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E-Learning Applications in Engineering and the Project-Based Learning vs Problem-Based Learning Styles: A Critical & Comparative Study

Abstract- The paper aims to critically review the learning styles and teaching methods of engineering curricula and to compare it with the requirements of engineering profession. Present engineers need to response effectively to the increasingly complex systems. The engineer has to deal with vector and scalar quantities, complex numbers, imaginary parts, electromagnetic fields, and complex constructions are designed and implemented in 3-Dimensions environment. This should be reflected in engineering education styles, where lecturers try to convey many aspects of complex systems. The purpose of engineering education is that to graduate engineers who can design and solve technical problems, and that design thinking is incremental and needs several skills. To be successful, engineers must have knowledge that goes beyond theories. However, problem solving is no longer the only essential skill required by the engineer. Rather, project-based thinking and team work skills are fundamental in practice. The paper briefly illustrates advantages and disadvantages of each learning styles considering the educational environment. Moreover, the currently most-favoured pedagogical model for teaching design, Project-Based learning (PjBL) along with the Problem-Based Learning (PbBL) is explored in this paper and its assessment criteria.

Keywords- E-Learning, Engineering Education, Learning Styles, Problem-Based Learning, Project-Based learning.

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education requires reviewing the earlier methods and learning systems. Going back to the roots of the teaching. The traditional engineering classes were chalk-and-talk lectures. The key objective in the advancement of engineering education was to enable the lecturer to deliver knowledge and concepts to the students as efficient as possible. However, the essential tool is the lecture where the lecturer explains, gives examples, discusses derivations and calculations. Moreover, traditional engineering curricula have been based largely on an "engineering science" model over the last decades (i.e., engineering is taught only after a solid basis in science and mathematics) [1]. On the other hand, the main skill of the lecturer was oral communications, which was supported by online hand-written messages using the blackboard and chalk. Hence, students had usually less time to understand the concepts due to the low speed of hand writing. Later, lecturers began to utilize the overhead projector because of the increasing complexity of the

systems to be discussed (more dimensions, dynamic structures and interactions). This enabled them to do much writing in advance (off-line, before the class). This was highly appreciated by the students as it replaced the unclear handwriting by well-structured and clear notes. However, this appreciation was different from the lecturer's viewpoint since the pace of dealing with subjects was dramatically increased. Another teaching problem is how conduct the dynamic structure and interactions as the slides of the overhead projector lack to the ability to demonstrate animations inserted in power point presentations. Nevertheless, from the students prospective, the improvement was still partial. Table1 summaries the negative and positive aspects of teaching of the different systems. It is shown that the lecturer's advantages could be disadvantages for student learning. It can be concluded that in the design of the education pedagogies, the achievement is in the teaching preparation, which results in beautiful lectures [2]. Thus, the advances in the teaching methods do not necessarily results better understanding for the recipient/students. However,

the new advances allow more material to be presented at the same time.

Table 1: Teaching methods from different viewpoints

Method	Lecturers point of view		Students point of view	
	Positive	Negative	Positive	Negative
Blackboard & Chalk	Limited preparation for the lecture	Low pace, limitation in topics, and risks of errors	low pace	Poorly legible
Overhead Projector (O.P.)	Lecture is better structured, and more subjects can be treated	More preparation is required	Better structured lectures and better legible	Higher pace and less time to present
PowerPoint	Preparation is same or a bit more than O.P., animation and movies possible, and sharing via internet	Still more preparation	Same as O.P. and accessibility via internet network	Same/more as/than O.P.
Smart Board	animation/ movies Sharing Network Using pen plus windows Tools Using GUI package	More preparation and required skills	Accessibility via network High interaction More suspense.	Higher pace

Recently, the development of electronic appliances (e.g. tablets, computers, and networks with connected PCs/Laptops etc.) has facilitated the interactive teaching environments.

2. Shifting Education from Teaching Oriented to Learning Oriented Style

In addition to the tools and equipment used in teaching, the improvements were also including qualitative paces that deals with the concept of engineering education itself. The aims and objectives of engineering course should be reflected on the teaching and learning styles. From the learning prospective, the engineering institutions realized that the market requirements had changed, recently, to focus on the skills of the engineers rather than knowledge they have acquired in their courses. Therefore, the reflection turned to be obvious in the engineering curricula and the assessment criteria such as ABET [3]. The assessment criteria were based on examining the students' abilities to convert the acquired information into professional skills. Therefore, the current goal of engineering teaching involves the development of students' skills turns the lecturer to act as a *coach* for the students.

The interpretation of the actual objectives of engineering courses should be derived by reconsidering the analysis of the learning problems. For instance: the original problem, can be defined as "it is difficult to explain the switching process of a three-phase electric inverter" (lecturer viewpoint) which was shifted to "the students have difficulties in understanding the switching of three-phase electric inverters". Obviously, a detailed problem analysis is required

to identify the potential solutions. This analysis must be run by the lecturer using as much information from students as possible, which may lead to the design and implementation of the solutions. However, the ultimate goal is to create an environment that facilitate defining and solving the problem. Nevertheless, there are many conditions that have to be taken into account such as [1,2]:

- a) Prior knowledge and skills of the students, engineers, later
- b) Facilities of the institution/faculty
 - Human resources: staff (lecturers, tutors, and laboratories technicians)
 - Material: laboratories, rooms/lecture theaters (LT), and IT-support systems
- c) Available time of studying (in terms of hours and schedules).

Nowadays, students often cannot follow courses simultaneously due to lack of one or more of the above conditions. They want to devote time to their studies when it suits them individually not collectively. Therefore, any solution should concern individual action, no matter when or where. Finally, learning methods should be such that students are able to learn and do assignments (in other words: an appropriate instruction in the learning material is an essential condition).

3. Requirements for an Educational Solution

According to the problem statement discussed above, the possible solution should the other meet the following design criteria [3,4]:

- a) A learning support system should allow students to acquire a deep insight into the

dynamic interactions of a number of parameters and concepts in engineering systems.

b) The learning system should be structured in such way that it is overcome the increased complexity.

c) Due to the multi-dimensional nature of the systems in engineering projects, a high degree of interactivity should be meet.

d) The learning system should provide a qualitative impression of different quantities.

e) The system should be accessible and independent of time and place.

f) Appropriate instructions for users of the system should be included.

g) Students should be motivated to comply these learning systems, so as to become skilled in designing such systems and other similar designs.

h) The system should allow self-assessment of student learning.

i) The system must include assignments as well as individual assessments tasks.

Accordingly, it was decided to develop a number of computer animations showing in a systematic way the interactions and complexity of engineering systems. The animations provide high degree of interactions with both the students and lecturer. The animations can be run via internet or transferred using CDs or USB-RAMs. Therefore, assignments and assessments can be carried out online which save time of the engineering course. Therefore, limited lectures need to be conducted with focusing on the background of the engineering course, how to employ these computer animations, and how assign the problems and projects among the students.

4. Dimensions of Learning Style

Numerous studies have been conducted in the recent years to identify the abilities required by engineers to the modern industry [4,5]. These studies indicate that the engineers must have strong and reliable communication, leadership, and teamwork skills. Moreover, engineers need to be aware about issues that affect their profession such as social, environmental and economic issues. Finally, they should graduate with good abilities of how to apply the acquired knowledge in their future career. The ways the students learn and the dimensions of teaching styles are illustrated in Table 2 [5].

5. Teaching and Learning Techniques for Engineering

As shown in Table 2, the responses of the students control and guide the teaching styles.

Therefore, active learners do not learn much in situations require passive students, whereas reflective learners do not learn much in situations do not provide opportunities to think deeply about the presented information [6].

On the other hand, global learners need a margin of freedom to acquire the methods of solving problems rather than being forced to employ the strategies of the lecturer. Therefore, the global learners need to be exposed to deep understanding before presenting the main concepts of the engineering course/problem.

Unfortunately, most of engineering classes belong to passive classes where the active experimenter and the reflective observer cannot learn effectively.

6. PbBL in Engineering Education

On the basis of the teaching and learning styles aforementioned, the recent studies of engineering education concern the fitness of PbBL and the PjBL for the engineering classes. The PbBL that is based on the problem analysis, has been utilised for training in medicine for the last five decades. The PbBL has also been suggested as a solution to many engineering education problems. However, the PbBL is still applied in a limited extent to some engineering courses and mainstreams.

As the design is one of the fundamental activities in engineering and all other engineering processes are associated with it, the strategies of teaching design thinking have applied and implemented in engineering programs in similar ways to the PbBL's strategy. These similarities are summarised as follows [6,7]:

- Both PbBl and PjBL have a large number of phases or stages during the project or problem.
- Both learning styles start with identification of the problem or situation which directs the students' research area or context of course.
- Either styles require high levels of student initiative, hence students need to improve their motivations and organisation skills.
- Both PjBL and PbBL suit long-term projects. Though PbBL is used over short time processes, this does not deteriorate its efficiency over longer time frames, that are usually related to projects techniques.

**Table 1:
of different
and
styles**

Learning style		Corresponding teaching style	
Sensory	Perception	Concrete	Content
Intuitive		Abstract	
Visual	Input	Visual	Presentation
Auditory		Verbal	
Inductive	Organization	Inductive	Organization
Detective		Detective	
Active	Processing	Active	Student participation
Reflective		Passive	
Sequential	Understanding	Sequential	Perspective
Global		Global	

**Comparison
learning
teaching**

- Both learning styles are open ended regarding the outcomes which allow the students to choose based on appropriate research.
- Regarding problems, observational skills are the high priority, especially during the stage identifying the problem.
- Both styles emphasizes student reflection where the students are encouraged to evaluate the entire outcomes.
- The PjBL and PbBL rely on group work and improve teamwork skills.

As per the above characteristics, primarily, the PbBL appear to be the logical choice of engineering education. However, the local environment may affect the performance.

7. The Performance of PbBL in Education Environment

As an example of PbBL in engineering, evaluations studies have been implemented using student interviews, surveys, and testing their responses to open-ended questions. In the light of PbBL, the evaluation studies are designed on behalf of the engineering courses and how they fit the requirements of problem-based classes [6]. The positive program evaluations of problem-solving program are referred to in [6], yet the role could not be easily determined due to multi-skill efforts that are involved in the programs. The evaluation depends on other factors.

Answering the main question about the validity of PbBL for engineering education, the application of the PbBL has clear obstacles to its implementation and outcomes. The problems are associated with the nature of engineering knowledge, compared to medicine where PbBL is

the dominant style in professional practice of medicine environments.

A recent research [7] concludes that PbBL has certain drawbacks that make it less preferable as a main strategy for engineering education styles. One important drawback is the constructive philosophy of the PbBL where the engineers have to follow the guides and apply the concepts, they learn at their universities to solve the problems in engineering systems.

8. Performance of PbBL in Professional Environment

In addition to the above limitations of the PbBL, problems encountered in practice (outside the classes) are usually different from those previously have tested in other practice and at the university as well. Recent studies report that that PbBL may not lead to the 'right' knowledge for professional engineers. Hence, it might not be suitable to engineering education in the view point of the acquisition of information that can be reused efficiently in the professional activities [7].

Metacognition skill is also fundamental for successful learning in PbBL environments. However, this skill might not be sufficient due to the nature and complexity of the required knowledge in engineering systems. Furthermore, the order of learning main topics in PbBL can be defined by the students themselves (not by the course coordinator). Therefore, some topics could be overlooked and overdetermined by the students more than others. However, in engineering, many topics should be learned in a certain order due to the hierarchical nature of the concepts in most of the engineering curriculum.

This issue might be hard for a student to correct, regardless how good their metacognitive skills. That is because they probably cannot entirely compensate missed topics as a result of using an oriented PbBL method. The nature of the hierarchical knowledge structure is the most basic obstacle for implementing problem-based engineering systems through the engineering education programs.

Regarding the available data, problem-solving skills usually require the ability to approach the solutions using information that is almost incomplete, while trying to satisfy the clients demands and government regulations that could be in conflict, and minimizing the effects of any solution on the social environment and doing all this for the minimum cost. On the other hand, the nature of the social system in each country can impact the preference of the PbBL system, which seems to be the dominate one in the developing countries.

Though problem solutions, in engineering, can be carried out over long time periods, problem solving in medicine usually differs as there is only one right diagnosis/solution, hence it can be implemented quickly. On the other hand, treatments may vary based on the diagnosis, though it is generally selected from a range of well-defined list of options. Therefore, a PbBL approach might be insufficient for the acquisition of problem-solving skills due to the time scale of the problems and the range of activities be included. Nevertheless, faculty reluctance may prevent the adoption of alternative innovative educational methods without an incremental modification on the courses.

Accordingly, the PbBL seems to be a partial answer for solving the critical problems of engineering education styles. Moreover, it may be used to illustrate the context of the applications in early stages of engineering education. Hence, other student-centred learning methods could be more appropriate for engineering curriculums. Particularly, the approach that reflect the professional behaviour of engineers can be successfully suit engineering education (which is the PjBL).

9. The PjBL in Engineering

This section answers ‘what is the PjBL style and how it differs from the PbBL’. Firstly, the definition of *project*, in engineering, is globally known as a *unit of work*, which is usually based on the client requirement. The term *project* almost includes all the tasks be undertaken by engineers in professional practice.

Unlike the problem’s nature, projects have various time scales. Many construction projects in civil and electrical engineering require several years, and thousands of engineers and numerous numbers of clients are involved in the project outcomes. On the other hand, projects have varying level of complexity, but all are related to the essential concepts and techniques of the engineer’s discipline area. However, while small-scale projects may only cover one area of engineering specialisation, large-scale projects are usually multidisciplinary (involving engineers from different majors and other professional and non-professional workers/employees). Yet, the integration of the various disciplines of engineering is the key role of successful accomplishment of the projects. Unlike the PbBL, the PjBL seems to be more preferable at the developed countries, where the real engineering projects are familiar to the students and the academic staff.

Compared to PbBL, many of the learning outcomes of the PjBL style look similar. The problem-based and PjBL styles are compared at tertiary level in [7]. The researchers indicate that the two learning styles have a multidisciplinary orientation and both are based on self-direction and collaboration. However, the differences include:

- Projects are usually closer to professional environment. Therefore, project tasks need a longer period of learning time than PbBL tasks (which may require only one session).
- Project assignment is, by nature, more directed to the applications of knowledge, whereas problem-based tasks are more directed to the collecting of the knowledge.
- PjBL is accompanied by particular courses such as mathematics and physics, whereas PbBL is not necessary to be associated with a particular subject/course.
- In PjBL, management of time and resources by the students as well as roles and jobs description are very important.

Furthermore, it must be mentioned that the ways of approaching design education offer both systematic payoffs and a framework for continuous quality improvement. These ways include the following merits:

- As potential laboratories of pedagogical research to be conducted, both engineering programs and their individual classes, must be conducted in ethical manners that abide to appropriate guidelines of human subject.
- for obtaining quantitatively and qualitative data, the curricula are instrumented to support metrics that are consistent with quality control. This is

consistent with what ABET requires from the engineering programs but it is invaluable in its right.

- Embracing the notions that engineering design the courses. Many engineering courses must be delivered over education environments that are geographically distributed, culturally diverse, and technically differentiate.
- Engaging the coaches/lecturers of design to help managing the context of engineering design theoretically and practically. This may not only provide valuable experience into design classrooms and laboratories, but could also help alleviate the shortage of faculty that want to teach design because they are comfortable with their own design experiences.

10. Is the PjBL or PbBL the Answer of Engineering Education Style

Generally, self-direction is stronger in project tasks, compared with PbBL, where the learning process is less directed. However, PjBL may also be applied in individual courses/curriculums as described by [6], who differentiates between “project-oriented studies” and “project-organised curriculum”. According to [6], an individual course may involve the use of project-oriented studies as small projects within the course, heading to the final year project. The projects are usually combined with conventional teaching methods and usually directed to the integration of the obtained knowledge and its applications. Projects can be implemented as individuals or in small groups of students/engineers.

Projects is the principle of project-oriented curricula, whereas the subject-organised courses eliminated or reduced to a minimum. Hence, students work in small groups with a team of lecturers who work as supervisor, mentors and consultants. Regarding the time scale, projects are carried out throughout the course and vary in duration from a few weeks up to a whole year. However, in reality, exclusive project-organised curricula do not yet be adopted, and the closest programs are where the project-related courses establish the majority of the education program (around %75).

11. Conclusion

The paper discusses the preference of the PjBL style over the PbBL in engineering education. It starts with the principles of teaching methods and the progress of these methods (starting with chalk and talk pedagogy) in favour of the engineering profession requirements and in the context of accreditation criteria (e.g. ABET). In addition, the

effect of the dimension of the learning styles and the reflection on the teaching methods in engineering class are demonstrated. It is shown that the demands for skilled, knowledgeable, and fully equipped engineers are unlikely to be satisfied by traditional engineering curricula. Hence, a mixed approach with some conventional courses, mixed with some project-based elements and sufficient autonomy of the students, seems to be the best way to comply the needs of industry. This approach can be implemented without sacrificing the knowledge of fundamental engineering concepts (which is closer to PbBL). It is also illustrated that the engineers and academics are more familiar with the concepts of projects in their careers, than the concepts of PbBL. Therefore, the PjBL is likely recommended by the author as the more feasible learning style to be adopted by university engineering programs.

The use of PjBL as a key element of engineering programs should be widely employed as any improvement to the existing predominant lecture-oriented programs would be welcomed by students, industry, course coordinators and accreditors as well.

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