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Problem Based Learning (PBL) for Engineering Education in India: Need and Recommendations

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Abstract Historical footprint of problem based learning (PBL) could be traced back at McMasters University, Canada 1968. Since then, PBL is enriched with development in the literature and multiple PBL models across the world. PBL, has gained importance in modern era of higher education as it has been implemented in many universities across the world in higher education. Although, world is weighing up for PBL and its positive outcomes, it could not extend much in Indian higher education. An objective of this manuscript is to give an overview of PBL across the world and in India. In addition to this, Indian higher education landscape and scope of PBL to Indian engineering education is discussed. Article ends with some recommendations to ensure growth of PBL in India.

Keywords Indian Engineering Education · Problem based learning · Status · Scope

1 Introduction to Indian Engineering Education

India has very rich history of education tracing back the 3rd century BC. In those days, sages and scholars used to impart education orally. Gradually, the letters are developed; and education took the form of writing. The written ancient literature can be found on Palm leaves and barks of trees. At that time education were imparted in Temples and community centers. During the period of Buddha world famous educational institutions such as Nalanda, Vikramshila and Takshashila were arose from the monasteries. The Nalanda University, flourished from the fifth to 13th century AD, and had around 10,000 resident students and teachers which include Chinese, Sri Lankan, Korean and other international scholars. During the same period, in 11th century the Muslims established schools and this led to the formation

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universities at cities like Delhi, Lukhnow and Allahabad. Later, with the arrival of British in India English education came into existence. Since then, Western education has made steady advances in the country [21].

Technical education in India is started in the mid of 19th century. With the setup of Constitution of Technical Education Committee of the Central University Board of Education (CABE) in 1943; preparation of Sergeant Report in 1944 and formation of All India Council of technical Education (AICTE) in 1945; technical education gained momentum in 20th century. In order to maintain the standard of technical education, a statutory authority—the All India Council for Technical Education (AICTE)—was set up in 1945. The AICTE is a body that is involved in the systematic planning and organized development of the technical education system in the country. After the independence in 1947, the set-up of Indian Institutes of Technology (IIT), Indian Institutes of Management (IIM) and Indian Institutes of Science (IISc.) was a major step in the development of technical education in the country [4].

After independence, the higher education system in India grew swiftly. Till 1980, there were 132 universities and 4,738 colleges enrolment in higher education about five per cent. In terms of enrolment, India is the third largest higher education system in the world; with 17,973 institutions (348 universities and 17,625 colleges) is the largest higher education system in the world in terms of number of institutions. Currently, India has four times the number of institutions both in the United States and entire Europe combined together have [3, p-05]. The number of universities has increased from 25 in 1947 to 348 in 2005. The total number of colleges has amplified from 700 in 1947 to 17,625 in 2005. The total enrolment improved from a paltry 0.1 million in 1947 to 10.48 million in 2005 [3, p-07]. This tremendous growth is achieved at the expense of quality. In the last decade in India, major changes have been demanded in engineering by industry, students and educational researchers. The questions are raised in many reports about the preparedness of Indian graduate engineers for the industry [6] and the quality of engineering education [23,19,30].

In following section, recent studies conducted by Ministry of Human Resource and Development (MHRD), India arranged in chronological order. These studies indicate true picture of engineering education in India. In 2005, the National Association of Software and Service Companies (NASSCOM) and McKinsey came with the report that, only 25 % of the engineering education graduates are employable by a multinational company. Most of the surveyed employers linked this situation to the shortcomings from the education system. In the same year, the Planning Commission, Government of India came with the broad agenda to focus on enhancing the quality of educational institutions and an emphasis for appropriate arrangement for the development of skills and transforming learning patterns (p-13) at these institutions. In view of recommendations by Planning Commission National Knowledge Commission [19] on higher education was constituted in June, 2005. The purpose is to prepare a draft for transformation of India's knowledge related infrastructure. The NKC submitted recommendations to the Government in 2008.

Following this report in February 2008, MHRD, higher education department constituted a committee under chairmanship of Prof. Yashpal. It reported a deep concern in respect of growing engineering colleges by saying they have largely become, mere business entities dispensing very poor quality education (p-05) and indicated that there exists a gap between learning from institution and expectations from industries. Committee also recommended that the universities must adopt a curricular approach which treats knowledge in a holistic manner to create opportunities to bridge the gap by relating to the world outside (p-12).

Table 1 Summary of ABET Criteria

Learning outcome (LO)	Statement of LO
(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 in 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

It hinted that Indian higher education system needs a drastic overhaul (p-54) with proposal of curricular reforms at undergraduate programs to enable students to have opportunities to access all curricular areas and integration of skills with academic depth (p-64). In view of these reports there was an increasing demand from teachers, administrators, and policy makers to identify the kinds of skills demanded by the employers from an engineering graduate. So, to identify skills demanded by the employers an Employer Satisfaction Survey was carried out in 2009. This survey was supported by Government of India, the World Bank and the Federation of Indian Chambers of Commerce and Industry (FICCI). In this survey 157 industries across the India responded. According to the survey, 64 percent of surveyed employers are not satisfied with the quality of engineering graduates skills. A major skill gap exists among Indian engineering graduates. The graduate engineer lacks in process skills such as teamwork, lifelong learning and communication skills. The graduates also lack in higher-order thinking skills, such as problem-solving, conducting experiments, creativity, and application of modern tools. The survey recommended the need of improvement in the assessment methods, and to build curriculum with emphasis on soft skills listed above [6].

An essence of all these reports is that Indian engineering institutions needs to raise the quality of education imparted and must make provisions to ensure that the graduate engineers' skill are getting developed to meet industry demands. With the backdrop of these reports, the Ministry of Higher Education in India has decided to change the accreditation criteria to become outcome based. India, being a member of the Washington Accord, applies Accreditation Board for Engineering and Technology, (ABET) criteria 2011–2012 [1] to assess the quality of education in educational institutes. These criteria will be referred to in other sections. Table 1 shows a summary of the ABET criteria.

So far in the above section, we have discussed current status of engineering education. In most of the engineering institutions in India instruction based pedagogy is practiced and focus is on to achieve good grades in end semester exams. The teacher's role is to prepare students to secure good grades. Furthermore, Indian students are exposed to multiple issues such as syllabi not at par with industry needs, less focus on skill development etc. Also,

teaching and teacher related issues are raised by students from time to time. These shortcomings in the education system have resulted in unemployable technical human resource in India. Hence, it is appropriate to search for the suitable alternative which will

a. Improve quality of teaching-learning process in engineering education
b. Promote skill development relevant to engineering profession and industry

In coming section, what PBL can offer to Indian engineering education is discussed in view of above demands.

2 Introduction to PBL

The first university to develop and implement the Problem Based Learning curriculum was McMasters University, Canada in 1968 for medicine courses. Later in Denmark, a problem based and project organized model was implemented at Aalborg University in 1974 for engineering education [16]. The six core characteristics of PBL was described by [5] are

1. The learning needs to be student-centered.
2. The learning has to occur in small student groups under the guidance of a tutor.
3. The tutor acts as a facilitator or guide.
4. The learning starts with the authentic problem.
5. The problems encountered are used as a tool to achieve the required knowledge and the problem-solving skills necessary to eventually solve the problem.
6. Self-directed learning for acquisition of new information.

PBL can be defined as educational strategies in which the learning of knowledge skills and competence is organized around contextual, ill-structured and authentic problems. In such a learning environment, students take responsibility for their own learning and work collaboratively with each other to achieve meaningful solutions of posed problems [12]. In this way, PBL encourages students to learn about aspects of collaboration, problem solving, co-operation and teamwork [24]. This is called as learner centric and participant directed approach in which students own their projects and make decisions to get desired outcome.

Since then, the PBL strategy has progressed well and embraced by many leading universities in the world. Although at present many PBL models coexist, [13] pointed out that these models share common principles of learning: cognitive learning, contents, and social. The cognitive learning approach means that the learning is organized around the problems and will be carried out in the projects. A problem becomes central part of learning process and becomes motivation for learning. The students learn by his experiences while confronting to tasks involved in the problem solving process. A content approach especially concerns disciplinary and interdisciplinary learning. It is an exemplary practice carried out to address learning objective of the subject or curriculum. It also supports the relationship between theory and practice. The third principle emphasize on the concept of working in a team. The team or cooperative learning is a process in which learning is achieved through dialogue and communication between the team members. Students not only learn from each other, but also share the knowledge. Also, while working in a team they develop collaborative skill and critical project management skills.

2.1 PBL in Western World

Victoria University (VU), Australia introduced PBL into engineering curricula for different courses in 2006. It suggests that PBL approach cannot be based on definitive educational

theories. There are many multivariate models that satisfy to what is defined to be PBL pedagogy. Implementation of PBL to engineering curriculum needs to be placed in a local context and must be developed with careful considerations of social, economic, ethnic diversity of the students and the university academic culture [25]. At Samford University, Birmingham also PBL has a positive impact on student learning. The need to work closely with other institutions that have incorporated PBL in their curricula to develop valid and comprehensive PBL assessment measures is felt [11]. To enhance engineering education by promoting and facilitating the use of PBL in engineering four British Universities undertaken a three-year project. This study shows effective and well-structured project work can improve student's key transferable skills and their grasp of subject content. Studies have also shown that information learned by project work has over 80 % retention after one year, whilst information derived from lectures has less than 20 % retention after the same time period [18]. There could be more examples; we have mentioned few of them.

2.2 PBL in Asia

Awareness and the usefulness of PBL spread across the world and many Asian universities were attracted to implement PBL in their institutions. The 'one problem per day' model of the Republic Polytechnic (RP), Singapore [20] is one of the popular examples from Asia. Apart from this, many more cases of PBL implementation in Asia can be found in the literature; China [7], UTM (University Technology, Malaysia), Malaysia [15], Tribhuvan University, Nepal [14], and Mae Fah Luang (MFU) Thailand [31], are a few to mention. It shows that PBL is disseminated and accepted by Asian countries along with the western world. These models differ in their designs, which are seldom adjusted to suit local culture, the history of education, and other local conditions.

2.3 PBL in India

It may be noted that the PBL is neither an accepted nor an officially recognized methodology for engineering education in any of the Indian universities. The application of the PBL approach in the teaching–learning process and in scientific investigations are very exceptional [2,17,22] in the Indian engineering education landscape. The results of these few experiments indicate that PBL implementation in India needs to be considered appropriately and that more focused and scalable efforts are needed [17]. It has also been reported that lack of proper guidance, trained staff and infrastructure have hindered the growth of PBL in India [26]. Hence, the research and training in PBL curriculum design and integration into the existing curriculum is needed to improve the acceptance of the PBL approach by Indian educators.

3 PBL and Indian Engineering Education

So far, in above sections we have discussed requirement of Indian engineering education, basic philosophy of PBL and it spread across the world including India. In this section, our aim would be to show that PBL can fittingly address two requirements of Indian education which were listed in the introduction part. Effect of PBL on students' learning outcomes and its usefulness to promote skill development is discussed with the aid of existing literature, in addition to this; an experience of Indian students in the PBL environment is discussed to support our claim.

4 Effect of PBL on Knowledge and Skills

One of the frequently cited works of literature about the effect of PBL on knowledge and skills was undertaken by Dochy et al. [8]. They pointed out that PBL has a strong positive effect on students' achieving Problem solving skills. They concluded that students in PBL gained slightly less knowledge, but remembered more of the acquired knowledge. Empirical studies conducted at Aalborg University concluded that PBL helped students to improve process competencies. Process skills are the skills which are used in the application of knowledge. These include problem solving, critical thinking, communication, teamwork, self-assessment, change management and life-long learning skills. The PBL environment provides ample learning opportunities in which students learn from cooperation, and collaboration with peers [9,27].

An increasing number of cases have adopted the PBL method in engineering education to boost students' problem-solving skills [29]. Research undertaken by four British universities showed that well-structured project work can improve students' key transferable skills and retention rates [18]. The problem-based learning method can be adopted in engineering courses to create learning environments that help students develop problem solving, collaboration, communication, and self-directed learning (SDL) skills, as well as content expertise [10]. The PBL method was found to be effective in developing and enhancing generic skills in students at UTM. The survey results indicated that the generic skills of 70 % of the students had improved due to the introduction of PBL [15]. Information from literature suggested that PBL helps students to gain knowledge, deeper understanding, and promote skill development. It could be judged that PBL is relevant to Indian engineering education to address issue of graduate skills [28].

4.1 Students Responses to Indian PBL Model

In previous section, we have discussed effect of PBL on students' skills and learning outcomes with the aid of literature. It would be more interesting to discuss Indian students' experiences in PBL environment. In 2010, we have started research for development the PBL model for Indian engineering institute. In 2011 and 12 we have developed two course level PBL models for Indian institute located near Pune, India. In this section, the emphasis is to discuss effect of this PBL model implementation on students' LOs and share students' experiences. The students responded positively to the PBL activity and felt satisfied with their experiences in new learning environment. Almost all, about 96 %, of the respondents recommended the PBL activity in forthcoming semesters and found project activity well integrated into the curriculum. Also, from the feedback it is evident that the majority of the students felt that their learning and understanding had improved. Furthermore, most of them hinted that they learned better while working in a team rather than in the classroom and quoted teamwork is better than individual learning. Overall, 95 % of the students felt that they were satisfied with their learning during the period of implementation. They felt satisfied being involved in something different than traditional instruction-based setting and to learn something beyond the curriculum through Projects. We conclude that this PBL model experiment has increased the possibility of PBL implementation in other courses and created a framework for PBL implementation in the Indian academic setting.

Referring to the effect of PBL activity on LOs defined earlier, based on our results and evidence, we concluded that the developed course level PBL model proved effective in directly advancing LOs 'a', 'b', 'd', 'e', 'g' and 'k'. The LOs 'c', 'f', 'h' and 'j' remain untouched. This is because the design activity was not included in the project work. In future

designs, efforts would be made to add a few design activities to ensure that this deficiency is addressed. Overall, PBL has been found to be a useful way to engage students in learning and to achieve LOs. Considering this was our first experiment in implementing PBL in an India institute which has practised traditional instruction based pedagogy since decades, we are satisfied and feel encouraged with its successful implementation and the responses from the students. For more concrete conclusions, few more experiments need to be conducted.

5 Recommendations for PBL Implementation

Based on the different PBL cases from the world, it is confirmed that PBL is an accepted educational strategy. Studies concluded that PBL helps to improve the skills and make engineers more employable. Also, it can fittingly address issues such as low motivation towards learning. PBL can be a suitable alternative to traditional pedagogy in Indian engineering education. Historically, teachers and students in India are practicing traditional teaching in which most of the focus is on content coverage. Furthermore, the students in India are habitual to traditional teaching and evaluation methods. In PBL settings they need to be active learners which may pose challenge to them. Motivation to change and lack of resources could be major barriers for PBL implementation. Hence, teachers training and motivating all the stakeholders to ensure further growth of PBL should be the first step in PBL implementation. Also, it has been found that there is lack of literature and guidance in PBL curriculum design, scarcity of scientific investigation in India, hence centre of PBL research and studies would be good step to ensure further progress of PBL in India.

Generally, an educational system; especially privately owned have conservative approach to embrace innovative methodologies due to financial implications. Also, these institutes do not promote educational research as compared to research in traditional engineering disciplines. Engineering education research (EER) is not main stream research in India and efforts could be made in this direction to recognize EER field. PBL as an alternative is just started to get the recognition in few of the universities in India. Although, PBL seems to be a suitable alternative to Indian engineering education, concentrated and scalable efforts are required to make PBL as an acceptable method in India. So far none of the university nor institute in India got recognition in PBL like Aalborg or Roskilde University. For sustainable growth of PBL there is an urgent need to build model institute based on PBL philosophy. This step will ensure people will get attracted towards PBL. There could be legislation and jurisdiction to ensure the growth of PBL in the country. To enhance knowledge exchange periodic conferences in the area of PBL could be arranged.

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