EPICES: Assessment Challenges of Problem- and Project-Based Engineering Education

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INTRODUCTION

EPICES or 'European Platform for Innovation and Collaboration between Engineer Students' is an Erasmus plus strategic partnership project (September 2014 – January 2017) co-funded by the EU[a]. There are eight partners in this project: ISMEP-Supméca (France, coordinator), Katholieke Universiteit Leuven (Belgium), Aalto University (Finland), Riga Technical University (Latvia), Politecnico di Torino (Italy), Università degli Studi di Napoli Federico II (Italy), Universitat Politecnica de Valencia (Spain) and the European Society for Engineering Education – SEFI (Belgium). The purpose of EPICES is to develop a European collaboration on at-a-distance problem- and project-based learning (PBL) frameworks and methods [1]. Hereinafter, PBL always refers to both project-based learning and problem-based learning. Integrating PBL in engineering education requires changes to the whole learning environment, including new approaches to assessment. Therefore EPICES implements sub-projects or uses sub-projects implemented in PLACIS[b] [2] that challenge students and teachers with authentic issues provided by industrial partners. In PLACIS, industry representatives take part to the evaluation of the results, however, EPICES also integrates projects that do not necessarily have an industrial partner. This format of PBL engineering education requires involvement and integrates the interests and needs of students, teaching and administrative staff and industry representatives.

All the participating universities operate according to their national requirements, have different curriculums, course lists, grading scales, learning environments and have differences in tradition, cooperation with industry etc. Moreover, in the EPICES sub-projects students from different countries and study levels take part, and some sub-projects even combine students from undergraduate and graduate courses. However, the unifying element for all engineering universities is to provide graduates with the skills that are needed to become a professional engineer with a successful career.

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This paper focuses on the overall assessment experience of the project partners during the EPICES project, as well as the usability and efficiency of the developed assessment tools.

LITERATURE REVIEW

An abundance of studies have been conducted in many countries on applying PBL to the engineering curriculum that meet the professional needs of modern industry. The EPICES project engages both problem-based learning and project-based learning. Many comparative analyses of both learning methods have been published [3], [4], [5], [6]. Project- and problem-based learning have many similarities and are sometimes confused with each other, however, previous studies have demonstrated clear differences. By definition, project-based learning:

- is multi-disciplinary;
- is closer to professional reality and involves real-world, fully authentic tasks and settings;
- includes the creation of a product or performance;
- often takes a longer period of time;
- follows a thematic stepwise process - [3], [4], [6].

Several studies have focused on development of new methods of and approaches for student assessment [7], [8], [9], [10]. According to research conducted by John W. Thomas, a project must correspond to the following five criteria in order to be considered to represent PBL: projects are central, not peripheral to the curriculum; are focused on questions/problems that ‘drive’ students to encounter the central concepts and principles of a discipline; involve students in a constructive investigation; are student-driven to some significant degree; are realistic, not school-like [11]. EPICES has aimed at applying these criteria in their student projects.

Even small changes in the assessment system can result in relatively large changes in students' learning and results [12]. Teachers should bear in mind that the changes in the assessment system may have a positive or negative influence on learning process and achieved results.

A wide selection of assessment tasks is available in PBL. Traditional assessment approaches, such as written examinations on their own, are considered to be less appropriate to measure the level of understanding and the skills that students acquire during PBL.

Teachers should start with an initial assessment at the beginning of PBL to collect information on a learners' starting point and ability to participate in PBL, using tests (true-false or multiple choice, problem solving) or essays.

A series of intermediate assessments will help to evaluate the learning progress and make adjustments if needed, for example by using classroom presentations, exhibits and demonstrations, performance tasks, or tests (true-false of multiple choice, problem solving).

Final assessment at the end of PBL will evaluate students’ skill acquisition and overall results of PBL by using a final presentation, final test or exam, student portfolio, self-assessment or peer-assessment.

University of Antwerp has tried to explore the instructors’ and students’ perceptions of a project-based learning environment. The study showed several problems of PBL. There are no single and unified approach to the assessment procedure that fulfils both the students' and the instructors' expectations towards assessment. According to this study, “students demand strict guidelines while instructors want their academic freedom” [10]. The study has indicated workload and coaching differences between the various projects, particularly with regard to organisation and assessment [10].

METHOD

This paper presents the application of the case study method in engineering education using PBL. The case study is based on the implementation of EPICES sub-projects using authentic issues chosen by teachers or provided by the industrial partners. The study analyses the relevance of the different skills for engineering education.

The project partners investigated and defined 29 main skills for engineering students that could be acquired during engineering courses (Fig. 1). These skills were presented and analysed in the EPICES project groups.

	METHODOLOGICAL AND TECHNICAL SKILLS
	Identify an issue, figure out the stakes
1	Understand an issue (from a third person, a customer, a service...), reformulate it, stand back, with a global and critical view of the context
2	Build and write a book of specifications
	Solve technical problems
3	Conceptualize an idea
4	Model and develop technical solutions with creativity and innovation
5	Check the work and pay attention to the details
6	Learn by yourself and use computer tools
7	Choose a solution
	Manage a project
8	Define objectively the deadlines and milestones of the various tasks of an activity
9	Grasp quality, costs, risks, and react to differences relating to the life of a project
10	Plan and manage the project during its lifetime
11	Adapt his / her attitude and accuracy of deliverables taking into account the requirements

	MANAGEMENT AND COMMUNICATION SKILLS
	Report in both written and oral form
12	Synthesize, structure and present information in a clear and precise manner
13	Communicate in both written and oral form in a foreign language
14	Use new ICT
15	Present and argue a solution or an idea to all kinds of public
	Find the necesary ressources
16	Identify the necessary skills and resources, both internally and externally
17	Negotiate / motivate and call upon his / her resources and skills
	Animate a working group or a team
18	Drive, unite and mobilize a team and delegate (leadership)
19	Take responsibility of decisions and be pro-active (maturity)

	BEHAVIORAL AND CULTURAL SKILLS
	Involvement
20	Make commitments (punctuality, deliverables, ...) and respect people
21	Be autonomous, persistent and take initiatives
22	Be curious and open-minded
	Adaptability
23	Get organized and manage complexity, unpredictable situations and stress
24	Adapt to a new environment (professional and / or academic and / or cultural and / or linguistic)
	Values and ethics
25	Show honesty, ethics and exemplary
26	Follow the procedures in place in institutions (companies and / or academic)
27	Respect the constraints of intellectual property and confidentiality
	Maturity
28	Self-assess
29	Assess the team work

Fig. 1. The main skills of engineering students

In the framework of EPICES, project faculty members (course leaders) were asked to:

- adapt their course content to PBL requirements;
- determine skills that are relevant to the course;
- add weight ratios of the selected skills;
- determine the assessment tasks, dates and weight coefficients by task workload;
- select skills assessed by each assessment task;
- add student assessment results and analyse acquired skills.

Numerically, impact factors of 29 skills were evaluated using weight ratios and the results were expressed as a percentage.

In September 2015, the EPICES partners set up case studies to validate the developed list of skills in practice. These case studies were conducted in 7 different courses that took part in the project and include at least one student sub-project. There were 3 courses “Project Bosch” – 12 ECTS, “Project Istituto Motori” – 12 ECTS, and “Robafis Contest and Cogibot Project” ” – 12 ECTS (hereinafter “P” courses) that are a direct reflection of the student sub-projects format. These courses were implemented as part of the PLACIS framework, but the assessment was performed by using the methods developed during the EPICES project, and represents the project–based learning method.

The other 4 courses “Cell and Tissue Engineering” – 5 ECTS, “Theoretical Mechanics” – 6 ECTS, “Automation of Calculations of Construction Durability” – 6 ECTS, “Engineering Experience 2” – 4 ECTS (hereinafter “T” courses) are more traditional engineering courses with an updated course content to realise the principles of PBL. These courses are more representative of the problem-based learning method.

RESULTS AND DISCUSSIONS

The defined 29 main skills were clustered into three main groups: Methodological and Technical Skills, Management and Communication Skills, Behavioural and Cultural Skills. Methodological and Technical Skills include: 2 skills to identify an issue and figure out the stakes; 5 skills to solve technical problems; 4 skills to manage a project. Management and Communication Skills contain: 4 skills to report in both written and oral form; 2 skills to find the necessary resources; 2 skills to animate a working group or a team. Behavioural and cultural skills include: 2 skills showing student involvement; 2 – adaptability; 3 – values and ethics; and 2 – maturity. These skills form the basis for updating the content of the study courses, assessment principles and even the study curriculums, because the assessment objectives of PBL are different from the traditional approach and focus on an evaluation of the skills acquired by the students and their ability to apply their knowledge instead of simply reproducing the previously learned material.

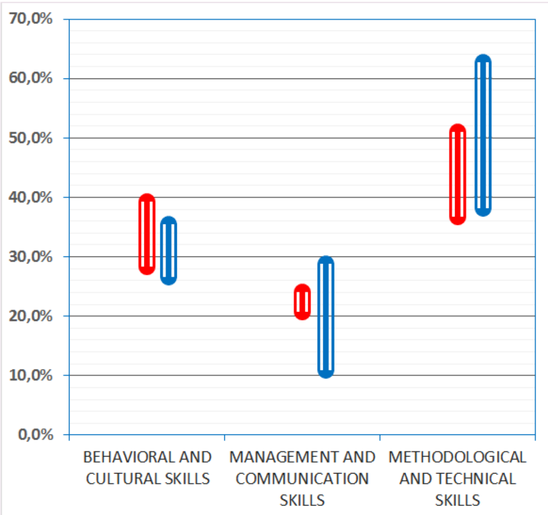

Fig. 2. Impact factors of skill groups expressed as a percentage
(red -“P” courses, blue -“T” courses)

This study shows that the Methodological and Technical Skills are dominant (Fig. 2). They reach 36,8% – 51,0% for the “P” courses and 38,0% – 62,7% for the “T” courses; followed by the Behavioural and Cultural Skills with 28,3% – 39,2% for the “P” courses and 26,5% – 35,4% for the “T” courses; and the Management and Communication Skills with 20,7% – 24,0% for the “P” courses and 10,8% – 28,7% for the “T” courses. There are clear common patterns for both “P” courses and “T” courses.

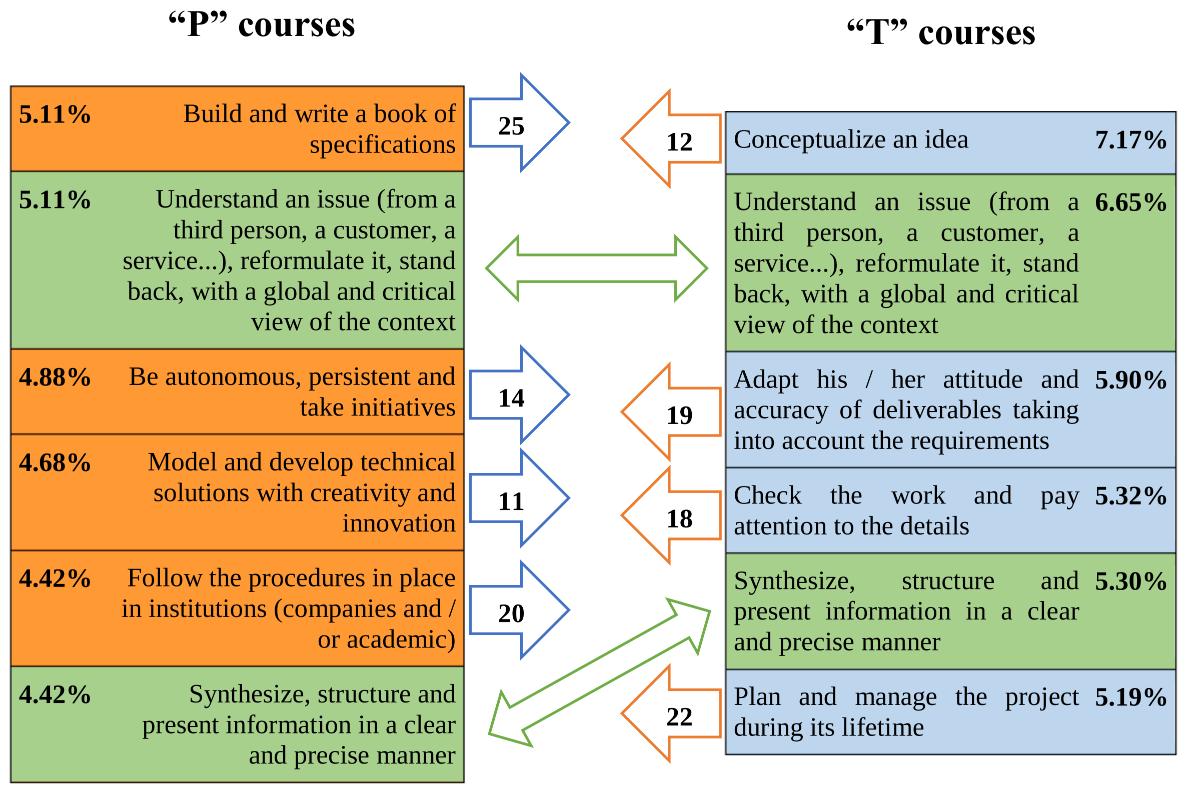

Fig. 3. The skills with the highest impact factors

The differences appear if we take a closer look at the skills individually (Fig. 3). The skills with the strongest influence in the “P” courses are: 1) To build and write a book of specifications – 5,11%; 2) To understand an issue (from a third person, a customer, a service and other), reformulate it, stand back, with a global and critical view of the context with average value of 5,11%; and 3) Be autonomous, persistent and take initiatives – 4,88%. These skills come from two groups: Methodological and Technical Skills; and Behavioural and Cultural Skills. Among the “T” courses the skills with the strongest influence are all from the group Methodological and Technical Skills: 1) To conceptualise an idea - 7,17%; 2) To understand an issue (from a third person, a customer, a service and other), reformulate it, stand back, with a global and critical view of the context – 6,65%; and 3) To adapt his / her attitude and accuracy of deliverables taking into account the requirements – 5,90%.

Among the 10 highest ranking skills in both groups are 5 common skills such as

- To understand an issue (from a third person, a customer, a service...), reformulate it, stand back, with a global and critical view of the context;

- To synthesize, structure and present information in a clear and precise manner;
- To be curious and open-minded;
- To make commitments (punctuality, deliverables, ...) and respect people;
- To learn by yourself and use computer tools.

The case study confirms that both the project-based learning method and the problem-based learning method have similar significance and influence on main skills groups.

On the other hand, there are clear differences at the level of individual skills. The skill ‘To build and write a book of specifications’ has the top position in the “P” courses (representing the project-based learning method), but it only ranks 25th in the “T” courses. Vice-versa the skill ‘To conceptualise an idea’ has the highest impact in the “T” courses, but only ranks 12th in the “P” courses. The “T” courses cover a wider range of subjects needed for engineering education than the “P” courses and are therefore clearly more theoretically oriented.

The development of an assessment tool is one of the expected outcomes of the EPICES project. The created excel tool helps teachers evaluate the students’ learning results and analyse the acquired skills individually and whole project group performance. Acquired skills are calculated using weight ratios for the skills and assessment tasks and student grades from the passed assessment. The tool also calculates the final grade of the course. The first collected feedback from the project partners is promising given the mainly positive evaluations. Partners have praised the usability and simplicity of the assessment tool. Finally, there will be two versions of the tool: one specially created for the course with the defined 29 main skills for engineering students; a second generic Excel template with macros to automate the editing of the skills and assessment tasks for any other course curriculum.

The traditional engineering curriculums are too focused on engineering science and do not provide sufficient design experiences to students. Stakeholders from the industry claimed that many graduates are lacking in specific skills needed by the industry [13].

Students recognise the industry role in PBL and they are interested in both projects that conformed to industrial standards and guidance by industry professionals. Some of them even remarked that they pay more attention to competencies associated with industry projects [14]. In the “P” courses of the EPICES project, the student group projects are based on authentic issues recommend by industry and industry experts take part in the evaluation process. Some modernization of the engineering curriculum can be achieved through including industry recommendations that are coherent to the overall educational targets of the course. However, there are additional challenges for industry involvement in PBL. Usually industry expects universities to provide:

- tertiary level input for training of personnel;
- quick solution of individual problem;
- research-based business development.

Industry participation in PBL can be beneficial for both sides, especially for SMEs that could use less resource for the solution of non-urgent issues and even for the development of new products.

CONCLUSIONS

The courses, implemented in the framework of PLACIS with the use of the EPICES assessment tools represents both the project-based learning method ("P" courses) and the courses that are specific for the problem-based learning method ("T" courses). This study confirms that project- and problem-based learning have many similarities and distinguishing differences at the same time.

The initial concept of a framework with 29 engineering skills in combination with the development of an assessment tool provided an efficient mechanism for assessing the development of engineering skills in PBL. Faculty members (course leaders) evaluated how the study course contributed to acquiring each of these 29 skills and set up a skill based assessment system. This study shows that the Methodological and Technical Skills are dominant for all courses. Project-based learning ("P" courses) and problem-based learning ("T" courses) have many similarities. The differences appear when a closer look is taken at the skills individually. There are 5 common skills among the 10 skills with the highest impact in both groups. At the same time, the top rated skill in the "P" courses only ranks 25th in the "T" courses; and vice-versa the top rated skill in "T" courses ranks 12th in the "P" courses.

The Excel-based assessment tool has been created to facilitate this case study and PBL assessment process in general. The tool helps teachers to evaluate the students' learning results, to analyse acquired skills individually, to calculate the final grade of the course and to analyse the whole project group performance.

The current EPICES project results and conducted case studies based on student sub-projects so far have shown promising results. Optimising the assessment system and tools is part of our future work. Further research will focus on the feedback of teachers and students on this method for assessing skills and the usability of the developed assessment tool.

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