,40	0,27	0,96
CH4	understand and take into account the requirements of the client	1,07	1,12	0,53	0,37
CH5	connect theory and practice	6,14	3,28	2,33	2,89
CH6	independently decide on the how to collect and use the information	1,93	2,32	1,53	3,63
CH7	accept the uncertainty of the final solution (there is not only one correct solution)	1,71	1,12	1,13	1,33
CH8	accept that there are limitations and compromises	0,50	3,20	1,40	2,44
CH9	clearly express my demands in communication with others	1,14	0,72	1,67	1,63
CH10	visually represent the problem (block diagram, sketch)	0,93	1,20	2,13	1,33
CH11	face the failure and continue looking for the solutions	1,50	2,40	2,00	1,63
CH12	face the reality during the site survey	0,36	2,16	0,93	0,74
CH13	define the criteria for evaluating the solutions	0,86	2,48	3,93	1,85
CH14	compare solutions, and decide which is best	1,21	2,80	1,80	3,11
CH15	plan and organize the work that has to be done on the project	1,21	1,04	1,73	2,15
CH16	describe the technical solution of the system	0,71	2,16	3,67	1,70
CH17	justify the solution	0,00	0,56	1,47	1,48
CH18	present the solution	0,00	0,08	0,60	1,63

Challenges with the variation of the rated values higher than 1,5 over T1, T2, T3 and T4 are presented in Table 8-2 and on Figure 8-1, while challenges with the variation of the rated values lower than 1,5 are presented in Table 8-3 and on Figure 8-2.

The challenges that have maximum rated values in T1 and then their rated value steadily falls are: understand where to start to solve the problem, connect theory and practice, and learn to ask questions. The first two are also the challenges with the maximum overall rated value.

TABLE 8-2 CHALLENGES WITH VARIATION HIGHER THAN 1,5

	Challenges
CH1	understand where to start to solve the problem
CH3	learn to ask questions
CH5	connect theory and practice
CH6	independently decide on the how to collect and use the information
CH8	accept that there are limitations and compromises
CH12	face the reality during the site survey
CH13	define the criteria for evaluating the solutions
CH14	compare solutions, and decide which is best
CH16	describe the technical solution of the system
CH18	present the solution

The results indicate that there is a set of challenges that are very low in T1 and reach their maximum in T2: independently decide on the how to collect and use the information, accept that there are limitations and compromises, face the reality during the site survey, compare solutions, and decide which is best. After this maximum their rated level falls in T3, and while some continue to fall in T4, there are others such as accept that there are limitations and compromises and compare solutions, and decide which is best whose value rises again in T4.

The challenges that reach their maximum values in T3 are: Define the criteria for evaluating the solutions and describe the technical solution of the system.

TABLE 8-3 CHALLENGES WITH VARIATION LOWER THAN 1,5

	Challenges
CH2	define the problem to be solved
CH4	understand and take into account the requirements of the client
CH7	accept the uncertainty of the final solution (there is not only one correct solution)
CH9	clearly express my demands in communication with others
CH10	visually represent the problem (block diagram, sketch)

CH11	face the failure and continue looking for the solutions
CH15	plan and organize the work that has to be done on the project
CH17	justify the solution

The challenges that do not have notable variation but are steady throughout the course are: face the failure and continue looking for the solution, accept the uncertainty of the final solution (there is not only one correct solution), clearly express my demands in communication with others and plan and organize the work that has to be done on the project.

Apart from the rated values, the other criteria for analysing the phased challenges data was the overall frequency of the challenge selection.

The combined values of percentages and rated values for T1, T2, T3, and T4 are presented in Table 13-1 in the Appendix 2 – Detailed results. The fields that are greyed represent either percentage higher than 30% or rated value higher than 1,5.

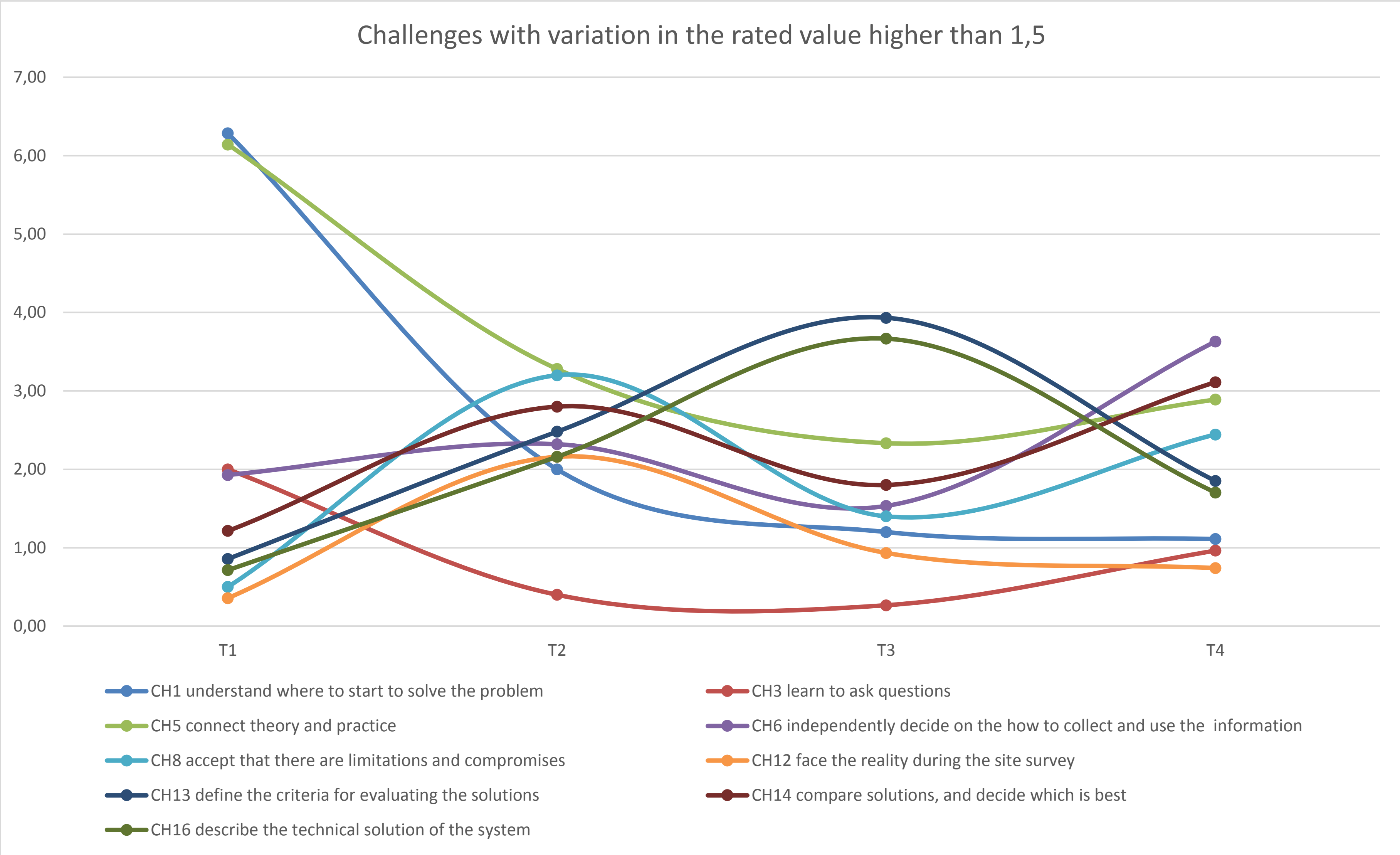

Challenges with variation in the rated value higher than 1,5
7,00
6,00
5,00
4,00
3,00
2,00
1,00
0,00
T1
T2
T3
T4
CH1 understand where to start to solve the problem
CH3 learn to ask questions
CH5 connect theory and practice
CH6 independently decide on the how to collect and use the information
CH8 accept that there are limitations and compromises
CH12 face the reality during the site survey
CH13 define the criteria for evaluating the solutions
CH14 compare solutions, and decide which is best
CH16 describe the technical solution of the system

FIGURE 8-1 CHALLENGES WITH VARIATION IN THE RATED VALUE HIGHER THAN 1,5

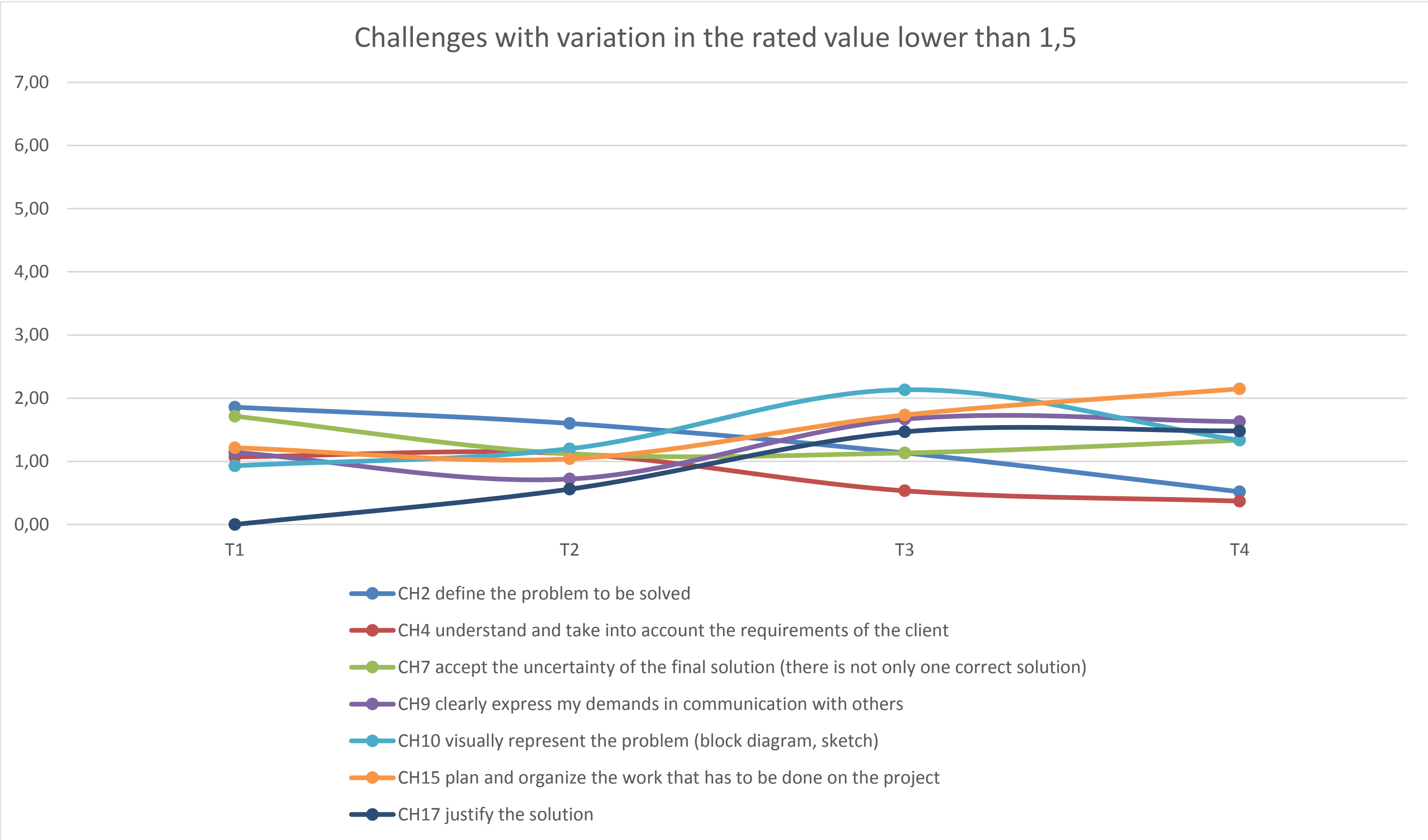


FIGURE 8-2 CHALLENGES WITH VARIATION IN THE RATED VALUE LOWER THAN 1,5

The challenges were selected by more than 80% of the students in T1 are:

- understand where to start to solve the problem (86%)
- connect theory and practice (82%)

The challenges selected by more than 30% of the students in T1 are:

- learn to ask questions (36%)
- independently decide on how to collect and use the information (32%)
- define the problem to be solved (32%)
- face the failure and continue looking for the solution (32%)
- clearly express my demands in communication with others (32%)

The challenge that was selected by 29% of the students but had a higher rated value than the last two challenges form the above list is accept the uncertainty of the final solution (29%), indicating that though it was selected by a lower number of students, generally it was rated high in their selection.

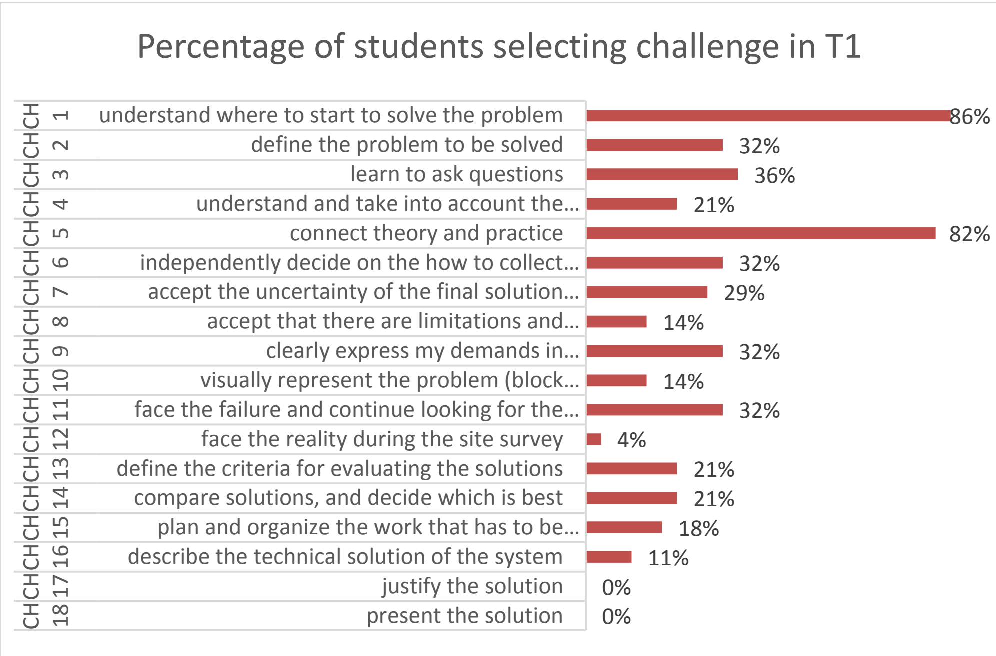


FIGURE 8-3 PERCENTAGE OF STUDENTS SELECTING CHALLENGE IN T1

The challenge that was selected by more than 50% of the students in T2 is:

- accept that there are limitations and compromises (52%)

The challenges selected by more than 30% of the students in T2 are:

- compare solutions, and decide which is the best (48%)

- connect theory and practice (48%)
- face the failure and continue looking for the solution (40%)
- define the criteria for evaluating the solutions (40%)
- face the reality during the site survey (36%)
- understand where to start to solve the problem (32%)

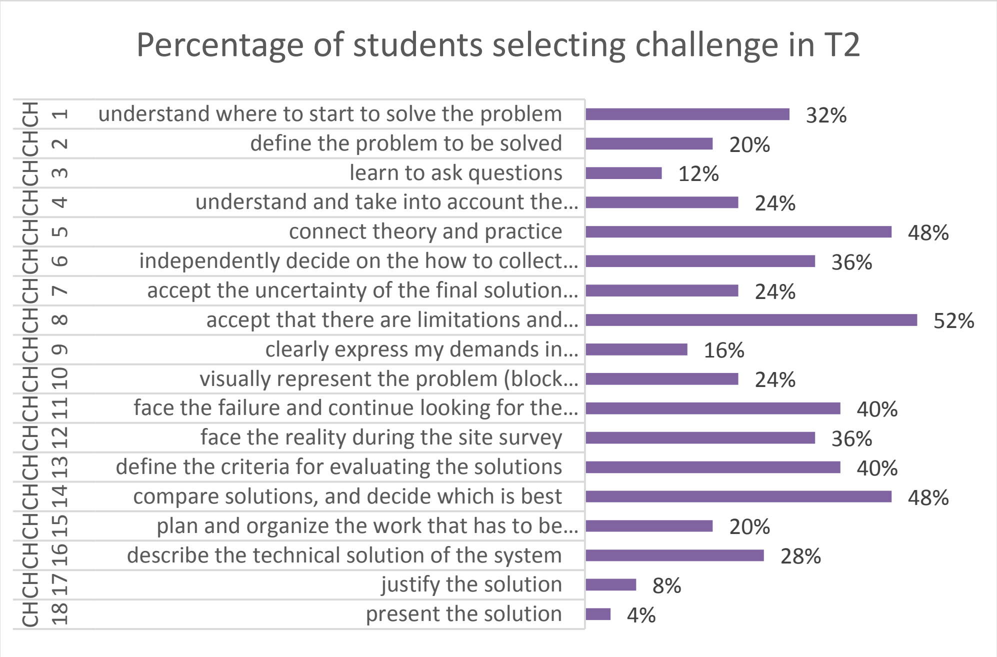


FIGURE 8-4 PERCENTAGE OF STUDENTS SELECTING CHALLENGE IN T2

The challenge that was selected by more than 50% of the students in T3 were:

- describe the technical solution of the system (63%)
- define the criteria for evaluating the solutions (50%)

The challenges selected by 30% or more of the students in T2 are:

- connect theory and practice (43%)
- face the failure and continue looking for the solution (40%)
- compare solutions, and decide which is the best (37%)
- visually represent the problem (block diagram, sketch) (33%)
- accept that there are limitations and compromises (30%)

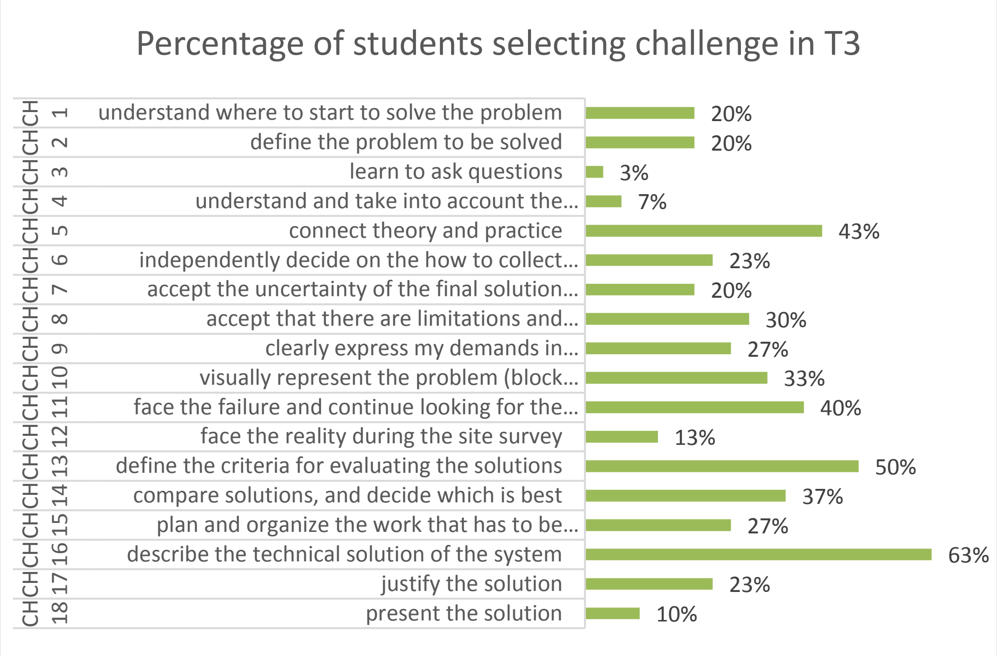


FIGURE 8-5 PERCENTAGE OF STUDENTS SELECTING CHALLENGE IN T3

The challenge that was selected by more than 50% of the students in T4 were:

- compare solutions, and decide which is the best (59%)
- define the criteria for evaluating the solutions (50%)

The challenges selected by 30% or more of the students in T4 are:

- independently decide on the how to collect and use the information (48%)
- plan and organize the work that has to be done on the project (41%)
- connect theory and practice (37%)
- accept that there are limitations and compromises (33%)
- define the criteria for evaluating the solutions (30%)
- face the failure and continue looking for the solutions (30%)
- present the solution (30%)
- accept the uncertainty of the final solution (there is not only one correct solution) (30%)
- clearly express my demands in communication with others (30%)

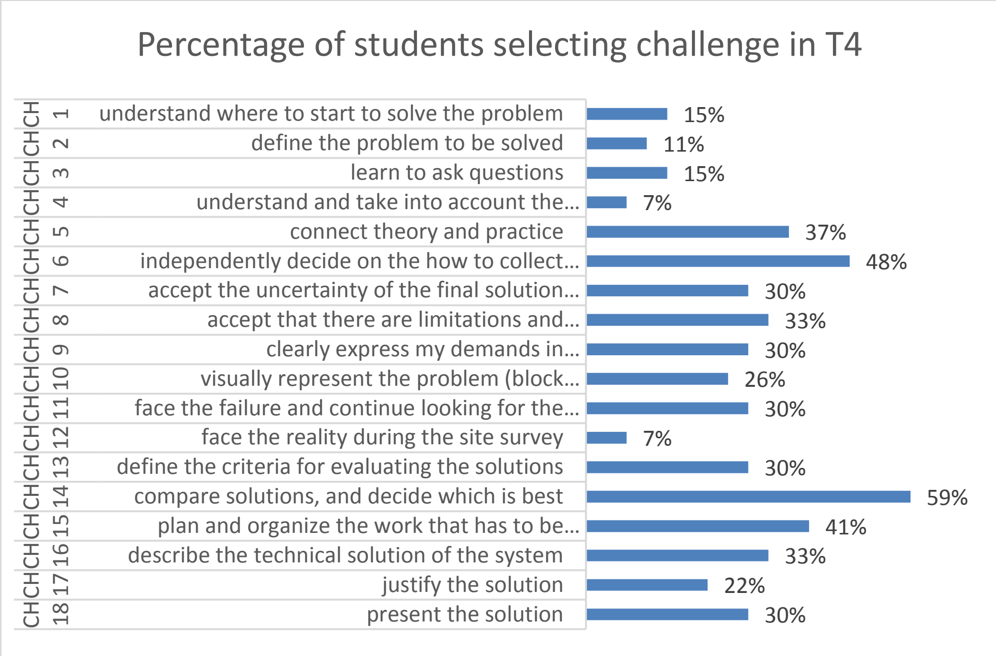


FIGURE 8-6 PERCENTAGE OF STUDENTS SELECTING CHALLENGE IN T4

8.2 FINDINGS ON PHASED SKILLS DEVELOPMENT

In this Section the findings on the phased skills development are presented.

Research questions:

- How is skills development distributed over different stages of the ill-structured problem solving

The results of the Course 5 and 6 phased skills development are shown in Table 8-4.

Table 8-4.

In order to determine how skills development was distributed over different stages of the ill-structured problem solving descriptive each skill development was assessed in each of the periods T1, T2, T3 and T4. Then, descriptive statistics was applied for data analysis and the mean value was calculated for each of the periods T1, T2, T3 and T4.

The resulting skills' development levels are shown in the Table 8-4.

TABLE 8-4 OVERALL SKILLS DEVELOPMENT ASSESSMENT T1, T2, T3, T4

	Skill	T1	T2	T3	T4
PH-S1	Expressing opinion	5,04	5,42	5,79	5,58
PH-S2	Asking questions	5,88	5,65	6,13	6,27
PH-S3	Willingness to contribute to a common solution	5,81	5,64	6,38	6,26
PH-S4	Willingness to accept differences of opinion	5,69	4,90	6,43	6,20
PH-S5	Finding relevant information on the Internet	5,69	5,43	5,62	6,32
PH-S6	Ability to apply knowledge in practice	6,19	5,56	6,07	5,93
PH-S7	Planning and organization	5,50	5,73	6,52	6,30
PH-S8	Solving ill-structured technical problems	5,92	5,39	5,40	5,60
PH-S9	Generating new ideas in the process of finding a solution	5,54	5,74	6,01	6,01
PH-S10	Systems thinking	5,88	5,80	6,37	7,01
PH-S11	Ambiguity tolerance	6,19	5,30	5,78	5,83
PH-S12	Presentation	5,81	5,56	6,07	6,20

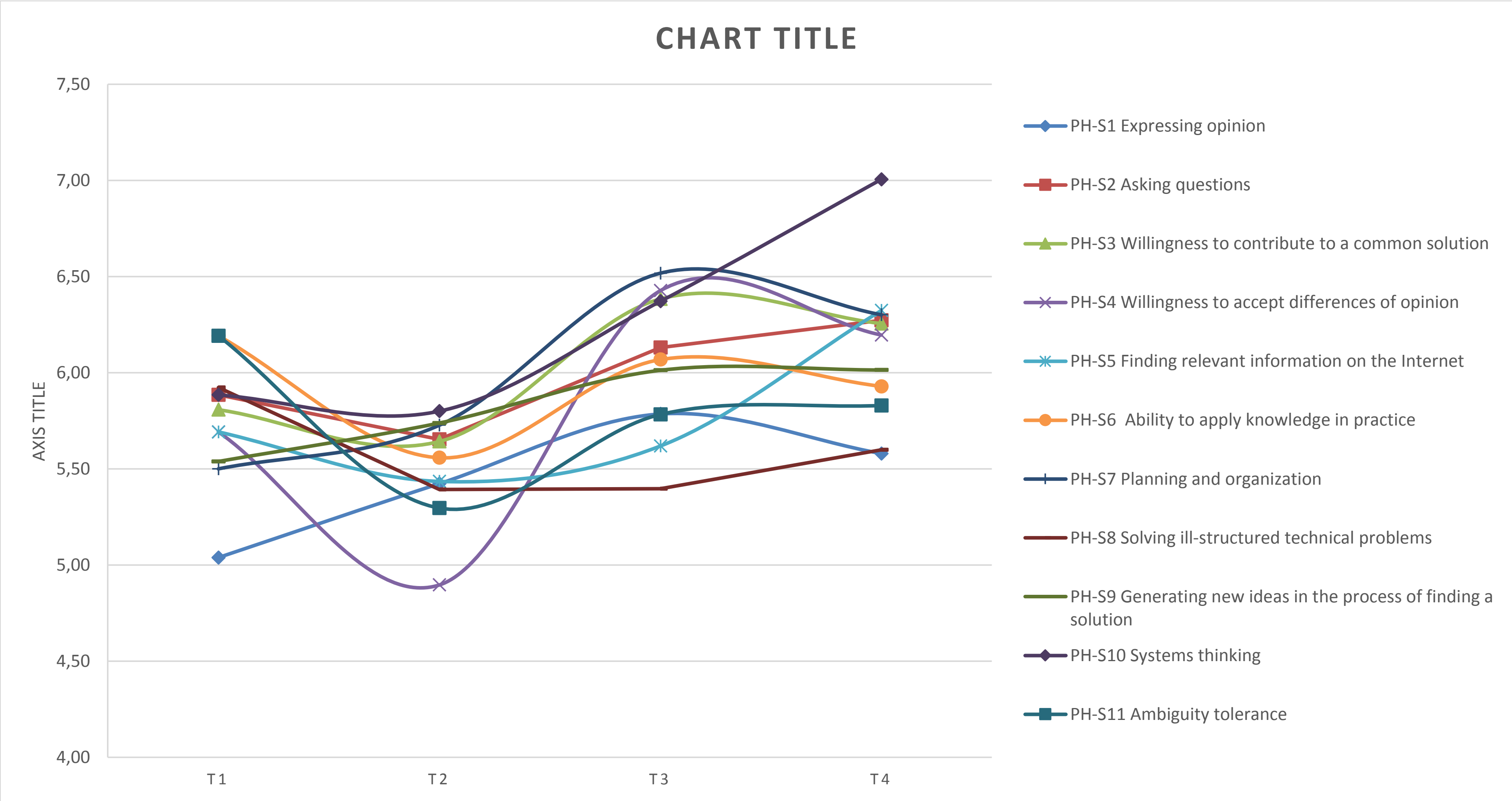
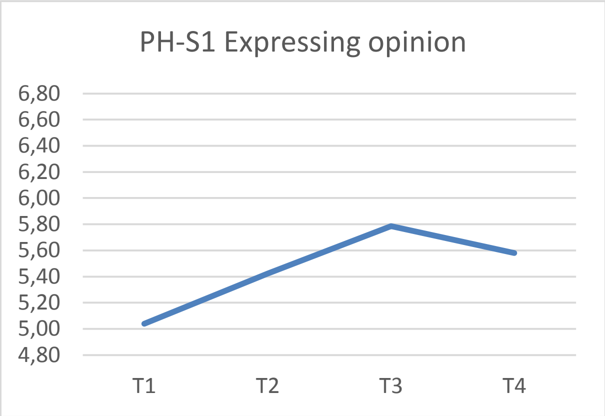
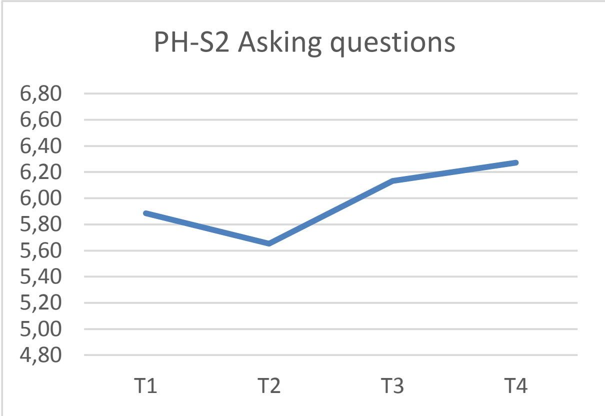
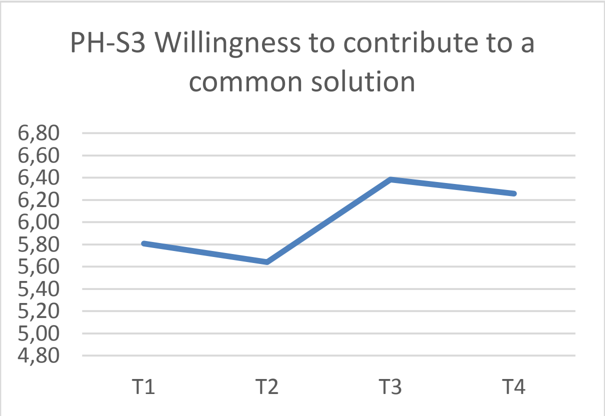
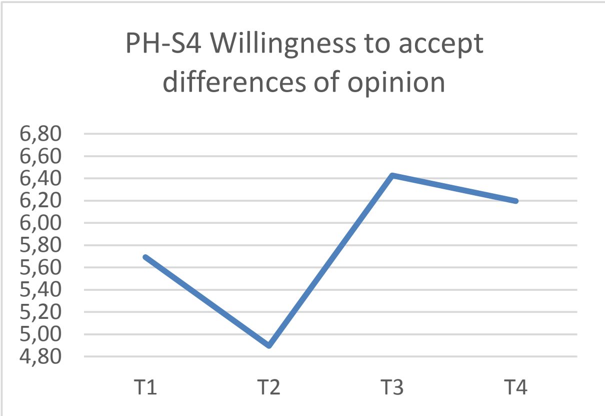


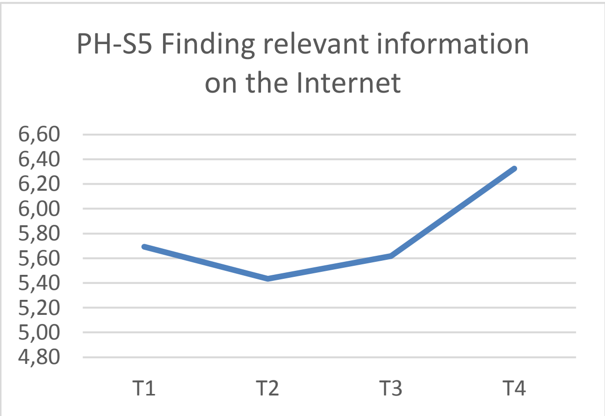
CHART TITLE
7,50
7,00
6,50
6,00
5,50
5,00
4,50
4,00
AXIS TITLE
T1
T2
T3
T4
PH-S1 Expressing opinion
PH-S2 Asking questions
PH-S3 Willingness to contribute to a common solution
PH-S4 Willingness to accept differences of opinion
PH-S5 Finding relevant information on the Internet
PH-S6 Ability to apply knowledge in practice
PH-S7 Planning and organization
PH-S8 Solving ill-structured technical problems
PH-S9 Generating new ideas in the process of finding a solution
PH-S10 Systems thinking
PH-S11 Ambiguity tolerance

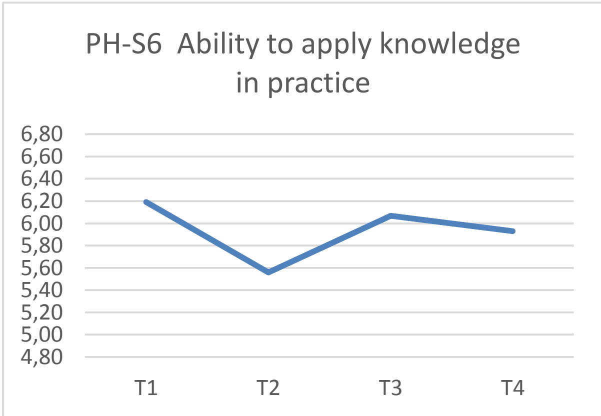

PH-S1 Expressing opinion
6,80
6,60
6,40
6,20
6,00
5,80
5,60
5,40
5,20
5,00
4,80
T1
T2
T3
T4


PH-S2 Asking questions
6,80
6,60
6,40
6,20
6,00
5,80
5,60
5,40
5,20
5,00
4,80
T1
T2
T3
T4

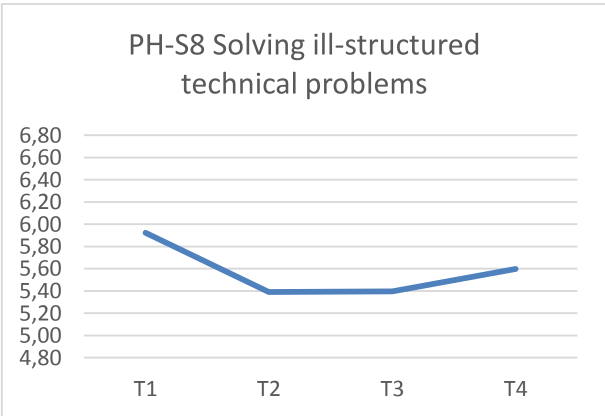

PH-S3 Willingness to contribute to a common solution
6,80
6,60
6,40
6,20
6,00
5,80
5,60
5,40
5,20
5,00
4,80
T1
T2
T3
T4

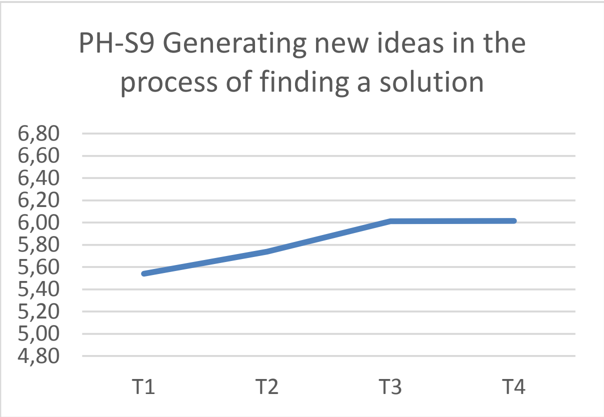

PH-S4 Willingness to accept differences of opinion
6,80
6,60
6,40
6,20
6,00
5,80
5,60
5,40
5,20
5,00
4,80
T1
T2
T3
T4

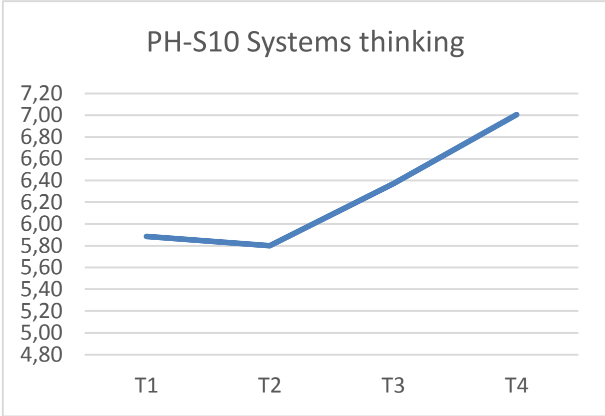

PH-S5 Finding relevant information on the Internet
6,60
6,40
6,20
6,00
5,80
5,60
5,40
5,20
5,00
4,80
T1
T2
T3
T4

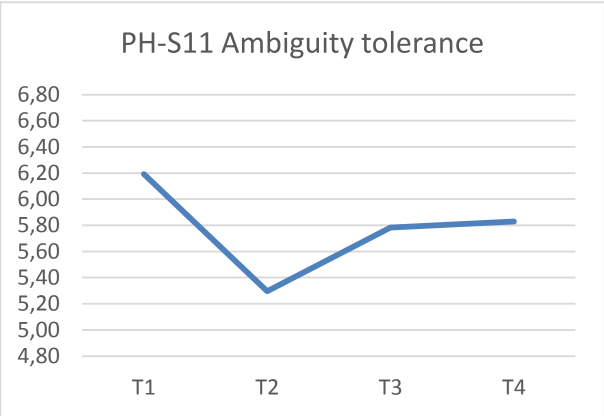

PH-S6 Ability to apply knowledge in practice
6,80
6,60
6,40
6,20
6,00
5,80
5,60
5,40
5,20
5,00
4,80
T1
T2
T3
T4

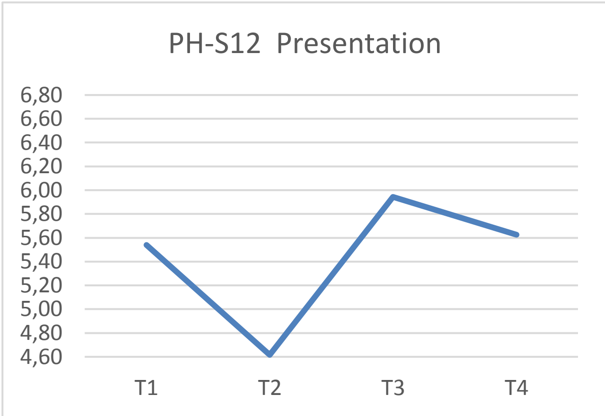

PH-S7 Planning and organization
6,80
6,60
6,40
6,20
6,00
5,80
5,60
5,40
5,20
5,00
4,80
T1
T2
T3
T4


PH-S8 Solving ill-structured technical problems
6,80
6,60
6,40
6,20
6,00
5,80
5,60
5,40
5,20
5,00
4,80
T1
T2
T3
T4









The results demonstrate the following:

- *Expressing opinion* mean value grows steadily from T1 to T3, where it reaches the maximum value and falls slightly in T4.
- *Asking questions* is assessed higher in T1 than in T2, while from T2 the mean value grows steadily to T4.
- *Willingness to contribute to a common solution* mean value falls from T1 to T2, and after growing from T2 to T3 it falls very slightly to T4
- *Willingness to accept differences of opinion* has a mean value that is higher in T1 but it falls drastically in T2, followed by steep growth to T3 and very slight fall in T4
- *Finding relevant information on the internet* mean value grow steadily till T4, though it falls slightly in T2
- *Ability to apply knowledge in practice* has a mean value that after enthusiastic start falls in T2, grows to T3 and falls again in T4, even to the level lower than T1.
- *Planning and organization* grows steeply to T3, falling only slightly in T4

- *Solving ill-structured technical problems* starts enthusiastically, falls in T2 and grows slightly through T3 and T4
- *Generating new ideas* in the process of finding a solution grows steadily.
- *Systems thinking* has the most marked growth of all the skills and at the same time this skill has the highest overall mean value
- *Ambiguity tolerance* has a mean value that starts enthusiastically in T1 but goes through constant variation from T1 till T4.
- Presentation has a constant variation from T1 till T4

9 DISCUSSION AND IMPLICATIONS

9.1 ISSUES, CHALLENGES AND EVALUATION OF THE LEARNING EXPERIENCE

The objective of the Layer 1 of this research was to empirically identify and describe students' overall perception of the learning experience.

The major research questions of the Layer 1 research were related to the issues and challenges that students experience during ill-structured problem solving together with the students' perception of the learning experience regarding module evaluation, like and dislike for the course, importance for their professional and personal development, their motivation to attend the course and their interest in pursuing instruction on sustainable development principles in the future. Additionally, students' learning styles were determined. The participants in the Layer 1 research were 85 students, all the students that participated in the course. The research was conducted for 4 years, extending over 6 one-semester courses.

With respect to the evaluation of the course, the overwhelming majority of students expressed the opinion that they liked learning based on real projects (98%), while around 80% stated that they liked problem based learning and enjoyed teamwork. This confirms the findings in the previous research though the percentages are notably higher, indicating that the course structure and content were especially well fitted to the audience. These results indicate that though problem based learning is well-accepted, project based learning that is based on real projects is what student like the most.

The vast majority of students were confident to have adopted project planning and organization techniques and a little less stated that they have adopted the process of solving technical problems. This indicates that these course objectives were met.

The way that instructor conducted the course was positively evaluated by the great majority of students as well, and curiously 100% of the students agreed that the instructor conducted the course well. A little less agree that the instructor provided guidance when necessary, a result which indicates that more care should be taken to design the appropriate methods for helping students throughout the course. This task could be informed by the in-depth results of the phased challenges in Section 9.3.

For the majority of students, this course presented the first opportunity to work independently in small teams through the development of a real engineering practice project.

The results indicate that students perceive the course as very important for their professional and personal development (on the scale from 1 to 5 the mean importance for professional development is 4,56 and for personal development 4,18). The fact that students perceive the course as important may be the key for developing the deep approach to learning and creating meaning as explained in (N. Entwistle, McCune, & Hounsell, 2003).

The results on the elements that constitute the instructional design are presented in continuation.

The learning process. The great majority of students expressed the opinion that the professional practice based on project and problem based learning is a novel approach compared to traditional classes at the university based on theory that were prevailing in their education. They felt that this active approach to learning provided them with the opportunity to find the new ways of approaching the practice problems. Project based learning and the opportunity to solve problems from practice is what a significant majority of the students consider as important for their professional development. As one of the students stated: '*The work on the real problem and the entire process of problem solving, from analysis to implementation' (S16),* and the other: *For the first time I was able to think as an engineer, to view the system as a whole (S62).*

The opportunity to enhance problem solving as well as other skills such as communication, organization and presentation has been evaluated as professionally and personally important, as well as an significant motivational factor. Students appreciate this opportunity in the area of competence building since they feel that this is important for their future workplace. On the personal level, they feel more self-confident as they had the experience to practice and "try" their skills, but hugely due to collaborative and social dimensions of learning that they experience with their peers and colleagues.

The students believed this experience would help them adapt better to the work environment and their future jobs, and that it helped them enhance their problem solving process: *"It is important because in the future I will know how to approach the problem I'm facing, where to start, what to be careful about and how to go for the final solution."(S2) Because the professional practice gave me an insight into how my future profession could look like, and we acquired the knowledge on how to get to the information we need, how to design a system, how to ask questions (S55);*

One of the important findings of this study was that the course helped students increase their self-confidence which may imply that reflective practice is what took place in their project work during the course (S4: "*A very positive impact on my self-confidence, making me aware of all the knowledge acquired during our studies.*").

The Content: Work on a real project as contextual learning. The opportunity to work on a real project was highly valued by the considerable majority of students, and it was significantly more important to the students than the problem based learning. Real project work was evaluated both as professionally important and as a crucial motivational factor. This may be interpreted as an intrinsic motivation that comes from contextual learning (Biggs & Tang, 2007). Students found that many of the problems that need to be solved in the workplace have non-engineering constraints and that they have to adopt a broader approach than just trying to solve well-structured problems they are used to. They repeatedly stated that being engaged in the real project work is one of the most valuable aspects of the course. As stated by some of the students: *"My main motivation was to do something practical and work on a real project for the first time." (S7) "To gain knowledge on the project processes and problems from practice, get to know real systems and equipment" (S6).* The value that creates meaning and motivation - this could serve as a guidance for the curriculum designers of the courses at the final years of the academic studies. Interestingly enough, none of the students stated that their motivation was to gain two ECTS points.

Process ownership: Reaching solution on their own. Process ownership where students investigate and reach the solution on their own was what students enjoyed the most during the course. In spite of being cognitively more demanding, as they had little or no previous experience in self-guided real project work, the majority of students felt that this was a great challenge for them to test themselves, their knowledge and their skills. The students highlighted the value of being in charge of the process of solving ill-structured problems and making decisions: this approach stimulated their creativity, engineering thinking and skills development. This intrinsically motivated them to do their best to reach the solution and overcome all the challenges they came across. The fact that they did not "have to" study is exactly what motivated them to do the job. They like to work, and they excel at it, but they do not like the pressure of having to gain high scores and pass exams. This is what created the positive atmosphere at the course that significant majority of the students mentioned as what they liked the most during the course.

Students valued highly the way that the instructor conducted the course – this was the only item in the evaluation survey where the students agreed 100% (no neutral or disagree statements). What they valued the most was that the instructor was providing them with valuable inputs and felt comforted that they could ask questions and receive guidance from the instructor. They also appreciated that they never received ready answers, which permitted them to create what they valued the most – the solution on their own.

Process ownership is what they will be faced with at the workplace, and gaining confidence in the process is one of the benefits students recognized in the course.

Teamwork: Collaborative learning. Teamwork has a special position in this context of social and collaborative learning at the course. It is both personally and professionally important and motivating; a vast majority of the students feel that they enjoy it very much. The team spirit motivates them to finish the task, and an important number of students stated that this was their motivation to persist along the task of ill-structured problem solving and project work. They learn how to overcome differences in personalities and opinions: *I got the insight of what it means to work in a team and what kind of person I am for collaboration (S58); Augment the levels of tolerance. Accept the differences, Work on self-confidence. Tangible work results. (S69).*

Self-directed learning activities were placed in the context of the interactions with proper team, other teams and the instructor. Within this context, a surprising finding was that the students grew more self-confident and found comfort in understanding that their peers lacked practical experience as well (S5: "*Because I realized that I was not the only one without any practical experience, it had a huge positive impact on my self-confidence.").*

Pitfalls. Students stated few issues that they disliked about the course, mostly related to the schedule, classes being too early or too late, too close to the exams, or even too short. Some of the suggestions for improvement were related to the fact that students would like to work on real world equipment, to be able to touch the equipment and install the designed system, and for the course to last longer.

Sustainable development. Sustainable development principles were new to almost all of the students; only a few of the students have ever heard of the term and only a couple of them had a vague idea what it was about. Therefore, it is significant that the vast majority of students showed a substantial interest in knowing more about the sustainable development principles in a future course

As a final point, by vast majority students confirm that they would like to attend another course like this and that they would recommend it to others.

Issues and challenges. Determining the key challenges that students face during the project work and ill-structured problem solving was important for following their progress during the course, adapting scaffolding as they progressed in the project work, but also for the further reflection and development of the research.

The identified issues and challenges of the learning experience that students went through during the course include: defining the ill-structured problem; learning to ask questions; connecting theory and practice; self-guided study and information gathering; facing the reality through site survey; dealing with ambiguity and trade-offs; learning to communicate clearly, facing the failure. Several of them are described in the existing research as part of ill-structured problem solving such as problem definition (e.g. Chi & Glaser, 1985; Jonassen et al., 2006) or as part of design process such as tolerating ambiguity and uncertainty, in part described by Dym et al. as relevant skills of engineering design that include "*the ability to: tolerate ambiguity that shows up in viewing design as inquiry; maintain sight of the big picture by including systems thinking and systems design; handle uncertainty; make estimates and decisions; think as part of a team in a social process; and think and communicate in the several languages of design.*"(Dym et al., 2005).

Findings on other issues, such as connecting theory and practice, were expected due to the strong theoretical inclination of the conventional curricula.

However, findings on learning to ask questions, facing the reality in a real engineering site survey and dealing with failure, presented a surprise as a more proactive approach was expected from the students and it was obvious that they needed more support in overcoming these challenges and fostering the appropriate skills.

These issues may inform further research, as the constructivist approach that was applied during the course for students' reflection on the problem solving process could be further explored to support students' learning.

Learning styles. The learning styles that were identified indicate significantly higher number of Assimilators than expected in the engineering profession, which is predominantly Converger. This is in line with the major challenge encountered, to connect theory with practice, which could be explained by dominant number of Assimilators which has a major characteristic of "theorist" as opposed to the Converger, which has a major characteristic of "practitioner".

The importance of the Layer 1 results of the study lies in the fact that the overall findings can inform future instructional designs for the development of professional practice. Students' perception confirms that this learning experience is important for their professional and personal development, and point out the motivational factors important for them.

9.2 COMPETENCE DEVELOPMENT

The objective of the Layer 2 of the research was to determine the course contribution to the generic and professional skills development.

The major research questions related to Layer 2 research were related to the importance and level of success that students perceive for their generic competences and to the course contribution to the generic and professional competence development. The participants in the Layer 2 research were 76 students. The research was conducted for 4 years, extending over 6 one-semester courses.

Overall results support previous research while adding further evidence with respect to specific generic and professional skills development.

Generic skills importance and development. The results indicate that generic skills, such as teamwork and communication, and ability to apply knowledge in practice are perceived to be the most important. It is interesting that more importance is given to the skills that are used in everyday life, while skills that are seemingly more domain specific such as systems thinking or solving ill-structured problems are perceived to be less important. This is in line with the findings of other studies (M. Gerasimović & Miškeljin, 2009).

Regarding the generic skills, important finding for the further development of this kind of instruction is that there was a significant difference in the self-assessed levels of success PRE and POST course ($p<0,05$), indicating that the course has contributed significantly to the development of precisely those generic skills that are important for engineering profession and probably the least represented in the formal curriculum, which are: *asking questions, presentation, ability to apply theory in practice, solving ill-structured problems, generating new ideas, ambiguity tolerance and systems thinking, both in technical and social contexts.*

These skills are found to be important in the context of engineering education for sustainable development as well (Cruickshank & Fenner, 2012), (Segalàs, Ferrer-Balas, Svanström, et al., 2009) thus supporting the assumption that the module based on the same instructional approach would support the development of these skills in the sustainability context.

On the other hand, the results of direct measurements indicate that the students' perception of the course contribution for individual skills in general is inclined towards generic skills such as *teamwork* and *communication*, *Planning and organization* and *find relevant information on the internet*, including *Systems thinking - technical systems.* This is in line with the previous research ((de Camargo Ribeiro, 2008), (Canavan, 2008), (Mitchell et al., 2009)), though systems thinking did not form part of the investigation conducted in these studies.

The *ability to apply knowledge in practice* and *solving ill-structured technical problems* are rated on a higher relative level for course contribution than for level of success, which could indicate that these learning objectives were reached by the course and that, though students perceive low level of success in these skills they do recognize the course contribution in developing them.

These results indicate that *generating new ideas in the process of finding a solution*, *ambiguity tolerance* and *presentation* need to be emphasized in this kind of instruction in order to reach higher perception of course contribution in the development of these skills, since these skills were shown to have significant difference in indirect course contribution measurements (PRE and POST levels). More time at the course can be dedicated to practice the necessary idea generation and presentation skills by introducing brainstorming sessions and mid-term presentations of the conceptual design, before the whole proposal is elaborated for final presentation.

Skills gap between importance and level of success. The fact that there is a gap between importance and level of success for some of the skills, namely: *ability to apply knowledge in practice, solve ill-structured problems, presentation* and *generate new ideas,* indicates that though the course contributed significantly to the development of these skills, more effort could be put into development of their skills throughout the curriculum in order to foster them gradually.

Professional skills. Interestingly, all of the professional skills are rated as below the theoretical mean PRE course, while all of the professional skills are rated well above the theoretical mean POST course, indicating significant development. The fact that a significant difference in levels of success PRE and POST course is noted for each of these skills (all are $p<0,05$) indicates that the professional skills required from the engineering graduates by engineering accreditation bodies' are fostered in this kind of instruction. These skills include: ability to design basic system taking into account the requirements and limitations; formulating and solving problems that are insufficiently structured; analysis and interpretation of specifications; evaluation and selection of solutions; creation of the realistic implementation plan for the simple project with constraints; analysis and critical evaluation of the problem.

The findings on professional skills are important since empirical evidence on professional skills development in this kind of instruction is still missing.

Overall findings on competence development fully correspond to the course objectives that were set for the Project Planning and Organization in Engineering Practice course, as well as with the theoretical conclusions of the existing studies(T. A. Litzinger, Lattuca, Hadgraft, & Newstetter, 2011b), indicating that the project based problem based workplace simulation course has the potentials to prepare students for work environment, supporting the development of professional practice.

9.3 PHASED CHALLENGES AND SKILLS DEVELOPED

The objective of the Layer 3 of the research was to explore where and how students could be best supported during the process of ill-structured problem solving.

The major research questions related to Layer 3 research were focused on determining phased challenges and skills in order to be able to use the finding in supporting students learning. The participants in the Layer 3 research were 33 students. The research was conducted for 2 years, extending over 2 one-semester courses.

In the beginning of the professional practice project based learning course, major challenges that the students face are understanding where to start to solve the problem and connecting theory and practice, while in the same time span students perceive that the skills that they develop the most are ambiguity tolerance and ability to apply knowledge in practice, which may indicate that major challenges trigger the development of the appropriate skills for their resolution.

As the course advances, major challenge that students perceive is *accepting that there are limitations and compromises.* The skills that students develop the most during the same period, are *systems thinking, generating new ideas in the process of finding a solution and planning and organization.* This point in time corresponds to the beginning of the solution finding process (developing various possible solutions and scenarios for the conceptual design) so students perceive that their creativity is fostered in the process of finding a solution. Systems thinking is necessary for the conceptual system design and the fact that systems thinking is being developed confirms that the educational approach fosters the development of this skill. At the same time students start organizing both the work on the solution and the future work on the project that they are developing through the proposal, which is why they may perceive the development of the skills of planning and organizing the project work.

Regarding the challenge of *accepting that there are limitations and compromises*, this is a challenge that every engineer faces constantly in the real world environment. The course was designed with the obligatory site survey so that the students would have to face the reality where they actually "feel and experience" limitations and compromises. Once they are out in the field I insist that they make a drawing of their solution respecting the real conditions at the site. This is a very important step of facing the reality since he other project work is performed in the classroom environment where though a real world solution is developed it is not connected to the real world until we go out to inspect a real site (in the park, at the lake, on the fortress). The other aspect of limitations and compromises could be the difficulty of finding the real equipment on the internet – no more calculations and theory but facing what really exists out there and adjusting the needs with what the reality has to offer.

With the course already advanced, in the third point of time, major challenges are to *describe the technical solution of the system* and to *define the criteria for evaluating the solutions*. At the same time, the skills that students perceive to have developed are: *willingness to accept differences of opinion, planning and organization and systems thinking*. This indicates that the teamwork is stabilized in this period and the members of the team have accepted one another in order to go towards the common goal. Planning and organization and systems thinking are needed to design the solution and the work of the project the team is proposing in order to plan the project work correspondingly and to design the system in an appropriate manner.

At the end of the project work, the major challenges that students perceive are to *compare solutions, and decide which is the best* and to *define the criteria for evaluating the solutions*. This is the culmination of the ill-structured problem solving process and this is what differs this process from the well-structured problem solving which is generally practiced throughout the university. The skills that are developed the most in the same period of time are: *systems thinking, finding relevant information at the internet and planning and organization*. The steadiness of the development of systems thinking and the planning and organization support the intention of the learning experience to foster these skills as skills necessary for conceptual systems design and project work. Finding the relevant information on the internet could be attributed to the final equipment and prices search in order to elaborate the offer.

One more issue should be noted. It is the periodicity of challenges for one group of challenges and relatively uniform rating throughout the course for the other group of challenges.

Firstly, there are challenges that are periodical and that would require appropriate support in different periods of the learning experience, in part confirming the results of (Purzer et al., 2011) about the challenges in overlapping waves. These were found to be all the above stated challenges, with the addition of: *learn to ask questions, independently decide on the how to collect and use the information, face the reality during the site survey* and *present the solution.*

The constant support throughout the course should be provided for the following challenges: *define the problem to be solved, understand and take into account the requirements of the client, accept the uncertainty of the final solution (there is not only one correct solution), clearly express my demands in communication with others, visually represent the problem (block diagram, sketch), face the failure and continue looking for the solutions, plan and organize the work that has to be done on the project and justify the solution.*

9.4 IMPLICATIONS FOR PROFESSIONAL PRACTICE IN THE CONTEXT OF EDUCATION FOR SUSTAINABILITY

In this Section the results deriving from the 4-year action research study are used to propose the guidelines for the instructional model for the ill-structured problem solving and competence development professional practice course in the context of education for sustainability.

Engineering profession requires that engineering graduates be equipped with the knowledge and skills to address sustainable development issues. In traditional engineering curricula, there is a need to design engineering professional courses that would provide basic knowledge on sustainable development, understanding of the complexity of sustainable development and develop skills that are needed for the complex problem resolution in the sustainability context.

Building on the results obtained on ill-structured problem solving and competence development in the professional practice module in engineering education, where the sustainable development basic principles were presented, this research has identified following guidelines that could inform the design of such a module in the context of education for sustainable development:

- Provide a problem that is relevant in the context of sustainable development
- Address issues and challenges that students face during ill-structured problem solving by module design and instructor support
- Foster competence for engineering profession and ill-structured problem solving in the context of sustainable development
- Support students during ill-structured problem solving
- Assure motivation to attend the course
- Understand the importance of the course for the students
- Address the learning styles of the engineering students

Engineering graduates need to be equipped with a core understanding of sustainability issues and opportunities as they relate to their practice.

The instructional design. The instructional design should follow the project and problem based learning principles based on ill-structured problem solving and real-world projects. This kind of instruction promotes higher order thinking skills, intrinsic motivation and deep approach to learning. It promotes systems thinking in societal context, and systems thinking is argued to be one of the vital competences needed for sustainable development (see Competence development below).

Problem relevance. In order to promote contextual learning which in turn motivates students and which they perceive as important for their professional development, the problem should be chosen carefully taking into considerations the following:

- In the field of electrical engineering faculty that includes energy department, telecommunication and ICT, as well as software development, the problem needs to be selected carefully reflecting possible aspects of sustainability in engineering for the better quality of life of citizens.

- Particularly, telecommunications have a vital role to play in sustainable development. With the level of development they have reached, modern telecommunication technologies, which are rapidly taking us from the industrial economy to the information economy, constitute extremely useful tools with which to take up this challenge.
- However, it has to be understood that ICT can only help achieve development – it is a means and not an end. To be meaningful, ICT has to be integrated into development as well as engineering and societal systems. It can be used in areas such as: energy management, smart grids, water management, transportation, education, healthcare, employment enhancement.
- In order to fulfil its role, ICT must focus on real innovations and new challenges, developing new models for research and development in the above areas (Chattopadhyay, Chattopadhyay, Das, & Das, 2004)
- Existing research provides well researched, peer reviewed and trialled examples of engineering education for sustainable development. One of these examples is the Australian programme described in (Paten, Palousis, Hargroves, & Smith, 2005) that contains three portfolios: the Critical Literacies Portfolio (CLP) for basic understanding of the principles of sustainable development; the Technical Design Portfolio (TDP) which covers sustainable design in detail; and the Industry Practice Portfolio (IPP) which focuses on the latest advances on eco-efficiency opportunities for industry. The course should be designed to facilitate the effective incorporation of key pieces of information ('*critical literacies*') and the latest advances in sustainable design approaches ('*design principles*') relating to sustainability into engineering curricula and capacity building

Problem relevance is widely recognized in the existing literature as a crucial factor of problem based learning (e.g. (D H Jonassen & Hung, 2008), (James Trevelyan, 2008))

Issues and challenges. Issues and challenges should be addressed both through a careful course design as well as by adequate instructor's support.

There are challenges that should be addressed periodically with peaks at different points of the ill-structured problem solving process, and those that need permanent support during the course.

Understanding where to start solving the problem, connecting theory and practice, defining the criteria and choosing the solution based on a defined criteria present the periodical challenges that can be applied to sustainability themes. These challenges need periodical support as defined in Section 9.

The challenges that need permanent support during the course are:

- Defining the problem to be solved

- understanding and taking into account the requirements (of the client, community, institutions)
- accept the uncertainty of the final solution (there is not only one correct solution)
- clearly express my demands in communication with others
- visually represent the problem (block diagram, sketch)
- face the failure and continue looking for the solutions
- plan and organize the work that has to be done on the project
- justify the solution

This support can be provided via scaffolding, readings, expert visits, field visits, a variety of management and decision making tools some of which are described in the existing literature (

Competence development. Competences that are essential for sustainable development and that are shown to be fostered by the proposed instructional design include: asking questions, presentation, ability to apply theory in practice, solving ill-structured problems, generating new ideas, ambiguity tolerance and systems thinking, both in technical and social contexts.

The fact that significant difference was found in the self-assessed level of the systems thinking – societal context is noteworthy, considering that the students were provided only with one lecture on sustainable development basics. Any further development of the theme would be expected to bring further awareness and competence development in this area.

Another important input is the fact that students have reported systems thinking as constantly developing competence throughout the course (in T1, T2, T3 and T4), and it was the competence with the highest mean level of all at the whole course.

It can be concluded that the educational methods described for this course would imply development of systems thinking as a crucial competence for sustainable development.

Professional competences that were found to be significantly developed during the action research all belong to engineering field, but the fact that they belong to higher order thinking skills makes them transferable to other fields as well. This makes me confident that they can be developed by applying similar process to the content in the sustainable development context. This is why I propose to generalize the list from Section 4.3.1 as follows:

- applying the basic principles (of engineering) in systems design taking into account the requirements and limitations;
- formulating and solving (engineering) problems that are insufficiently structured;
- analyse and interpret specifications (of telecommunication devices and systems);

- use (engineering) techniques for evaluation and selection of (technical) solutions;
- create a realistic implementation plan for the simple project with time and resource constraints;
- perform technical analysis and critical evaluation of the problem, along with the recommendations and conclusions (based on technical knowledge)

Instructor's support. It appears necessary to guide students in ways that help them consider the underlying structure of the problem. In this study, guidance was provided in the form of role-play and "suggestions" that were designed to focus novices' thinking when analysing a problem situation.

Therefore, design of the learning environment has to support and challenge the learner's thinking. The most critical teaching activity is in the questions the teacher asks the learner in that consulting and coaching activity. It is essential that the teacher value as well as challenge the learner's thinking. (J. R. Savery & Duffy, 2001)

It is important for the teacher not to take over thinking for the learner by telling the learner what to do or how to think. This is appreciated by the students who put great value in finding the solution on their own, but at the same time appreciate the instructor's guidance.

The described approach requires a different approach to teaching and the development of instructors' skills as well, which is already recognized as challenging in the previous research.

What has been shown by this study confirms previous findings that by asking questions, teachers can guide students to act in 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 questions they should be addressing in learning and problem-solving practice (Xie & Bradshaw, 2008)

Motivation and Importance. Students should be offered to work on a real project, with a problem from real engineering practice as this is the essential motivational factor for them. The fact that grades don't exist liberates them of the pressure and leaves them to dedicate themselves to work on the project within their team. Teamwork is both personally and professionally important and motivating. In addition, students are motivated by the fact that they will develop skills, which they value in the field of personal development as well.

Learning styles. In the particular setting of the engineering course in this study, the major challenge that students encountered was connecting theory and practice, and that could be attributed to the high proportion of Accomodators in the group where it would be expected to have a vast majority of Convergers. This can be taken care of by gradually introducing student centred learning and project based learning based on real world problems and engineering practice throughout the studies.

Additionally, previous research offers a number of ways in which the learning experience could be shaped in order to accommodate for different learning styles.

(Crawford et al., 2003) propose:

- *to activists, the opportunity to engage with new ideas and experiences as part of a team, with a 'here and now' focus*
- *to reflectors, the opportunity to investigate, assemble and analyse information within a structured learning framework*
- *to theorists, the opportunity to apply models and concepts help understand complex problems and situations*
- *to pragmatists, the opportunity to test out ideas and techniques by applying them in 'real life' contexts*

(Milosevic, Brkovic, & Bjekic, 2006) present a scenario of adapting learning content towards individual student characteristics taking into consideration his/her learning style type and subject matter motivation level. The resulting guidelines are based on pedagogical strategy and motivation factor with a strong psychological background.

10 CONCLUSION

Generic and professional competences are identified as necessary learning outcomes for engineering programs by professional accreditation engineering bodies around the world. In order to achieve this goal existing educational practices are being modified from teacher centred to student centred learning. However, more evidence is needed as empirical support that active learning environments are adequate for developing competences for engineering practice.

This study addressed the issue of competence development from several perspectives that form a novel approach both in terms of instructional design and research methodology design and implementation. Therefore, the contributions of this study are:

- **Breadth and depth of the research in real time engineering education context:** The professional practice instructional module, that we have named the "P*i*ng" model was designed, implemented and empirically evaluated as a leaning environment in the engineering education context during 4 years and 6 courses that the researcher held as instructor for 85 engineering students. This kind of consistent research expanded both in time and in depth on competence development is present in only a few examples in engineering studies ((Woods, 2006b), (Daniels, 2011))
- The instructional model was designed building on **Research-Based Instructional Strategies (RBIS)** (Froyd, Borrego, Cutler, Henderson, & Prince, 2013) and it included previous thorough study of educational practices, their implementation and enhancement through cyclical action research course improvement. Main educational approaches included problem and project-based learning with workplace simulation and role play that were chosen as the most implicated for the generic and professional skills development, in a learning environment based on experiential learning and constructivist approach to learning.
- **The novel research design:** the research design for this study was developed to follow both the complexity of the investigated problem and the multi-cycle action research. The application of research phases and layers which was developed and applied in this study is unique contribution not found in the existing literature on engineering education research (Borrego et al., 2009). This research structure facilitates the application of research instruments and data analysis, as a way of comprehending the investigated problem and its complexity in an extended research and the interpretation of the obtained results.

- **Real project work as main driver for competence development:** In addition to verifying the existing research conclusions, this study has provided evidence that the use of real project work in the described instructional model can foster generic and professional competences in students, by determining that real project work is main motivational factor in the professional practice course and that they perceive it as the most important for their professional development. These two factors, motivation and importance, are the main drivers for promoting deep learning which in turn has been found to be necessary for competence development. Therefore, the significance of this study is that it suggests that the major driver for competence development may be the use of real project work in the instruction, a conclusion that was present in theoretical considerations on motivation and deep approaches to learning (Biggs & Tang, 2007).
- This study found **significant differences in the perceived levels of success of generic competences** before and after the course such as **systems thinking, both in technical and social contexts, idea generation and ambiguity tolerance**, ability to apply theory in practice, solving ill-structured problems, asking questions and presentation, competences which are not sufficiently developed in traditional engineering education.
- This study found **significant differences in the perceived levels of success of all the professional competences** that were investigated. The significant development can be noted after the course in the ability indicates that all elements of the Bloom taxonomy are present in this kind of instruction, which is a novel empirical finding based on the perception of the skills- levels of success before and after the course.
- **Phased issues and challenges during ill-structured problem solving derived empirically in this study, periodic and constant:** This study empirically defined issues and challenges that students face by following the students' problem solving process closely, as an active participant (instructor) in the teaching process. This permitted me an insight into students' challenges that were empirically found and further applied to the next cycle of the research, thus making them relevant for the observed phenomena in its natural setting. By following the process of ill-structured problem solving in engineering real project work, which is limited in existing research, in spite of its importance for understanding the process of teaching and learning for engineering practice. One of them, Purzer et. al. (Purzer et al., 2011), inspired the approach to in-depth challenges research in this study, though significant differences exist between the implementation strategies and the two approaches, as described in the Discussion sections of this work. This study has found that the challenges that students face during ill-structured problem solving are twofold, in part periodical and in part constant, thus requiring different

approach by educators, which represents a step forward with respect to the existing research that was mainly theory based.

- **Phased skills development during ill-structured problem solving derived empirically in this study, growing and variable:** This study found that students' skills levels such as systems thinking and generating new ideas in the process of finding solution are growing constantly during the process of ill-structured problem solving. Others, such as expressing opinion, asking questions, willingness to contribute to a common solution and planning and organization have variation along the process but are growing quasi-steadily. Skills such as teamwork – willingness to accept differences in opinion, ability to apply knowledge in practice or ambiguity tolerance have steep falls during the process. These results permit new insights into skills developed through the process of ill-structured problem solving and provide directions for further research.
- **Instructional design of the professional practice in the context of sustainable development** based on this research results and on the theoretical considerations of the similarities of the problems and essential competences in engineering and sustainability (systems thinking in technical and societal context, idea generation, ambiguity tolerance) should have the following characteristics: a problem that is relevant in the context of sustainable development, in a project environment based on the real project work where students practice and foster skills for engineering profession and ill-structured problem solving in the context of sustainable development, thus assuring students'' intrinsic motivation and deep learning; address periodic and stable challenges that students face during ill-structured problem solving by appropriate module design and instructor support; address the students' learning styles.

The obtained results provide answers to the research objectives and open new perspectives for transferring the new "P*i*NG" model to other domains.

These results are firmly rooted in the practice, therefore they can be easily transferred to instructional practice: having been empirically tested they can inform future instructional designs that include ill-structured problem solving and teaching and learning for practice.

The limitation of this study is that the skills levels for generic and professional skills are subjectively evaluated, and there is no objective measure of achievement, which may be introduced in future work. However, self-assessment is at the same time one of the strong points of the applied methodology since it provides the space for reflecting on teaching, learning and skills development advocated by Schon.

This study provides results that can be considered of value for the continuity of this line of research, as well as for opening the new ones.

One of the aspects that could be introduced in the future studies in order to better understand where students can be better supported for skills development is to let students explain which aspects of the course specifically contributed to the development of individual skills.

The results of this study are transferable to other domains whose practice is based on solving ill-structured problems and competence development corresponding to the competences presented in this study. Therefore, the course design could be used in other domains where professional practice courses are needed, both as internships and internship-like courses.

Improvement of the course for the future also requires a closer connection with the real company environment, and some of the students have proposed that. Cooperation with companies that may find their interest in providing real equipment for the course could be established, and a step further would be having professional engineers assess and act as consultants for the teams' preliminary designs and final proposals.

In the future, the follow-up with the graduates who participated in the study could be performed to evaluate the course contribution in the employability and in their real workplaces.

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12 APPENDIX 1 – RESEARCH INSTRUMENTS USED IN THE STUDY

This section provides an overview of content that has been developed to address the academic need for peer reviewed sustainable development content that is readily adaptable in the classroom. It addresses the elements of 'Existing Course Renewal' (Integrated Approach) and 'New Course Development/ Replacement' (Flagship Approach).

Although the terminology used to describe programmes and practices varies, all are based on a common understanding of the importance of enabling students to integrate theoretical knowledge gained through formal study, with the practice-based knowledge gained through immersion in a work or professional context.

the study conducted by (Daniels et al., 2007a) addresses issues of open or ill-structured problems from learning aspects covering concrete examples to inspire education designers preparing students for their future careers by improving their problem solving capabilities. (Purzer & Hilpert, 2011) engaged participants in cognitive processes critical for ill-defined problem solving: linking theory, research, and classroom implications.

Therefore, one of the important purposes for learning is preparation for future work, which includes the ability to solve problems and to learn independently and collaboratively. For engineering programs, preparation for future learning in work situations should be one of the goals.

Course: **Project Planning and Organization in Engineering Practice**
Date:

GENERAL DATA

Name:

Survey 1 (SURV1) -COURSE EVALUATION

The following questions are related to how you perceive this course. There are no wrong and right answers, it is important to try to express precisely your attitude. Your task is to assess the extent to which you agree with the following statements by marking for each claim the number that corresponds to your position:

1. Strongly Agree
2. Agree
3. Neutral
4. Disagree
5. Strongly Disagree

1	The content of the course is such that I understand the learning objectives	1	2	3	4	5
2	I adopted the **project planning and organization** techniques enough to be able to apply them to simple projects in the future	1	2	3	4	5
3	I adopted the process of **solving technical problems** enough to be able to apply it in the future	1	2	3	4	5
4	It is difficult to perform the course work without previous theoretical lectures	1	2	3	4	5
5	I like problem based learning	1	2	3	4	5
6	I like learning based on real projects	1	2	3	4	5
7	I enjoy working in a team	1	2	3	4	5
8	The lecturer used good judgment to provide information when necessary during the project work	1	2	3	4	5
9	The lecturer has conducted this course very well	1	2	3	4	5
10	The course has fulfilled my expectations	1	2	3	4	5
11	I would like to attend another course based on the real problems	1	2	3	4	5
12	I would recommend this course to others	1	2	3	4	5
13	I am interested in learning more about the concept of sustainable development in some of the courses in the future	1	2	3	4	5

Survey 2 (SURV2) – SKILLS EVALUATION

The following questions relate to the general skills and abilities that you acquire during your studies. Please rank the offered skills/abilities as follows:

a) **IMPORTANCE** of skill/ability for performing the work in your future profession

b) **LEVEL OF SUCCESS** of a given skill/ability that you estimate to possess at the moment

You will assign the highest **rank 4** to the skill/ability that you assess as **the most significant** or for which you possess the **highest** level of success, and the lowest **rank 1** to the skill/ability that you assess as the **least significant** or for which you possess the **lowest** level of success.

IMPORTANCE				SKILL/ABILITY	LEVEL OF SUCCESS			
1	2	3	4	Communication -expressing opinion	1	2	3	4
1	2	3	4	Communication-asking questions	1	2	3	4
1	2	3	4	Teamwork-willingness to contribute to a common solution	1	2	3	4
1	2	3	4	Teamwork-accept differences of opinion	1	2	3	4
1	2	3	4	Presentation	1	2	3	4
1	2	3	4	Finding relevant information on the Internet	1	2	3	4
1	2	3	4	Ability to apply knowledge in practice	1	2	3	4
1	2	3	4	Planning and organization	1	2	3	4
1	2	3	4	Solving ill-structured technical problems	1	2	3	4
1	2	3	4	Generating new ideas in the process of finding a solution	1	2	3	4
1	2	3	4	Ambiguity tolerance	1	2	3	4
1	2	3	4	Systems thinking-technical systems	1	2	3	4
1	2	3	4	Systems thinking-engineering in a social context	1	2	3	4

And now we would like to ask you to assess the extent to which attending this course **CONTRIBUTED** to the development of these abilities and skills:

SKILL/ABILITY	COURSE CONTRIBUTION			
Communication -expressing opinion	Not at all	Little	Moderately	Very much
Communication-asking questions	Not at all	Little	Moderately	Very much
Teamwork-willingness to contribute to a common solution	Not at all	Little	Moderately	Very much
Teamwork-accept differences of opinion	Not at all	Little	Moderately	Very much
Presentation	Not at all	Little	Moderately	Very much
Finding relevant information on the Internet	Not at all	Little	Moderately	Very much
Ability to apply knowledge in practice	Not at all	Little	Moderately	Very much
Planning and organization	Not at all	Little	Moderately	Very much
Solving ill-structured technical problems	Not at all	Little	Moderately	Very much
Generating new ideas in the process of finding a solution	Not at all	Little	Moderately	Very much
Ambiguity tolerance	Not at all	Little	Moderately	Very much
Systems thinking-technical systems	Not at all	Little	Moderately	Very much
Systems thinking-engineering in a social context	Not at all	Little	Moderately	Very much

Questionnaire 1 (QUEST1) - COURSE EVALUATION

P1. To what extent the experience gained at this course is important for your future profession?

0 1 2 3 4

Why?

P2. To what extent the experience gained at this course is important for you personally?

0 1 2 3 4

Why?

P3. What was your motivation to attend this course?

P4. What did you like the most on this course?

P5. What did you like the least on this course? /How can the course be improved?

THANK YOU!

Survey 3 (SURV3) – SKILLS EVALUATION PRE/POST

The following questions relate to the general skills and abilities that you acquire during your studies. Please rank the offered skills/abilities as follows:

a) **IMPORTANCE** of skill/ability for performing the work in your future profession

b) **LEVEL OF SUCCESS** of a given skill/ability that you estimate to possess at the moment

You will assign the highest **rank 4** to the skill/ability that you assess as **the most significant** or for which you possess the **highest** level of success, and the lowest **rank 1** to the skill/ability that you assess as the **least significant** or for which you possess the **lowest** level of success.

IMPORTANCE				GENERAL SKILL/ABILITY	LEVEL OF SUCCESS			
1	2	3	4	Communication -expressing opinion	1	2	3	4
1	2	3	4	Communication-asking questions	1	2	3	4
1	2	3	4	Teamwork-willingness to contribute to a common solution	1	2	3	4
1	2	3	4	Teamwork-accept differences of opinion	1	2	3	4
1	2	3	4	Presentation	1	2	3	4
1	2	3	4	Finding relevant information on the Internet	1	2	3	4
1	2	3	4	Ability to apply knowledge in practice	1	2	3	4
1	2	3	4	Planning and organization	1	2	3	4
1	2	3	4	Solving ill-structured technical problems	1	2	3	4
1	2	3	4	Generating new ideas in the process of finding a solution	1	2	3	4
1	2	3	4	Ambiguity tolerance	1	2	3	4
1	2	3	4	Systems thinking-technical systems	1	2	3	4
1	2	3	4	Systems thinking-engineering in a social context	1	2	3	4

Survey 4 (SURV4)

PROFESSIONAL SKILL/ABILITY	LEVEL OF SUCCESS			
Apply the basic principles of engineering in telecommunications in the design of simple systems, taking into account the requirements and limitations	1	2	3	4
Formulate and solve engineering problems that are insufficiently structured	1	2	3	4
Analyse and interpret technical specifications of telecommunication devices and systems	1	2	3	4
Use engineering techniques for evaluation and selection of technical solutions	1	2	3	4
Find the equipment needed for the technical solution	1	2	3	4
Create a realistic implementation plan for the simple project with time and resource constraints	1	2	3	4
Perform technical analysis and critical evaluation of the problem, along with the recommendations and conclusions based on technical knowledge	1	2	3	4

CHALLPH

Module: Project planning and organization in engineering practice ***Log number 1 2 3 4***

***Name* ______________________________________** ***Date*____________**

1. CHALLENGES FACED DURING LEARNING

How to fill in the survey:

Carefully read all of the following options and select **<u>FIVE</u>** statements that you think that have presented the greatest challenge for you in your project work **during the last two sessions**. Then rank the selected challenges by assigning the **rank 1** to the challenge that was the **biggest,** and **rank 5** to the challenge that was the **smallest** of the five challenges.

Rank	The **biggest** challenge for me **during the last two sessions** was to
_____	understand where to start from in order to solve the problem
_____	define the problem that should to be solved
_____	learn to ask questions
_____	understand and take into account the requirements of the client
_____	connect theory and practice
_____	independently decide on how to collect and use information
_____	accept uncertainty final decision (there is not only one correct solution)
_____	accept that there are limitations and compromises
_____	clearly express my demands in communication with other stakeholders
_____	visually present the problem (block diagram, sketch)
_____	face the failure and move on in search of solutions
_____	face the reality during the site survey
_____	define criteria for evaluating solutions
_____	compare solutions and decide which one is the best
_____	plan and organize the project work
_____	describe the technical solution of the system
_____	justify the offer of the system
_____	present the offer of the system
_____	other: ____

SKILLPH: CONTRIBUTION OF CLASS WORK TO THE DEVELOPMENT OF SKILL/ABILITY

The class work **during the last two sessions** contributed to my fostering of the following s**kills/abilities**:

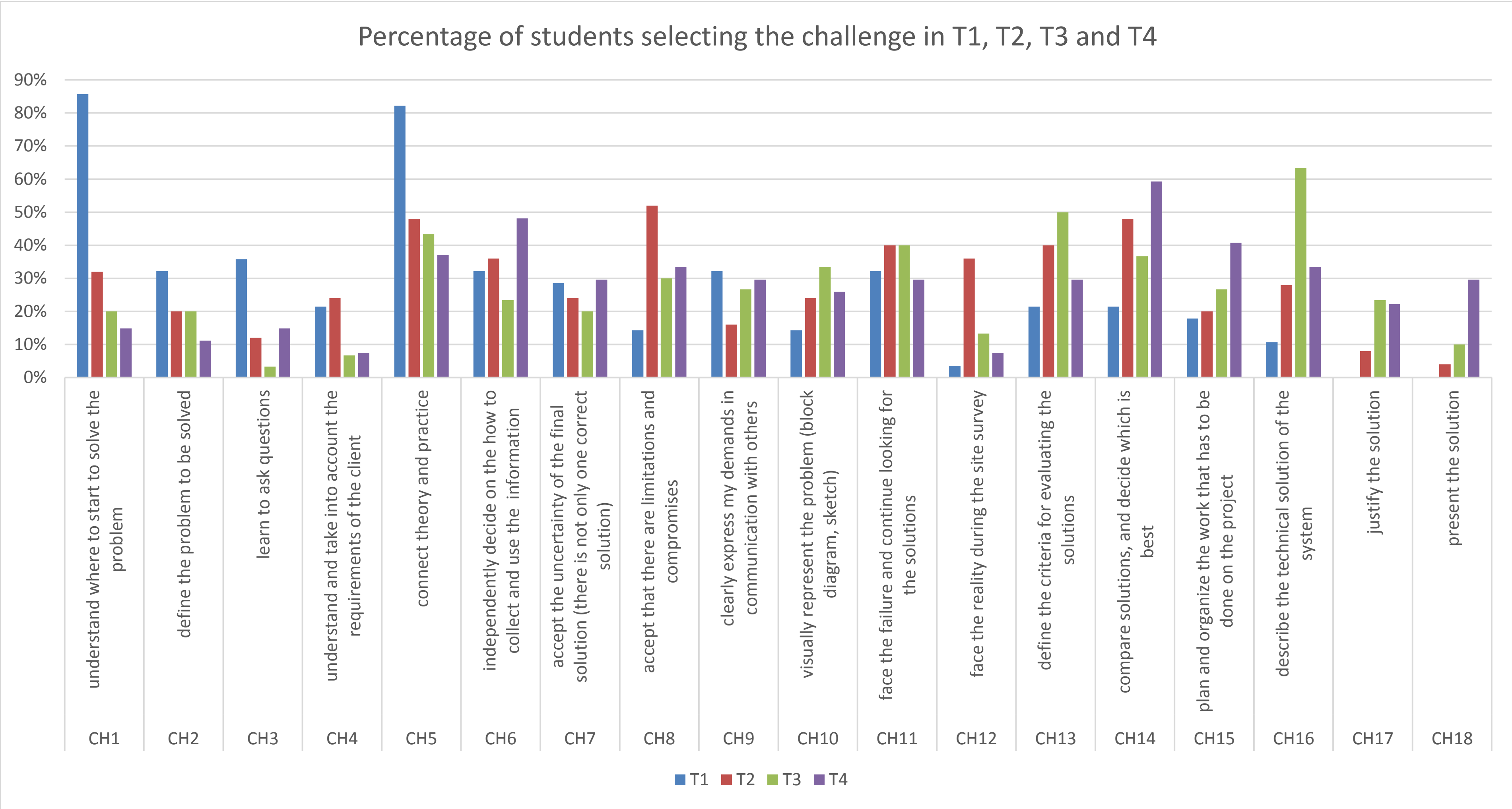
Skill/ability	Not at all 1	2	3	4	5	6	7	8	9	10 Very much
Expressing opinion	○	○	○	○	○	○	○	○	○	○
Asking questions	○	○	○	○	○	○	○	○	○	○
Willingness to contribute to a common solution	○	○	○	○	○	○	○	○	○	○
Accept differences of opinion	○	○	○	○	○	○	○	○	○	○
Finding relevant information on the Internet	○	○	○	○	○	○	○	○	○	○
Ability to apply knowledge in practice	○	○	○	○	○	○	○	○	○	○
Planning and organization	○	○	○	○	○	○	○	○	○	○
Solving ill-structured technical problems	○	○	○	○	○	○	○	○	○	○
Generating new ideas in the process of finding a solution	○	○	○	○	○	○	○	○	○	○
Ambiguity tolerance	○	○	○	○	○	○	○	○	○	○
Systems thinking	○	○	○	○	○	○	○	○	○	○
Presentation	○	○	○	○	○	○	○	○	○	○

13 APPENDIX 2 – DETAILED RESULTS

TABLE 13-1 CHALLENGES FREQUENCY AND RATING IN T1, T2, T3 AND T4

		T1		T2		T3		T4	
CH1	understand where to start to solve the problem	86%	6,29	32%	2,00	20%	1,20	15%	1,11
CH2	define the problem to be solved	32%	1,86	20%	1,60	20%	1,13	11%	0,52
CH3	learn to ask questions	36%	2,00	12%	0,40	3%	0,27	15%	0,96
CH4	understand and take into account the requirements of the client	21%	1,07	24%	1,12	7%	0,53	7%	0,37
CH5	connect theory and practice	82%	6,14	48%	3,28	43%	2,33	37%	2,89
CH6	independently decide on how to collect and use the information	32%	1,93	36%	2,32	23%	1,53	48%	3,63
CH7	accept the uncertainty of the final solution	29%	1,71	24%	1,12	20%	1,13	30%	1,33
CH8	accept that there are limitations and compromises	14%	0,50	52%	3,20	30%	1,40	33%	2,44
CH9	clearly express my demands in communication with others	32%	1,14	16%	0,72	27%	1,67	30%	1,63
CH10	visually represent the problem (block diagram, sketch)	14%	0,93	24%	1,20	33%	2,13	26%	1,33

CH11	face the failure and continue looking for the solutions	32%	1,50	40%	2,40	40%	2,00	30%	1,63
CH12	face the reality during the site survey	4%	0,36	36%	2,16	13%	0,93	7%	0,74
CH13	define the criteria for evaluating the solutions	21%	0,86	40%	2,48	50%	3,93	30%	1,85
CH14	compare solutions, and decide which is best	21%	1,21	48%	2,80	37%	1,80	59%	3,11
CH15	plan and organize the work that has to be done on the project	18%	1,21	20%	1,04	27%	1,73	41%	2,15
CH16	describe the technical solution of the system	11%	0,71	28%	2,16	63%	3,67	33%	1,70
CH17	justify the solution	0%	0,00	8%	0,56	23%	1,47	22%	1,48
CH18	present the solution	0%	0,00	4%	0,08	10%	0,60	30%	1,63


Percentage of students selecting the challenge in T1, T2, T3 and T4
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
understand where to start to solve the problem
define the problem to be solved
learn to ask questions
understand and take into account the requirements of the client
connect theory and practice
independently decide on the how to collect and use the information
accept the uncertainty of the final solution (there is not only one correct solution)
accept that there are limitations and compromises
clearly express my demands in communication with others
visually represent the problem (block diagram, sketch)
face the failure and continue looking for the solutions
face the reality during the site survey
define the criteria for evaluating the solutions
compare solutions, and decide which is best
plan and organize the work that has to be done on the project
describe the technical solution of the system
justify the solution
present the solution
CH1
CH2
CH3
CH4
CH5
CH6
CH7
CH8
CH9
CH10
CH11
CH12
CH13
CH14
CH15
CH16
CH17
CH18
T1
T2
T3
T4

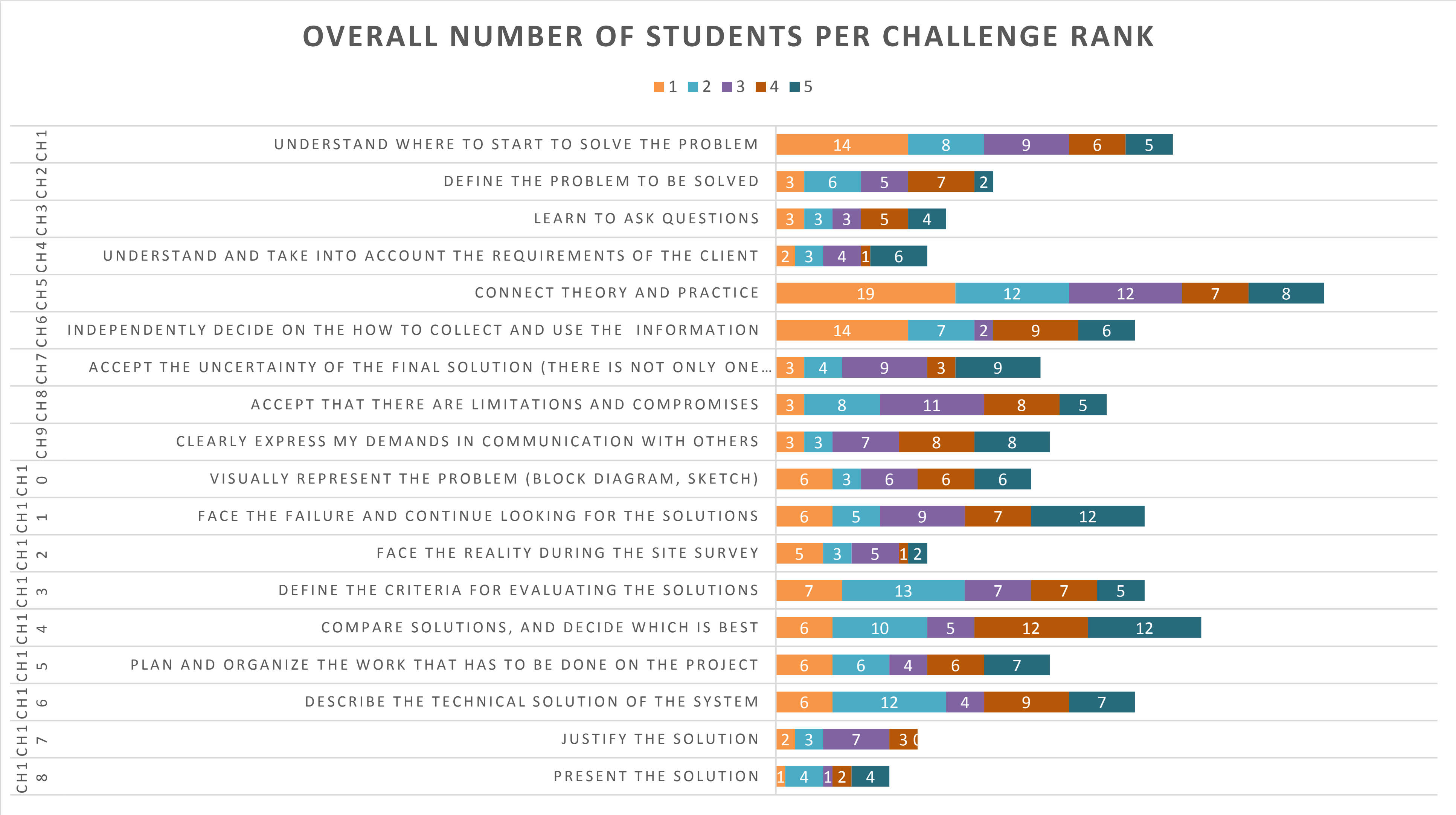
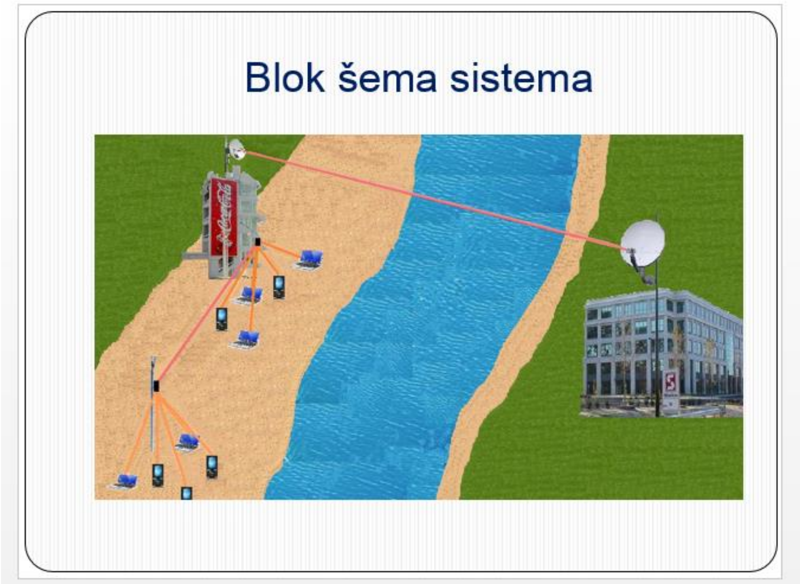
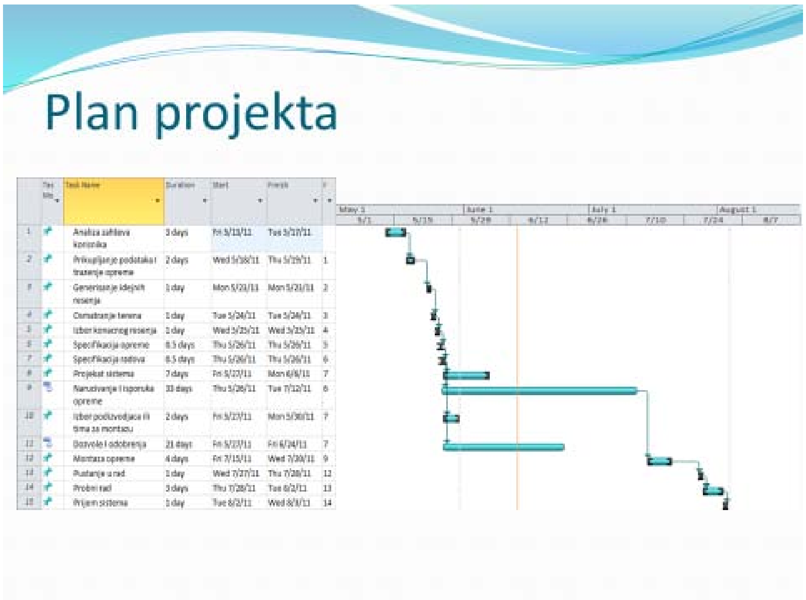


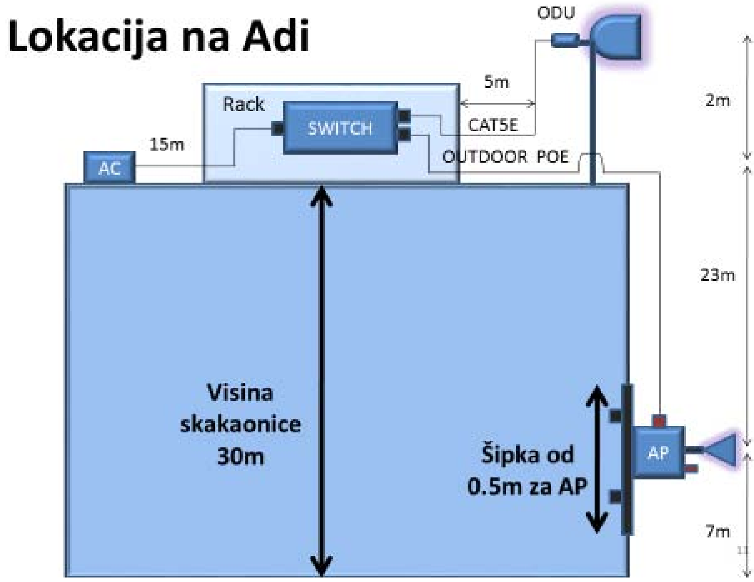
FIGURE 13-1 OVERALL NUMBER OF STUDENTS PER CHALLENGE RANK

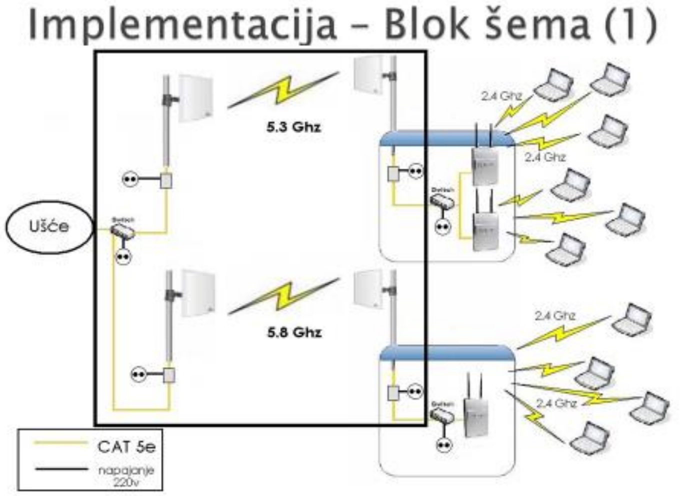
14 APPENDIX 3 – SAMPLE STUDENT SLIDES FROM FINAL PRESENTATIONS

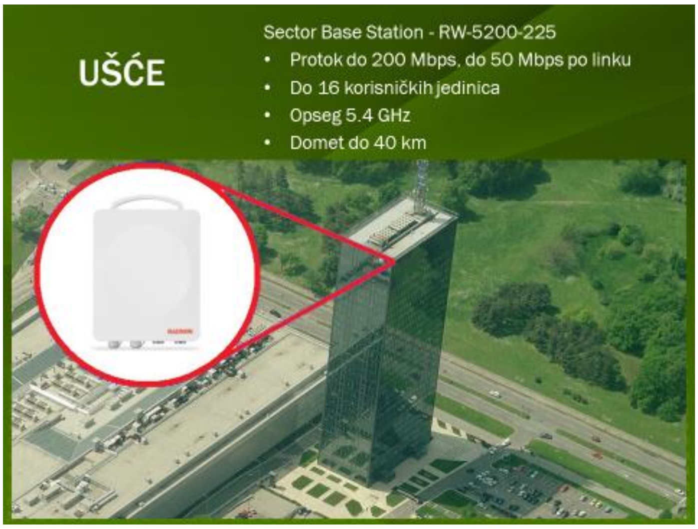




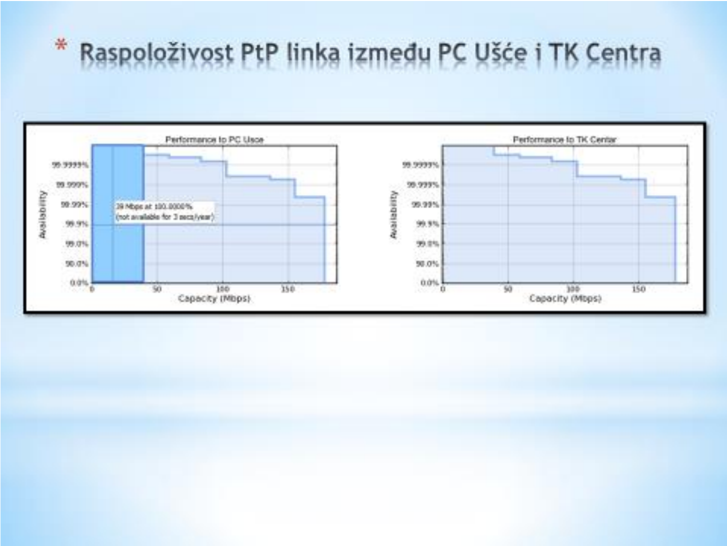
1	Analiza zahteva korisnika	3 days	Fri 5/13/11	Tue 5/17/11	
2	Prikupljanje podataka i trazenje opreme	2 days	Wed 5/18/11	Thu 5/19/11	1
3	Generisanje idejnih resenja	1 day	Mon 5/23/11	Mon 5/23/11	2
4	Osmatranje terena	1 day	Tue 5/24/11	Tue 5/24/11	3
5	Izbor konacnog resenja	1 day	Wed 5/25/11	Wed 5/25/11	4
6	Specifikacija opreme	0.5 days	Thu 5/26/11	Thu 5/26/11	5
7	Specifikacija radova	0.5 days	Thu 5/26/11	Thu 5/26/11	6
8	Projekat sistema	7 days	Fri 5/27/11	Mon 6/6/11	7
9	Narucivanje i isporuka opreme	33 days	Thu 5/26/11	Tue 7/12/11	6
10	Izbor podizvodjaca ili tima za montazu	2 days	Fri 5/27/11	Mon 5/30/11	7
11	Dozvole i odobrenja	21 days	Fri 5/27/11	Fri 6/24/11	7
12	Montaza opreme	4 days	Fri 7/15/11	Wed 7/20/11	9
13	Pustanje u rad	1 day	Wed 7/27/11	Thu 7/28/11	12
14	Probni rad	3 days	Thu 7/28/11	Tue 8/2/11	13
15	Prijem sistema	1 day	Tue 8/2/11	Wed 8/3/11	14



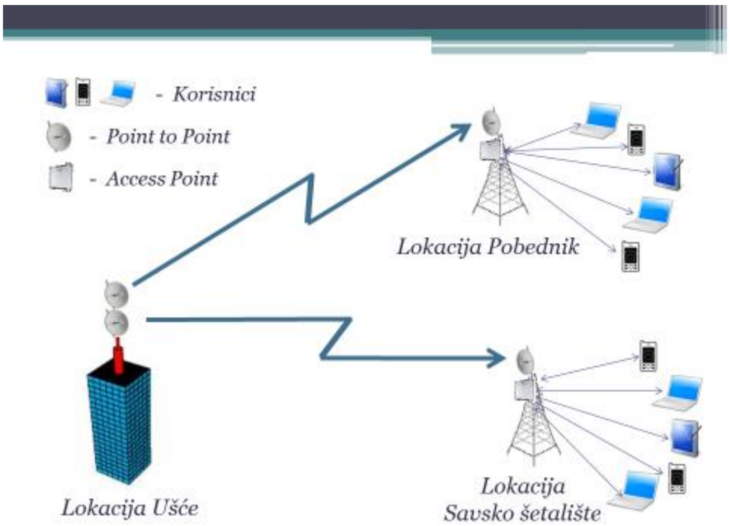

Implementacija – Blok šema (1)
5.3 Ghz
5.8 Ghz
Ušće
2.4 Ghz
2.4 Ghz
2.4 Ghz
2.4 Ghz
CAT 5e
napajanje 220v


UŠĆE
Sector Base Station - RW-5200-225
• Protok do 200 Mbps, do 50 Mbps po linku
• Do 16 korisničkih jedinica
• Opseg 5.4 GHz
• Domet do 40 km

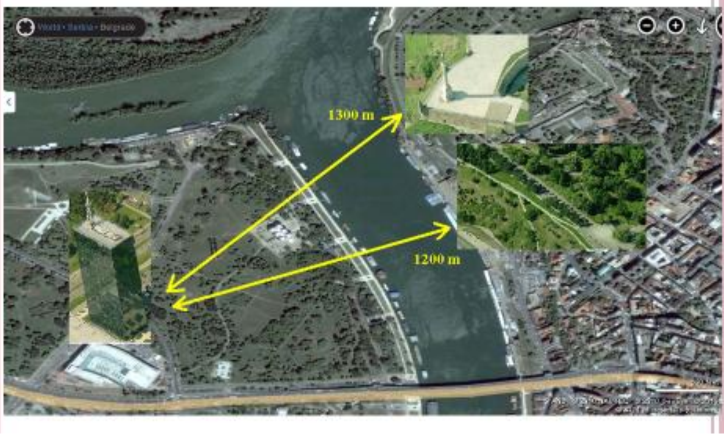

PRISTUPNI SISTEM (2/2)
• Upotrebljiv protok svakog AP je 27 Mbps
• Poređenje po broju korisnika i protoku (po jednom AP-u)
– 230 korisnika po ≈ 115 Kbps (GPRS)
– 70 korisnika po ≈ 384 Kbps (EDGE)
– 25 korisnika po ≈ 1 Mbps
– 13 korisnika po ≈ 2 Mbps (UMTS)
– 2 korisnika po ≈ 13 Mbps (HSPA)


* Raspoloživost PtP linka između PC Ušće i TK Centra
Performance to PC Usce
Performance to TK Centar
Availability
Capacity (Mbps)


* SITE1 – Savsko šetalište
90m
87m
SITE 1
Razvodni orman
JKP Javno osvetljenje Beograd
CAM1-2
55m
50m

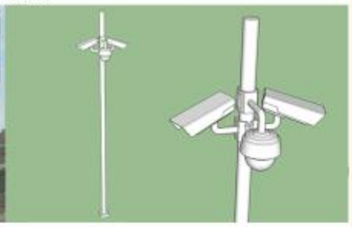

- Korisnici
- Point to Point
- Access Point
Lokacija Pobednik
Lokacija Ušće
Lokacija
Savsko šetalište

LOKACIJA

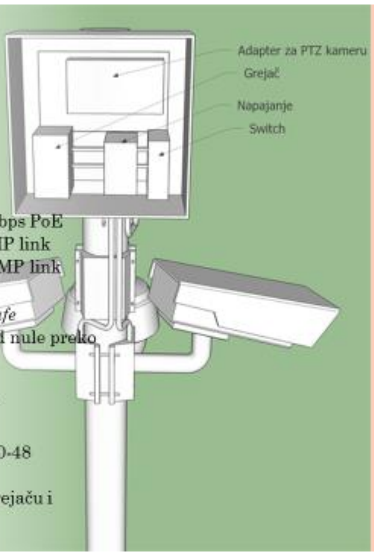


MONTIRANJE KAMERA

- Montiranje na krov
  - Plato kod Spomenika Pobedniku, krov zgrade Zavoda za zaštitu spomenika
- Montiranje na stub visine 4.5m
  - Glavno (Savsko) šetalište
  - Plato ispod Velikog Stepeništa



DODATNA OPREMA

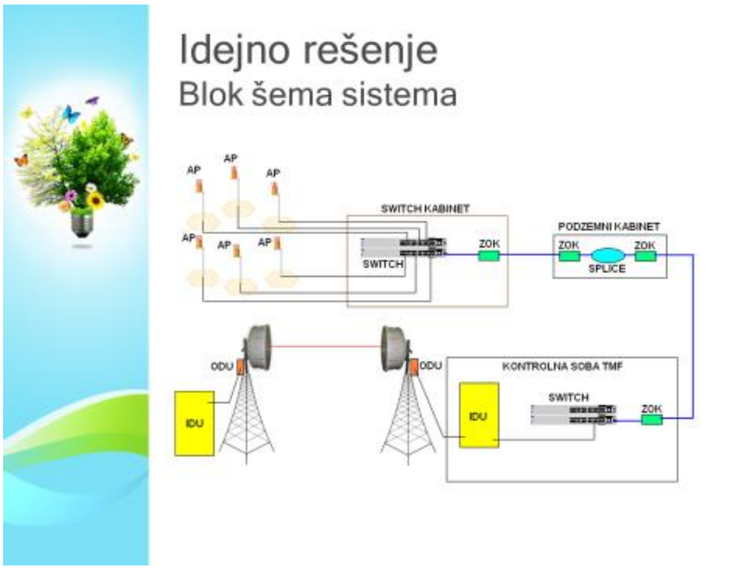


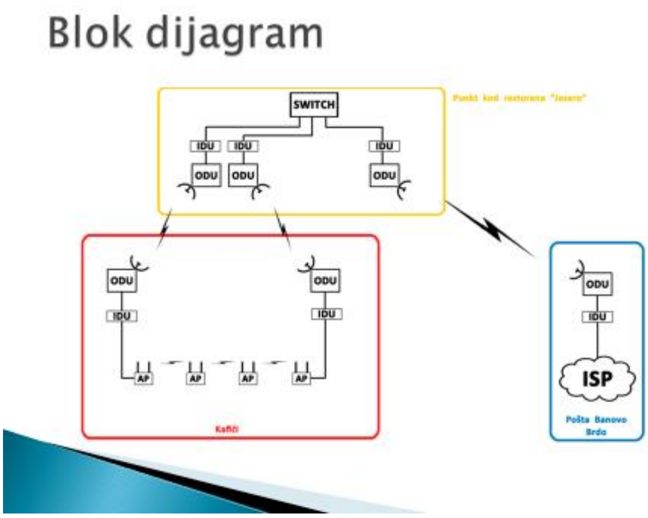
- Mali kabinet:
  - *Switch*:
    - Model: NS-205PSE
    - 5-Port *Industrial* 10/100 Mbps PoE
    - Povezuje sve kamere i PTMP link
    - Napaja fiksne kamere i PTMP link
  - Grejač:
    - Model: CSF06011 *Touch-safe*
    - Održava temepraturu iznad nule preko zime
  - Adapter za PTZ kameru:
    - HighPoE, max. snaga 60W
  - Napajanje:
    - Model: MeanWell MDR-100-48
    - 100W, 48VDC, DIN RAIL
    - Daje napajanje *switch*-u, grejaču i adapteru za PTZ kameru

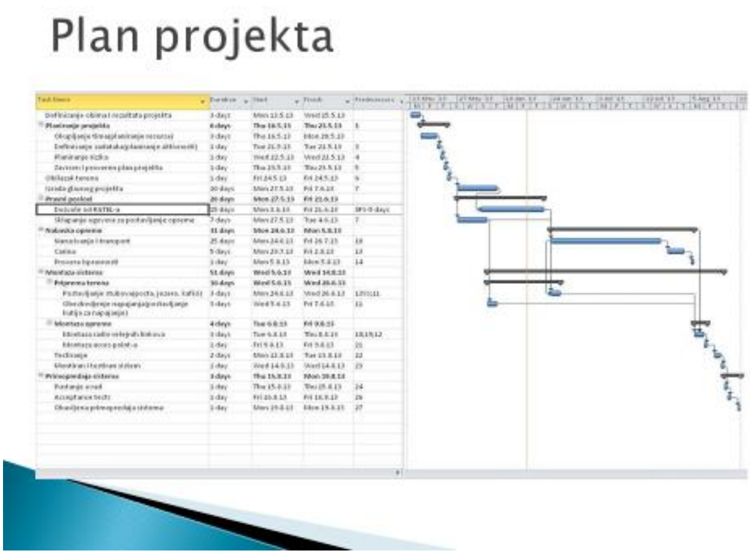

Oblast pokrivanja
130 m
Lokacija pobednik


Wi-Fi МРЕЖА
Ради на учестаности 2.4/5GHz
Инсталирање једног switch-а и три access point-а у циљу покривања целе територије
AP 2
switch
AP 1
AP 3


Wi-Fi System
Mali Taš
Company
SANTEL - net


Idejno rešenje
Blok šema sistema
AP
SWITCH KABINET
PODZEMNI KABINET
ZOK
SWITCH
SPLICE
ODU
IDU
KONTROLNA SOBA TMF


Blok dijagram
SWITCH
IDU
ODU
AP
ISP
Pošta Banovo Brdo

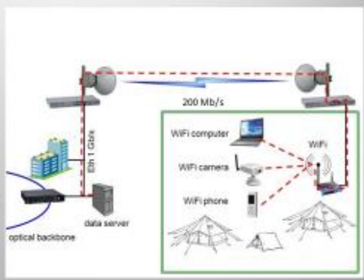

Plan projekta

RR veza „Jezero-kafići“

- Predajna antena za ovu RR vezu je na mestu na kom je i prijemna antena za prvu RR vezu.
- Na prijemnoj strani, antena se nalazi na terasi/krovu kafića na stubu visine 1,5 m.

Protok

Na traženoj lokaciji je obezbeđen internet sa ukupnim protokom od 200 Mb/s koji se dinamički dodeljuje korisnicima u zavisnosti od njihovog broja, postavljanjem dva access point-a koji pokrivaju celokupnu oblast kafića.



Specifikacija materijala

redni broj	naziv	opis	količina	jedinična cena	ukupna cena
1	UTPcat5	kabl	110	0,3	33,00
2	IF cable	kabl za povezivanje ODU - IDU	20	1,2	24,00
3	bakarni kabl	kabl za napajanje 4x2.5	70	0,78	54,60
4	OEM B2B SEPARATOR	UTP konektori	20	0,14	2,80
5	kućište za opremu		1	130	130,00
6	obujmica	obujmica za pričvršćivanje kabla.	40	0,44	17,60
7	stub	stub visine 3m i prečnika 0.15m	1	87	87,00
					349

Pristupna mreža