Experiential learning: integrating learning and experience in shaping the future of the engineers

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ABSTRACT

The industry demands skill-equipped engineering graduates who could be efficient enough to adapt to face the challenges of uncertainty posed by a lack of skills and resources. Accreditation boards have identified problem-solving, teamwork, communication, etc. as the workplace required skills. However, industry/employers feel that the engineers seem to lack problem-solving, teamwork, etc. To groom these skills, experiential learning (EL) platform provides hands-on practice. Thus, the study aims to gain insights into the need of experiential learning to integrate learning and experience. The study, qualitative in nature, focuses on the essential skills, specifically problem-solving skills, against the applicability of experiential learning. Experiential learning allows engineering students to get a hands-on approach to practise their acquired skills to understand industrial needs and constraints. In the given context, problem solving helps in knowing what is learnt and what needs to be learnt.

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1 INTRODUCTION

In 2018, the Organisation for Economic Co-operation and Development (OECD) raised two well-reasoned questions: what knowledge and skills future engineers require; and how instructional systems can help develop that knowledge and skills? This being an unavoidable issue tends to seek attention on multiple facets. Employers and various agencies, after having understood the essentiality of such skills, give high importance to problem-solving skills (86%) followed by teamwork (79%) among the key future skills (Hristov, Minocha & Sreedharan, 2018). Only 33% of employers feel that graduates possess the necessary higher-level skills and knowledge that they are looking for in their industry. Supposedly, engineering programmes must prepare engineering graduates for the practice of engineering at the professional level (IEA, 2021). However, employers and industrial representatives seem to be congruent in their understanding that the graduated engineers lack specialised knowledge as well as employability skills, the expected learning outcomes of engineering education.

Some of the assumptions associated with skills are: the skills develop on their own during the learning phase; their understanding and acquisition is implicit; explicit efforts are not needed; and only technical aspects need attention. Various stakeholders are making conscious efforts to draw attention to skills, their finer aspects, implementation, urgency, and benefits Accreditation boards (IEA, 2021) have identified twelve skills: engineering fundamentals, knowledge of a particular domain, environment and sustainability, design, problem-solving, the engineer and society, independent work settings, lifelong learning, teamwork, communication, conflict management, and ethics.

Engineering education seems to address essential life and career skills to deal with financial pressure, career opportunities, time management, workplace etiquette, and other necessary skills. Engineering education, being technical in nature, needs to be more practice oriented. Learning-oriented involvement (to observe, analyse, interpret and solve) of students in experimental data, a case study, a complex real-world problem, etc. (Prince & Felder, 2006) makes students active agents. Theory-based teaching, outdated curriculum, academic environment isolated from industry work (Hristov, Minocha, & Sreedharan, 2018), etc. lead to lack of skills. Various benchmark and policy statements emphasise creative and critical problem solving skills. Problem solving skills, recognized as one of the key concepts of the learning framework (International Engineering Alliance (IEA), 2021) (https://www.ieagreements.org/assets/Uploads/IEA-Graduate-Attributes-and-Professional-Competencies-2021.1-Sept-2021.pdf), is still a big challenge for Indian engineering education (Büth et al., 2017). The employees who can work in groups to identify problems, sift solvable unsolvable problems, understand causality, form problems, take calculated risks, and be resourceful enough to solve uncertain, ill-defined, and unthought-of problems, apparently seem to be an asset to any industry.

Learning seems to comprise a complete set of contextual skills. Experiential learning (EL), comprising active as well as reflecting learning, helps learners acquire knowledge, understand theoretical concepts, foster complex problem solving, develop other skills, apply previous knowledge to current problems, and attain superior performance. EL techniques (theory-practice integrated), such as problem based learning, project based learning (Savery, 2015), make learners realise that problems are valuable; difficulties and problems lead to learning; and knowledge is applied in real life. Thus, the study aims to gain insights into the need of experiential learning to integrate learning and experience. The questions addressed are:

- Which skills are required the most by industry?
- What are the types of experiential learning techniques?
- Does the curriculum of premier institutes of India give space to EL?
- How experiential learning enables developing the skills in the Indian context?

2 METHODOLOGY

The study, qualitative in nature, focuses on the development of problem-solving skills against the applicability of experiential learning. Deductive approach was used to extract skills and EL from literature review. Inductive approach was used to analyse curriculum documents of the two leading premier institutes (higher education) of India, based on the pedagogical approaches: teaching techniques, learning environment, content, and assessment.

3 SKILLS OF ENGINEERING GRADUATES

94% of employers termed problem-solving and teamwork as the two top skills urgently required in their sector (Hristov, Minocha & Sreedharan, 2018). There is an improvement in teamwork but problem solving still remains a challenge (Sting, 2016). Problem solving is a complex yet systematic process with criticality to address a dynamic issue and seek multifaceted and open ended solutions (Priemer et al., 2019). Problem-solving skills is not only about process (stages and strategies) but also about problem (nature and context) and solution (types) (Sangwan & Singh, 2021).

The process has two to five stages; each stage has specified strategies. Reflection is one of the important stages in the process. Learners should be able to describe, explain, design, and produce with what they know, understand, think, and believe. The complexity and difficulty of problems are relative, depending on the learner's own existing knowledge, strategy application, and situated context. Thus, the approaches and teaching-learning techniques need to be explored to find their effectiveness in improving problem solving skills.

4 ROLE OF EXPERIENTIAL LEARNING IN ENGINEERING EDUCATION

Despite intense focus on multifaceted aspects, students seem to lack exposure to practice-based higher education curriculum and pedagogies (Hristov, Minocha, & Sreedharan, 2018). The challenge is not only to infuse domain specific and disciplinary insights but also to make the learners competent. Skills (and outcomes) comprise three concepts (problem solving process constituents): head (intellectual development), hand (skill development), and heart (modes of thinking, habits of mind). Intellectual development enables engineers to analyse and evaluate; skill development eases tools usage to manipulate the knowledge; and thinking habits sharpen motives and strategies for learning and performing.

All three elements (teacher, learner and environment) impact skill development. Real work environment/practical experience must comprise active and interactive actions in teaching-learning. An integrated framework of problem-solving, addressing domain-specific, complex, and interdisciplinary problems (Priemer, et al., 2019), can equip the learner not only with the theoretical knowledge (concept of 'what' - deductive approach); but also with the situated knowledge application ('how and why' - inductive approach).

Conducive environment encourages students to re/construct knowledge through metacognition - the process of assessing their own understanding and performance through reflection - a stage of EL cycle (Venugopal, Singh, & Devika, 2019; Kolb & Kolb, 2017). Metacognition corresponds to problem solving. Next, heterogeneity of learners changes the role of learners and teachers; same instructions and same environment cannot check performance variance. EL (student-centred pedagogy) provides a platform to learners to realise and assess their own learning, errors and improvements, and changes the role of teacher as a mentor and the role of learner as a performer.

EL theory (Kolb & Kolb, 2017) has four stages: experiencing, reflecting, thinking, and acting. Experiencing is necessary for learning. EL involves both active and reflective learning (learning by doing, experiencing, discovering, and exploring). Reflecting, an iterative learning experience, develops self-awareness, a part of the problem solving process. In the EL curriculum (like PBL), projects enable students to identify and analyse multidisciplinary problems and problem-solving processes, develop critical thinking skills, and experience deep learning (a comprehensive grasp on the meaning) (Edström & Kolmos, 2014). Prior knowledge, knowledge organisation, motivation, skill development for mastery, goal directed practice and feedback, interaction between learner development and course environment, and approaches monitoring and adjustment are the principles of EL. The EL techniques - problem based learning (PBL), Project based learning (PrBL), Research based learning (RBL), Inquiry based learning (IBL), Case based learning (CBL), and Discovery based learning (DBL) - cater to engineering education particularly (Camacho, Valcke, & Chiluiza, 2017; Savery, 2015; Prince & Felder, 2006). Subsequent to the identification of types of EL, the study compares these six techniques (see table 1) in the context of suitability of engineering education and problem-solving skills. The comparative analysis is based on the four parameters such as role, encouragement, practice and hands-on-experience, and learning outcome (skills) (Hristov, Minocha,

& Sreedharan, 2018). Besides these four, one more parameter (discipline applicability) was identified through literature.

4.1 COMPARATIVE ANALYSIS OF EL TECHNIQUES

Abducitve (mix) approach, learner-centred pedagogy, and active learning are predominant in all EL techniques. PBL and RBL contribute to the development of problem solving skills to the maximum followed by PrBL. These three learning techniques do contribute to the development of problem solving skills to a higher level (Singh et al., 2019; Winarti & Waluya, 2019; Efstratia, 2014). PBL (being engaged, hands-on experience) makes learners challenge things, develop a deeper understanding of the subject, and enhance deep learning. (Hristov, Minocha & Sreedharan, 2018). Learners become more active, self-dependent, and owners of the learning process in PBL and RBL than PrBL; facilitator guides the students with ideas, methods, and tools in PBL (Edström & Kolmos, 2014).

Teacher acts as a facilitator (student centred - contemporary) than a conventional lecturer (teacher centred - traditional). In EL techniques, learners receive sufficient scaffolding (both support and supervision followed by gradual withdrawal of the support and feedback (multidimensional, non-evaluative, timely, specific)) as a powerful driver.

PBL is not a simple application of the methodology that may be transferred to the classroom without making structural changes. Implementation of EL techniques like PBL needs consideration at all three levels: teacher/learner, course, and organisation. This represents the shift in classroom culture. Implementation of EL into engineering education helps achieve the learning outcomes, as it leads to the development of problem solving skills required at the workplace. Overall, it has been found that EL provides a platform to the teacher/learner to develop and improve problem solving skills.

Table 1. Comparative analysis of EL techniques

EL techniques: Types → Parameters ↓		**PBL**	**PrBL**	**CBL**	**IBL**	**RBL**	**DBL**
Role	**Teacher**	Facilitator	Coach	Instructor	Facilitator	Facilitator	No guidance
	Learner	Very Active	Less Active	Active	Active	Very Active	Active
Encouragement		Very High	Moderate	Low	High	Low	Moderate
Practice and	**Product oriented**	Low	High	Low	Low	Low	Low

hands-on experience learning	**Process oriented**	High	Low	High	High	High	High
Learning Outcome (skills)	**Analytical**	High	High	High	High	High	High
	Decision-making	High	High	High	High	Moderate	Low
	Team work	High	High	High	High	High	High
	Problem solving	High	High	High	High	High	High
	Self-directed learning	High	High	Low	High	High	High
	Self-awareness and management	High	Moderate	Low	High	High	High
Applicability in disciplines		Education	All areas of education	Law, medicine, business management, teacher education	Science education	All areas of education	School education

4.2 Analysis of Curriculum of engineering education in Indian context

The analysis of curriculum of Indian institutes of engineering education would help in developing basic understanding about the concept of graduate attributes development holistically. For this, the curriculum of high ranking, fully government universities such as Indian Institute of Technology (IIT) and private university such as Birla Institute of Technology and Science Pilani (BITS) were analysed based on the documents available in the public domain as well as interacting with the past and current students of these institutes. The analysis was performed on parameters of teaching techniques and learning environment, content, and assessment.

Teaching techniques and learning environment: Both universities have classroom environment and industry internships within the curriculum. The internships provide the opportunity of a real work environment to the students for a very short period. The Indian engineering graduates are taught based on input-output orientation (PrBL approach). Most of the core courses have laboratory classes but unfortunately these laboratory classes have input-output orientation, which does not foster real life environment problem solving skills. Though the faculties in these universities are highly qualified but lack industrial exposure, a probable reason for the gap between theory and practice in teaching-learning. Theoretical basis of Indian teachers is very strong but they fall short of new developments (Hristov, Minocha & Sreedharan, 2018). BITS Pilani, known for innovation in teaching and learning, particularly in India, provides full semester project courses (study, laboratory, design, special projects, etc.) to cater to the students' learning in newer or advanced areas. BITS Pilani also has a minimum seven-month internship with industry while IITs have short duration internships.

Content: The curriculum includes foundation courses (engineering, mathematics, sciences, humanities, technical arts, and application oriented courses), core (compulsory disciplinary), discipline electives, and open elective courses, indicative of content rich curriculum to develop the required skills among engineering graduates. Core courses develop strong fundamental knowledge in particular domains forming the part of theoretical knowledge. Also, the students admitted in these institutes have highly competitive entrance examinations, ensuring high quality students.

Assessment: The assessment is done majorly through written examination (mid semester, end semester, continuous assignment, quiz, etc.) and practicals (experiments, viva-voce, quiz, etc.). The written examination at BITS Pilani is both open book and close book. The questions in the open book are application oriented, with more flexibility to construct prior experience based knowledge. Open book examination develops application oriented learning and knowledge transforming ability.

The analysis also reflects that with the current teaching approach the Indian engineering graduates are likely to lack problem solving skills. The Indian higher education institutes have to redesign their laboratory classes based on open ended experiments rather than input-output based experimentation. Overall, it can be stated that current pedagogy, predominantly PrBL, is not solely sufficient to develop problem-solving skills. Based on the analysis of the lack of problem solving skills, the study recommends integration of EL aspects in the teaching-learning techniques and environment to develop and improve problem-solving skills.

- More exposure to practice and problem solving along with self-awareness
- Engagement of learners in an authentic environment
- Need to bring familiarity with the cultural aspects of EL techniques in comparison to traditional teaching-learning
- Need to arouse interest and motivation among learners to solve the problem with an emphasis on reflection

The present study recommends an experiential learning integrated teaching-learning for problem-solving skills development and improvement.

5 SUMMARY

The accrediting boards, academicians, and practitioners have acknowledged the importance of good problem-solving skills along with adequate knowledge of self-reflection and self-awareness. Problem solving skills, found lacking in Indian engineering graduates, tops the set of skills needed for survival and success in industry/workplace. EL techniques sharpen problem solving skills through authentic learning situations such as learning factory, virtual laboratory, simulation, etc. Linking learning approaches and strategies with a real work environment empowers engineering training, research, and education.

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