Global Journal of Engineering Education

A project-based learning approach in an engineering curriculum

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ABSTRACT: Industry requirements for engineering graduates evolve and demand changes to the educational approach used. Experiential learning, with its *reflection on doing* is the most likely answer to the new demands. Within that educational approach, problem-based and project-based learning stand as the most successful methods. They are widely regarded as effective and innovative methods for engineering education. Special consideration should be placed on project-based learning that introduces the students to professional engineering practice by providing them with an opportunity to work on an open-ended engineering problem. The author discusses features of project-based learning and the need for introduction of that approach within an engineering curriculum. This consideration concludes that project-based learning is the best way to fulfil industry needs.

Keywords: Experiential learning, project-based learning, problem-based learning

INTRODUCTION

The main stream engineering education follows traditional classroom teaching. In such an environment, the focus is mainly on the lecturer and the student has very little (if any) choice on the learning process. In many cases, this approach is very effective. It has been effective for years and the best examples of such a method are all the engineering *wonders of the world* including cars, bridges, etc. They have been designed and manufactured mainly by engineers educated in the traditional system. However, there is also a possibility that some of the very talented and promising engineering students have not been successful due to that rigid approach in which students and the learning process is not the focus of the activities.

In addition, there is no doubt that in the new designs, the engineers, who may have been educated in classroom teaching, have used a project approach to the problem. This is a demand of the modern world and the educators have to respond to that. As a response, there has been a growing tendency in recent years in engineering education to include project-based learning. A number of engineering educators report on application of problem or project-based learning incorporated into the classroom teaching [1-3]. The project-based learning (PjBL) approach in engineering programmes should go beyond the typical final year, capstone project, it should be introduced throughout the curriculum and should start earlier in the programme.

HISTORY OF PROJECT-BASED LEARNING

The benefits of experiential learning have been reported by educators, such as John Dewey, for over 100 years [4][5]. Experiential and hands-on learning has a long history in engineering education. The medical field also has a long practice of problem-based and project-based learning [6].

Planned field trips and, especially, laboratory investigations have been always part of the curriculum of engineering programmes. The same applies to projects; *doing projects* is a long-standing tradition, especially, in American education [7][8]. However, the actual formal introduction of the project-based learning had to wait until the learning theories, based on research in neuroscience and psychology, claimed knowledge, thinking, doing and the context for learning were interrelated and, also that learning was a social activity and it took place within the context of culture, community and past experience [9].

At the moment problem-based (PBL) and project-based learning (PjBL), are used as *key* words to cover an incredible diversity of educational practices, ranging from typical inquiry-based learning, through problem-oriented lectures to completely open experiential learning.

Project-based learning (PjBL) has been developed with two other, closely related methods: inquiry-based (or problem-based) learning and experiential learning. Some believe that project-based learning is problem-based learning by definition. Although PjBL shares some overlapping characteristics with problem-based, PjBL is designed to acknowledge the importance of standards and evaluation of student learning [5], and its focus is on the application, and possibly the integration of previously acquired knowledge [4].

Both problem-based learning and project-based learning are widely regarded as a successful and innovative method for engineering education. Problem-based learning is also considered very successful in lower levels of education, both primary and secondary. Almost any American teenage film has some elements of a successful learning, either project or problem-based. It normally shows some nerd teenager or group of them, who, although not very successful in school, suddenly flourish and blossom when working on a particular task or project. They usually either use computers or design and manufacture something, which brings the movie to its happy ending.

Problem-based learning was developed at McMaster University in Canada in the late 1960s [9]. It is driven by the problem that is encountered by the students and focuses on research and inquiry; it starts with a problem, and solving the problem becomes the main focus of the students. On the other hand, project-based learning is driven by the end product; the process begins with the assignment to accomplish, which indicates certain tasks leading to the production of the final product.

NEED FOR A CHANGE

The current educational approach in engineering education needs substantive change in order to provide students with attributes which they require in professional practice [10][11]. The need for a change is a wide one and covers employers, students and lecturers.

Need of Employer

Quick development in engineering and technology requires adopting a teaching approach that would assist students not only in developing a core set of industry relevant skills, but also enable them to adapt to changes in their professional career. Industry stakeholders look for graduates who are able to adapt to rapid changes in technology. This is very important even if one does not believe that most technical skills appear to become obsolete within five years [12]. The employers' demands are:

- Communication skills;
- Interpersonal qualifications (including ability to work in teams);
- Flexibility and initiative;
- Analytical skills;
- Management skills.

At the same time, the companies generally are not inclined to decrease demands on the academic qualifications of their employees.

Needs of Learners

In the traditional classroom teaching, which dominates engineering education, the assumption is that the knowledge can be transmitted from one person to another and that it can be accumulated in a linear way. It also assumes that everybody will learn in the same way and at the same pace. However, learning theories suggest that knowledge is individually constructed by the learner; that learners need to be engaged in the process, and that they have different styles and different speeds of acquiring the knowledge [13]. The obvious solution to the above would be to put greater focus on the learner and to allow for:

- Varying pace;
- Team learning (discussion groups, peer support by peer tutoring and assessment);
- Developing students' learning skills (study skills, judgment skills).

Needs of Educators

Engineering educators are faced with the challenges of preparing graduate engineers able to work in an increasingly diverse work place environment. This, along with a global paradigm shift to outcome based tertiary education that demands generic or transferable skills, as well as technical excellence, is driving the need for a change in the teaching approach.

PROJECT-BASED LEARNING MODEL

Problem-based learning is an educational approach whereby the problem is the starting point of the learning process. It is crucial that the problem serves as the basis for the learning process. It is argued that project work or project-based learning is problem-based by definition [13].

The primary reason for project-based learning (PjBL) is a need to adapt to a changing world. The argument is that students should strive in an environment centred on learning instead of on teaching. PjBL is an attempt to create a student-centred setting in which tasks are being attempted and solved. The more the task reflects reality, the more the students feel motivated, so working on a project can be seen as a way of organising various simultaneous and/or integrated learning processes.

PjBL intends to cultivate students' ability to learn actively, to think critically and to solve problems through an instruction process that focuses on practical problems and encourages students to conduct group discussions. PjBL offers an attractive alternative to traditional education by shifting the focus of education from what instructors teach to what students learn.

By engaging students in real-life projects, and involving them in active inquiry, the learning process is intensified and improved. The emphasis moves from the result to the process, and the lecturer transforms from the classroom main actor and a dictator to an advisor. It is colourfully described as a shift of a lecturer from a *sage on the stage* to *a guide on the side* [14].

Student Centred

One of the primary features of PjBL is that it is student-centred. The lecturer selects authentic assignments/projects from the discipline, preferably those that would be relevant and meaningful to student interests. Hence, the project presents the student with a real-world challenge similar to one encountered in practice in a particular discipline. The other element of the *student-centred* feature of PjBL is that the student, at least partially, determines the goals. It creates an environment of self-directed learner who also receives motivation from the relevance of the project. The central part of the learning process using PjBL is activity-based learning, which forces the student to perform activities involving research, decision-making and writing.

Teaching through Skills

Teaching content through skills is one of the primary distinguishing features of PjBL. In traditional teaching, the lecturer introduces students to a subject via lectures and texts. After a certain amount of course content has been presented, students are tested on their understanding of the topics introduced. Introduction of a project creates a more inductive scenario: students learn the content as they try to address a project. The projects in PjBL are typically in the form of *cases*, narratives of complex, real-world challenges common to the discipline being studied. There is no right or wrong answer; rather, there are reasonable solutions based on application of knowledge and skills deemed necessary to address the issue. The *solution*, therefore, is partly dependent on the acquisition and comprehension of facts, but also based on the ability to think critically.

Process-Centred

Another primary feature of PjBL is that it is process-centred more so than product-centred. The emphasis is on the ability to generate problem-solving strategies, which is especially important in ever-changing technologies. It is also related to the transfer of information or precisely to the student's ability to find and create information. PjBL, by having students demonstrate for themselves their capabilities, can increase students' motivation to tackle problems.

Group-Based

The majority of the learning process takes place in groups or teams. The idea is to have students work in small groups in order to address the presented case. By collaborating, students see other kinds of problem-solving strategies used, they discuss the case using their collective information, and they need to take responsibility for their own learning, as well as their classmates.

Experiential

PjBL is also experiential in the sense that participants experience what it is like to think as a practitioner. How do biologists think? What distinguishes the way a criminologist might address a problem as opposed to the way a mathematician might? How might these two specialists work together on a problem, a question more germane as disciplines become ever more inter-disciplinary. It is also a question of great concern to employers. Three major complaints from employers about university graduates are graduates' poor written and verbal skills, their inability to solve problems and their difficulties working collaboratively with other professionals. PjBL addresses all three areas.

DISCUSSION

Project-based learning is to be an efficient way to acquire new knowledge. It requires students to utilise all of their skills in order to answer driving questions. They must research; collect data, interview and adapt information in order to present a possible solution to the presented problem. It helps them in reaching a proper understanding and remembering new information as students tend to remember things they have experienced or had to research on their own, because it feels like it is their own question, not just one presented during class [15].

How does the above description relate to the typical way the projects are done in engineering programmes? Do students really acquire a lot of new knowledge through projects?

There is no clear answer to these questions as it depends on the way the projects are done in a particular institution. Whether the students would be learning new methods or acquiring new knowledge during the process of doing the projects is debatable. They may actually be applying the knowledge acquired in other courses. However, they certainly do acquire skills in solving problems and also in time management and technical communication [16].

Communication is actually a key word in the project. Firstly, the supervisor would communicate with student on what is expected, what is the progress and what still needs to be done. Secondly, the student must communicate with the supervisor on what has been accomplished and what the plans are for subsequent tasks. Students also communicate with each other during the process of undertaking a project. PjBL shifts the classroom focus from teaching to learning. The ultimate goal of learning is not about finding the best answer to a question, but rather to train students to learn through the process of doing the project, i.e. thinking steps, research topics, development plans, etc.

Learning through projects is without any doubt a student-centred educational approach. The student is normally presented with a real-world problem, and is responsible for tackling and solving the problem. The student receives motivation from being a self-directed researcher, although the self-direction is to some extent limited by the supervisor. His/her opportunity to make their own decisions regarding the direction of the project is, however, normally quite restricted by the obligation to stick to the topic of the project.

Features of PjBL include an element which can be assigned to different heading; it is so called *critical thinking*. Critical thinking refers to the ability to analyse, synthesise and evaluate information, as well as to apply that information appropriately in a given context. It requires the learner to take what information is known, review it critically in order to combine it with some other information to construct some creative solution to a problem. Under this understanding, the creative thinking is certainly covered in project work.

For project work to be meaningful in the educational process, it should be done in groups. That would allow the students to practise communication skills by free exchange of ideas with peers. Also, group projects allow for building experiences how to resolve team conflicts or how to work with people who are not necessarily friends. The other aspect of project work is the issue of assessment, which is of high importance in group work. Group assessment or rather assessment of individual performance in group work, is still not easily tackled by academic instructors [17].

PjBL is one of the learning methods that support life-long learning (LLL). The lifelong learning concept is no longer some courses after graduation, it encompasses the entire active life of a professional and the development of LLL skills and abilities should start during university studies [18]. Engineering instructors consider project work to be the most effective method of inducing life-long skills into students. It is also considered to be the most effective method of assessing whether those skills are achieved [19].

CONCLUSIONS

In order to prepare students for their professional careers, university courses should be designed to assist students to acquire problem-solving and lifelong learning abilities, rather than simply spoon feeding them to memorise prescribed content and design methods. Project-based learning provides such an opportunity. Projects in the engineering curriculum make an attempt to prepare students to face real-life problems. It provides them with the opportunity to synthesise the knowledge already acquired rather than to provide them with new fundamental engineering knowledge.

Project work supports the development of life-long skills and students' autonomy. PjBL emphasises the development of engineering skills by providing real life engineering problems. Therefore, engineering students who participate in project work should have a better picture of the engineer's job. It can be concluded that project-based learning is the best way to fulfil industry needs.

REFERENCES

1. Mahendran, M., Project-based civil engineering courses. *J. of Engng. Educ.*, 84, **1**, 75-79 (1995).
2. Chandrasekaran, S., Stojcevski, A., Littlefair, G. and Joordens, M., Learning through projects in engineering education. *Proc. 40th Annual SEFI Conf. on Engng. Educ. 2020 - Meet the Future* (2012).

3. Graham, R., UK Approaches to Engineering Project-Based Learning (2010), 1 April 2016, http://web.mit.edu/gordonelp/ukpjblwhitepaper2010.pdf.
4. Mills, J.E. and Treagust, D.F., Engineering education - is problem based or project-based learning the answer? *Australasian J. of Engng. Educ.* (2003), 1 April 2016, http://www.aaee.com.au/journal/2003/ mills_treagust03.pdf
5. Frank, M., Lavy, I. and Elata, D., Implementing the project-based learning approach in an academic engineering course. *Inter. J. of Technol. and Design Educ.*, 13, 273-288 (2003).
6. Bédard, D., Lison, C., Dalle, D., Côté, D. and Boutin, N., Problem-based and project-based learning in engineering and medicine: determinants of students' engagement and persistence. *Interdisciplinary J. of Problem-Based Learning*, 6, **2** (2012), 1 April 2016, http://dx.doi.org/10.7771/1541-5015.1355
7. Dutson, A.J., Todd, R.H., Magleby, S.P. and Sorensen, C.D., A review of literature on teaching engineering design through project-oriented capstone courses. *J. of Engng. Educ.*, 86, **1**, 17-28 (1997).
8. De los Ríos, I., Cazorla, A., Díaz-Puente, J.M. and Yagüe, J.L. Project-based learning in engineering higher education: two decades of teaching competences in real environments. *Procedia Social and Behavioral Sciences*, 2, 1368-1378 (2010).
9. De Graaff, E. and Kolmos A., Characteristics of problem-based learning. *Inter. J. of Engng. Educ.*, 19, **5**, 657-662 (2003).
10. Walczak, M., Uziak, J., Oladiran, M.T., Baeza, C.C. and Paez, P.T., Industry expectations of mechanical engineering graduates: a case study in Chile. *Inter. J. of Engng. Educ.*, 29, **1**, 181-192 (2013).
11. Johnson, B. and Ulseth, R., Professional competency attainment in a project based learning curriculum. *Proc IEEE Frontiers in Educ. Conf. (FIE)*: 1-5 (2014).
12. Lloyd, B.E., Ferguson, C., Palmer, S.R. and Rice, M., *Engineering the Future: Preparing Professional Engineers for the 21th Century.* Association of Professional Engineers. Histec Publications, Melbourne, Victoria (2001).
13. Helle, L., Tynjäla, P. and Olkinuora, E., Project-based learning in post-secondary education - theory, practice and rubber sling shots. *Higher Educ.*, 51, 287-314 (2006).
14. King, A., From sage on the stage to guide on the side. *College Teaching*, 4, **1**, 30-35 (1993).
15. Mckay, A. and Raffo, D., Project-based learning: a case study in sustainable design. *Inter. J. of Engng. Educ.*, 23, **6**, 1096-115 (2007).
16. Crosthwaite, C. and Cameron, I., Project centred-learning in chemical engineering - an Australian perspective. *Proc Inter. Conf. on Engng. Educ.*, 2, 381-387 (2005).
17. Kommula, V.P., Uziak, J. and Tunde Oladiran, M., Peer and self-assessment in engineering students' group work. *World Trans. on Engng. and Technol. Educ.*, 8, **1**, 56-60 (2010).
18. Lenschow, R.J., From teaching to learning: a paradigm shift in engineering education and lifelong learning. *European J. of Engng. Educ.*, 23, **2**, 155-161 (1988).
19. Uziak, J., Walczak, M., Oladiran, M.T. and Gizejowski, M., Understanding of lifelong learning by engineering instructors. *Inter. J. of Engng. Educ.*, 31, **6A**, 1576-1586 (2015).

BIOGRAPHY

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