Contents

1. Introduction:

Education is a fundamental human right (European Convention for the Protection of Human Rights and Fundamental Freedoms, Article 2 of Protocol 1, 1950; Constitution of India, Article 21-A, 1950, amended 2002, 2009) and is a cornerstone for sustainable development. Provision of fundamental schooling and quality education is a strong agenda for 'Agenda 2030', to build long term human capital, enabling and improving higher education is a must.

In the traditional 'gurukul' system of the Indian sub-continent, dating back to the Vedic era, the 'guru' or teacher-mentor directed the 'shishya' or students through two modes of learning; 'shruti', i.e. sound or oration, i.e., instructional teaching and discussion, and 'smriti', i.e., memory or recall, for contemplation, self-reflection and critical thinking on open-ended problems. Several centuries later, formal universities which were part of Buddhist monasteries, such as those in Nalanda (modern day Bihar, India) founded in 5th Century BC, and Takshashila (modern day Taxila, Pakistan) dated to 10th Century BC, flourished. However, they did not survive due to natural calamities and foreign invasions, and eventually, these indigenous pedagogical traditions and institutions were replaced by formal, English education brought in by colonial rule. Though efforts to retain traditional teaching approaches were made by Nobel Laureate, Rabindranath Tagore, who founded the Vishva-Bharti University in 1921, it focussed on learning and research in non-technical areas. Thereby leaving a gap in the contextualised learning of technical – engineering and management - studies in the region. And though the three South Asian partner nations – India, Nepal and Bhutan, largely share a common history, they do not share a convergent nor comparable standard for higher education.

1.1. Key focus areas to empower future generations: SDGs

The need to strive towards sustainable development was recognized and felt in the early 1980's, which led to various worldwide attempts to define and develop action plans and guidelines. 'Our Common Future', also known as the Brundtland Report, from the United Nations World Commission on Environment and Development (WCED,1987), defined Sustainable Development as the development that meets the need of the present without compromising the ability of the future generation to meet their own needs".

In 2011, the idea of SDGs (Sustainable Development goals) was proposed at a preparation event for the United Nations Conference on Sustainable Development (UNCSD), also known as Rio+20, to be held the following year. At the event, a resolution known as "The Future We Want" was reached, which paved the way towards the development of the 2030

Development Agenda titled "Transforming our world: the 2030 Agenda for Sustainable Development", set by the United Nations General Assembly and adopted by 193 member states in 2015. The Agenda outlines the 17 global goals that act as a "blueprint" to guide development plans with169 targets and 232 approved indicators to measure the compliance and progress towards them. Sustainable Development Goal, SDG 4, stresses on "inclusive and equitable quality education and promote lifelong learning opportunities for all" (UNDP, 2017) with 'Education for sustainable development' (ESD) explicitly recognized as part of Target 4.7. SDG 8 seeks to promote "sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all" (UNDP, 2018), while SDG 11 emphasizes the importance to support "positive economic, social and environmental links between urban, per-iurban and rural areas by strengthening national and regional development planning" (UNDP, 2018).Thus, these goals lend a holistic picture of the effort required for capacity building in the youth and highlights the focus areas that need attention, i.e., quality education, lifelong learning, sustained and inclusive employment, and societal involvement and impact.

1.2. Education across the Partners: Process and Policy

The European Union and its states identified the common challenges in the EU with respect to "growth and diversification of higher education, the employability of graduates, the shortage of skills in key areas, the expansion of private and transnational education", from which stemmed the Bologna process (http://www.eees.es/pdf/bolognaEUA.pdf). As a result, the Joint Declaration of the European Ministers of Education, popularly called the 'Bologna Declaration', convened in 1999, with the intent to reform the higher education systems across 29 member states of the European Union. It aimed to create convergence while respecting the autonomy and diversity of the signatory countries, their governments and universities. The declaration outlines objectives that promote employability, mobility for pursuing study, training, etc., and cooperation in quality assurance, through strategies such as, common system of credits and degrees, wide recognition of degrees to allow ease of pursuing higher education in other countries, and development of comparable criteria and methodologies. It also stresses on the importance of higher education and research systems adapting to "changing needs, society's demands and advances in scientific knowledge".

<<EU Partner country specific policies, if any >>

In India, the National Education Policy was first framed in 1986 and a most recent version, termed as the Draft National Education Policy (DNEP) 2019 is currently under iteration, having gone through the Parliamentary standing committee on Human Resource development in November 2019. The committee was ably chaired by Padma Vibhushan, Dr.Kasturirangan, the former Chairman of ISRO (Indian Space Research Organisation) and ex-Member of Parliament. Propped on the pillars of Quality, Innovation and Research, the DNEP prioritises access, affordability, equity, quality and accountability. Under Higher Education (DNEP, Part II, pg.201-338), the draft policy focusses on institutional quality, restructuring and consolidation as a whole while supporting its various stakeholders, such as the students, faculty and institutional governing bodies. It outlines the need for imbibing liberal education and creating 'Optimum learning environments' for students which entails ; Innovative and responsive curriculum and pedagogy, Student support for learning and development, Open and distance learning for life-long learning and Internationalisation of higher education. It also aims to support faculty through improved engagement and capacity-building strategies, establishment of teacher education within multi-disciplinary institutes, as well as empower the governance through effective leadership development. It also highlights the need of transforming the regulatory system under a unified regime of standards and accreditation.

The Department of Higher Education (DHE), under the auspices of Ministry of Human Resource and Development (MHRD), is responsible for the basic infrastructure – both policy and planning – for higher education. It adopted a National Institutional Ranking Framework (NIRF) in Sept 2015, to rank institutions of higher education in India based on a methodology that broadly covers the following parameters - Teaching, Learning and Resources; Research and Professional Practices; Graduation Outcomes; Outreach and Inclusivity; and Perception (www.nirfindia.org). The MHRD also has several statutory bodies for recognising, accreditation, and quality and standard maintenance, for institutes of higher education across the country under its purview, as follows;

- **UGC** (University Grants Commission) set up by an Act of Parliament, the UGC Act, in 1956 under MHRD, is a statutory organization of the Government of India for the "coordination, determination and maintenance of standards of teaching, examination and research in university education" (www.ugc.ac.in). It conducts the National Eligibility Test (NET) for appointments of teachers in colleges and universities along with CSIR (Central Scientific Research Institute). As on 1st Feb 2020, there are 50 Central Universities, 409 State Universities, 349 Private Universities and 127 Deemed to be Universities (https://www.ugc.ac.in/oldpdf/Consolidated%20list%20of%20All%20Universities.pdf).

- **AICTE** (All India Council for Technical Education) is a national-level council for technical education under DHE, MHRD established in November 1945 as an Apex Advisory board. It is responsible for development, planning and accreditation of technical and management programs; conducts national level entrance examination called CMAT (Common Management Admission Test). It has several quality initiatives, such as; revision of curriculum, examination reforms, training of technical teachers, mandatory internship and industry-readiness, start-up and innovation focus, etc (www.aicte-india.org).
- **AIU** (Association of Indian Universities) established in 1925, is an association of major universities that looks into the recognition of Degrees and Diplomas offered by universities recognised under UGC and equivalence of the standards and credits of foreign universities in relation to India, to evaluate admissions in India for higher education. Its key objectives are to act as a bureau of information to facilitate communication through newsletter, publications, etc. and to behave as a liaison between universities and government (www.aiu.ac.in).
- **NAAC** (National Assessment and Accreditation Council) is an autonomous body established by the UGC to assess and accredit institutions of higher education in the country. It ensues assessment of an institute if it seeks Institutional Eligibility for Quality Assessment (IEQA), either at university, college or departmental level, following which seven weighted criteria - Curricular aspects, Teaching-learning and evaluation, Research, Consultancy and extension, Infrastructure and learning resources, Student support and progression, Governance and leadership and Innovative practices - are assessed (www.naac.gov.in).
- **NBA** (National Board of Accreditation), India was initially established by the AICTE under section 10(u) of AICTE Act, in the year 1994, to assess the qualitative competence of the programs offered by educational institution from diploma level to post-graduate level in engineering and technology, management, pharmacy, architecture and related disciplines, which are approved by AICTE. However, in 2013, it was made an independent body with the amendment of The Memorandum

of Association and Rules of NBA. It conducts evaluation of programs of technical institutes on the basis of, but not limited to; institutional missions and objectives, organization and governance, infrastructure facilities, quality of teaching and learning, curriculum design and review, support services, such as, library, laboratory, instrumentation, computer facilities, etc. and any other aspect as decided by the General Council and / or Executive Committee of NBA (www.nbaind.org)

- **NCTE** (National Council for Teacher Education) is a statutory body of Indian government set up under the National Council for Teacher Education Act in 1995 to formally oversee standards, procedures and processes in the Indian education system. It was first conceptualised as a part of the National Policy on Education (NPE), 1986 and was later established in 1973 with its Secretariat in the Department of Teacher Education of the National Council of Educational Research and Training (NCERT).Its main objective of the NCTE is to achieve planned and coordinated development of the teacher education system throughout the country, the regulation and proper maintenance of Norms and Standards in the teacher education system and for matters connected therewith (www.ncte.gov.in).

In addition, there are several domain-specific societies, associations and councils, such as; FTII (Film and Television Institute of India, registered under Societies' Registration Act of 1860), AIMA (All India Management Association), MCI (Medical Council of India), etc., that look into the quality of education and practice of these fields in India.

<<Nepal & Bhutan's country specific policies >>

1.3. Capacity-building in Higher Education through Problem-based learning (PBL):

The Bologna declaration states that, "*successful learning and studying in higher education should involve students in deep learning*". But with the advent of diverse job opportunities and socio-cultural challenges, the youth of these nations require more than bookish knowledge, they require empowerment. Survey from faculty across the partner institutes highlight that the engineering students lack skills needed to be industry ready. They face difficulty in getting employed after graduation and if placed, then struggle during their employment due to insufficient practical experience, lack of good communication skills and unawareness of larger socio-economic contexts. Strengthening Problem-based learning in South Asian Universities is an endeavour to address these pressing concerns in education quality, employability and overall sustainable development of the region and to imbibe deep learning capabilities.

2. Current Engineering Education

Engineering is a popular course of study for many students across the world. With the emergence of new fields of engineering, more specialized training in very niche fields are the order of the day. Conversely, these new fields of engineering promote “inter-disciplinary” fields of study where the students are applying concepts of core engineering to a wide array of problems. Engineering education is usually a four year affair at the undergraduate level leading to a degree in any of the specializations (e.g. Computer Science, Electrical, Electronics Mechanical, and Civil) or a combination of specializations as prescribed by particular universities. Universities also usually offer a masters level specialization degree in specialized areas of the core engineering areas as well. These graduate studies range from one to two years. The terminal degree in the areas usually leads to a PhD which are focussed on very specific topics in a specialized area. This pattern is more or less common across the world. The challenges involved in the engineering education and pedagogy are multi-fold and they tend to revolve around the value addition imparted to the students as a result of undergoing the training. Conventional engineering curriculum and teaching approach is saturated with too much amount of information and yet less relevant with industrial practice and a lifetime of learning as it fails to foster real-world/ professional problem-solving skills in the students. In conventional classroom scenario, problems are pre-defined, well-structured and encountered at the end of chapter after reading text or hearing the lectures; communication happens one way (i.e. from teacher to students, lack of interactive environment); mostly assignments problems are asked to solve individually, and assessment questions evaluate retention ability of students rather then transfer. Mills and Treagust (2003) mentioned the common critical issues in traditional engineering education which is summarized as below:

- Programs
    - content driven instead of need-driven
    - do not provide sufficient design experiences to students.
- Students
    - lack of communication skills and teamwork experience
    - lack of awareness about social, environmental, economic and legal issues
- Faculty

- lack of practical experience (not able to adequately relate theory to practice or provide design experiences)
- having outdated teaching and learning strategies

As a result, students failed to apply or integrate knowledge in real world problem solving. Conventional methods of teaching and assessment in engineering universities inhibit the development of important skills like problem-solving, critical thinking, creativity, collaboration and communication. Different reports have identified the above-mentioned skills as important skills required in the future workforce. Because traditional teaching techniques has failed to develop the skills required by industry into the students, it has raised needs from industry people to make existing education more effective and efficient.

2.1. Global scenario (as per literature) – issues faced

Curricula in engineering across the world aim to develop students into excellent engineers who apply the principles of science to everyday world. The objectives mainly involve the imparting of fundamental theories and principles involved in a particular stream of engineering. At an undergraduate level, the primary focus is significantly on developing the acumen related to analytical ability and exposure to various theories related to the engineering stream. Such an approach usually translates to an emphasis on assessment of students based on their understanding of the fundamental principles. The engineering education over time has evolved predominantly into a teach and learn method where the significant principles are explained in a class room. Such learning is usually a “broadcast-subscribe” model. The students register for a course and the teacher decides on what to be taught in the class. Such structured classes and curriculum are important for uniform evaluation and assessment of students. However, such models have inherent limitations. First, such mode of learning tend to expose students to only well-structured problems. That is the contours of the problems are usually given with a number of assumptions to simplify the problem for class study and the students are expected to use a principle (typically involving application of a formula/ algorithm/ method) to solve a given problem.

Second, the existing approaches tend to focus on the solution of certain given problems/challenges rather than formulation of such problems. Third, the courses usually

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focus on individual learning rather than the learning in team. Finally, such courses are usually quite insulated from the vagaries involved in the real-life problem definitions.

Such limitations have led to some pertinent problems in engineering education. There is question of the readiness of the engineering graduates to be absorbed by the industry. The questions on the skills developed during the undergraduate/graduate courses in terms of their use and utilization in the industry remains. The industry feels that sometimes the technical prowess and competency required are not really reflected by the grades in their respective courses. Reasons could be faulty assessment methods based on rote learning rather than application among many other reasons. The curriculum also do not provide sufficient exposure for the students to understand the gravity and scope of real-life application of the technical principles involved. A case in point is the technical design courses across the world where the focus is more on the methods involved understanding the response of a system given some loading conditions. Though this is an essential skill, it does not complete the picture. The loadings are usually given to students where the student’s role comes into picture to translate such loads to responses. However, the students are not usually exposed to ways to determine the loading conditions and loads in the first place.

Another important limitation is the focus on individual learning in curriculum which unnecessarily lays a huge weight on individual brilliance rather than teamwork. Many problems in the real world involve teams to solve them. Such skills like communication, team behaviour etc. are usually lacking in the students.

Lastly, the students are seldom exposed to larger context. The engineering education is usually restricted to technical aspects and the larger social, environmental, economic and legal issues are usually ignored from the curriculum.

Such limitations usually makes the engineering education incomplete. Further, the courses overtime leaned more towards theory rather than hands-on do and learn and thus rendering an inadequacy in terms of practical application and pragmatic skills required by engineers in solving a problem in general. The courses have become focussed and usually missed out on embedding the problems in real-life contexts to give meaning to the principles and appreciate the uncertainties and complexities involved in modelling the physical world into engineering models.

2.2. Local (South Asian) scenario – Gaps identified upon Needs Assessment

The South Asian nations have imbibed engineering education very seriously. There are a number of engineering colleges/universities in the countries which impart world class engineering training and education to aspiring students in various streams of engineering. The countries of India, Nepal and Bhutan have a very similar institutional context when it comes to engineering education. The engineering education and curriculum development is usually overseen by a national level body on technical education (e.g. All India Council for Technical Education – AICTE in India). The engineering courses are offered on university campuses or in affiliated colleges. While the university campuses enjoy a relatively greater freedom in designing and execution of curriculum for engineering courses (based on broad guidelines from the national bodies), the affiliated colleges are constrained to use the syllabus prescribed the university to which they are affiliated. Further, the evaluation schemes vary differently between universities and the colleges as well. The university based engineering courses have greater flexibility in assessment schemes, whereas the affiliated colleges are more restricted to follow the guidelines of the universities. The engineering assessment is usually done by a common exam across all affiliated colleges within a university. Thus, the teaching in colleges are geared up in preparing the students for these common examinations. The limitations discussed in global context are applicable to the south Asian engineering education as well. The problems of students not being employable at the end of the course is a major issue as highlighted by various forums. The problems of rote learning, insufficient exposure to real-life problems, the development of soft-skills and the exposure to larger contexts is present in the South Asian context as well. Further, the focus on examination and grades rather than learning is a major concern for this part of the world. This is compounded by the fact that in countries like India, the majority of employers for engineering graduates are in IT and services sector across various streams of engineering, thus leading to the questions among students the usefulness of core engineering courses as compared to industry ready courses. The employability of students is a huge concern. This has led to a phenomenon in the industry where the companies recruit the graduates based on their general aptitude rather than industry ready skill-sets and subject them to an extended training programme which span more than a year in some cases. This shows the lack of confidence of the industry in direct deployment of students in the industry without making them ready in such prolonged training exercises.

2.3. Need for strengthening Problem-based learning:

2.3.1. Capability to foster deep learning through critical thinking, enable complex, real world problem solving, imbibe self-learning by increasing motivation in students, collaborate & communicate

<<TO BE DISCUSSED @PMT; FROM NEEDS ASSESSMENT >>

2.3.2. Objective: *To review the best practices in PBL pedagogy and to develop a PBL schema that is contextually suitable for Engineering education South Asian Universities*

3. Problem-based learning

Problem-based learning (PBL) is a leaner-centered approach (Savery,1999) where students strive to resolve “real world problems”(Torp and Sage, 2002). PBL methods are reported to support the development of specific skills, such as, **critical thinking; complex problem solving, self-learning, due to increased motivation and engagement; collaboration and people management; and communication** (Duch, Groh and Allen, 2001). These skills are also recognised as top skills for 2020 and the upcoming decade by the World Economic Forum (2016).

3.1. A brief history of PBL: Introduction in clinical practice

Problem Based Learning (PBL) is an innovative teaching method which was developed and implemented in McMaster University (medical school) around 1965 and then became popular in among medical institutes. Later, this approach was adopted in other fields like MBA, law, engineering, education, etc.. It was derived from the theory that, learning is a process in which the leaner actively construct knowledge (Gijselaers, 1996). It is a method where students in a small group understand, discuss, study and solve real life problems under the supervision of tutor. Learning is organized around a problem.

3.2. Definitions, Characteristics and Learning Principles:

Problem-based learning (PBL) is defined as a “focused, experiential learning organized around the investigation and resolution of messy, real-world problems” (Torp and Sage, 2002), in which “students learn through facilitated problem solving that centers on a complex problem that does not have a single correct answer” (Hmelo-Silver, 2004). But it is important to note that PBL is “not problem-solving” (Savery,2006) alone but is an “instructional (and curricular) learner-centered approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem” (Savery,1999).

Barrows (1996) identified six core characteristics of PBL, explained as follows:

1. Learning is student-centred: students take responsibility of their own learning, identify the knowledge that required to learn and determine the way/ resources to get information by themselves.

2. Learning occurs in small student groups: A group generally consists of five to nine students who work together along with a tutor. Students share their knowledge and learn from other and learning happen in collaboration.
3. Teachers are facilitators or guides: tutor asks students the kinds of questions to better understand and manage the problem.
4. Problems form the organizing focus and stimulus for learning: Problem represents the challenge students will face in real-life and provides the relevance and motivation for learning. Students realize what they will need to learn in order to solve the problem.
5. Problems are a vehicle for the development of problem-solving skills: the problem format is in same way that it occurs in the real world (ill-structured, complex) which allow students to inquire the problem in deeper. The students don't restrict to a single subject rather, they focus for integrating information from many disciplines.
6. New information is acquired through self-directed learning: the students are expected to learn from the world's knowledge and accumulated expertise by virtue of their own study and research.

PBL is an approach to learning which is well matched with prescribed principles of cognitive and constructivist theories of learning. PBL process promotes the activation of prior knowledge and its elaboration. Also, discussion of a relevant problem in a small group facilitates processing of new information. This problem-oriented study allows mastery of principles and concepts such that that can be transferred to solve new problems. Solving problems via PBL method enhance integration of different subject/ domain knowledge. Also, PBL makes learning intrinsically interested and keep students self-engaged in learning. These propositions underlying PBL have been validated and have empirical basis (Schmidt et.al. 2011, Schmidt, 1993; Norman et.al., 1992).

3.3. PBL compared to other learning approaches

3.3.1. Difference between conventional teaching and PBL approaches:

The difference between conventional learning and PBL learning are tabulated (Table1) below:

Traditional/ conventional learning	**Problem-Based Learning**
Teacher centric	Student centric
Passive learning (teacher transfers knowledge)	Active learning (Teacher facilitates the learning process)
A subject-oriented approach	A problem-oriented approach
Discipline-oriented	Interdisciplinary
Based on basic and applied technical knowledge	A complex understanding of technological knowledge
Individual tasks	Group + Individual tasks
Isolated	Contextualized

3.3.2. Differences with other, non-conventional approaches:

Apart from Problem-based learning, there are other approaches to learning, such as, Case-based or Case study Learning and Project-based Learning.

The key differences between PBL and Project-based learning are ;

- Project tasks are closer to professional reality and therefore take a longer period of time than problem-based learning problems (which may extend over only a single session, a week or a few weeks).
- Project work is more directed to the application of knowledge; whereas problem-based learning is more directed to the acquisition of knowledge.
- Project-based learning is usually accompanied by subject courses (eg maths, physics etc. in engineering); whereas problem-based learning is not.
- Management of time and resources by the students as well as task and role differentiation is very important in project-based learning; as opposed to PBL.
- Self-direction is stronger in project work, compared with problem-based learning, since the learning process is less directed by the problem.

The key differences between PBL and Case-based learning are ;

- Case-based or case study Learning is predominantly task oriented, with activity often set by tutor; while in PBL, problem is usually provided by tutor witht eh students defining the 'what' and 'how' they learn.
- In Case-based, tutor supervises while in PBL, tutor facilitates

- In Case based, students are required to produce a solution or stategy to solve the problem which maybe a worked example; while in PBL, focus is on the problem 'management' rather than problem solving, which is just a part of the process, with no clear or bound solution
- In Case-based learning, supporting lectures to undertake the activity is pivotal; while in PBL, students are expected to define the required knowledge to solve the problem and usually, lectures are not included

3.4. Effectiveness of PBL Approach: Measures and Metrices

Earlier studies revealed that the 'level of knowledge tested', as a learning outcome, was found to be equivalent to that of traditional approaches, however, students who experienced PBL showed; (i) improvement in problem-solving skills (Albanese and Mitchell, 1993; Vernon and Blake, 1993) and (ii) increased engagement and motivation to learn, as they preferred PBL to the traditional methods of teaching (Denton, Adams, Blatt, & Lorish, 2000; Torp & Sage, 2002).

Dolomons et.al. (2016) study, across curriculum-wide PBL implementation and single-course PBL implementation, noted similar findings to the earlier studies, where PBL has profound implications on the motivations of the student to learn, stating that "the freedom to select their (students) own resources to answer the learning issues, which gives them ownership over their learning", and has capability to foster deep learning. Thus, the onus falls on the shoulders of the students as peer teacher (Caswell, 2017) to ensure the motivation of the team is maintained. Several studies in engineering provide empirical support that students learning gains for conceptual understanding is higher than traditional lectures (Yadav, 2011). PBL approach offers the opportunity for students to enhance their critical thinking and self-directed learning skills, and engages students in solving problems (Williams,1999). Students' perceptions that the curriculum encouraged critical thinking significantly increased after PBL curriculum was conducted (Birgegard, 1998). Students' critical thinking skills are fostered through their group discussions (Rideout and Carpio, 2001). Yuan (2008) suggested that PBL encouraged them to share their opinions with others, analyze situations in different ways and think of more possibilities for solving problems.

Schmidt et. al. (2009) reported that students and graduates from the curriculum perform much better in the area of interpersonal skills, and with regard to practical domain skills. In addition, they consistently rate the quality of the curriculum as higher. Moreover, fewer students drop out, and those surviving need less time to graduate. Smith et.al. (2009) verified that peer discussion enhances understanding, even when none of the students in a discussion group originally knows the correct answer.

As percentage of students failing the course and average of final grade are the direct measure of long-term knowledge retention ability and problem- solving skills; pre-test and post-test are very useful to check relative change in the pursued skills by students. Skills like Critical Thinking can be evaluated using California **Critical Thinking** Skills Test CCTST, **Motivation and engagement** of students can be evaluated using Motivated Strategies for Learning Questionnaire (MSLQ) Manual (Pintrich, 1991), effectiveness of **group activities and interpersonal skills,** i.e., Collaboration, can be evaluated with Team Assessment Tool (Moore et.al. 2006), while **Problem-solving** and **communication** skills maybe assessed (summative) by peer, mentor and expert/jury across the duration of the course or curriculum.

3.5. PBL Process

There are many variants of PBL as it can be molded according to institute traditions and individual course requirements. In order to make learning experience most effective for various kind of students, PBL approach can be modified according to domain or subject. Also, PBL can be implemented at a chapter level as well as entire course level. Having flexibility in teaching and learning, PBL process have been developed by many researchers dividing it into several steps and sub steps. However, broadly speaking, all these representations can be addressed with three basic phases which are analyzing a given problem, identifying information, and applying and discussing new knowledge to the given problem. Here, we present a detailed process model of PBL.

3.5.1. A Description

The process starts with an ill-defined, real life problem formulated by tutor/ teacher. Students in a small group starts analyzing the problem systematically. The terms and concepts are understood and clarified first. Students in a group have agreed opinion on meaning of the problem. Then, students construct a tentative theory explaining the phenomena or events described in the problem-at-hand in terms of its underlying principles or mechanisms. Students then identify the facts that they already know and what they require to know in order to solve the problem. Learning issues for individual study are formulated. These learning issues usually consist of questions arising from the discussion. Students search and evaluate resources which can be useful to learn problem domain. Students pursue learning issues through individual, self-directed learning usually using a variety of resources: books, articles, movies, and Internet sites where, tutor scaffolding takes place. Students return to their tutorial group, review and share what they have learned, propose the solution and elaborate different aspects of it. Explore to what extent the students' understanding of the problem has developed and whether misconceptions remain that need to be addressed. Students self-evaluate themselves and evaluate others in the group (peer evaluation)

Though the above process is blending of collaborative learning phase and self-directed learning phase, it is important to note that a single phase alone have insufficient impact on learning in PBL (Schmidt et.al., 2009).

3.6. Role of Tutor /Mentor in PBL

Traditionally, teachers have been teaching the concepts as well as applications of the concept whereas PBL methodology asks teachers to be facilitator and help students to manage metacognitive activities. Thus, adopting PBL is difficult for teachers as they must transform the whole methodology that they have been following for years. Being a mentor, faculty has to keep in mind that learning is a constructive, not receptive process. They need to permit students to discuss issues. They need to ensure that learning issues are raised and discussed. Being a tutor, faculty should not stifle students' discussion by giving mini-lectures or factual information, asking stream of questions, giving answers or telling students whether they are right or wrong in their thinking, telling students what they ought to study or read, etc.

3.7. General guidelines for problem formulation in PBL

Delisle (1997) prescribed the general guidelines for problem statement formulation in the form of checklist (Table2). Marchais (1999) identified criteria for constructing problem and subsequently evaluating them. (e.g. Stimulating thinking, analysis, and reasoning, assuring self-directed learning, using previous basic knowledge, proposing a realistic context, leading to the discovery of learning objectives, arousing curiosity etc.). Gijselaers (1996) identified the features of problem that make PBL ineffective. (i.e. description of problem have questions which are substituted for students generated learning issues, title of problem is same as title of the book chapter, problem is too simple (well- structured/ having only one acceptable solutions) which can be completely resolved during initial analytic process).

Table 2 : Checklist for Developing a Problem Delisle (1997)

Have I	**Yes**	**No**
Selected appropriate content?		
Determined availability of resources?		
Written a problem statement that		
- is developmentally appropriate?		
- is grounded in student experience?		
- is curriculum based?		
- allows for a variety of teaching and learning strategies and styles?		
- is ill-structured?		
Chosen a motivation activity?		
Developed a focus question?		
Determined evaluation strategies?		

3.8. Importance of Problem to drive learning

In design domain, it is observed that problem-finding is as important at problem-solving and requirement identification, i.e., “right problem”, is critical for seeking appropriate and satisfactory solution. However, in existing PBL approaches, a problem is defined, though ill and often complex, whilst leaving the activity of problem solving open-ended and the expected solution. This raises serious reservations on the ‘self-learning’ process of undergraduate students in technical schools across South Asia as course syllabus is heavy, which may inadvertently demotivate the students and they aren’t naturally inclined to question. Therefore, an exposure to design i.e., problem-finding and problem-solving, has potential to imbibe reasoning, questioning, curiosity, and drive the students to pursue a valuable problem, with motivation and purpose.

It is also noted that certain attributes of other approaches, such as, application of knowledge, accompaniment of lectures and management of time and resources are noteworthy and should ideally be inculcated into technical teaching through PBL methodology.

4. Understanding what is a problem?

Chi & Glaser (1985) defined problem as a situation in which one is trying to reach some goal and must find a means for getting there. Problem-solving is one of the important skills that humans need to learn. Learning which helps human to improve living condition and comfort.

4.1. Classification of "problem": Types and Attributes

(Ill-structured vs. well defined, simple vs. complex, domain-specific vs. domain-independent)

The problems that students learn to solve during the classroom teaching and test in conventional engineering education and the problems exist in everyday practice are different. Jannassen (2000) classified the problems into various types (i.e. logical problems, algorithms, story problems, rule-using problem, decision-making problems, troubleshooting problems, diagnosis-solution problems, strategic performance, situated case analysis problems, design problems, dilemmas). On one hand, story problems and algorithms are typical classroom problems that are well structured, procedural and predictable in nature. On the other hand, design problems and situated case analysis problems are real-world, ill-structured problems. The above discussion leads to the conclusion that there is a need of modern education system where students can get exposure to learning to solve more meaningful real-life problems.

More recent research in situated and everyday problem solving makes clear distinctions between thinking required to solve well-structured problems and everyday problems. Dunkle, Schraw, and Bendixen (1995) concluded that performance in solving well defined problems is independent of performance on ill-defined tasks, with ill-defined problems engaging a different set of epistemic beliefs. According to Jonnassen (1997), the problems which are at the end of textbook chapters in schools and universities are well structured, less complex (less no. of issues, functions, or variables involved) and domain-specific problems which cover a finite number of concepts, rules, and principles being studied to a constrained problem situation, whereas the problems encountered in everyday practice are ill-structured, more complex and cover knowledge of multiple domains. Shin et. al (2003) discovered that solving well-structured and ill-structured problem needs different mental skills. This shows that the performance of classroom problem-solving skills is independent and learning of which does not necessarily help to solve practical real-life problems. Hong, Jonassen, and McGee (in press) found that solving ill-structured problems in a simulation called on different skills than solving well-structured problems, including metacognition and argumentation. Jonassen and Kwon (in press) showed that communication patterns in teams differed when solving well-structured and ill-structured problems. Clearly more research is needed to expand these findings, yet it seems reasonable to predict that well-structured and ill-structured problem solving engage different intellectual skills.

Real-life problems are ill-structured and complex. Problem complexity is defined by the number of issues, functions, or variables involved in the problem; the degree of connectivity among those properties; the type of functional relationships among those properties; and the stability among the properties of the problem over time (Funke, 1991). Therefore, the different types of problems enlisted below have been broadly identified as 'well-structured and simple' (in cyan highlight) or 'ill-structured and complex' (in yellow highlight);

- *Logical Problems*
- *Algorithms*
- *Story Problems*
- *Rule-Using Problem*
- *Decision-Making Problems*
- *Troubleshooting Problems*
- *Diagnosis-Solution Problems*
- *Strategic Performance*
- *Situated Case-Policy Problems*
- *Design Problems*
- *Dilemmas*

4.2. Importance of the right problem for the right impact: Design & PBL

Drawing relevance to the SDGs and social impact (long-term/ short-term, local/regional/global)

A problem is usually a description of a set of phenomena or events observable in the real world that are in need of an explanation in terms of a theory, an underlying principle, process, or mechanism. The two critical attributes of a 'problem' are;

i. A problem **must be an unknown** entity in some situation (the difference between a goal state and a current state).vary from algorithmic math problems to complex social problems, such as violence in the schools.

ii. Finding or solving for the unknown **must have some social, cultural, or intellectual value**, i.e., someone believes that it is worth finding the unknown.

5. "Design thinking" as a strategy to inculcate PBL in Undergraduate Education:

By taking review of top technologist, Halfin (1973) identified total 17 mental process used by practitioners, as follows ; defining the problem or opportunity operationally, observing, analyzing, visualizing, computing, communicating, measuring, predicting, questioning and hypothesizing, interpreting data, constructing model and prototypes, experimenting, testing, designing, modelling, creating and managing. Here Haflin refers to 'designing' as an activity or task, while latter literature clarifies that, "Design is a type of problem solving in which the problem solver views the problem or acts as though there is some ill-defined-ness in the goals, initial conditions or allowable transformations", (Thomas and Carroll, 1978). Cross (2001) describes designing as, 'finding' appropriate problems, as well as 'solving' them, and stressed that it includes substantial activity in problem structuring and formulating, rather than merely accepting the 'problem as given' (Cross, 2001). He further adds that, designers' behavior is characterized by their treating the given problems as 'ill-defined', for example, through exploration where goals and constraints are changed even when they could have been treated as well-defined problems.

Williams & Williams (1994) reported the similarities between PBL and design process (i.e. large no. of stages, identification of problem as an opening phase, require motivation, organization skills and capability to initiate things, open-endedness to outcomes, group work and collaboration.). Awang and Ramly (2008) used creative thinking approach for implementing PBL in the classroom combination of both enhanced creative skills and technical abilities. There exists a strong parallel between the PBL methodology and the methods of design practitioners, i.e., design thinking.

5.1. A PBL SA schema to support problem identification and formulation – a distinction from existing PBL methods

5.2. A two fold strategy: (i) to inculcate PBL into students and young faculty (as students), through case-study and workshop at IITB, Mumbai, and (ii) to develop PBL courses by faculty, through faculty workshop at IISc, Bangalore

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6. Preparation Events : Workshops at IITB and IISc, India

The previous sections described the various aspects of the PBL best practices how PBL based pedagogy should be adopted in curriculum with a special focus on the engineering education in South Asian countries. In the following sections, such aspects were further strengthened and clarified by immersing them in a prototype/scaled down model workshops conducted at IIT Bombay and IISc Bangalore. These workshops aimed at preparing the HEIs of South Asian countries to various aspects of PBL with a special focus on understanding how PBL should be customized to South Asian HEIs. While the IIT Bombay workshop consisted of testing the development of prototype case-studies by students and faculty of Nepal, Bhutan and India with students and faculty from the European partners, the workshop at IISc Bangalore focussed solely on issues related to curriculum development in Nepal and Bhutan with partners from India and Europe playing a facilitator role to understand the complexities involved in implementing PBL in the context of Nepal and Bhutan.

6.1. Case Studies and Workshops at IITB, Mumbai

The first workshop in terms of the preparation for the project was conducted at Mumbai in August 2019. It was hosted by IIT Bombay and spanned for two weeks. A total of 70 participants from all the partner universities marked their presence in the workshop. The participants include a mix of faculty as well as students from each of the university. The students from European universities largely had prior exposure to PBL based curriculum. Such participation was done by design so that the knowledge transfer to the South Asian HEIs would happen at faculty as well as student levels. Most of the participants are faculty from Nepal and Bhutan, as case participants. Some faculty from IITB (as expert mentors), Aalto, KTU, IISc and TU Delft participating as mentors. The rest of the participants are students from Aalto, KTU, IISc, IITB and TU Delft participating as case participants. There were 7 cases in total with 7 mixed teams of students from (Aalto, KTU, IISc, IITB and TU Delft) and faculty members from (NEC, SEC, RUB, AITM, KU) participated. Each team is about 6-8 members and very diversified in terms of its composition: across ages, skill-sets, hierarchies, roles in their home institution and also project, disciplines, cultures and so on which is interesting case in itself. Most of the case participants from Nepal and Bhutan were relatively new or unknown to the working concepts, relevance, methods and tools of PBL. A mix of different fundamentals of PBL was introduced through PBL working sessions and PBL based experience sharing and actual case works.

Figure 1 Participants at IIT Bombay workshop

The participants worked on case studies related to four broad areas in sustainable development, namely;

- Liveability in slums
- Affordable Housing
- Construction and Demolition Waste
- Net zero energy development

Each team went through an extensive series of lectures and workshops primarily focused on design thinking and PBL methods. The teams worked for two weeks to discover socially acceptable and sustainable solutions to problems given to them. During this journey, they were facilitated to interact with the social communities to whom the problem assigned to team was related. Moreover, they talked with non-governmental organizations and NGOs for having a broad understanding about the problem and various stakeholders involved. In the concluding session of the workshop, each team presented the solutions developed by them. The workshop presented some key directions in terms of implementation of PBL in South Asian universities. The key findings which are important are

Faculty from being teacher in a course to a mentor in a PBL based curriculum

The transformation of faculty from teachers to mentors was appreciated the most significant factor in terms of shifting to a PBL based curriculum. As discussed in the earlier sections, the mentor's role is quite different from that of a teacher. The hands-off approach where the students are allowed to freely discuss the issues with minimal intervention and direction by the mentor is the key to self-learning. However, it is a difficult role as the mentor still has to balance the learning objectives of course while allowing students to explore freely and define their problems/spheres of work.

Upfront uncertainty in goal setting may not be comfortable to students

The important dynamic observed the faculty from Nepal and Bhutan who transformed themselves as students for this workshop is that the upfront uncertainty in the early stages of the case-study where the goals are not defined and where the problem is ill-structured is a big challenge for both students and teachers. The mentors' major role is to keep the morale and motivation of the team going so as to meaningfully achieve the learning objectives and still expose students to the uncertain nature of the problem definition in real world. Tools to get constant feedback from the students especially like a mood meter is essential to understand the team spirit to create quality problems.

Appreciation of learning objectives is a natural outcome of PBL process

The students (including the teachers from Nepal and Bhutan) acknowledged the effectiveness in PBL based methodology in appreciation of the learning outcomes. The workshop was geared up towards sustainable development goals. The case studies made the teams contact local communities and interact with NGOs and various other entities on the field. Such interactions have sometime led to a drastic change in their case-study objectives. The interactions also helped dispel some of the initial notions and biases that existed in the team. The teams were naturally passionate about their solutions by the end of the case study exercises and owned their work in a much better fashion than normal learning method.

Finally, the participants, especially the faculty, from Nepal and Bhutan felt that such method could be implemented in their countries. The ned for a proper assessment scheme for students in a PBL based course is a concern which the faculty have pointed out. Overall, the workshop has concluded on a positive note with a good feedback on the PBL practices important for Nepal, Bhutan and India.

The case studies were then followed by a more focussed workshop in IISc Bangalore where the participants are only faculty from partners to develop PBL based curriculum for their respective universities/colleges.

6.2. Design Curricula Workshop at IISc, Bangalore

The design curricula workshop at IISc Bangalore is a focused workshop by faculty of the partnering HEIs to focus and develop a curriculum especially for the Nepal and Bhutan HEIs. Centre for Product Design and Manufacturing (CPDM), Indian Institute of Science (IISc) hosted the PBL South Asia Curricula Design Workshop for 14-18th October 2019. Representatives from the ten partner HEIs (higher education institutions) – Aalto University, Finland; TU Delft, Netherlands; KTU, Lithuania; IISc and IITB, India; JNEC, Bhutan and AITM, NEC, Sec and KU, Nepal - participated in the Erasmus+ funded project, Strengthening Problem-based Learning in South Asia (PBL-SA). Overall, about 30 participants attended the weeklong workshop in October 2019. The workshop included components of experience sharing by some the partnering HEIs who had experience in implementing a PBL based course combined with a hands-on workshop by the teams.

Participants as IISc Bangalore workshop

The workshop was conceptualized under preparation, led by IISc and supported by IITB, for the implementation of PBL in curricula across South Asia. Its main objectives was to apply ‘design thinking’ strategies to collaboratively design the curricula suitable for each of the beneficiary HEIs, across disciplines, in Nepal and Bhutan. The European and Indian institutions presented on their know-how in the area of PBL, and faculty and research associates mentored sessions to co-create courses. The long-term aim is to build a strong network of PBL practitioners and collate best practices across partner institutions, to improve the implementation and dissemination of PBL in the South-Asian context.

Some key points raised and addressed during the workshop are

PBL is best suited for project based courses which are usually at the end of the course in fourth year projects for undergraduate students

PBL has been adopted with some success in core engineering courses as well. Some experience in this regard was shared by a few partnering HEIs

The scoring schemes should reflect the work done throughout the project and have weightage for even failed prototypes etc.

PBL is excellent method especially if the course involves teams working on inter-disciplinary areas

The number of students registered should not have a bearing on the pedagogy. PBL has been shown to be adopted on class sizes of more than 100 as well. However, as the class size increases, there is a need for specific mentors for teams which are usually about 5-6 students strong. Thus there is a need for strong mentors as day-to-day facilitators and a overall course instructor who guides the philosophy of the course. For smaller number of students, the faculty can double as mentors for the teams

A lot of discussion on the course evaluation is necessary to capture the assessment in line with course objectives. Usually a combination of continuous evaluation throughout the course study with a final assessment based on one or a combination of presentations, peer evaluations, prototype fairs and presentations to the community would be warranted in the case of a PBL based course.

A template was designed for the HEIs to structure their new course adoption under the PBL mode. The template is given later in this document.

7. Conclusions and Discussions

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