Designing "Theory of Machines and Mechanisms" course on Project Based Learning approach

Vikas V Shinde[a]*

[a]*PhD Fellow, Aalborg Univsrsity,Department of Development and Planning,Denmark*

Abstract

Theory of Machines and Mechanisms course is one of the essential courses of Mechanical Engineering undergraduate curriculum practiced at Indian Institute. Previously, this course was taught by traditional instruction based pedagogy. In order to achieve profession specific skills demanded by the industry and the learning outcomes specified by the National Board of Accreditation (NBA), India; this course is restructured on Project Based Learning approach. A mini project is designed to suit course objectives. An objective of this paper is to discuss the rationale of this course design and the process followed to design a project which meets diverse objectives.

Keywords: Theory of Machines and Mechanisms, project based learning, profession specific skills, learning outcomes

1. Introduction

There is a huge requirement of skilled engineers across the world. Internationally there is a trend moving towards outcome based engineering education. New accreditation models focus on outcome based learning. The national academies and many governments call for change in engineering education (National Academy, 2004; Royal Academy, 2007; Litzinger et al 2011). Engineering Education (EE) responds with detailed curriculum change taking place by changing the instructional methods and integrating entrepreneurial and innovation competences. In India, an engineering education is under pressure as professional engineering bodies and Indian industries call for additional set of skills and competencies such as professional, soft and personal skills (Blom and Saeki, 2009, Goel, 2006). To meet the demand of skilled engineers, the capacity of engineering educational institutions in India were increased by increasing the capacity of existing colleges and by establishing new colleges. It has resulted in an increase in the volume, but the quality of the graduate engineer is still uncertain (Rao, 2006). In most of the engineering education in India traditional instruction based pedagogy is followed and resources are available to support instruction based pedagogy. It has been observed that students focus on grades and motivation towards learning is reduced. Recent surveys conducted by National Association of Software and Services Companies (NASSCOM, 2005) and World Bank (Blom and Saeki, 2009) reported that the Indian engineers lack critical employable skills, and there is a difference between industry expectations and graduate engineering skills. These surveys reported that, the educational settings offered in India are not conducive for development of skills. Furthermore, various government reports indicated the genuine concern about the quality of an engineering education pointing towards the need for radical changes in the curriculum and the teaching-learning practices in India (NKC, 2010, Yashpal, 2010).

Given this situation, Project Based Learning (PBL) is considered as relevant (Shinde, 2011c) and suitable alternative as the past results shown that if properly designed and implemented PBL leads to the development of industry relevant skills and prepare students for life long learning (Du and Kolmos, 2006, Shinde and Kolmos, 2011b). Problem Based Learning has originated in McMaster University Canada in 1968. Later in Denmark at Aalborg, 1972 and Roskilde, 1974 two PBL models emerged. These models are designed from scratch (Graaff and Kolmos, 2003). Also, culture in these countries is different from India. Indian education systems are built for traditional teaching i.e. instruction based pedagogy. Also, teachers and students are used to traditional methods of teaching and assessment. Hence, it is necessary to develop PBL model suitable for Indian conditions. Also, challenge is to achieve learning outcomes and skills demanded by the industries. The objective of this paper is to look at different parameters considered for the design of Course Level PBL (CLPBL) model. The project design is very critical part of PBL model. The focus of this paper is to discuss development process of a project.

2. Methodology

Design based Research (DBR) methodology allows to innovate, design and modify instructional practice. At the same time DBR encourage research embedded in practice. Designing new and improved practice is a goal of DBR. The DBR phases typically include previous research and contextual understanding, design formulation or intervention design, implementation and

* Corresponding Author: Vikas V Shinde. Tel.: +91-9762051751
E-mail address: vikas@plan.aau.dk

reflection on design leading to further refinement (Cobb et al 2003). Table 1 shows DBR phases and a framework followed for this research. In this paper, we have limited our discussion within 'preparation phase' till the development of theoretical design.

Table 1. phases in DBR and Research framework

Phases in DBR	Sub phases	Major Activities in the Phases	Outcome
Preparation Phase	Prior research	PBL learning principles and learning theories. Review of PBL models and related literature. Case study on Aalborg Model Literature review on Skill and competence for engineers	Understanding And Knowledge Of Pbl Philosophy And Practice
	Contextual understanding	Identifying National and local requirements Identifying drivers and challenges Pilot work in India to understand issues and curriculum practices.	Understanding And Knowledge Of local and national level requirements, drivers and challenges
	Design formulation	Theoretical Course Design	Design ready for implementation
	Implementation Plan	Theoretical plan of implementation or Plan of learning trajectory	Plan of implementation
Design Enactment	Implementation	Design refinement in cycles and simultaneously Data collection to supplement research	Refined design and research data
Design validation	Data analysis and Reflection	Analysis for effectiveness of the design and effect of PBL implementation on students' learning outcomes.	Effectiveness of the design and outcome of research
	Reflection (Re-Design)	Reflection on data and defining prerequisites for the improvement in the original design to implement in a next cycle	Perspectives and recommendations for new designs

2.1 Contextual Understanding- Indian Requirements

As discussed above, it is most important to understand the context in which model is to be implemented. We have carried out literature review to understand the current requirements of Indian engineering education. We found important publications related to Indian system which set the objectives of the design. Also, we visited the institution at which PBL is to be implemented. We read curricular documents and understood its requirements. Also, interaction with the administrators, students and teachers has given us critical insight in the educational environment and procedure followed in the institute. An outcome of these two interactions is discussed below.

2.1.1 Need of the Design

2.1.1.1 Profession specific skills from surveys

In 2005, the NASSCOM and McKinsey came with the report that, only 25% of the engineering education graduates are employable by a multinational company (NASSCOM, 2005). Most of the surveyed employers linked this condition to the shortcomings from the education system. In the same year, the Planning Commission, Government of India came with the recommendations to focus on enhancing the quality of educational institutions and a priority for proper arrangement for the development of skills (p-13) at these institutions. Accordingly, a National Knowledge Commission (NKC, 2008) on higher education was constituted in June, 2005. The purpose is to prepare a draft for reconstruction of India's knowledge related infrastructure. The NKC submitted its recommendations to the Government in 2008. Following this report, the Ministry of Human Resource Development (MHRD), higher education department constituted a committee under the chairmanship of Prof. Yashpal. It reported a serious concern in respect of growing engineering colleges by saying they have largely become, just business entities dispensing very poor quality education (p-05) and indicated that there exists a difference between learning from an 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). It hinted that Indian higher education system needs a drastic overhaul (p-54) with a 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 understand 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 (Blom and Saeki, 2009). This study was supported by Government of India, the World Bank and the Federation of Indian Chambers and Commerce Industries (FICCI). In this survey, 157 industries from India responded. According to the survey, 64 percent of surveyed employers are not satisfied with the quality of engineering graduates skills. It reported that the graduate engineer lacks in process skills such as teamwork, lifelong learning and communication skills. The graduates 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 curriculum to ensure that the graduate engineers' skill is getting developed (Blom and Saeki, 2009). These requirements are considered while designing a project.

In addition to national surveys, we also studied international research (National Academy, 2004; Royal Academy, 2007). We found that skills like teamwork, problem solving, creativity and innovations along with communication skill are valued by most of the industries. This review helped us to gain knowledge about change happening in the field of engineering education. The main purpose of the CLPBL would be to provide platform for students to be trained on these industry relevant skills.

2.1.1.2 Learning outcomes specified by National Board of Accreditation (NBA)

In response to the recent developments in Higher education in India and across the world; 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 2011-12 to assess the quality of education in educational institutes. Table 2 shows a summary of the ABET criteria. Since, NBA is the apex body which ensures quality education is imparted in India, these criteria along with the survey results are critically considered for the project design.

Table 2 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

2.1.2 Course level requirements

The University of Pune (UoP) is located in the Maharashtra state; the western part of India. It should be noted that the engineering institution at which PBL is to be implemented is affiliated to the (UoP). Hence it is important to understand the role of UoP. Affiliation means that the UoP will award degrees to all students educated by this institute. Also, it means that the institute has to follow the rules, regulations and the curriculum designed by the UoP. The UoP is also responsible to conduct a common written examination (final evaluation), for the affiliated institutes' students. In abstract, an institution's role is limited only for preparing students for the final evaluation. To achieve this, all institutes practice traditional instruction, lecture based strategies. In the next section the existing curriculum is discussed.

2.1.2.1 Existing curriculum requirements and procedure

In the existing curriculum, there are five courses carrying equal marks for the final theory examination (UoP, 2012). However, the PBL model is to be designed for only one course "Theory of Machines and Mechanisms" out of these five. Table 3 shows the existing course structure. The syllabus content (UoP, 2012) to be taught for above course is provided by the university. It is divided into six units which carry equal marks in the examination. The topics to be covered are listed under each unit. A list of the experiments which the students must perform during the semester is also provided in the syllabus.

Table 3 Existing Scheme

Course name	Teaching scheme		Examination scheme		Total marks
	Lecture (Hrs/week)	Practical (Hrs/week)	Theory	Term work	
Theory of Machines and Mechanisms	4	2	100	50	150

Responsibility to prepare students for final evaluation lies with the teacher. Mostly the traditional instruction based pedagogy is practiced for which the teacher has been allotted four hours per week (refer table 3). The lectures are scheduled and the timetable is displayed on a notice board. This is followed for all the courses in the curriculum. To perform experiments (Practical) students visit laboratory for two hours in a week. Generally, a class of 60–70 students is divided into three groups of equal sizes. Each group visits the laboratory (table 3) as per the timetable. At the end of the semester, each student has to write a journal which has to be certified by the subject teacher before the final term work submission.

Table 3 also provides a summary of the examination scheme for the given course provided by the university. It may be noted that the university is responsible for the final evaluation (to conduct 100 marks theory exam). Responsibility to prepare students for this final examination lies with the institute (mainly course teacher). To do that, the unit tests are designed and conducted by institute. The aim of these tests is to assess the students' knowledge, understanding gained from classroom instructions, and also to provide them timely feedback on their performance. At the end of the semester, all the students from the course have to appear in the written examination arranged and administered by UoP. This examination is based on the content of the syllabus, so, the students' goal is to score good marks and teacher's focus is to prepare students for the same.

After analysing the curriculum the following observations are made:

1. The course teacher does not have any right to change the syllabus and examination scheme, though there is a flexibility to adopt any teaching-learning strategy.
2. The students' learning takes place mainly in classrooms and laboratories.
3. In the existing evaluation scheme, the students' abilities to remember and reproduce are assessed
4. The current curriculum structure does not contain a project head and students are graded individually.

2.1.2.2 Summary of expectations from the Design

After assessing the requirements at the national and curricular levels, it can be concluded that there is an urgent need to provide an opportunity to make students active in the learning process and to provide opportunities to achieve the skills and abilities desired by the industry, and ABET criteria. It is also very important to prepare students for final evaluation. These are the main objectives of the CLPBL.

2.2. Research on PBL

2.2.1. PBL learning principles

Problem Based Learning (PBL) and Project Based Learning (PBL) terms are used interchangeable with each other. The six core characteristics of Problem Based Learning was described by Barrows (1986) are:

1. The learning needs to be student-centred.
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 an 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.

Various authors (Prince and Felder, 2006; Savin-Baden, 2000) tried to differentiate between these two. A project has a broader scope and the focus is one the end product. The completion of the project mainly requires application of previously acquired knowledge, while in Problem based learning the focus is on the acquisition of new knowledge and the solution is less significant. In other words, the importance in problem-based learning is on acquiring knowledge whereas in project- based learning is on applying it. Some similarities are also been researched; at root level both approaches share same learning principles viz. cognitive, content learning, and social (Graff and Kolmos, 2003). The both approaches share some common elements: both are student centred approach in which learning is organised around problems (Graff and Kolmos, 2007, p-6), involves teams and call for the students to formulate solution strategies and to continually re-evaluate their approach in response to outcomes of their efforts (Prince and Felder, 2006).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.

To elaborate more about the projects, Graaff and Kolmos (2003) defined three types of projects as *Task project, Discipline project and Problem project* that differ in the degree of student autonomy. *Task projects* are the projects in which student teams work on projects that have been defined by the instructor, and provides minimal student motivation and skill development. In *Discipline projects* the instructor defines the subject area of the projects and specifies tasks in it. The students have autonomy to identify the specific project and decide how to complete it. In *Problem projects,* the students have practically entire autonomy to choose their project and their approach to it. They noted that the students face difficulty in transferring methods and skills acquired in one project to another project of different discipline. In this paper, the Project Based Learning approach is used.

2.2.2 Review of PBL models and related literature

Victoria University (VU), Australia introduced PBL into engineering curricula for different courses in 2006. 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 (Rojter, 2006). 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 (Eck and Mathews, 2002). 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 (Moore and Willmot, 2003). 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 (O,Grady and Alvis, 2002) is one of the popular examples from Asia in Problem Based Learning model. Apart from this, many more cases of PBL implementation in Asia can be found in the literature; China (Cheng, 2003), UTM (University Technology, Malaysia), Malaysia (Khairiyah et al. 2005), Tribhuvan University, Nepal (Joshi and Joshi, 2011), and Mae Fah Luang (MFU) Thailand (Yooyatiwong and Temdee, 2012), are a few to mention. There could be more examples; we have mentioned few of them.

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. Considering Indian case, it may be noted that the PBL is neither an accepted nor an officially recognized methodology for engineering education in India. The application of the PBL approach in the teaching–learning process and its scientific investigations are very rare (Mantry et al 2008, Raghav et al, 2008, Abhonkar, Harode and Sawant, 2011). The results of these few experiments indicate that PBL implementation in India needs to be considered appropriately and that more focused, scalable efforts are needed (Mantry et al 2008). It has also been reported that lack of proper guidance, trained staff and infrastructure have hindered the growth of PBL in India (Shinde and Kolmos, 2011a). 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.

2.2.3 Case study on Aalborg Model

The author spent 18 months in Denmark to learn PBL philosophy and practice. To get practical insight into PBL curriculum and practice, a six months case study on Aalborg PBL model was conducted in 2010-11 (Shinde and Kolmos, 2011b) autumn semester. Following figure 1 shows Aalborg PBL model practiced for Masters Programme in Mechanical Engineering. It could be seen that 50% European Credit Transfer System (ECTS) are allotted to the courses and 50% ECTS for project in this model.

<table>
<tr><td>COURSE 1
5 ECTS</td><td>COURSE 2
5 ECTS</td><td>COURSE 3
5 ECTS</td></tr>
<tr><td colspan="3">PROJECT
15 ECTS</td></tr>
</table>

Figure 1 Aalborg PBL model for Masters Programme in Mechanical Engineering.

Curriculum practiced at Aalborg is analysed in terms of Biggs (1996) constructive alignment, which says that to achieve educational objectives; content, teaching-learning practice and assessment should be aligned to each other. Accordingly Aalborg curricular analysis showed that learning from courses is closely aligned with learning outcomes to be achieved through projects. In other words there exists very close alignment between courses and projects. Regarding assessment, the students are assessed through project presentations, and viva-voce. It has been observed that the courses (content approach) and projects (cognitive approach) are designed to suit educational objective of the programme. Also, we have seen students working in the teams, which indicated cooperative and collaborative approach of PBL. We have found that to facilitate group work each group has been provided with a group room consisting of seating arrangement, pin-up boards, black or white board and internet connections. These gadgets are found useful for PBL practice. From this case study, we understood important aspects of PBL model design and practice.

3. Course Level PBL model (CLPBL) - Theoretical design

The first step in the design was to define the prerequisites and objectives of the project design. Accordingly, we envisioned the nature of the design and defined objectives which guided the project design.

3.1 Design prerequisites and objectives

These are as follows:

1. The design must meet the PBL principles and enable scientific investigation.
2. It must be inline with the existing academic structure and current course content leading to improved content learning.
3. It must improve and facilitate the attainment of LOs as defined by ABET and survey skills.
4. It must ensure students' continuous engagement and must not stress participants in the project activities.
5. The project should be completed within the time frame of 12 weeks and should not cause any financial burden on the participants.
6. It can be completed within the existing infrastructural facilities at the institute.

After defining objectives, the next step was to find an opportunity to embed a project work in existing academic structure. As discussed in the earlier sections, there is no possibility for change in the course content and the examination pattern. During curriculum analysis, we found the term 'term work', which means, work which needs to be carried out by the individual students in a given term. There is an element of flexibility involved in the term work. The teacher can assign any work or design activities related to the course which could be possible to accept as term work. Accordingly, we decided to embed project work within the term work. Hence, we divided the 50 marks for term work into two parts, being 25 marks for assigned laboratory activities (as per the UoP) and 25 marks for a project as shown in Table 4.

Table 4. Modified Academic Structure with Project

Course name	Teaching scheme		Examination scheme		Total marks
	Lecture (Hrs/week)	Practical (Hrs/week)	Theory exam marks	Term work marks	
Theory of Machines and Mechanisms	4	2	100	25	125
Project Work	-	-	-	25	25
Total	4	2	100	50	150

The following change has been made in the current curricular settings to evolve the new design.

1. Course objectives were defined.
2. The team based project activity is adjusted in the existing curricular scheme
3. Field work for each team was made mandatory.
4. Technical report writing is added to improve technical writing skills.
5. An end-of-term presentation is added to improve communication skills.
6. Assessment norms are designed and group evaluation is added.

3.2 Project design – Characteristics of Model and Project

The course approach is typically used in the traditional system where there are parallel courses. The lecturer decides on the specific learning objectives, teaching and learning methods. This means that students participate in mix of traditional and PBL course (Graff, Kolmos and Du, 2009). In our design course approach is followed pertaining to various challenges and constraint associated to system level implementation. As can be seen from the figure 2, the highlighted portion shows the course in which PBL is implemented whereas other courses are taught by traditional instruction based strategy. Savin-Baden and Major (2004) defined different curriculum modes in problem based learning in which they explained eight modes. Mode 1 is characterized when PBL is applied in a one module and Mode 2 is characterized by module run by teacher interested in implementing PBL and other teachers are not interested. In our case, PBL is to be implemented in one of the course of the curriculum (Mode-I) and implemented by a single interested teacher in his class (Mode-2). Hence, we concluded that our design could be in between with Mode 1and 2.

Courses	Teaching Learning Strategy	Students activities	Assessment
Course-1	Classroom Teaching	Individual Reading and Writing	Individual Assessment
Course-2	Classroom Teaching	Individual Reading and Writing	Individual Assessment
Course-3	Classroom Teaching	Individual Reading and Writing	Individual Assessment
Course-4	Classroom Teaching	Individual Reading and Writing	Individual Assessment
Course-5 Theory Of Machines And Mechanisms	**Classroom Teaching and Project Based Learning**	**Team working on Project-collaborative learning, researching and writing**	**Assessment in Team and Individual grading**

Figure 2. Course level PBL model

Experience gained through the case study conducted at Aalborg University (Shinde and Kolmos, 2011b), a review on PBL models (Graaff, Kolmos, and Du, 2009, Cheng Charles, 2003) and the Content, Context, Connection, and Researching, Reasoning Reflecting (3C3R) model of problem design (Hung, 2009) guided the process of project design. We designed the project activity in such a way that we could cover course objectives or the syllabi of existing courses and graduate LOs. The project activities are designed and adjusted to suit institutes' existing academic culture and infrastructure. We finalized a problem statement and developed a series of project activities as shown in table 5.

Table 5. the Major Activities in the Project

Problem statement	Analyse any real life engineering mechanism (case) to evaluate its degree of Freedom (DOF).
Defined project activities	Form the team. Identify, submit and justify the case. Text book problem solving in a group. Laboratory work in a group Undertake field work. Explain the working of the mechanism. Find types of links, pairs and joints used in the mechanism. Classify, specify and calculate them. Apply Grubler's criteria. Find the DOF and justify your answer. Draw kinematic diagram Find and locate types of Instantaneous centre of rotation Calculate velocity and accelerations of each link. Prepare a technical report. Present to an audience. Questions and answers.

As per the Savin-Baden (2000), given model could be characterized by Model I and II. Model –I is characterized by a view of knowledge that is essentially propositional with students are expected to become competent in applying knowledge in the context of solving and managing the project. In Model II, an emphasis is on actions which enable students to become competent in practice. In designed model, students are applying propositional knowledge and doing many activities to ensure they become competent in engineering practice. The given project can be characterized as Task-Discipline project (Graff and Kolmos, 2003). The project tasks (table 5) are predefined by teacher to suit curricular (course) objectives pertaining to specific discipline. Students' role is to perform the project tasks given by the teacher. There is amount of autonomy given to the students to choose any mechanism according to their interest. This will provide them intrinsic motivation. Also, they decide their team and set up their project plan for the entire semester. Also, acquiring additional information for getting the desired output is decided by them. The table 6 shows, a coherence of project activities, learning outcomes and skills demanded by the industry. It shows that after implementation above design will ensure achievement of desired objective of achievement of skill. For example, undertaking the fieldwork with team will ensure application, acquisition and construction of knowledge along with understanding relation between theory and practice.

Table 6. Mapping of the project activities, targeted learning outcomes and skills

Project activities	Target Learning Outcome (LO)	Target skills from survey
Form the team.	d	Negotiation, Teamwork
Identify, Submit and justify the case.	a,i	Knowledge, reading, willingness to learn
Laboratory work in a group.	b,d,i,	Teamwork, reading, conduct experiments/data analysis
Text book problem solving in a group	d,e,a	Teamwork, problem solving, knowledge
Undertake the field work.	a,k,i	Knowledge, theory and practice, willingness to learn
Explain the working of the mechanism.	a	knowledge
Find types of links, pairs and joints used in the mechanism.	a	Application of knowledge
Classify, specify and calculate them.	a	Application of knowledge
Apply Grubler's criteria.	a	Application of knowledge, technical skill
Find the DOF and justify your answer.	a	Application of knowledge
Draw kinematic diagram	a	Application of knowledge
Find and locate types of Instantaneous centre of rotation	a	Application of knowledge
Calculate velocity and accelerations of each link.	a	Application of knowledge
Prepare a technical report.	g,k	Written communication, Modern tools
Present to an audience.	g,k	Verbal communication or presentation skills, Modern tools.
Questions and answers	g	Communication in English

3.3 Assessment and evaluation criteria for project work

The project work undertaken by the students needs to be assessed and evaluated. Accordingly, we designed an assessment and evaluation scheme for 25 marks as shown in table 7.

Table 7. Assessment and Evaluation Scheme for a Project Activity

Assessment marks			Evaluation marks		Total marks
Teamwork	Feedback	Attendance in all sessions	Quality of technical report	Presentation and question answer session	
5	5	5	5	5	25

Teamwork is assessed through observations and feedback from team members on a five-point scale. Feedback in the assessment norm means the completion and timely submission of questionnaires, essays and informal discussions. Attendance in all sessions means attendance during feedback sessions, presentations and interaction sessions. The quality of the technical report is assessed for the technical content, plagiarism and adherence to the given format. Five marks are allotted for students' performances in a presentation and a question-answer session. Finally, the marks for all the sub-headings are summed to grade the individual students' project work out of 25. It may be observed that students in new academic settings are assessed to a group and graded individually. Hence, a course in Mechanical Engineering was designed based on the PBL approach. This design meets the criteria mentioned in Section 2.

4. Experiences during implementation and reflection

Historically, in most of the academic institution in India instruction based pedagogy is practiced and institutes are built to support it. Designing PBL course was a challenging task. Since, we knew the system constraints well in advance, hence contextual understanding helped enormously while designing CLPBL model. For design purpose many challenges (Shinde and Kolmos, 2011a)) like motivation for change, lack of resources, curricular and students' preparedness are considered. Understanding derived from case study at Aalborg University, Denmark and a literature review of PBL models, influenced our model. While designing we have mainly included course objectives, skills from the survey and learning outcomes defined by NBA.

So, far we have implemented this design in two semesters. The data collected was analyzed to interpret effectiveness of design. The results from these experiments indicated encouraging results with the students and staff accepting the course designed on PBL approach. We understood that given design encompasses 50% of course content, which ensured students are prepared for evaluation. This aspect was very important for students' motivation. In the last semester results for this course increased to 87% from 64% which partly can be attributed to our design. Also, it helped engineering graduate for promotion to acquire 13 skills demanded by the industry and seven learning outcome defined by NBA. Further, research is required to assess learning outcome and skill achievement. This design so far influenced 249 students of the second year mechanical engineering students and could be a representation to design PBL courses in other courses in the Institute.

Acknowledgements

We would like to thanks the European Union for funding this research through Mobility for Life Scholarship programme. Also, authors would like to thank students and staff members of Indian institute for their co-operation and support

References

ABET 2012, Accreditation Board for Engineering and Technology, *http://www.abet.org/uploadedFiles/Accreditation/Accreditation_Process/Accreditation_Documents/Current/abet-eac-criteria-2011-2012.pdf,* Assessed 10th Dec 2012

Abhonkar P., Harode A., and Sawant N. (2011), Effect of Projects on Learning: An Indian Case Study, *PBL across the disciplines: research into best practice, 3rd International Research Symposium on PBL 2011, Coventry University, U.K*, 28–29 November2011, 489–501.

Barrows, H.S.(1986), a taxonomy of *Problem based learning methods, medical education, 20, 481-486.*

Biggs J. (1996), Enhancing teaching through constructive alignment**,** *Higher Education*, **32:**, pp-347-364,

Blom A, and H. Saeki (2009), Employability and Skill Set of Newly Graduated Engineers in India, *Bank Policy Research Working Paper Series, Volume 11.*

Cheng Charles (2003), Introducing Student-centered Teaching Strategies to Improve Teaching and Learning, in Theory of Machines and Mechanism, *the China papers*, July 2003, pp. 5–9.

Cobb, P., Confrey, J. diSessa, A., Lehrer, R. and Schauble, L. (2003). Design Experiments in Educational Research. Educational Researcher. 32(1) 9-13, downloaded on 17/11/2011, at Aalborg University, Denmark.

Du X. Y., and Kolmos A. (2006), Process Competencies in a Problem and Project Based Learning Environment, *35th SEFI Annual Conference: Engineering Education and Active Students*, Uppsala, Sweden, 2006.

Eck J C., Mathews D G. (2002) "A Sample of Assessment Findings Related to Samford University's PBL Initiative.

Goel ,S (2006), *Investigations on required core competencies for engineering graduates with reference to the Indian IT industry*, European Journal of Engineering Education, 31:5, 607-617.

Graaff E. D., and Kolmos A (2003)., Characteristics of Problem-Based Learning, *Int. J. Eng. Ed.* Vol. **19**, No. 5, pp. 657–662.

Graaff E D, Kolmos, A.(2007) "*Management Of Change ;implementation of problem and project based learning in engineering*", sense publishers, pp-1-8.

Graaff E D, Kolmos, A. Du, X, (2009) "*Diversity of PBL; PBL learning principles and models*" *Research on PBL practices in engineering education*, sense publishers, pp-9-21.

Hung W. (2009), the 9-step problem design process for problem based learning: application of 3C3R model, *Educational research review***, 4,** pp-118-141.

Josef Rojter, PBL as means to better engineering education? Victoria University, Melbourne City, Australia.Graaff E. D., and Kolmos A (2003)., Characteristics of Problem-Based Learning, *Int. J. Eng. Ed.* Vol. **19**, No. 5, 2003, pp. 657–662.

Joshi R.K., and Joshi M. (2011), Problem Based Learning in Engineering at the Institute of Engineering: Prospects cum Challenges, *Journal of the Institute of Engineering*, 8.1-2, 2011, pp-291-300.

Khairiyah M. Y., and M.K.A. Hamid, A. Hassan, M. Ariffin, M. H. Hassim, S. Hassan, S.A. Helmi, and Z. T. Khairiyah (2005), Outcomes of PBL Implementation from Students' Perspectives, *Proceedings of the Regional Conference on Engineering Education*, Johor, Malaysia, December 12–13, 2005.

Litzinger, T.A., Lattuca, L.R., Hadgraft, R.G.& Newstetter, W.C. (2011).*Engineering Education And The Development Of Expertise - Journal Of Engineering Education* (pp. 123-150).100 (1).

Mantri A., Dutt S., Gupta J., and Chitkara M. (2008), Design &Evaluation of PBL-based Course in Analog Electronics, *IEEE Transactions on Education*, Vol. **51**, N. 4, November 2008, pp. 432–438.

Moore A. and Willmot P. (*2003)*, PBLE-Guidelines for PBL in Engineering, *Proceedings of the International Conference on Engineering Education, 2003,* University of Nottingham,

NKC, 2010, Knowledge Commission, Report to the Nation, 2006–2009, http://www.knowledgecommission.gov.in/downloads/report2009/eng/report09.pdf, Assessed 10th August 2012

National Academy of Engineering. (2004). *The engineer of 2020 - Visions of engineering in the new century*. National Academies Press.

Nasscom,2005, McKinsey Report http://www.mckinsey.com/locations/india/mckinseyonindia/pdf/nasscom_mckinsey_report_2005.pdf

O'Grady, and G. Alvis, W.A.M (2002), One Day One Problem: PBL at Republic Polytechnic, *4th Asia-Pacific Conference On PBL*, Hatyai, Thailand, December 2002.

Prince M, Felder R., Inductive Teaching and Learning Methods: Definitions, Comparisons, and Research Bases, *Journal of Engineering Education,* April 2006,pp-123-138

Raghav M. S., Jain S. and Saha S.K. (2008), Robotic Competition Based Education in Engineering (RoC-BEE), *Proceedings of NCMSTA'08 Conference National Conference on Mechanism Science and Technology: from Theory to Application National Institute of Technology, Hamirpur,* 13–14 November 2008, pp-1-11.

Rao (2006), Rao Committee Report, Faculty Development in India, July2006.

Royal academy of engineering, (2007).*Educating Engineers For 21st Century*, Retrieved March 29, 2012, from http://www.raeng.org.uk/news/release/pdf/Educating_Engineers.pdf

Savin-Baden,M. (2000), Problem Based Learning In Higher Education: Untold Stories, Society For Research Into Higher Education and Open University Press.

Savin-Baden,M.and Major, C (2004), Foundations Of Problem Based Learning, Maidenhead, Open University Press/SRHE.

Shinde,V. and Kolmos A., (2011a) PBL In Engineering Education: Drivers And Challenges, *Proceeding of International Conference WVITAE2011*, 28 Feb – 3 Mar 2011, p. 42.

Shinde V., and A. Kolmos (2011b), Students Experiences in Aalborg PBL Model: A Case Study, *SEFI Annual Conference, Lisbon*, 27–30September 2011.

Shinde V. (2011c), Relevance of the Problem and Project Based Learning (PBL) to the Indian Engineering Education, *across the disciplines: research into best practice*, *3rd International Research Symposium on PBL, Coventry University, U.K,* 28–29 November2011, 489–501.

UoP, (2012), University of Pune, http://www.unipune.ac.in, assessed 12th Nov 2012.

Yashpal (2010), Yashpal Committee, Report of The Committee to Advise on Renovation and Rejuvenation of Higher Education, http://www.hindu.com/nic/yashpalcommitteereport.pdf, Assessed 23rd Sept 2011.

Yooyatiwong Thongchai and Punnarumol Temdee, (2012) IT-PBL model and implementation framework for Mae Fae Lung University, case study: school of information technology, *1st international conference on "Mobility for Life: Technology, telecommunication and PBL",* Mae Fae Lung University Chiang Rai, Thailand, 5-7th March 2012, p-61.