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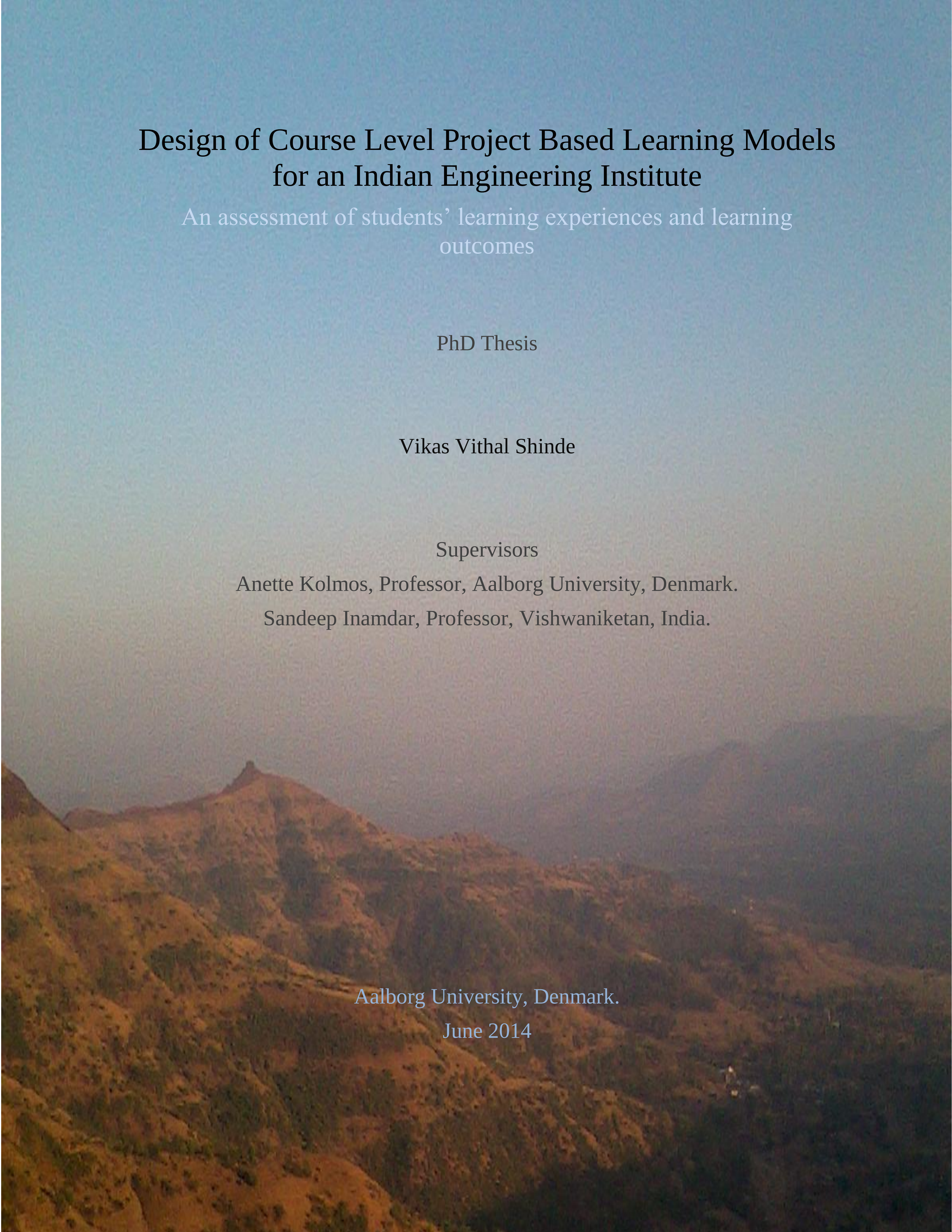

Design of Course Level Project Based Learning Models for an Indian Engineering Institute

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PhD Thesis

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Anette Kolmos, Professor, Aalborg University, Denmark.
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Aalborg University, Denmark.
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Dedicated To,

My wife Shilpa and family whose sacrifice, support and constant encouragement made this research possible

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Abstract (English Summary)

Various government reports have expressed serious concern over the quality of engineering education in India and have indicated the need for change in the teaching-learning practices followed at Indian institutes. A recent nationwide survey, conducted by Federation of Indian chambers of Commerce and Industry (FICCI), stated that 64% of newly graduated engineers are unemployable and lack important employability skills. In a similar report, National Association of Software and Services Companies (NASSCOM) also discussed the unemployability of software engineers in 2005. Such reports have caused widespread demand for changes in the Indian education system. In response to these demands, the National Board of Accreditation (NBA) has switched to an outcome-based education by adopting ABET (Accreditation Board of Enginerring and Technology) learning outcomes. In the literature, it is emphasised that the academic practices followed at Indian engineering institutes must be improved. There is a need for curriculum development, which could address the needs of the engineering profession and inculcate innovative teaching-learning practices to improve the quality of engineering education. It is evident that there is an urgent need for change and to look for alternative education strategies. In my research, the Project Based Learning (PBL) philosophy is considered as an alternative strategy.

The choice of PBL as a suitable approach is reinforced by the PBL literature in chapter 2. It has been found that, to motivate students for learning and to improve skill levels, the problem and project based learning approach has been adapted by many institutions in the world. However, research on PBL is at a very nascent stage in India. The review of research done on PBL around the world indicates that PBL could be a suitable option to improve the quality of engineering education and under graduate engineering skills in India. It is also understood that PBL is practiced under different acronyms in different countries. It is recognized that these various practices have been designed to suit local academic cultures. Furthermore, through this literature review, it was understood that PBL originated in a Western culture where academic practices are different than in India. The challenge for my research was to study PBL philosophy and to develop a model suitable for Indian conditions. Hence, the objectives of this research were to design a PBL model for an Indian institute and to assess its impact on students’ learning experiences. I also intended to test the PBL model’s usefulness for promoting the achievement of the Accreditation Board for Engineering and Technology ABET learning outcomes.

A review of existing Indian PBL models and related research was done for the development process of my PBL models. There were a very limited number of examples of PBL implementation at engineering institutes in India. There was a lack of trained faculty and representative PBL models to ensure further development of PBL in India. As a result, the Indian education system lacked practice in PBL. During the initial phases of the model development, I perceived many drivers and challenges for PBL implementation in an Indian institute. The status of PBL research in the Indian education landscape indicated that there was a substantial research to be done in the areas of curriculum development, staff training and management of change to PBL. Modest research in the areas of PBL showed that, though needed, research done on PBL in India is less, which made my research particularly challenging. With both favourable and challenging conditions, I began my research in 2010.

To conduct this research, Sinhgad Institute of Technology, Lonavala (SITL) was selected as a representative institute. The research focused on developing a PBL model to suit the academic and administrative settings at SITL. The research also aimed to assess the model’s impact on the students’learning and skills development process. To address these research objectives, the design-based research methodology (DBR) was chosen over action research.

DBR literature was discussed and the DBR framework was prepared to guide the flow of research. DBR as a research framework proved to be useful for designing the PBL models and for conducting the research.

The main motivations for the PBL implementation were 1) the need to bring change to the teaching-learning practices, 2) industry demand for skilled engineers and 3) newly adapted accreditation norms. These three elements were critically examined and were placed at the centre of the model's development. The main challenges in this process mainly included 1) a traditional set of values and beliefs creating resistance to change, 2) the academic setting and 3) the curriculum structure. The first course level PBL model (CLPBL) was designed in 2011. This model included the project, project evaluation scheme, and teaching-learning and supervision strategies. It also included the strategic use of resources such as time and institutional infrastructure. This first CLPBL model played a significant part in the outcome of this research. With the success of the first CLPBL, two more CLPBL models were designed. Thus, three CLPBL models were designed for two important subjects in the mechanical engineering undergraduate programme in which three hundred and seventy five students participated. These three models were an important outcome of this research. In the three models, three innovative projects were designed, as well as a project evaluation strategy that proved effective for the overall assessment of the student projects and groups. The project and its evaluation strategy are also an important research outcome. These models were adjusted to suit the institutional academic culture and were influenced by PBL philosophy and ABET learning outcomes. It is thought that these three course-level PBL models could serve as a representative framework for PBL implementation at similar Indian institutes.

The mixed methods sequential design approach was used for data collection. To collect the data a mix of qualitative and quantitative methods were used. The essays, survey (open-ended questions) and interviews provided qualitative data. In addition, observations, project presentations and project reports proved useful for gaining insight into the students' experiences. At the end of each model, responses to the surveys, project and course grades provided quantitative data. The qualitative and quantitative data was analysed by using content analysis and descriptive statistical techniques respectively. Although essays were useful for preparing the initial themes and categories for analysis, considerable variation in the essay lengthswas observed and produced much unstructured data. Short interviews at the end of the presentations proved helpful for patching up and reinforcing the essay data from the first two models. At the end of the third model, in-depth interviews were used to verify observations made during the implementation of all three models. Along with qualitative data, quantitative data was collected by using the survey instruments, with an overall Cronbach alpha in the range of 0.85. The instrument had four major groups, for which the Cronbach alpha value was found to be in the range of 0.7. This survey instrument was tested three times during the research and proved to be effective and consistent enough to generalise the findings of the research. The response rate in all three models was close to 86%. During the initial phases of the research, quantitative data was analysed using descriptive statistics. Later, a two-way ANOVA (Analysis of Variance) test was found to be useful for comparing the results. Important research outcomes and contributions are discussed from various perspectives. These instruments could be further developed in due course to improve reliability. In this research, in three models 187 esaays, 46 interviews, 80 reports, 442 open ended questions, 325 questionnaires were analysed. Also, project grades and course grades of 375 students were analysed.

The design-based research proved to be an effective methodology for designing and testing the CLPBL models. It permitted me to conduct the research and could be used to

improve the current academic practice at SITL. The PBL environment was useful for making students active in the learning process and for promoting the achievement of skills needed for their profession. The data indicated that the model was successful in improving students' learning experience and enhancing problem solving, project management, teamwork, and communication skill levels. Results indicated that students enjoyed working on the projects and felt it was challenging to work on a project in the second year of their undergraduate studies. Students gained the confidence to work on more challenging projects and recommended PBL for future courses. Student responses indicated that the PBL environment is conducive to improving the students' learning experience. The projects helped students in content learning and in receiving practical knowledge. Importantly, these models promoted the application of learning and higher order skills such as critical thinking and problem solving. More cross-institutional research is required to generalise the results.

Danske Resume

Litteratur om indisk ingeniøruddannelse bliver diskuteret som baggrundsmateriale med henblik på at forstå den aktuelle status for ingeniøruddannelserne. Forskellige statslige rapporter har udtrykt alvorlig bekymring over kvaliteten af ingeniøruddannelser i Indien og har udtrykt behov for forandring i undervisningen på indiske undervisningsinstitutioner. En nylig landsdækkende undersøgelse udført af Federation of Indian chambers of Commerce and Industry (FICCI) viste, at 64% af de nyuddannede ingeniører ikke er egnet til ansættelse og mangler vigtige færdigheder. I en lignende rapport fra 2005 drøfter National Association of Software and Services Companies (NASSCOM) også uarbejdsdygtigheden af software ingeniører. Sådanne rapporter har medført udbredt krav om ændringer i det indiske uddannelsessystem. Som svar på disse krav har National Board of Accreditation (NBA) skiftet til en resultatbaseret undervisning ved at indføre Accreditation Board of Engineering and Technology (ABET) læringsmodeller. I litteraturen er det understreget, at de nuværende praksisser på indiske ingeniørinstitutioner skal forbedres. Der er behov for udvikle undervisningen så den imødekommer behovene i ingeniørfaget og til stadighed at indprente innovative undervisningsformer for at forbedre kvaliteten af ingeniøruddannelserne. Det er klart, at der er et presserende behov for forandring og til at søge alternative uddannelsesformer. I min forskning betragtesproblem baseret læring (PBL) som et sådant alternativ.

Valget af PBL som en egnet tilganger i kapitel 2 underbygget af litteraturen vedr. PBL. Det har vist sig, at problem- og projekt baseret læring (PBL) motiverer de studerende og forbedrer deres kvalifikationer, og den er derfor blevet tilpasset til mange institutioner verden over. PBL-forskning i Indien er dog på et meget begyndende niveau. Gennemgang af PBL-forskning rundt om i verden indikerer, at PBL kunne være et passende valg for at forbedre kvaliteten af ingeniøruddannelser og bachelorers ingeniørfærdigheder i Indien. Det er også underforstået, at PBL praktiseres under forskellige akronymer i forskellige lande. Det menes, at disse forskellige praksisser er blevet designet til at passe de lokale faglige kulturer. Desuden er det, ved denne litteratur gennemgang,klarlagtat PBL stammer fra vestlig kultur, hvor akademisk praksis er anderledes end i Indien. Udfordringen for min forskning var derfor at undersøge PBL filosofi og at udvikle en model som var egnet til indiske forhold. Derfor var målet at designe en PBL model til en indisk institution og at vurdere indvirkningen på elevernes læring. Jeg ville også teste PBL-modellens anvendelighed til at fremme kompetenceudvikling og gennemførelsen af ABET's læringsresultater.

En gennemgang af de eksisterende indiske PBL-modeller og relateret forskning blev lavetmhp. udviklingsprocessen af mine PBL-modeller.Der var et meget begrænset antal eksempler på gennemførelse af PBL på ingeniøruddannelsesinstitutioner i Indien.Der var en mangel på uddannet videnskabeligt personale og repræsentative PBL-modeller for at sikre yderligere udvikling af PBL i Indien. Det indiske uddannelsessystem manglede praksis i PBL. I de indledende faser af udviklingen af modellen var der mange udfordringer mht. implementeringen af PBL på en indisk institition. Status for PBL forskning i de indiske uddannelsesystem indikerede, at der var omfattende forskningsom skulle udføres inden for udvikling af undervisningen, uddannelse af personale og håndtering af forandringer til PBL.En mindre mængde forskning på de områder af PBL viste, at selv om det er nødvendigt, er forskning udført på PBL i Indien mindre, hvilket gjorde min forskning særligt udfordrende. Med både gunstige og udfordrende betingelser, begyndte jeg min forskning i 2010.

For at udføre denne forskning valgte jeg Sinhgad Instiute of Technology, Lonovala (SITL) som institution. Forskningen fokuserede på at udvikle en PBL-model, der passer til de faglige og administrative forhold på SITL.Forskningen havde også til formål at vurdere modellens effekt på elevernes læring og udvikling af færdigheder. For at løse disse forskningsmål valgte jeg design-baseret forskning (DBF) frem for aktionsforskning. DBF litteratur blev drøftet, og en DBF ramme blev udviklet til at guide forskningen. DBF som rammeforskning vist sig at være nyttigt for udformningen af PBL modeller, og for at gennemføre forskningen.

De vigtigste motivationer for PBL implementering var 1) behovet for at bringe forandring til undervisningspraksis, 2) industriens efterspørgsel efter dygtige ingeniører og 3) nyligt tilpassede akkrediteringsnormer.Disse tre elementer blev kritisk gennemgået og blev centralefor modellens udvikling.De største udfordringer i denne proces var hovedsagelig 1) et traditionel sæt af værdier og overbevisninger som skaber modstand mod forandring, 2) akademisk miljø og 3) pensumstruktur.Den førstePBL-model på kursusniveau (PBLKN) blev udformet i 2011.Denne model omfattede projekt, projektevalueringen og undervisnings- og vejledningsstrategier.Den omfattede også en strategiske anvendelse af ressourcer såsom tid og institutionel infrastruktur. Denne første CLPBL model spillede en betydelig rolle i resultatet af denne forskning.Med den succes den første CLPBL blev,blev yderligere to CLPBL modellerdesignet. Således blev tre CLPBL modeller designet til to vigtige fag i maskininingeniørbacheloruddannelser.Disse tre modeller var et vigtigt resultat af denne forskning. I disse tre modeller deltog 375 studerende.I de tre modeller blev tre innovative projekter udformet, samt en projektevalueringsstrategi, der viste sig at være effektive ved den samlede vurdering af de studerendes projekter og grupper. Projekt og dets evalueringsstrategi er også et vigtigt resultat af forskningen.Disse modeller blev tilpasset den institutionelle akademiske kultur og var påvirket af PBL-filosofi og ABET læringsresultater. Det tænkes, at disse tre PBL-modeller på kursusniveau kunne tjene som en repræsentativ ramme for PBL gennemførelse på lignende indiske institutioner.

Den mixed methods sequential designtilgang blev brugt til indsamling af data. Til at indsamle data blev en blanding af kvalitative og kvantitative metoder anvendt. Essays, spørgeskema(åbne spørgsmål) og interviews genererede kvalitative data.Desuden viste observationer, projektpræsentationer og projektrapporter sig nyttige til at få indsigt i de studerendes erfaringer.Ved afslutningen af hver modelgenereredespørgeskemaer samt projekt-og kursusbedømmelserkvantitative data.De kvalitative og kvantitative data blev analyseret ved hjælp af hhv.indholdsanalyse og beskrivende statistiske teknikker. Essays og interviews gav et nyttigt indblik i de studerendes erfaringer i PBL miljø, genereret som kvalitative data.Selvom essays var nyttige til fremstilling af de første temaer og kategorier til analyse, var der en betydelig variation i længder af essay hvilket gav mange ustrukturerede data.Korte interviews i slutningen af præsentationerne vist sig nyttig til at sammenstykke og underbygge essaydata fra de to første modeller.Ved slutningen af den tredje model, blev dybdeinterviews brugt til at verificereobservationer under gennemførelsen af alle tre modeller.Disse kvalitative data blev analyseret ved hjælp af indholdsanalyseteknikker.Parallelt med kvalitative data blev kvantitative data indsamlet ved hjælp af spørgeskemaer resulterende i Cronbach alpha værdieromkring 0,85. Analysen havde fire hovedgrupper, for hvilke Cronbach alpha’s værdi lå i størrelsesordenen 0,7.Dette undersøgelsesinstrument blev testet tre gange i løbet af forskningen og viste sig at være effektivt og konsekvent nok til at kunne generalisere resultaterne af forskningen. Svarprocenten i alle tre modeller var tæt på 86%.Under de indledende faser af undersøgelsen blev kvantitative data analyseret ved anvendelse af deskriptiv statistik. Senere blev en to-vejs ANOVA (variansanalyse) brugt, som viste sig at være nyttig til at sammenligne resultaterne.Vigtige forskningsresultater og bidrag diskuteres fra forskellige perspektiver. De designede instrumenter viste sig nyttige til at indsamle forsknings data. Disse instrumenter kunne videreudvikles med tiden og forbedre pålideligheden.I denne forskning blev tre modeller, 187 essays, 46 interviews, 80 rapporter, 442 åbne spørgsmål, 325 spørgeskemaer analyseret. Ligeledes blev, projekt-og kursusbedømmelservedrørende 375 studerende analyseret.

Designbaseret forskning har vist sig at være en effektiv metode til at designe og teste CLPBL-modeller.Det tillod mig at gennemføre forskning og kan bruges til at forbedre den nuværende akademiske praksis på SITL.PBL-miljøet var nyttigt til at gøre de studerende aktive i læringsprocessen og for at fremme opnåelsen af de nødvendige kvalifikationer for deres professionsudøvelse.Data indikerede, at modellen var succesfuld i forbindelse med at forbedre studerendeslæringsoplevelse og forbedre problemløsning, projektstyring, teamwork, og kommunikationsfærdigheder.Resultaterne indikerede, at de studerende kunne lide at arbejde på projekterne og følte, at det var udfordrende at arbejde medet projekt på andet år af deres universitetsstudier.De studerende fik tillid til at arbejde med mere udfordrende projekter og anbefalede PBL til fremtidige kurser.De studerendes svar indikerede, at PBL miljøet er fremmende for at forbedre de studerendes læringsoplevelser. Projekterne har hjulpet de studerende med læringsindhold og i at modtage praktisk viden.Vigtigst er det, at disse modeller fremmer anvendelsen af det lærte og højereordens-kvalifikationer såsom kritisk tænkning og problemløsning. Mere tværinstitutionelt forskning er nødvendig for at generalisere resultaterne.

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Vikas Shinde

Chapter 1

The Research Background

Recently, the Indian engineering education system has been criticized for being unable to offer quality education and for not producing employable graduate engineers (Blom & Saeki, 2011). In view of the increasing demand for skilled engineers, and to improve the students' learning, Indian educators are looking for suitable alternatives (Rao, 2006, Pal, 2009 and NKC, 2010). The Problem and Project based learning (PBL) strategy has been considered as a suitable alternative (Shinde, 2011). However, PBL philosophy has origined in the western world, where the educational culture and values are different than those in India. Hence, the focus of this research is to design a PBL model for an Indian engineering institute and to assess its impact on students' learning and learning outcomes. This chapter is positioned to provide a background of the Indian engineering education system, its culture and the institute in which this research was conducted. This introduction is intended to remind the readers that India is a very different culture compared to Europe or the USA.

1.1 History of technical education in India

India has a history of education tracing back to the 3rd century B.C. In those days, sages and scholars used to impart education verbally. At that time, education was imparted in ashrams (for Hindus) in local languages. The Guru (teacher) and Shishya (student) Parampara (tradition) was a cornerstone of education at that time. Gradually, the written letters were developed and education transitioned to take the form of writing. The ancient written literature can be found on the Palm leaves and bark of trees. During the period of Buddha, world famous educational institutions such as Nalanda, Vikramshila and Takshashila came into existence. The Nalanda University prospered from the 5th to 13th centuries A.D. It is mentioned in the literature that the university had around 10,000 resident students and teachers, including international scholars from China, Sri Lanka, Korea and other countries. During the same period, in 11th century, the Muslims established Madarasas (Muslim schools) for their children. Later, with the arrival of the British in India, English education came into existence. Since then, Indian education has been influenced by practices from western countries (Perkin, 2006).

The foundations of the engineering (technical) education in India were laid by the British Government in India. In the pre-independence era of 1794, under the British Government in India, the first survey school (named so because it was aimed to train surveyors) was started in Madras. It started with eight students. None of them were Indian. Similarly, many schools were set up in Bengal in 1817. In 1843, the importance of civil engineering as a branch of instruction for Indian people began to be asserted by the authorities. Around the same time (1844) in the Bombay province, at Elphinstone institute, an engineering class was started that focused on developing surveyors and builders. In 1847, at Roorkee, a Civil Engineering College was opened. This college had four teachers, two of whom were Indian. With the success of Roorkee College, a few more engineering colleges at Calcutta, Madras and Poona were established. The first batch of Civil Engineering College affiliates to Madras University received their Bachelor of Civil Engineering (BCE) degrees in 1864. In 1890, courses in Mechanical and Electrical engineering were first offered running two year as duration. Later, in 1897, the courses in Civil and Electrical engineering were extended to three years' duration. In 1894, Madras University also started offering Bachelor of Engineering (B.E) degrees in Mechanical engineering. Three universities were in existence at that time named Madras, Bombay and Calcutta (Biswas, 2010).

The total enrolment in 1884-85 in the four engineering (Calcutta, Madras, Poona and Roorkee) colleges was 608. At the end of the 19th century, the educated people of India started pressing for an expansion in technical education. Accordingly, after World War-I many engineering institutes were established. As a result, by a few years before independence (around 1940) there were 46 engineering colleges with a total intake capacity of 2500 students (Biswas, 2010). All these engineering colleges, excepting only a few, were operating under government funding and control. In 1945, on the recommendations of the Sarkar committee All India Council for Technical Education (AICTE) was established (Biswas, 2010). After independence in 1947, the establishment of the Indian Institutes of Technology (IIT), Indian Institutes of Management (IIM) and Indian Institutes of Science (IISc.) was a major step in the development of technical education in the country (AICTE, 2012). The growth of engineering education continued. By 2012 in India, 3393 engineering colleges have been set up with a total annual intake of 1.486 million (TOI, 2012). This is more than 595 times the capacity of engineering colleges in 1940.

Similar trends have also been seen in non-technical streams of higher education institutions. The number of universities has increased from 25 in 1947 to 348 in 2005. The total number of colleges has multiplied from 700 in 1947 to 17625 in 2005. Accordingly, the total enrolment improved from 0.1 million in 1947 to 10.48 million in 2005. In terms of enrolment, India is the third largest higher education system in the world. It is the largest higher education system in the world in terms of number of institutions (17973 institutions). This is four times to the sum of number of institutions in both the United States and Europe (Agarwal, 2006).

1.2 Engineering education in India

Since the focus of the current research relates to engineering education, this part will discuss the current status of engineering education, the existing university system and the academic practices implemented at engineering institutes.

1.2.1 University System

Engineering education institutions in India can be broadly classified into three categories – central government, state government and self-financed or private institutions. The central and state government institutions are financially supported by the Indian government. These include central and state universities and autonomous institutes under the aegis of the government. Apart from these government-run institutes, there are also private or self financed institutes. These institutions get very little financial support from the government. They are approved by AICTE and have an affiliation to one of the state universities. This affiliation means that the university will grant degrees to all students educated by these institutes. It should be noted that the universities do not provide any finance to the private or self-financed institutions; on the contrary, the institutes pay a fee to the university and is required to follow the rules and regulations, curriculum, and evaluation patterns mandated by the university. The private institutes receive finance in the form of tuition fees from students. The private institutes must manage this finance properly to function satisfactorily. Despite this hindrance, private institutes comprise 90% of the current capacity of engineering education systems in the country (Goel & Sharada, 2004 & Goel, 2006). It may be noted that the current research is done at Sinhgad Institute of Technology, Lonavala (SITL), which is a self-financed institution with an affiliation to the University of Pune (UoP). More details about SITL are discussed in the later part of this chapter.

1.2.2 Teaching-learning practices

Throughout history, education in India has been teacher centred ('Guru Shishya Parampara') and verbal instructions have been the preferred strategy to pass on knowledge. Historically, education was delivered in the local language, although today English is an official formal language for education. An instruction based, teacher centred practice is rooted in the higher education culture of the country. The engineering education institutes operate within the same tradition.

1.2.3 Curriculum

The engineering programme in India runs for eight semesters across four years. The curriculum is specially designed for each semester. To determine curriculum design, the university's board of studies appoints a core committee. The members of this committee are the subject experts. These members are selected from the university's affiliated institutes and one representative is appointed from the industry. The course structure and syllabus are decided by this committee. Generally, a semester includes five theory courses and a lab practice. In the curriculum, for each theory course a syllabus is defined. This syllabus contains units, or topics to be taught, and the list of experiments. It is standard practice to revise the curriculum design after three years. In summary, an affiliated institute does not directly contribute to the design of the syllabus, although selected teachers or subject experts from the institute may be invited to contribute. The curriculum design determined by the committee is implemented at all of the affiliated institutes (UoP, 2012). For example, UoP has 114 affiliated engineering institutes (UoP, 2013) at which the same curriculum is practiced. Usually, the engineering curriculum assigns one project in the final year of the programme. This is a group project to be completed in one academic year. An industry expert or examiner appointed from the university does the evaluation of the project.

1.2.4 Assessment and examination

At the end of the each semester, the university administers and conducts a common written examination for all the students of the affiliated institutes. For example, UoP conducts common written examination for its 114 engineering institutes (UoP, 2013). This written examination is based on the syllabus of the courses provided by the UoP, for respective branch of engineering. The affiliated institutes are responsible to prepare students for this examination. Most of these institutes prefer a traditional instruction-based pedagogy for preparing students for the final evaluation. Since, the grades obtained in this examination significantly influence students' career and job prospects, both teachers and students tend to focus on securing good grades in this final examination.

In the preceding section, the Indian engineering education system and academic practices were discussed. The issues relating to engineering education in India that are most attributable to the academic practices discussed above (curriculum, teaching-learning practices and examination) are examined in the following section.

1.3 Issues in engineering education

1.3.1 National Issues

The first section of this chapter discussed the growth of engineering education from the pre-independence period until today. From this discussion, it is evident that engineering education has expanded exponentially, giving rise to the establishment of numerous new institutes and increased enrolment capacity. National-level studies (Rao, 2006, NKC, 2010 & Pal, 2009) have reported the many problematic implications of this growth. In these reports, it is mentioned that there is a dearth of qualified teachers in these institutes. Also, there has been a gradual decline in the quality of entry level students. The Pal committee (2009) remarked that many institutes have become business entities that dispense poor quality education. The committee claimed that there exists a gap between the learning provided by the institutions and the expectations of the industries. It has been generally reported that the expansion of engineering education has resulted in a gradual decline in the quality of education. These reports (Rao, 2006, Pal, 2009, NKC, 2010 & Blom & Saeki, 2011) recommend major changes to the curriculum development process and teaching-learning practices.

Based on discussionsof academic practice at Indian engineering institutes, it is evident that the curriculum and evaluation processes promote rote learning. Goel &Sharda (2004) reported that semester after semester, according to per the Bloom’s Taxonomy students are tested for low level cognitive skills such as memory and understanding. As a result students tend to memorize the content as opposed to understanding the content. A lack of motivation and innovative methods in the teaching-learning process, and a high emphasis on grades, negatively impact the students’ psychology, making them passive learners who are less engaged in learning process. Furthermore, it is reported that the curriculum offers very limited opportunity for students to develop higher-level cognitive skills such as analysis, synthesis, and evaluation. Institutes’ focus on preparing students to get good grades in an examination means giving less priority to the skill development needed for the engineering profession. These observations are confirmed by many national-level studies such as National Association of Software and Service Companies (NASSCOM) and McKinsey report (NASSCOM, 2005) and Blom& Saeki (2011). These studies raise important questions about the preparedness of Indian graduate engineers for the industry.

In 2005, the NASSCOM and McKinsey report stated that only 25% of software engineers were employable by a multinational company (NASSCOM, 2005). In 2009, the Government of India, the World Bank and the Federation of Indian Chambers of Commerce and Industry (FICCI) conducted a national survey of Indian Industries. Responses were gathered from 157 engineering industries across India. The results showed that 64 percent of surveyed employers were not satisfied with the quality of engineering graduates and their skills (Blom & Saeki, 2011). These were very critical remarks on the employability of engineers.

In their survey, Blom & Saeki (2011) used a five point Likert scale to identify important skills demanded by the Indian engineering industry (please refer to the Appendix A_1) and to measure how well newly-employed graduate engineers satisfied the demand for these important skills.The skills gap is the difference between the level of importance and the level of satisfaction described by the employers in terms of these skills. In the survey, the Indian industry representatives placed high emphasis on higher-order thinking skills such as problem-solving, conducting experiments, creativity, and application of modern tools. Industry representatives stated that that graduate engineers lack in these skills. Respondents also demonstrated low satisfaction levels on important process skills such as teamwork, lifelong learning and communication skills. The results of the survey strongly illustrate the need for improvement in assessment methods and for a curriculum that emphasizes the skills listed above (Blom & Saeki, 2011). There may not be enough evidences to substantiate the claim made in this survey. However, it is important to note here that the surveyed industries demand particular skills, while the Indian engineering graduates and institutes focus on grades. This discrepancy in focus naturally leads to a gap in the industry's expectations and students' skills. Employers think that the Indian education system must develop graduate engineers who are able to demonstratethe skills demanded by the industry.

Summing up

The Indian engineering education system places a high emphasis on grades and a low emphasis on the skill development required for the engineering profession. From the reports, it can be concluded that the Indian engineering institutions need to alter the quality and type of education offered and must make provisions to ensure that the graduate engineers' skill are developed to meet industry demands. Against the backdrop of these reports, the Ministry of Higher Education in India has recently decided to change the accreditation criteria to an outcome-based criterion. As India is a member of the Washington Accord, the Accreditation Board for Engineering and Technology (ABET) criteria 2011-12 (ABET, 2012) is applicable for assessing the quality of education in educational institutes in India. Table 1.1 shows the ABET criteria.

In the higher education landscape in India, this shift to outcome based education is considered as a step in the direction of matching the global trend of outcome based education. However, the question could be raised, 'can we achieve these learning outcomes without appropriately modifying the current academic practices used by Indian engineering institutes?' It seems that there is a contradiction between the structures of the education system and practices used in Indian engineering institutes and the practice required to achieve the learning outcomes above. Decades ago, universities from developed parts of the world like the USA, Europe and Australia (Mills & Treagust, 2003) initiated changes by adopting student centred, active learning practices in their teaching-learning processes, in order to align with the outcome based education. Mills & Treagust (2003) and Barneveld & Strobel (2009) reported many institutions around the world which have adopted the Problem and Project based learning (PBL) approach to overcome similar issues. Indian institutes may need to consider also adopting PBL. In line with this belief, this research considers PBL strategy to be a suitable alternative. However, PBL philosophy has origins in the western world, whose educational culture and values are different than in India.These differences mean that the PBL model must be adapted and redesigned to fit the Indian context. Hence, the focus of this research is to design PBL intervention for the Indian context and to investigate its impact on students' learning and achievement of learning outcomes.

Table 1.1 The ABET Criteria. (ABET, 2012)

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)	Recognition of the need for, and an ability to engage in life-long learning
(j)	Knowledge of contemporary issues
(k)	An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

1.4 The research context

Since I work at Sinhgad Institute of Technology, Lonavala (SITL), I selected this institute to serve as a representative to conduct the research. SITL is situated in the small city of Lonavala, 96 km from Mumbai, India. SITL is affiliated with the University of Pune (UoP), which was started under the British regime almost 70 years ago. The UoP is located in Maharashtra, which is one of the 29 states of India. The local language is Marathi; however, the language of instruction at SITL is English. It runs five major engineering programmes, namely mechanical, electronics and telecommunication, computer, information technology and electrical engineering. It may be noted that an intake capacity of each programme is different. For example, intake capacity of mechanical engineering programme is 360 whereas for electronics and telecommunication department it is 240. Considering students in all programmes together, SITL has an enrolment capacity of 900 students per year.

Due to its affiliation with UoP, SITL must follow the rules, regulations and curriculum designed provided by the university. Each programme has four year duration comprised of eight semesters. Each semester lasts approximately six months (24 weeks). The first three and half months (14-16 weeks) are used for teaching the courses. Later weeks are used by UoP to conduct the examinations. Before the final examination, two to three week’s preparatory leave are given to the students. SITL is responsible for preparing its students for the final evaluation. SITL has a number of classrooms, laboratories and a central library to fulfill the needs of the traditional teaching and learning practices.The participants of this study are students of SITL studying in the second year mechanical engineering programme. Figure 1.1 shows a typical classroom of second year mechanical engineering students. The number of students in this class was 97.

Figure 1.1 The Second Year classroom

In general, 90% of these students are from Maharashtra and 10% from other states of the country. Since, there is variation in the curriculum structure across states of the country, these students have varied intellectual abilities and academic backgrounds, and have demographic differences in terms of place of living and spoken language. Also, the class has a mixture of male and female students ranging in age between 19 and 21.

The PBL intervention in this study will be designed for these students. It can be anticipated that the PBL intervention will have an impact on students' learning experiences. They may have varied opinions and experiences in this newly designed learning environment. These opinions and experiences will create research data and will be used to gauge the effectiveness of the PBL intervention. This research is carried out at SITL with the intention of modifying academic practices used at the institute and promoting the achievement of ABET learning outcomes referred in the table 1.1.

An outline of the coming chapters is provided here. To understand the PBL philosophy and refine the research area, PBL-related literature is acknowledged in Chapter 2. Based on chapters 1 and 2, the research objectives and questions are defined in Chapter 3. The selection and application of the Design Based Research (DBR) methodology for this study are discussed in Chapter 3. Also, various data collection strategies are elaborated in the chapter 3. In Chapter 4, the framework replicating various DBR phases in order to conduct this research is developed. The main activities such as contextual understanding and design of First Course Level PBL (CLPBL) are also discussed in Chapter 4. The implementation and results of the first CLPBL model are elaborated in Chapter 5. Based on the reflections from the first CLPBL model, two more models are developed. These two models and their results are discussed in detail in chapters 6 and 7 respectively. The overall experience and the conclusions of this research are outlined in Chapter 8, followed by directions for future research. With this short overview of the chapters of this thesis, I invite you to read further.

Chapter 2

Literature Review

The first chapter of this report presented the status of the Indian engineering education. National reports claimed that Indian graduate engineers lack critical employability skills. The reports described the existing gap between skills demanded by the industry and skills possessed by the graduate engineers (Blom & Saeki, 2011). Various national reports attributed this discrepancy to curriculum design and existing teaching-learning practices (Rao, 2006, Pal, 2009, NKC, 2010, Blom & Saeki, 2011). In response to this information, the Higher Education Ministry decided to pursue outcome based education by adopting ABET learning outcomes. In line with this initiative, there is a need to make the appropriate changes incurriculum organisation and existing teaching-learning practice. In this research project, I treat PBL as a suitable alternative to achieve these objectives. However, there is a need to understand PBL philosophy and elements of PBL curriculum design in order to implement PBL effectively in the Indian context.

The objectives of this chapter are:

1. To understand the learning principles and philosophy of PBL
2. To review literature on the effects of PBL
3. To identify elements of PBL curriculum design and its organisation within the curriculum
4. To identify relevant PBL practice or examples from the literature

In this chapter, there are two main sections. The first section discusses PBL principles and characteristics, motivation for PBL implementation, effects of PBL and parameters for PBL curriculum design. In the second section, multiple cases of course level PBL implementation are reported and synthesised on the basis of the identified parameters. It is anticipated that this synthesis will be a useful to guide the research at the SITL.

Part 1

2.1 Origin, characteristics and principles of PBL

The first university to develop and implement a problem-based learning curriculum was McMaster University, Canada, in 1968, for medicine courses (Woods, 1994). With simultaneous development in Denmark, a problem-oriented, project-based learning model was implemented at Roskilde University (RU) in 1972, (RU, 2014). Two years later, a problem-based and project-organised model was implemented by Aalborg University (Kolmos, Fink & Krogh, 2004). These universities are recognised as pioneering universities in the initiation of PBL practice. University of Linkoping, Sweden embraced PBL in medical education in 1986 (Bin & Bin, 2010). Maastricht University, Netherlands has used PBL in its programmes for over 35 years (www.maastrichtuniversity.nl). While these universities emerged as pioneers in the field of PBL, other universities were still practicing traditional pedagogy. In the years that followed, researchers sought to conceptualise and describe PBL. In the literature, the abbreviation PBL is used to refer to diverse practices; two frequently cited practices are problem-based learning and project-based learning. Barrows (1986) described the six core characteristics of McMaster's problem-based learning approach as follows:

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

These characteristics helped others to design and practice problem-based learning. Some examples of PBL practice in medical, engineering; law and architecture are reported by Boud & Feletti (1991). The outcome of these practices proved to be an important aid for the growth of problem-based learning. In the coming years, more models emerged. For example, inspired by the McMaster model, PBL was used for medicine courses in Brazil in 1994 (Marcos, 2009). The P^5based learning (P^5bl) lab model of Stanford University, California, is famous for its work on Global Project-Based Learning. Here P^5 stands for problem, project, process, product and people (http://pbl.stanford.edu). The Central Queensland University, Australia, introduced PBL in its Bachelor of Engineering programme in 1998 (Howard, Mark & Jorgensen, 2008). The University of South Australia, Australia, integrated project-based learning throughout its curriculum (Graham, 2010). Since 1998, Samford University, Birmingham, has incorporated the problem-based learning into various undergraduate programmes (www.samford.edu). In the recent past, the problem-based learning philosophy has gained attention in Asia also. One of the prominent models from Asia is the Republic Polytechnic (RP), Singapore, "one problem per day" model (O Grady & Alvis, 2002). It may be noted that the above list of PBL cases provides representative examples. There are many other prominent PBL models and practices around the world. Acknowledging all of them is beyond the scope of this chapter.

Graaff & Kolmos (2003) pointed out that above mentioned examples share common principles of learning: cognitive, content, and social. The cognitive learning approach means that learning is organised around problems and will be carried out in projects. Resolving a problem becomes a central part of the learning process and becomes the motivation for learning. The students learn through the experience of confronting tasks involved in the problem solving process. A content approach involves disciplinary and interdisciplinary learning. It is an exemplary practice used to address learning objective of the subject or curriculum. It also reinforces the relationship between theory and practice.

The third principle, social learning, emphasises the concept of working in a team. Team or cooperative learning is a process in which learning is achieved through dialogue and communication between team members. Students learn from each other and share knowledge. Also, while working in a team, students develop collaborative skill and critical project management skills. PBL is called as learner centric and participant directed approach, in which students take ownership of their projects and make decisions together to get the desired outcome.

Problem-based learning and project-based learning are both student centred approaches in which learning is organised around problems, involves teams of students, and calls for the teams of students to formulate solution strategies, and to continually re-evaluate their approach in response to outcomes of their work (Kolmos, Graaff & Du, 2009, Prince & Felder, 2006).

Prince & Felder, (2006) provided following definations of the Problem-based learning and Project-based learning approaches.

> ***“Problem-based learning (PBL) begins when students are confronted with an open-ended, ül-structured, authentic (real-world) problem and work in teams to identify learning needs and develop a viable solution, with instructors acting as facilitators rather than primary sources of information”. (P-128)***
>
> ***“Project-based learning begins with an assignment to carry outone or more tasks that lead to the production of a final product—a design, a model, a device or a computer simulation. The culmination of the project is normally à writen and/or oral report summarizing the procedure used to produce the product and presenting the outcome” (P-130).***

Furthermore, Prince & Felder (2006); added that there is a certain degree of variation and difference between the problem-based learning and project-based learning.

> ***“A project typically has a broader scope and may en-compass several problems. Also, in project-based learning, the end product is the central focus of the assignment and the completion of the project primarily requires application of previously acquired knowledge, while solving a problem requires the acquisition of new knowledge and the solution may be less important than the knowledge gained in obtaining it. In other words, the emphasis in project-based learning is on applying or integrating knowledge while that in problem-based learning is on acquiring it”. (P-130)***

Since, the difference between Problem based and Project based learning is not clearly defined, it is difficult to choose and prioritise any one approach for use in engineering education. Rather, Prince & Felder (2006); pointed out using both approaches could be adavantageous. Aalborg model is one of the best example in which both approaches are used in engineering education.

Perrenet, Bouhuijs, & Smits, (2000) pointed out that, the problem-based learning approach has been readily adopted in medical education which may be because problem-based learning approach more obviously mirrors the professional behaviour of a physician than that of an engineer. In a problem-based learning approach, a problem or problem scenario is given to the students at the beginning. Here, I am referring to the examples from the medical field where a problem scenario is given to the students (Woods, 1994). Problem-based learningis centred on problems that tend to be of short duration (for example problem scenarios, carrying out tests for diagnosis of disease etc). In this case, problem-based learning focuses on the solution of a problem and may not produce a technology product. Problem-based learning relies on knowledge being constructed by the students while solving given problem.

Engineering curriculum has a hierarchical approach, which means that knowledge of some basic subjects is necessary before learning other subjects. For engineering studies, courses like math, physics and mechanics provide basic prerequisite knowledge that is necessary for continued study. As a result, the learning process begins with knowledge acquisition through traditional modes and moves to application of that knowledge in the later stages. In this way, the projects approach relates more closely to engineers' discipline or specialisation by leading to the application of already learned tools, techniques and standard sets of procedures and calculations. Furthermore, in engineering practice the term 'project' which refers to a set of tasks or an activity, is commonly used. Projects can have varying time scales ranging from months (maintenance or process studies) to years (construction of machines, dams, buildings etc.). In engineering field, a real life engineering projects often culminate into the technology products.

From the above discussion, it is evident that project-based learning is more suited to the engineering curriculum than to problem-based learning. However, the problem-based learning approach should not be wholly dismissed as there are examples in which engineering problems have been used in the engineering curriculum (see examples Cawley, 1991, Woods, 1991, Mohd Yusof et al 2005, Mantry et al 2008, Graham 2010). Hence, it would be advantageous to use both approaches at different levels of the curriculum. For example, projects based learning can be used at the initial level of the curriculum where students get experience of handling contextualised sets of activities and tasks or short duration projects. Such experience could be vital for learning teamwork and project management skills. Later on, more complex or open-ended problems can be used to develop problem solving and critical thinking skills. Aalborg University, Denmark is an example where project- and problem-based learning approaches have been used together.

2.1.1 Summing up

In many cases, problem-based learning (PBL) and project-based learning (PBL) terms are used interchangeably. Many leading universities around the world have embraced PBL strategy. Through efforts to localise the strategy, many local PBL models and practices have emerged. As a result, many acronyms for PBL have been generated, such as project-based learning, project-led education, problem-based and project-organised learning etc. As discussed, the practices share similar learning principles, namely cognitive, content, and social learning (Graaff & Kolmos, 2003). It could be advantageous to use both strategies; however, in my opinion project-based learning is best suited to the engineering field.

2.2 Motivation for PBL implementation

The aim of this segment is to understand the motivation behind implementing PBL in the curriculum. Such understanding would likely help in establishing the relevance of PBL for the Indian case. At McMaster University, the problem-based learning strategy is used to improve students' self-directed learning skills, interpersonal skills and problem solving skills (Woods, 1991). The problem-based learning approach is used to achieve professional and or technical skills at Imperial College, London (Cawley, 1991). In one of the Japanese examples of PBL implementation, the strategy is used for improving the information technology skills of students (Yoshio, 2009). At the Institute of Engineering in Nepal, at Tribhuvan University, project-based learning activities are introduced to produce qualified people for the country (Joshi & Joshi, 2011). At The polytechnic school of Agueda, Portugal, a focus is on students' personal growth along with the appropriate skill development (Oliveira, 2006).

At the Electrical Engineering Foundation in Sichuan University and at the National University of Singapore (NUS), the use of PBL strategy is emphasised to improve the quality of teaching and motivation of students (Ying, 2003, Mohanan, 2009). British universities are promoting the use of project led education in engineering (PBLE) to enhance engineering education (Moore & Willmot, 2003). Victoria University (VU) introduced problem-based pedagogy to address deficiencies in the professional engineering education in Australia and to attract students to engineering. Furthermore, these methods intend to help students understand the principles of engineering and engineering working environments (Graham, 2010). Other reasons include student recruitment and retention (Graham, 2010 & Royal Academy of Engineering, 2007). In addition, Barnveld & Strobel (2009) have summarised many more examples where PBL is practiced to improve student's motivation, learning, knowledge, and professional and process skills.

From the above examples, it is understood that PBL is implemented in programmes or courses worldwide for the following common reasons:

a. To enhance the quality of engineering education by improving teaching and learning practices
b. For conveying engineering principles and content learning
c. To motivate students for learning
d. To provide the authentic learning experience of solving engineering problems
e. Responding to changes in accreditation requirements
f. To enhance professional and interpersonal skills of students to prepare graduates for employment
g. To attract students to engineering education and to improve the retention rate of students.

After comparing these goals with the Indian case discussed in the previous chapter, it can be concluded that PBL could be relevant to the Indian context. However, the question still remains; does PBL practice help students to improve their professionally relevant skills? In the next section, the effectiveness of PBL to improve learning and professionally relevant skills is discussed.

2.3 Effects of PBL

A number of studies on student perceptions found that students were motivated to try a more active learning mode like PBL. Dochy et al (2003) analysed the effect of PBL on knowledge and skills. He pointed out a strong positive effect of PBL on the skills of the students. He concluded that, while students in PBL gained slightly less knowledge, they remembered more of the knowledge acquired. In the coming paragraphs, a review of literature is carried out to understand the effect of PBL practice on students' learning and skill levels.

2.3.1 Effect of PBL on student's learning

Chung & Chow (1999) reported that a PBL environment helped students in the development of skills and the improvement of their attitudes towards learning. PBL has also had a positive impact on student learning at Samford University, Birmingham. Introduction of the PBL curriculum was intended to improve academic performance (Iputo & Kwizera, 2005). A case study was conducted on first-year undergraduate students at Tun Hussein Onn University of Malaysia (UTHM) **(**Zainal & Nurzakiah, 2007). The results of this study indicated that the overall self-directed learning readiness (SDLR) level increased with PBL exposure **(**Zainal & Nurzakiah, 2007). Salleh et al (2007), mentioned that the students' content learning is improved. The research undertaken by four British Universities showed that project work can improve students' information retention rate. This study also revealed that information learned by project work had more than 80% retention compared to lectures, which had less than 20% retention when tested for one year (Moore & Willmot, 2003).

Eck & Mathews (2003) indicated that PBL has a favourable impact on students' learning. In other research, students claimed that PBL allowed them to better integrate theory into practice (Lo, 2004). Empirical studies conducted at Aalborg University concluded that the PBL environment provides ample learning opportunities through cooperation and collaboration with peers (Du & Kolmos, 2006, Shinde & Kolmos, 2011). Joshi & Joshi (2011), found that students' commitment toward group and project work is increased. Students particularly felt that they continued to learn much more from projects than from other traditional methods. The results showed that PBL lead to profound enhancement of the learning outcomes. Abdulwahed & Balid et al. (2007) mentioned that PBL influenced the intrinsic motivation to solve complex problems. They observed significant participation, attitude and motivation enhancement in the experimental group of students as compared to control groups. Mantry et al. (2008) found that the students achieved better scores in knowledge and skill tests, showed better attitudes towards learning and utilised the class time more effectively when taught in a PBL environment. She found that students supported PBL.

In another study, students reported that PBL is an effective method for learning course content (Javier & Perez, 2009). Debnath & Pandey's study (2011), also found PBL to be useful in helping students for content learning. Abhonkar, Sawant, & Horade, (2011) had collected students' responses who were working on an industry project. Students in this study mentioned that the project provided a good learning experience. Oliveira (2006) has found improvement in the students' grades.

From the above examples, it is seen that the PBL environment is conducive to increased motivation for learning in students and to providing an authentic learning experience. It has been found that PBL implementation resulted in improving academic performance, better content learning and information retention rate. In general, students found that the PBL intervention provided opportunity and motivation to learn, made the class livelier and stimulated the development of interpersonal and research skills.

2.3.2 Effect of PBL on skill levels of the students

The research performed in a number of British universities showed that project work can improve students' key transferable skills (Moore & Willmot, 2003) and has a favourable impact on skill levels (Eck & Mathews , 2003). Said et al. (2005) mentioned that PBL is a useful tool to develop the relevant transferable skills expected of professional engineers, such as critical thinking skills, communication skills and analytical skills. The findings also revealed that students improved in the generic skills like leadership, conflict management and decision making (Salleh et al 2007). Empirical studies conducted at Aalborg University concluded that PBL helped students to improve process competencies. Process skills are the skills, which are used in the application of knowledge. These include problem solving, critical thinking, communication, teamwork, self-assessment, change management and lifelong learning skills (Du & Kolmos, 2006, Shinde & Kolmos, 2011).

PBL methods were found to be effective in developing and enhancing generic skills in students at University Technology, Malaysia (UTM). Survey results indicated that the generic skills improved in 70% of students due to the introduction of PBL at UTM (Mohd Yusof et al, 2005). A case study conducted with first-year undergraduate students at Tun Hussein Onn University of Malaysia (UTHM) indicated that the overall self-directed learning readiness (SDLR) level increased with PBL exposure **(**Zainal & Nurzakiah, 2007). Mantry et al. (2008)

found that the PBL students achieved better scores in skill tests and showed better time management, presentation and teamwork skills. Singh et al. (2008) found that the use of projects helped students to understand aspects of engineering product development, techniques of team and project management.

In other research, (Javier & Perez, 2009) students reported that the PBL intervention stimulated the development of interpersonal and research skills. The students learned to work in a team and to search for the needed knowledge. Students mentioned that they learned to respect and adapt to other opinions. Students finished their projects successfully in time (Javier & Perez, 2009). In evaluation of the successful project led education (PLE) editions at University of Minho, Portugal, it has been found that students developed competencies mainly through project activities. Project management competencies like time management and management skills are being developed, as are team working competencies such as responsibility, leadership and problem solving.Writing and oral communication skills and personal competencies such as critical thinking and creativity are also being developed through this method. Also, ability to work in the group is increased (Bin & Bin, 2010).

In another example, Oliveira, (2006) has found that the students welcomed the PBL approach and noted that the students' grades were improved. He noted that PBL facilitated the development of personal and professional capabilities. The teachers (participants) in this research also agreed that PBL was in line with the requirements of professional education. Yoshio (2009) found PBL is effective for students developing the skills needed to be an IT professional. Debnath & Pandey (2011) remarked that PBL was useful in helping students acquire a skill needed for placement.

From the above synthesis, it can be concluded that the PBL environment is conducive to improving students' skill levels. The PBL approach has been found to be effective in developing students' technical or cognitive skills such as problem solving, critical and creative thinking and application of knowledge, and process skills such as project and time management, teamwork and leadership and writing and oral communication. Comparing these results with the skills demanded from the Indian engineering industry, the relevance of PBL for the Indian context could be established. Such comparison helped me to authenticate the choice of the PBL approach as a method for Indian engineering education (Shinde, 2011).

Having understood the usefulness of PBL for learning and improving skills, it was important to understand design aspects of PBL curriculum. In order to design a PBL curriculum, it was necessary to identify the important elements of a PBL curriculum. In the next section, various parameters involved in the PBL curriculum design are identified.

2.4 Parameters for PBL curriculum design

The PBL parameters can be defined as the essential elements required for the design of a PBL curriculum. The goal of this review section is to identify these parameters. From the PBL characteristics (Barrows, 1986) and PBL principles (Graaff & Kolmos, 2003) I understood that in PBL strategy, learning starts with an authentic problem. Hence, the choice of problem and its relative placement in the curriculum is considered to be an important parameter for design. Accordingly, in the coming section, I discussed the types of problems or various ways the PBL curriculum can be designed.

2.4.1 Types of PBL curriculums and Projects

Morgan (1983) suggested three methods of designing project curriculum. The first method is the project 'exercise' in which students apply previous knowledge. The second is the project 'components' in which projects are intended to add educational experiences.The third methodis called project 'orientation', in which the complete curriculum is organised around projects.

Ross (1991) developed a framework for problems that could be used for the design activity and to assess PBL practice. He offered three types of possible curricula – problem oriented, problem-based and problem solving. He further elaborated the different ways by which problems could be selected and presented in each type of curricula. These problems may last anywhere from a week to an entire semester in length. The problem could be selected to cover predefined areas of knowledge, to cover important concepts, ideas and principles of the course or in line with the field, professional practice and students' interests. The problem could be presented as an event, set of questions or statement (Ross, 1991).

According to Heitmann (1996), project-based learning could be applied to a single course as well as to the complete curriculum. These methods will be classified as project oriented approach or project-organised approach. The characteristics of project-oriented approach are as follows:

a. Approach is useful to integrate a small project within a single course and can be used with traditional teaching
b. Approach focuses on application and integration of previously acquired knowledge
c. Projects could be carried out in small groups

In his review paper on project-based learning, Thomas (2000) offered the following definition:

> ***"Projects are complex tasks, based on challenging questions or problems, that involve students in design, problem solving, decision making, or investigative activities; give students opportunity to work relatively autonomously over a period of time; and culminate in realistic products and presentations".(p-1)***

Thomas (2000) also discussed what qualifies as a PBL project. He mentioned five essential characteristics of PBL projects:

1. Projects are central to the curriculum and not peripheral
2. Project must drive students to struggle with central concepts and principles
3. Project encourages students in constructive investigation
4. Project must be student driven to some significant degree
5. Projects are realistic

These five characteristics are discussed in this paragraph. The first characteristic places emphasis on the relative placement of the project within the curriculum. Typically, this is aligned with the classical problem-based learning characteristics provided by Barrow (1986); where in problems are the starting point for learning. The second and fifth characteristics emphasise the content aspect of the project. The project must be authentic and must motivate students to learn central concepts and principles in the curriculum. In other words, the project must replicate the intention of the learning and must be placed within the disciplinary learning of the students' major. The third characteristic emphasises the learning process and motivation. The project should encourage students to investigate 'what they know' and 'what is to be learned'. In addition, the project should progress students through a continuous reciprocation between the application of existing knowledge (application) and new knowledge (construction). This reciprocation allows students to learn and construct knowledge. The fourth characteristic focused on the students' autonomy. In PBL projects it is expected that the students should take responsibility and lead the project independently and autonomously (self-directed learning). Thomas further mentioned that, in PBL projects, students have a significant degree of autonomy.

Gjengedal (2000) described three categories of projects based on students' autonomy and the project complexity. Basic projects help students to learn project skills. The second project type can be used for content delivery, and the third type is complex like an industry project. Alternatively, Graaff & Kolmos (2003) defined three types of projects as *task projects, discipline projects and problem projects* that differ in the degree of student autonomy. *Task projects* require student teams to work on projects that have been defined by the instructor and provide minimal student motivation and skill development. In discipline projects, the instructor defines the subject area of the projects and specifies tasks within it. The students have autonomy to identify the specific project and decide how to complete it. In problem projects, the students have almost complete autonomy in choosing their project and their approach to it. Hung (2009) described 3C (Context, Content and Connection) and 3R (Research, Reflect and Reason) approaches for PBL problem design.

Further explanation on design aspects PBL models could be referred to Savin-Baden (2000), who described five ways in which PBL models could be designed. These five models could be designed with respect to relative position and type of knowledge. For instance, a given model could be characterised by Model I or II. Model I is characterised by a view of knowledge that is essentially propositional. In this model, students are expected to become competent in applying knowledge while solving and managing the project. In Model II, the emphasis is on actions that enable students to become competent in practice.Model II is based on the overarching concept of 'know-how'. In Models III and IV, students might be motivated to move from 'know-how' to 'know-that' within disciplinary boundaries (Model III) or may transcend disciplinary boundaries (Model IV). The Model V *(critical contestability)* is characterised as a blend of all of the above models. In this model, students are challenged to critically contest, examine, reason and reflect.

In addition to the five models explained above, Savin-Baden & Major (2004) defined eight different curriculum modes in a problem-based learning approach. Each mode is characterised by the manner in which PBL is implemented and its position in the curriculum. For instance, Mode 1(*single module*) is characterised when PBL is applied in a single module or the course. Mode 2 (*a shoestring*) is characterised in which PBL is implemented in the curriculum for multiple courses. Teachers who are interested in implementing PBL run these PBL courses. Other teachers follow their preferred practices.

Mode 3 (*funnel*) is characterised by having students funnelled from a traditional lecture based curriculum in the earlier years of a programme to problem-based learning in pre-final or final years. In a way, this is a gradual approach to making students confront complexity. Mode 4 (*foundational*) is similar to Mode 3, with basic subjects being taught first and students gradually applying propositional knowledge to solve problems. This is a curriculum approach. Mode 5 (*two strands*) is characterised by two distinct and visible strands; one being in PBL and another being not necessarily traditional. Mode 6 (*patchwork*) is a curriculum approach in which students are presented with a variety of problems requiring a different number of times to solve (two, three, or four times) and in different courses. These courses may be related to each other or may not.

Mode 7 is characterised as an *integrated approach,* in which all the problems are arranged in order sequentially and better coherence is achieved in various courses. Also, there is vertical coherence with students presented simple problems in the earlier years and increasing complexity as students' progress to the next level. PBL is used as a philosophy to design curriculum. Mode 8 is a *complexity model* that is one step further than Mode 7. This model can be understood as the management of knowledge and capabilities. Savin-Baden shows with the development of these different curriculum models, that the CLPBL approach can be tight up in many different ways at the curriculum level.

2.4.2 Summing up

From the above analysis, it is understood that different authors preferred different definitions for the types of PBL problems, for example, basic or task projects, discipline projects or projects for content delivery, and complex or open projects. Furthermore, it is understood that the choice of project type depends on intention. For example, if intention is to give students a project experience then task projects will be preferable. If the intention of the project is to improve students' content learning, the discipline project would be preferred. If the objective is to give students more autonomy and exposure to critical thinking and problem solving, then the complex project would be best suitable. In addition, interdisciplinary projects can be designed to involve many students from different disciplines to develop interdisciplinary knowledge. The PBL curriculum type depends on the way the project is placed into the curriculum: at the beginning or end, or integrated into the whole curriculum. From the literature, it is understood that there are various ways PBL problems can be selected and integrated into the curriculum and still fall under one of the categories of PBL models (Savin-Baden, 2000) and modes (Savin-Baden & Major, 2004).

Although different authors preferred different definitions of the projects, they were in agreement that the chosen project must give students an authentic learning experience. The implied meaning of this is that the projects must be relevant to the profession and must be in line with the objectives of the programme or course. In this sense, it is understood that the choice of project is the most important design parameter for the PBL curriculum. In the PBL alignment model Graaff & Kolmos (2009) argued that, for effective PBL implementation, teaching-learning and evaluation strategy must also be aligned with the project. Also, as pointed out by Biggs (1996), effective learning in a curriculum requires that there be close alignment among the content, the teaching–learning methodologies, and the assessment and evaluation schemes. In view of these two statements, teaching-learning strategy and project evaluation are two important parameters for the design of PBL curriculum.

According to PBL principles and characteristics, in the PBL environment students are expected to work on a given project in small groups in the presence of a tutor. Hence, this method requires a tutor, project guide or a supervisor to comment on the project work. Consideration of different aspects of supervision can be given in the PBL curriculum design. To facilitate the PBL process, groups may be provided with a group room or physical space to meet where students can discuss project work. Furthermore, during the project work the group may need to refer to books and other published material for which a well-equipped library would be helpful. In the PBL alignment model, Graaff & Kolmos (2009) stated that institutional resources like group rooms and library resources could play important role in the effective change to PBL curriculum. From the above discussion it is concluded that, to make an effective design of the PBL curriculum, it is required to choose a project in line with the course content, teaching learning and evaluation strategy. It is also necessary that physical resources of the institute can be utilised.

Part 2

In this section, a review of course level PBL (CLPBL) practices in engineering education is presented. The intention of this review is to understand how researchers and practitioners have used different strategies to practice PBL. It is important to examine the variety of practices to get motivation for the design of an appropriate model for the Indian case. Furthermore, it is my objective to find the gaps or areas where there is a need to carry out research in national and international perspectives.

To carry out this review, four national and 19 international examples are selected from different continents and countries where PBL is used inthe undergraduate engineering curriculum. Most of these examples are referenced from international journals like EJEE (European Journal of Engineering Education), JEE (Journal of Engineering Education) and IJEE (International Journal of Engineering Education) and international conferences, and research symposiums. Most of the selected examples were published during the years 2000-2013, making them representative of recent practices. The synthesis of these practices was made in order to understand the types of problems or projects, the project evaluation methods, group composition, role of teacher and supervisor and resource utilisation. In the coming subsection, all practices are elaborated first, and then discussed on various predefined parameters.

2.5 Examples of Course level Implementation

At McMaster University, Canada, a concept of problem-based learning is used in an engineering economics course for chemical engineering. The teacher used the course objectives to design the set of problems. The whole class (class size 20-45 students) was divided into groups of five students. Students were then asked to grapple with the assigned problems. In this case, the same teacher also acted as a resource to support the problem-solving process. The students were asked to discuss their solutions in a mini lecture with facilitation from teacher. The teacher observed that, in these mini lectures, students taught each other and discussed the content. In this way, PBL was helpful forlearning (Woods, 1991).

In a public university in São Carlos, Brazil, PBL was implemented in an administration course for a postgraduate production-engineering curriculum. The class size was 23. The students formed groups of four or five. In line with the instructional goals, a set of 12 PBL problems was designed and presented to the groups each week. The teacher held discussions with the student groups on each problem initially, and then they were asked to solve the problems during the semester. To assess the groups’ performance, the teacher used presentations, reports and peer evaluation strategy. In the course feedback, students stated that this intervention provided opportunity and motivation to learn, made the class livelier and stimulated the development of interpersonal and research skills. The students learned to work in teams and to search for knowledge. Students mentioned that they learned to respect and adapt to other opinions (Luis et al 2005).

At the Stevens Institute of Technology (SIT), Hoboken, USA, project-based learning was implemented in the junior-level mechanical engineering course on mechanisms and machine dynamics. The existing course was revised to incorporate the project-based learning approach. Projects were designed with the course structure and content in mind. The intention was to improve student's motivation, create an interest in learning, and develop analysis skills and non-technical skills. The project was presented to the students and important requirements were outlined at the beginning of the semester. The class was divided into groups of three or four students. The project was assessed via a progress report, two progress presentations and a final presentation by each student team. In addition to this, peer assessment was used to evaluate individual contributions. The introduction of PBL was shown to significantly improve interaction between the instructor and the students. It resulted in a better learning environment. The researcher mentioned that it is difficult to evaluate individual contributions and achieved skill levels of the team members in the group projects (Esche, 2002).

In one of the examples from Syria, a traditional and PBL pedagogy was compared in a quasi-experimental setting with reference to the embedded system course. The experimental group was assigned problems to solve during and after each session. These problems were kept for the purpose of analysis and comparison. The teacher observed significant participation, better attitude and motivation enhancement of the experimental group students. In addition, PBL influenced the intrinsic motivation to solve complex problems (Abdulwahed & Balid et al., 2009).

At Curtin University of Technology, Australia**,** Principles & Communications is a fundamental 14-week unit for all first-year engineering students. For this unit**,** the design/build project is offered to the students. The project is structured around the usual processes, as seen in actual engineering projects. Students groups are asked to make elementary engineering constructions such as bridges, to satisfy the certain stipulated conditions. The aim of this exercise is to encourage first year engineers to understand the various stages and challenges associated with a real engineering project (Graham, 2010).

To incorporate the PBL approach, a new course '1006ENG Design and Professional Skills' was designed at Griffith University in Australia. This course aimed to introduce engineering design and practice and to enhance problem-solving abilities, and student learning. In this course, three projects were designed in accordance with the students' major. For example, mechanical engineering students were asked to design products like cars, electrical engineering students were offered motors, and civil engineering students were asked to prepare scale models of construction sites. Students in this course were evaluated by using self and peer assessment, as well as test scores. To evaluate the outcome of this course, a survey was conducted at the end of the semester. In this survey, 72 students responded, a response rate of 30.4. A one-way ANOVA (Analysis of Variance) was used to find significant difference between the responses of the students. An evaluation revealed that the students enjoyed the PBL experience. The data suggested that the courses were effective for their intended purposes. Students perceived teamwork as valuable and enjoyed designing 'real world' practical applications that related closely to the engineering profession (Palmer & Hall, 2011).

In another example, the mechanical engineering department at Imperial College, London, applied problem-based learning to its final year course on vibrations. The teacher designed three pairs of problems (six problems) related to the course. The whole class (class size of 48 students) was divided into groups of three or four. Groups were then asked to solve the problem and prepare a report about their proposed solution. In this example, the student groups evaluated the solutions proposed by the other groups. These activities were all done in the presence of a teacher, who also acted as supervisor for the groups (Cawley, 1991).

The Faculty of Engineering and Computing at Coventry University implemented an ‘activity-led’ curriculum. This curriculum had a six-week project at the start of each academic year. The results of these activities indicated a positive impact on the participating students’ results. The Electronic and Electrical Engineering department of UCL has adopted problem-based learning in a number of modules across the first three years of its curriculum. These initiatives are led by the interested faculty. In another case, the Department of Civil, Environmental and Geomatic Engineering at UCL recently restructured their undergraduate curriculum. The first two years of the program run on five-week cycles. At the beginning of each cycle, students are given a project based learning scenario, followed by 4 weeks of relevant lecture notes and an intensive week of working in teams on the problem set (Royal Academy of Engineering, 2007).

The Department of Mechanical Engineering at the University of Strathclyde re-designed the first three semesters of their program around PJBL with a view to engage and motivate students. This curriculum has three types of projects. First is the first year mechanical dissection module, in which students are asked to dismantle complex mechanical assembly. The second project type is the artefact analysis project, which requires student groups to take one element of a more complex engineering product such as a car and investigate its properties, function, design and manufacture. The third project type is the ‘low-tech’ community-based project, in which final year student groups are asked to develop robust and sustainable solutions to solve real community problems (Royal Academy of Engineering, 2007).

In the mechanical engineering department of the Catholic University of Louvain, Belgium, the machine design course has been modified. Two projects were designed to address learning objectives. The intention of the PBL intervention was to make the students more active in their learning. Two types of projects were used in this course: assembly and disassembly of a car and the process design of a machine. The first project type was split into three parts: engine disassembly, functional analysis and drawing. Teams of two students were allowed to disassemble and reassemblean engine, followed by a functional analysis of an engine component. This was done in the presence of expert faculty. In the functional analysis, students took measurements to examine the constructional and structural features and to investigate the tolerances and surface finish required for the component to perform its intended functions. The groups were then asked to make a drawing of the part, first manually and then using AUTOCAD (it is a drawing and drafting software). In this way, students were exposed to active learning and course objectives were achieved. In the second project type, students were explained the basics of a process design, using a washing machine, lawn mover etc. as examples. Students worked in teams of four. The students were required to design a machine or a part of a machine for use by the relevant industry. The students carried out the design at the university and presented it in front of a jury composed of academic staff and engineers from industry. Assessment of the projects was based on the report, and group work performed during the semester. This is followed by an oral examination. Evaluation was also based on efforts put for solving a problem and drawing a part of a machine (Raucent, 2001). Evaluation of these projects showed that students’ improved their problem-solving skill capabilities. Feedback from students revealed that they experienced difficulties in finding relevant information and in time management. The researcher realised that relatively less topics are covered in the project work, however the work led to a deeper understanding of the content. The researcher added that designing a good problem to cover learning objectives appeared to be a difficult task (Raucent, 2001).

At the University of Minho, Portugal, PLE (Project Led Education) methodology was implemented for a course on Industrial and Management Engineering (IME). An interdisciplinary project was proposed for the course. This model focused on a coaching strategy in which the supervisors facilitated the students' learning. The University of Tampere collaborated on the curriculum design process. It was found that students developed project management competencies like time management and management skills, team working competencies such as responsibility, leadership and problem solving, and personal competencies such as critical thinking, creativity, writing and oral communication skills. In addition, the ability to work in a group increased. However, teamwork was recognised as a difficult aspect of the whole process (Bin & Bin, 2010).

The Technical university of Madrid, Spain, used PBL methodology to design the Real Time System course. The main aim was to explain to students the theoretical basis used for the construction of the real time system. The groups were asked to go through various learning tasks such as tutorials, presentations, lectures, tests and lab sessions. The project was divided into six practical tasks. The evaluation strategy included: written test, project work, oral presentations and teamwork. The students maintained portfolios of their work. The survey method was used to assess the usefulness of the course. Students reported that PBL was an effective method for learning the course content (Javier & Perez, 2009).

Since 2001, the polytechnic of Agueda, Portugal, has been using project-based learning in its engineering programmes. A group of courses are used to create project themes and vice versa. The projects are given to small groups of students, to whom meeting space, a computer and a supervisor are provided. The role of the supervisor is to help, guide and monitor the progress of the students. The supervisor also takes part in the project evaluation. The projects are evaluated based on an oral presentation, reports and question answers. To assess the effectiveness of this initiative, a case study was conducted during which surveys and interviews of staff and students were used to collect data. Students welcomed the PBL approach and indicated the development of personal and professional capabilities. Most of the teachers agreed that PBL was in line with the requirements of professional education. The teachers pointed out the increase in their workload due to PBL activity. The new teachers said it was challenging to keep up with this new course culture. The evaluation suggested that the students' grades improved (Oliveira, 2006).

In the year 2004-2005, the University of Technology, Malaysia (UTM), introduced PBL for a process control course. About 70% of the syllabus was covered in classes using PBL; the rest used cooperative learning (CL) and mini lectures. At the end of the semester, a survey was taken during a forum with the students who had undergone PBL and the top academic administrators of UTM in order to evaluate the outcomes of PBL (Mohd Yusof et al., 2005).

In the Department of Electrical Engineering, at University of Malaya, Malaysia, problem-based learning can be found in the first-year undergraduate engineering course on digital systems. In this course, the students were given a course related problem. The problem focuses on design of two-switch staircase lighting. This problem focused on the skills required to design digital circuits. The problem was designed by the researcher to provide useful engineering experience to the students. In view of this, PBL is thought to be a useful tool in developing the relevant transferable skills expected of engineers such as critical thinking skills, communication skills and analytical skills (Said et al., 2005).

In one Japanese case, PBL implementation was is used in the curriculum for the master's programme of Information System Architecture. The professor designed the projects and gave them to groups of 3-7 students. The aim of the model was to allow students to develop the skills needed for an IT professional. The researcher noted that PBL was effective in developing the skills fitting of an IT education (Yoshio, 2009). At Tribhuvan University, Nepal, in all programmes at the final year of bachelor level courses, one project (capstone) is compulsory for every student. Students said that they learned much from the projects, compared to other traditional methods, and showed good commitment toward group and project work (Joshi & Joshi, 2011).

PBL practices from India

The effectiveness of PBL instructions on the knowledge and skills of students in the undergraduate program for Electronics & Communication Engineering at Chitkara Institute of Engineering and Technology, Punjab, was assessed in three subjects over a period of four semesters. Mantry et al. (2008) compared traditional pedagogy with PBL. The authors designed open-ended technical problems (TPs) to achieve learning objectives. The scope of the TPs was designed such that the students could achieve all the technical nodes while attempting to solve them. Students were informed about PBL and the evaluation strategies before implementation. In this experiment, the students achieved better scores in knowledge and skill tests, showed better attitudes towards learning and utilised the class time more effectively when taught in the PBL environment. At the end of the semester, feedback from students was taken for a particular course and showed that the students supported PBL. Presentation and teamwork skills were also largely improved in the PBL class (Mantry et al., 2008).

In another example, the engineering students of the Indian Institute of Technology (IIT), Delhi were asked to build the Robot to perform specific tasks (the project) under the concept of Robotic Competition. Singh et al. (2008) collected the experiences of engineering students who participated in this competition. Authors realised the impact of such a competition and found that the use of projects helped students to understand aspects of engineering product development, techniques for team and project management (Singh et al., 2008).

At the Jaipur Engineering College and Research Centre, Jaipur, project-based learning was applied to improve students' on-campus recruitment. Students had projects as a compulsory course in their curriculum in the final semester of engineering. In this study, PBL was found useful in helping students acquire the skill and content learning needed for campus placement (Debnath & Pandey, 2011). In Sinhgad Institute of Technology, Lonavala, students' experiences working on an industry project were gathered. Students' responses suggested that their learning was improved by the project. Although these projects gave good experience, students mentioned that they needed to work beyond normal working hours to finish these projects (Abhonkar, Sawant, & Horade, 2011).

In addition to the above listed experiments, there are numerous initiatives taking place in India to implement PBL. Chattisgarh Swami Vivekanand Technical University, Bhilai, has established a PBL learning centre and has offered PBL in Bachelor degree courses of engineering and technology since 2008 (http://targetstudy.com). Apart from engineering, many studies of PBL and its implementation in medical curricula can be found in the literature (Roche & Abraham, 2011; and Shrivastava S, Shrivastava P & Ramasamy J., 2013). Homi Bhabha Centre for Science Education, Mumbai conducted a PBL workshop series for middle school teachers of humanities science (HBCSE, 2008). In a bid to get rid of rote learning, the Gujarat state education department introduced project-based learning from 9th class in the schools affiliated with the Gujarat Secondary and Higher Secondary Education Board (GSHSEB). The National Council for Education Research and Training (NCERT) has provided training to teachers on the design of course projects and preparing students for the projects (Yagnik, 2010). Suzie Boss (2011) also reported their experiences from Indian secondary schools.

In this section, 23 examples are quoted showing the widespread practices of PBL in different continents. In the coming section, the above examples will be analysed for different parameters. From fewer PBL practices from India, it can be concluded that the PBL in India is less researched and there is a need for representative framework for PBL implementation in India.

2.5.1 Types of problems

In most of the cases, teachers used the course content or objectives to design the set of problems or project (Woods, 1991, Esche, 2002, Raucent, 2001, Said et al. 2005, Mantry et al. 2008). To design the project the existing course may be revised (Woods, 1991, Raucent, 2001) or may not be (Esche, 2002) revised. Thus use of course content may help in designing an authentic project according to the students' intended profession and in line with the instructional objectives.

The next step is to explain this problem or project to the students. Many authors informed or presented students about problems or projects at the start of the semester. Important requirements and evaluation strategies were told to the students at the start or during the semester (Woods, 1991, Esche, 2002, Mantry et al., 2008). Then the student groups were asked to discuss or grapple with these problems. Sometimes, students were asked to solve multiple problems during a semester (Woods, 1991, Cawley, 1991, Mantry et al., 2008) or they worked on a single project (Esche, 2002, Graham, 2010) which was divided in the set of tasks or activities (Javier & Perez, 2009).

In many cases, the design or build projectwas offered to the students in the form of asking students to prepare products to satisfy certain stipulated conditions. For example, students were asked to build abridge (Graham, 2010), car, motor, scale model of a construction site (Palmer & Hall, 2011) or to design two-switch staircase lighting (Said et al., 2005. Sometimes final year student groups were asked to complete one major project (capstone) and to develop solutions to solve real community problems (Joshi & Joshi, 2011, Royal Academy of Engineering, 2007, Debnath & Pandey, 2011).

In some examples, a mechanical dissection or assembly-disassembly module was used. Artefact analysis projects, which require student groups to each take one element of a more complex engineering product, such as a car, and investigate its properties, function, design and manufacture, were used in two programmes (Raucent, 2001, Royal Academy of Engineering, 2007).

In the Industry-based projects, student groups are asked to solve real commercial problems in the presence or for the industry (Raucent, 2001, Royal Academy of Engineering, 2007, Abhonkar, Sawant, & Horade, 2011). These projects provide scope for interaction with the industry experts. Sometimes interdisciplinary project proposals were created to give students scientific knowledge and breadth (Bin & Bin, 2010). In one case, the concept of a robotic competition was used (Singh et al., 2008).

From the above examples, it can be concluded that there is a huge variety in the problems or projects. In the referred cases, the duration for completion of the project varied from one week (Woods, 1991, Cawley, 1991) to a year (Joshi & Joshi, 2011, Royal Academy of Engineering, 2007). For example, at the Department of Civil, Environmental and Geomatic Engineering at UCL, the students were given a PjBL 'scenario' in which students spent one week working on the problem set (Royal Academy of Engineering, 2007). Sometimes the projects may require many weeks. For example, the Faculty of Engineering and Computing Coventry University incorporates full-time 6-week projects (Royal Academy of Engineering,

2007) or a whole semester for completion (Said et al., 2005). In capstone projects, students are required to work for a complete year (Joshi & Joshi, 2011, Royal Academy of Engineering, 2007). Generally, these are placed in the final years of undergraduate courses. These projects mostly resemble problem, innovation or design projects. The final year students in this type of project apply knowledge gained from the previous courses.

Summary

In most of the cases, a teacher or group of teachers who understood PBL, have started use of PBL in their course or programme. It is understood that problems or projects used in the referred cases are of many types. These projects are designed with course content in mind. Hence, Indian curriculum or courses must be referred to in designing projects for Indian institutes. In the examples given, the teacher at the beginning of the semester presented the problems and evaluation strategies to the students and informed them of expectations. Project scenarios, course related problems, assignment problems, or open ended technical problems were a few simple projects which could be done by the students in a few weeks. Less complex projects such as the design or construction of artefacts, artefact analysis/ dissection or assembly-disassembly, or robotic competition may take an entire semester. The capstone project, innovation projects, community based projects andindustry problems are relatively complex projects and needed longer duration, as much as one year, for completion. These examples and their process shed light on various types of projects and provide practical ways by which projects can be prepared for the Indian case.

The project is important. However, in the project work, it is also necessary that the project groups or learning process or both must be supported by a suitable supporting structure. In many cases students were asked to go through various learning tasks such as tutorials, presentations, lectures, tests and lab sessions (Javier & Perez, 2009). At the polytechnic of Agueda, similar to Aalborg University, Denmark, the project groups were provided meeting space, a computer and a supervisor (Oliveira, 2006). At the University Technology, Malaysia (UTM) about 70% of the syllabus was covered in classes using PBL and the rest using cooperative learning (CL) and mini lectures (Mohd Yusof et al., 2005). From these few examples, it is learned that tutorials, presentations, lectures, tests and lab sessions play a significant role in supporting the learning process in the PBL strategy. Hence, while designing a PBL model for the Indian case, it is necessary to have a strategy for the effective usage and organisation of these elements.

2.5.2 Project Course Evaluation

To assess the PBL course, teachers may use different strategies. In most of the cases, students carried out the design and made a presentation in front of a jury composed of teachers and an external evaluator. Assessment of the projects is based on the work performed during the semester (report, group, work, etc.), an oral examination on basic knowledge in engineering design, answers to theoretical questions, solving a problem and drawing a part of a machine (Raucent, 2001). Javier & Perez (2009) included a written test, project work, oral presentations and teamwork in the evaluation strategy. Luis et al. (2005) mentioned that the students' final marks were derived from the teacher's evaluations of group work, presentations, reports and peer evaluation (Luis et al., 2005, Raucent, 2001). In another case, the project was assessed through a progress report, two progress presentations and a final presentation made by a student team. In addition, to evaluate individual contributions, peer assessment was used (Esche, 2002). In some cases, the student groups evaluated the performance of students (Cawley, 1991). Mantry et al., (2008) used knowledge and skill tests or course grades to compare the performance of control and treatment groups.

In summary, it can be said that the assessment and evaluation of the PBL course could be done on the basis of the work performed by the students during the semester and by assessing students project reports, group work, an oral examination, answer to theoretical questions, solving a problem and/or drawing a part of a machine. The academic performance of the students can also be used to assess theevaluation of the project course. For the Indian case, few of these strategies can be used.

2.5.3 Group composition

Learning in groups or cooperative learning is one of the PBL principles. In the above mentioned cases, it has been observed that the whole class is divided into manageable groups by the teacher. The choice of teammates, however, is left to the students. For example, one teacher divided his class size of 20-45 students into groups of five students (Woods, 1991). In another case, the 23 students formed groups of four or five (Luis et al., 2005). In two other cases, the class were divided into groups of three or four students (Cawley, 1991, Esche, 2002). In one case, a team of two students was used for a dissection module and, in the same class; teams of four students were formed for an industrial project (Raucent, 2001). In an IT strategy course, the projects were given to groups of 3-7 students (Yoshio, 2009).

In most of the practices discussed above, groups are made from four-five students. There are multiple variables based on which group composition is decided. The group composition is dependent on the type of problem (see Raucent, 2001). The workload of the group can also be dependent on the type of the problem. In my opinion, the teacher who designed the project is in the best position to judge the workload that students may have to deal with. He needs to think about this factor in determining group size, as fewer students in a group may put undue pressure on the students while more students per group may reduce the workload considerably. If the number is large, there is a possibility of the group dividing in to two subgroups, which is not good for group dynamics. This number may also be decided based on the number of students in a class and the availability of staff or supervisors. So, group composition is a part of the strategic or practical decision of the teacher or the programme managers.

2.5.4 Role of Teacher and supervisor

In the referred cases, the teacher used the course objectives and content to design the set of problems or project (Woods, 1991, Cawley, 1991, Yoshio, 2009, Mantry et al., 2008). In some cases, a teacher also acted as a resource person who observed students project activities (Woods, 1991, Cawley, 1991). In other cases, the teacher acted as one of the supervisors for the groups (Cawley, 1991, Bin & Bin, 2010, Mantry et al., 2008). The role of the supervisor was to help, guide and monitor the progress of students. He also took part in the project evaluation (Yoshio, 2009).

Apart from usual role of teacher and evaluator, the teacher in PBL courses may have to assume different roles based on various situations. He could be the consultant (mostly applicable in medical education), mediator, learner, or resource person (Woods, 1991). When the groups have conflict due to attitude or difference in opinion, the tutor has to step in to soften the situation. The goal would be to bring the group to work on the project. The situation may arise where students bring forth a problem related to content, which the tutor cannot answer. In these circumstances, the tutor’s ability to admit his own lack of knowledge and willingness to learn will be tested. It is acceptable that it may not be possible for a tutor to know each aspect of the problem, which the students are trying to grapple with. In such cases, the teacher would assume the role of a learner (Wilkerson & Hundert, 1991). The tutor may not be necessarily an expert in the topic. The tutor's role is to guide and help the students through each of the successive stages of their discussion and decision-making. He would also prevent or remediate difficulties that may arise in the dynamics of group interaction. For PBL implementation, staff training in the areas of curriculum design, assessment and in the role of tutor is emphasised (Engel, 1991). The role of the facilitator is also to supply additional learning material to the students on request (Ross, 1991). Barrows (2001) summarised the teacher's role as a facilitator, guide, co-learner, tutor or professional consultant. The teacher is also a designer, researcher (in most of cases) and can become an agent of change for the institute.

2.6 Perspectives for the research

In this chapter, the theoretical framework of PBL approaches to professional education was reviewed. This framework suggests that PBL pedagogy cannot be defined, as there are many models and diverse practices, which satisfy PBL principles. Worldwide, the PBL word in its abbreviated form is used to describe diverse educational practices. This may be because these practices are developed by considering local context, academic and administrative culture. Furthermore, from this review it is concluded that the characteristics of PBL model also depends on motive behind PBL implementation. It is reported that PBL is a useful strategy in motivating students' learning by engaging them to confront problems. The use of projects helped students to understand aspects of engineering and subject content, and developed their ability to apply it to a real world context. Research showed that well-structured project work can improve students' technical skills such as problem solving and process skills such as communication, teamwork and project management. Studies have also shown that information learned through project work is better retained than lecture based learning. From this review, it is concluded that PBL as a successful approach in the field of engineering education. In addition to the positive results of PBL discussed above, there are areas where research can be done.

As a result of globalisation, a professional engineer is expected to work in diverse international, social and cultural environments. From the global employment perspective, the industry expects its professionals to have a different set of skills such as technical, personal and social skills. In view of these changing demands from the industry, many education systems, including India, have responded by adapting to outcome based education. In the backdrop of changing scenarios new competencies and accreditation requirements, there is a need to modify the existing PBL models or to develop new PBL models. It has been identified that the design and implementation of the PBL model is one of the important issues (Mohanan, 2009), which may be due to a lack of confidence, knowledge and experience for design. The design of PBL curriculum in response to changes in engineering education could be an important research area. Since social, academic, economic, and political culture of the country influence PBL model design (Josef, 2008), this influence could be investigated further. In this sense, India being a different culture, the development of the PBL model for India would contribute to this research. It has also been questioned whether, in the project work, the students really learn what they are supposed to (Raucent, 2001) as relatively fewer topics are covered. The project design's ability to cover learning objectives and to provide authentic learning experience is another research possibility at the Indian institute.

PBL originated in the western world, whose academic culture, facilities and resources are different than in India. In India, the traditional instruction based strategy is followed. Institutional facilities are provided to support this instruction based pedagogy and Indian educators and students are used to it. It is understood that, for effective PBL implementation, the motivation of staff and top management would be required. It is anticipated that there will be resistance to change. There is a shortage of trained faculty to deal with the huge student population. Usually engineering classes have a large number of students (60-80). In addition, finances, material artefacts and time management are factors, which could influence implementation efficiency and could be investigated. How PBL could be implemented in the Indian institute with existing academic facilities could be another area of the research. Also, research could be done to find out the drivers and challenges of PBL implementation in the Indian institute.

Research results from the past seemed to be inconclusive on the effectiveness of PBL. The data at Samford University suggested that the standardised tests provided little information to support PBL. Hence there is a need to develop criteria for PBL assessment and evaluation (Eck & Mathews, 2003). The design and application of both the assessment and evaluation processes for the PBL experiences are important areas of research. Furthermore, the different dimensions of PBL such as group work, learning and effect on grades add further complexity to the assessment issue. For example, the evaluation at University of Minho, Portugal shows that teamwork is a difficult aspect of the PBL process (Bin & Bin, 2010). Also, there is a considerable challenge to evaluate individual contributions and achieved skill levels of the team members in the group projects (Esche, 2002). Investigating the effectiveness of the PBL in different contexts and in the variety of professional fields could be a major research area. In the context of the current research, the effectiveness of PBL in the Indian engineering educational context can be assessed. For assessment and evaluation purposes, suitable instruments could be designed. As discussed in the first chapter, the objective of this research would be to design a PBL model for the Indian engineering institute and assess its effects on student learning and the achievement of learning outcomes.

Addressing all the research areas is beyond the scope of this paper. In this paragraph, the areas, which may not be directly dealt with in this research, are noted. There is ascope to assess the impact of PBL on staff and students' life and workload, upon the institution, or on the cost of education. In the literature, I found that many course-level PBL implementation was exercised by 'champion faculty'. A review of theUK approaches to engineering highlighted an issue in sustainability, as most PBL activities cannot move forward due to the absence of 'champion faculty' due to retirement or moving on. In line with this issue, research could be done on the sustainability of PBL in the department in the presence and in the absence of a 'champion faculty'. Similar research can be applied in the case of changes in top management. Also, many universities have designed or modified their existing resources to support the transition from traditional teaching to PBL. This change results in a need for training and change in the educational philosophy of that institution including staff, students, management and educators. There is a possibility to explore the effect of these training or orientation activities in motivating and managing the change from traditional pedagogy to PBL.

Concluding remarks

From this review, it is concluded that PBL could be a useful strategy to motivate Indian students for learning and to achieve the desired set of skills required from graduate engineers, and that it can form the basis for choosing problem and project-based learning over traditional pedagogy. From limited number of PBL practices from India, it is evident that there is a need to evolve system level or structural changes in engineering education to ensure growth of PBL in India. It is concluded that there is a huge scope for scientific research in the design and implementation of PBL in Indian institutes and in assessing its effectiveness in addressing the issues in engineering education in India. For the current research, this literature guided me to understand the different parameters that need to be considered for the PBL curriculum design. Developing a PBL curriculum is a difficult task as it involves finding out relevant contextualised problems, evaluation strategy, alignment of resources, staff and management support etc. Also, it is understood that change to the PBL pedagogy needs to be managed through a properly designed model with careful planning and given consideration to the local conditions.

Chapter 3

Research Questions and Methodology

The previous chapter highlighted the need for a PBL model design to address the issues in engineering education in India. Also, the literature review provided theoretical insight into the parameters improved by the use of PBL curriculum design. It is understood that this design must be done in line with local academic conditions and culture. It has been shown that the research questions influence the research methodology. Accordingly, in this chapter the research objectives and questions will be formulated. Furthermore, the methodology that has been adapted for the research will be explained.

3.1 Research objectives and questions

From the literature review, it has been shown that the PBL approach originated in western countries. In recent years, many Asian universities have developed PBL models to suit their local academic culture and values. In line with this, there is a need for the design of a PBL model for the Indian context. Sinhgad Institute of Technology, Lonavala (SITL) was selected to represent the Indian context for the purpose of this study. The focus of this research was to design a single course using the PBL principles within the existing academic setting of the SITL. Furthermore, this PBL course was to be implemented and investigated to assess its effect on SITL students. The objectives for the study are as defined below:

> *1. To design a course using PBL principles to fulfil students' learning requirements and to promote achievement of learning outcomes*
>
> 2. *To evaluate the impact of the designed course in relation to objective 1.*

To attain the above research objectives, the following research questions were formulated:

Table 3.1 Research Questions

The Main Research Question	What are the effects of the course level PBL model on Indian students' learning?			
Subsidiary research questions	A	What are the teaching and learning elements in the design of a CLPBL?	B	What is the impact of the CL PBL model on students' learning?

From table 3.1 it can be seen that the overall research question is split into two parts. Part A focuses on the design of the PBL course by adjusting the PBL principles to the existing course. The focus of this research is to understand the constraints, issues and opportunities available in integrating PBL into the existing course. Hence, the objective is to decide the nature of problem and design activities that would best suit the students' learning requirements.This study also aims to determine the nature of supervision and resource management (time, facilities) which may be needed to support the PBL course. The overall framework that combines course and project activities, supervision, and resources is termed as course level PBL (CLPBL).

In Part B, the focus is to evaluate the effectiveness of the CLPBL in fulfilling students' learning requirements and in promoting the achievement of the learning outcomes defined by ABET criteria. The research in this part includes the design of instruments for data collection to facilitate the evaluation of CLPBL. Having introduced the research objectives and questions, please proceed to the next section where I elaborate onwhich methodology is adapted to address the research questions.

3.2 Methodology

Case & Gregory (2011) defined methodology as the following:

> ***"Methodology can be seen as the process which links a choice and use of particular methods to the desired outcomes and objectives. There is not a right methodology, choice of which is determined and depends on the research question and decision to opt for a particular methodology lies to the assumptions and beliefs of the researcher(s)"(p-189).***

The choice of methodology largely depends on the objectives of the research and the research questions. Therefore, to suit the objective and questions of this research project, the methodology should meet following criteria:

1. It should enable modification of the current teaching-learning practices to establish new practices for the institute

2. It should enable the design of a CLPBL model

3. It should enable the desired research to be conducted

To find a suitable methodology that would qualify in terms of the above criteria, I referred to the literature available on methodologies used in other engineering education research (Case & Gregory, 2011). Initially, case study and action research methodologies were considered and will be explained later in this chapter. However, Design Based Research (DBR) emerged as the most appropriate methodology to meet the stated requirements. The characteristics of DBR are discussed in the next section.

3.3 Design Based Research (DBR)

Ann Brown coined the concept 'design experiments' (Barab & Squire, 2004). She found that laboratory settings were not sufficient to explain classroom learning. Owing to the limitations of laboratory experimentation, she envisioned the need to develop an approach for better understanding learning in a classroom setting (Brown, 1992). Instead of controlled experiments, Brown envisioned the classroom as a natural lab. Thus the idea of conducting a classroom experiment by intervention design arose. During the same year, Collin (Collin, 1992) defined the term 'design science'. He defined design science as the science of 'designing the artefacts and studying the behaviour of these artefacts under the different conditions'. In his view, design science could be implemented in educational research. Collin suggested that there were similarities between the two fields. He suggested that, instead of engineering artefacts, the 'learning environment can be designed and tested to investigate its effect on teaching and learning'. This insight is in very close alignment with the research objectives mentioned earlier.

Since, the pioneering work of Brown (1992) and Collins (1992), design experiments as a methodology have steadily increased in educational research. Examples of experiments can be found in the Handbook of Research on Math and Science Education (Kelly & Lesh, 2000).Although 'design experiments' and 'design science' have historically had similar meanings, the method has been commonly referred to as design based research (DBR) in the recent literature (Sandoval & Bell, 2004).

3.3.1 Definition of DBR

DBR is considered to be an emerging field in the landscape of education research (DBRC, 2003). Its ability to ground the research in practice makes DBR a promising methodology for educational interventions. DBR is used as a method for understanding learning in the complex environment or for designing a new learning environment to improve the learning of the participants involved.

Shavelson et al. (2003) described DBR as follows:

> ***"DBR is a research which strongly relies on a prior research, and is seldom carried out in an educational setting. It seeks to trace the evolution of learning in complex and messy settings like classrooms and schools. DBR tests and build theories of teaching-learning. It produces instructional tools that survive the challenge of everyday practice" (p-25)***

This definition provides deeper insight and interconnection between three important goals of DBR as a research, development of theory and improvement in pedagogical practice. One of the most cited definition of DBR (Cobb et al 2003) in the literature is as follows

> ***"Design experiments entail both "engineering" particular forms of learning and systematically studying those forms of learning within the context defined by the means of supporting them. This designed context is subject to test and revision, and the successive iterations that result play a role similar to that of systematic variation in experiment" (p- 2).***

The above definition addresses three aspects of DBR: design, test and revision of design. The definition indicates that DBR provides the required characteristics for designing educational interventions and test them in a real life context. Furthermore, the newly designed interventions could be revised in successive iterations. Wang &Hannafin (2005) similarly defined DBR as,

> ***"A systematic but flexible methodology aimed to improve educational practice through iterative analysis, design, development and implementation, based on collaboration among researchers, and practitioners in a real world setting, and leading to contextually sensitive design principles and theories" (p. 5)***

This definition outlines the suitability of the DBR method in addressing issues of context by designing an intervention to improve practice. Thus, intervention design requires an understanding of the context in which it is to be implemented and collaboration with practitioners. Salomon (1993) asserted that the learning environment could be designed to initiate cognition and to improve learning. In this sense, DBR complements the cognitive process. Barab & Squire, (2004) stated that DBR is based on the fact that individuals and learning environments are inseparable. In other words, there exists a close relation between the learner and learning environment. The learning environment could be designed to enable an effective learning process.

3.3.2 Characteristics of DBR

The previous discussion identified DBR as a useful methodology for the design of educational interventions and for studying its effect on teaching and learning. DBR illustrates how elements (or issues) of the learning environment can be suitably modified to improve students' learning (Sandoval & Bell, 2004). Hence, the intention of DBR is to bring improvements in educational practice. In this sense, DBR can be suitable for addressing the issues in the Indian education system discussed in the first chapter.

The purpose of the design experimentation is to explain both the process of learning and how designed artefact supports this process of learning (Cobb et al., 2003). Such explanation would elaborate successive patterns of student's learning. The DBR researcher must explain why and how these patterns are generated and must collect the data for proper explanation of these patterns. This kind of reflective process has potential to develop the underlying theory behind the patterns. The purpose of the design experiments is to carry out formative research to test and refine educational designs (Collins, Joseph and Bielaczyc, 2004). Hence DBR is useful methodology for conducting the formative research and development of improved practice that is in line with my second and third requirement for suitable methodology.

Many authors (Wang & Hannafin, 2005, Barab & Squire, 2004, DBRC, 2003) have described the characteristics of DBR. The characteristics have been outlined as follows:

1. Design experiments are carried out in a natural context.
2. Design experiments are pragmatic and involve multiple methods of data collection.
3. Design Experiments promotes innovations in education.
4. Since the design experiments are conducted in a complex setting, it is not possible for a single design to address all issues. To achieve a more robust design, experiments must be progressively refined. Hence, design experiments are iterative in nature.
5. DBR is characterised by multiple variables. The focus of DBR is to identify the variables so as to understand how they affect the learning process and characterise the learning context. This is unlike lab experiments where variables are controlled.
6. DBR often leads to development of a theory.

Collins (1999) outlined many differences between psychology experiments and DBR including location of the research, number of variables, procedures, and amount of social interactions, nature of research and role of participants in the research. These differences are used to reinforce the choice of DBR for this research. Psychological experimentation is conducted in laboratory settings, whereas DBR is conducted in real life settings. In this research, a classroom, and fieldwork provide real life settings. Psychological experimentation frequently involves one or two dependent variables whereas DBR is characterised by multiple variables. In the current research, content learning, learning patterns, and experiences are a few of the identified outcome variables. Also, system variables such as institutional academic and administrative culture influence the design. Psychological experimentation focuses on identifying a few variables and holding them constant. However, the focus of the current research is on characterising the PBL model and it's utility to address the issues of the Indian institute.

In psychology experiments, fixed procedures are typically followed. DBR is characterised by flexible design revisions in which a tentative initial set is revised depending on its success in practice. In this research, three designs were prepared. The first design was modified to prepare the second design, and the third design was modified based on the outcomes of the first and second models. These systematic revisions of the design are carried out based on feedback from the students, the research data and self-reflection. In psychology experiments, the learner is isolated from social environment to control the interaction. DBR, however, frequently involves complex social interactions in which participants share ideas, distract each other etc. In this study, 375 students participated in the group work. The group work comprised a social system in which many students of varied intellectual, cultural and academic backgrounds studied and worked together on the project. In this research, these social interactions are not controlled. On the contrary, the goal is to explore them.

DBR involves looking at multiple aspects of a design and developing the profile that characterise the design in practice. Undoubtedly, the focus of this research is to develop the design by considering multiple aspects of current academic practice. However, psychology experiments focus on testing a hypothesis. A psychology experiment tends to treat participants as subjects. In DBR, participants play an active role in helping to improve the design through feedback. In this research, a researcher, three teachers and 375 students participated. They provided useful insight and feedback to improve designs.

3.3.3 Summing up

The previous section discussed a few definitions of DBR and the characteristics and differences between DBR and psychology experiments. Considering the research objectives outlined in this chapter, DBR appears to be a suitable methodology to conduct this research. In the following paragraph, the basis for selecting DBR is discussed. Firstly, I selected DBR because of my design engineering background. During my preliminary reading on DBR, I noticed the similarities between design engineering and DBR. This background helped me to understand DBR and to generate the self-confidence to follow this methodology. However, this was one of the less significant factors in choosing DBR as a methodological framework.

The focus of my research is to design a PBL intervention, and to research its effectiveness in giving students an authentic learning experience. DBR fits these requirements, as discussed at the start of this chapter. Also, the characteristics of DBR are in close alignment with my research objectives. Although DBR appears to be the appropriate method for this research, it brings many challenges that must be considered in the design and development stage of this study. In the following section, these challenges are noted.

3.3.4 Challenges in DBR

3.3.4.1 Interventionist process

In Design experiments, a researcher (or team of researchers) must deal with multiple variables that can affect the learning process. These multiple variables are difficult to control in complex situations like a classroom and can affect design enactment. To make the design work in a complex situation, the researcher must adapt as per the situation. To adapt changes in variables, the researcher needs to make change in the planned design experiment which is counter to traditional methods of the scientific planned experiment. This raises a methodological issue (Sandoval & Bell, 2004).

3.3.4.2 Design and comparing across designs

Design is considered to be a creative but demanding process. Every design must be considered from multiple perspectives. Designing even a single experiment is a challenging task. Design experiments are often criticised for being context dependent. One design may not work as well when transferred to another context. For example Aalborg PBL model may not work if it transferred as it is to Indian context. Appropriate change in the design must be done to be effective in Indian context. Designs are context dependent and comparing them is natural in DBR. Thus, the researcher has to be sure to make the research feasible and applicable in similar contexts, which provides a challenge. Also, the same design may not work in the given context; because variables may change. Hence, the design has to go through successive iterations to improve the learning experience.

In the current research, efforts have been made to design an Indian version of the PBL model. As a result, the designs are different from Aalborg's PBL model in terms of organisation and implementation point of view. These designs have been adjusted to address context dependent issues. The designs used in this research are unique in its characteristics and modified in each successive semester. The designs were modified according to the learning requirements of the students. This kind of flexibility in research is characteristic of DBR.

3.3.4.3 Large amount of the data

Since DBR is carried out in a practical context, researchers usually prefer to use a mixture of qualitative and quantitative data as evidence for and against the design. Such data is useful for judging the effectiveness of the design and for improving the design. This process tends to produce a large amount and variety of data to be analysed, which is a challenging task. In the context of the current research, I have dealt with a large amount of data during the collection and analysis stages.

3.3.4.4 Role of the researcher and team

Due to its characteristics, DBR is usually carried out by a research team comprising of a designer, researcher and practitioner. These team members have different roles to play depending on the stage of the research. Designing the single experiment requires design, research, and analysis skills. It is always beneficial to have a range of expertise on the team in order to build workable designs and to develop alternative interpretations of the data and results. Finding a suitable team for conducting DBR is a challenge. In the context of the current research, all roles (designer, researcher and practitioner) were held by me, which put me under considerable stress. Detailed discussion of these roles and their management is discussed in the coming chapters.

3.3.4.5 Role of technology for collecting data

In DBR, the researcher has to collect the data in support of the design. This often requires a variety of instruments, which leads to challenge in integrating technology within the construction of the design. The available technology (e.g. video cameras, audio-recording systems, and mass electronic storage devices), technological support (software and technical experts) and possible integration challenges (space and use of devices in a class or system) must be thought of in the design process itself. It is also expected that the DBR team be a reasonably competent in operating these instruments. The generation of multiple forms of data also creates challenges in managing and analysing the large quantities of data.

In this research, the handling of video cameras and audio-video devices to collect data was done predominantly by me. For the transcription and storage of data web services, an available technology is used. Microsoft office Word and Excel programmes were used for data analysis. Most of the time, I was involved in the collection and processing ofdata. More detailed discussion on data collection and analysis is done in the later part of this chapter.

3.4 Comparable Methodologies

At the early stage of this research, a case study and action research were taken into consideration. In this section, DBR is compared with the case study and action research in order to highlight the advantages of DBR over other research methods.

3.4.1 Case study

A case study can be described as an in-depth study of a class of phenomena such as an event, an individual, a group, an activity, or a community (Abercrombie, Hill, & Turner, 1984; Shephard & Greene, 2003). Case study as a methodology can be used as motivation for the validity of the findings emerging either from analysis of a single case or across multiple cases. The case study has strength as a methodology because it can reveal concrete, context dependent knowledge. Case studies can therefore be particularly appropriate in addressing research questions concerned with the specific application of initiatives or innovations to improve or enhance learning and teaching. The case study method appears to be close to the research questions of this study. However, we found that this method doesn’t allow researchers to change or modify the natural setting of the research. Also, the focus of the case study is to report what is happening in a context rather than to change it. Furthermore, case studies as a methodological approach have frequently been critiqued for its limitations in generalizability. A single case study does not allow the development of general propositions and theories (Case & Gregory, 2011). In the literature, the case study method is used by many researchers (Oliveira, 2006, Mohd Yusof et al., 2005, Zainal & Nurzakiah, 2007, Debnath & Pandey, 2011, Abhonkar, Sawant, & Horade, 2011).

3.4.2 Action Research (AR)

Action Research is an important educational research methodology that can be applied to natural contexts in order to foster change in social practices. This research is carried out in a natural context where social interaction takes place, rather than within the controlled settings of a laboratory (Cousin, 2009). These characteristics make action research different from a case study. In a case study, the focus is to study what is happening whereas in action research the focus is on changing or improving the practice. Kember (2000) describes action research as being reflective, systematic, and cyclical. Action is at the centre of this method and these actions are deliberate to improve, enhance, and realise practice. Kemmis & McTaggart (1988) describe AR as a research method which is carried out in a continuous cycle. This cycle consists of a plan of action to improve what is already happening, action to implement the plan, observation of the effects of the action in the context in which it is occurs, and reflection on these effects for subsequent action and through a succession of cycles. Knowing these attributes, I gave due considerations to action research as a method for my study. AR appeared to be very nearly suited the desired methodology. However, although action research can be an effective methodology for improving educational practices, is relatively rarely used in engineering education research (Case & Gregory, 2011). In addition to case studies and AR, researchers (Iputo & Kwizera, 2005, Mantry et al., 2008, Abdulwahed & Balid et al., 2009) have used experimental designs comparing the performance of students in lecture based learning (LBL) and in PBL. In these designs, the class was usually divided into two groups as a control group and an experimental group. The control group follows lecture based learning and the experimental or treatment group is taught with the PBL pedagogical methodology. At the end of the course, data can be used to evaluate the effectiveness of PBL over LBL.

The characteristics of AR are more closely correlated than that of a case study to the objectives of my research. However, I felt that the DBR had better methodological advantages (as explained earlier) over AR. I felt that action research was more appropriate for social science studies, as pointed out by Case & Gregory (2011). In addition, while reading DBR literature I was able to easily relate it to design engineering. As a result, I opted for DBR over AR.

3.5 Process and phases of DBR

Many researchers have explained the different ways in which DBR can be conducted. Cobb & Gravemeijer (2008) explained the three phases of DBR as, 'preparation, experimentation and conducting retrospective analysis'. Reimann (2011) outlined the activities in each phase as shown in table 3.2.

Table 3.2 Summary of the phases and activities for conducting DBR (Reimann, 2011)

Phase	Activities
Phase 1 Preparing the experiment	Clarifying the instructional goal. Documenting the instructional starting point Delineating the learning trajectory Placing the experiment in a theoretical context
Phase 2 Experimenting to support learning	Collecting data in cycles of design and analysis Applying interpretive framework Formulating and testing domain specific theories
Phase 3 Conducting retrospective analysis	Explicating the argumentative grammar Establishing trust in finding Ensuring repeatability Ensuring generalisability

From the table 3.2, it can be seen that there are three phases in DBR. In the first phase, the focus is to design a theoretical model considering instructional and learning objectives. In the second phase, the focus is on putting the theoretical model into practice and gathering evidence of the effectiveness of the design. In the last phase, data from the previous phases is analysed in order to understand the performance of the design in practice. In this analysis, what worked and what did not is determined in order to modify the existing design. Cobb et al. (2003), in their definition of DBR, identified the three phases of DBR as, ‘design, test and revision of the design’. This revision of the design is generally done at the end of the data analysis phase. In the re-design phase, loopholes of the previous design are identified and sorted out to create a new design. Usually, the new design is better than the first design. Much iteration may be required to create successful design.

In DBR, research takes place through continuous cycles of ‘design, enactment, analysis and redesign’ (DBRC, 2003). There are three steps in the DBR process: ‘design formulation, design implementationand design validation’ (Sasha & Barab, 2004). Design formulation includes stating the rationale for the design and the elements of the design. In the implementation stage, the design is implemented in a context. During the implementation process, the relevant evidence is collected to support and validate the design.

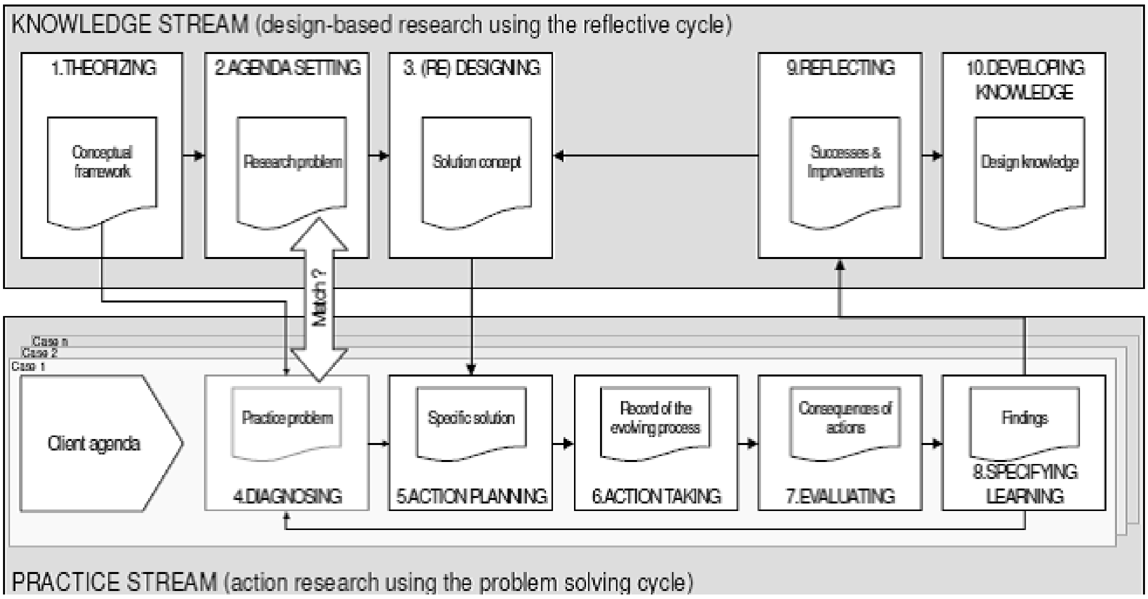

Figure 3.1 Combination of design based and action research (Andriessen, 2006).

Andriessen (2006) combined DBR and action research for application to the management field. He argued that the dual purpose of DBR to develop theory and improve practice requires two streams of inquiry: knowledge stream and practice stream. Figure 3.1 above illustrates this. Andriessen’s methodological framework for DBR has ten steps. The first five steps (theorising, agenda setting, re-designing, diagnosing and action planning) can be considered as a preparation phase. The sixth step could be treated as design implementation. The last four steps could be related to the analysis phase.

3.5.1 Reflection on Phases of DBR

From the above discussion, it can be understood that most researchers described three stages of DBR: design (design formulation, preparation etc.), design implementation (experimenting, implementation, action taking, enactment etc.) and design validation (retrospective analysis, reflective analysis etc.). However, there can be exceptions. Some authorsdescribed more than three phases of DBR. Based on my understanding of DBR and its research requirements, I have modified the DBR framework in order to adapt it for the research at hand, as shown in figure 3.2 below.

Phases in DBR	Activities	Major Activities in the Phases
A. Pre-design	Preliminary research	Conducting preliminary research Preparation of the conceptual design
	Contextual understanding	Pilot work to understand the context
B. Design	Design formulation	Design of theoretical model Design of instruments for data collection
	Implementation plan	Preparing a plan of implementation
C. Design enactment	Implementation	Implementing the theoretical design Simultaneously collecting the research data
D. Design validation	Data analysis	Analysis of research data
	Reflection (re-design)	Reflection on the analysed data and its patterns Defining changes in the original design to create new design.

Figure 3.2 The DBR Framework

Furthermore, it is understood that the context influences the design and choice of design elements. Accordingly there is a need to understand the context before designing the intervention. The researcher’s abilities, knowledge, and experience also have a bearing on the design and outcome of the DBR process. Therefore, there is a need of a ‘pre-design stage’ before the design stage. This pre-design stage may include contextual understanding and prior research.

3.6 Structure of the Research

In line with the DBR framework (see figure 3.2), the structure of the research was prepared. Figure 3.3 (next page) shows the structure of the research, as well as the organisation of the thesis.

3.6.1 The pre-design stage

This research was carried out in two main phases, equally divided. The first phase took place in Denmark from September 2010 to December 2012 (17 Months). The second phase took place in India from January 2012 to May 2013(17 Months). The pre-design stage was completed in Denmark. In the pre-design stage, the focus was to prepare myself for the educational research and to understand Indian academic practices in the context of PBL model design and implementation. The main work completed in this phase included the literature review and a case study on the Aalborg PBL model, the details ofwhich are discussed in chapter 4.

3.6.2 Design of three PBL models: an overview

Every design, whether engineering or educational, has an objective and is designed to address specific needs. The specific needs of the Indian education system were collected from the existing literature referred to in chapters 1 and 2. Firstly, PBL principles were used in a single course named “Theory of Machines-I”. The design of the first CLPBL was prepared in accordance with this course. This first model was implemented at SITL and the subsequent data was collected. This data was analysed to address the research questions of my study. This concluded the first cycle of implementation. Chapter 5 of this paper is dedicated to illustrating the design of the first model and its results. In the following year, two more models were designed and implemented. In this way, three CLPBL models were designed. Chapters 6 and 7 of this paper elaborate on the design of the second and third models respectively.

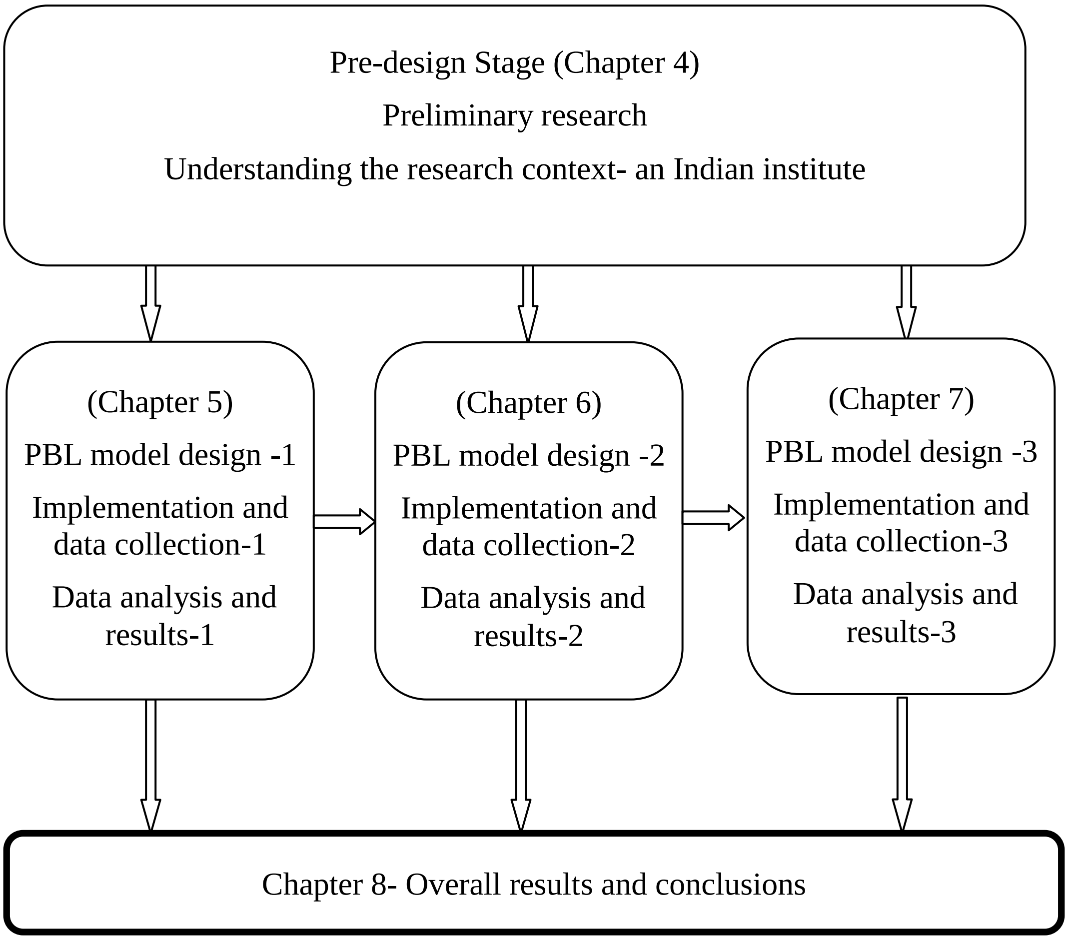

Figure 3.3 Framework for conduction of the research

3.6.2.1 Three experiments and their relative positions in the research

In this research, I have designed and implemented three CLPBL models at SITL. The table 3.3 gives a summary of this. From table 3.3, it may be noted that the experiments E_1 and E_3 were conducted for the same course *Theory of Machines–I*, over two different academic years i.e. 2011-12 (Feb-2012 to May-2012) and 2012-13 (Jan-2013 to May-2013). It may be noted that an academic year in SITL starts in June and ends in May. This means that the student groups involved in these experiments were from two different cohorts. The first cohort included 97 students, the second included 152. These two cohorts combined had a total of 249 students. For my research purposes, these two cohorts brought different perspectives and varied experiences. Compared to E_1, the project design in E_3 was more complex and had more activities. By making these changes in the project design and implementing them on the new cohort, I intended to bring systematic variation to the experiments. I hoped that these variations would bring new outcomes and evidence for the research. The rationale behind these designs and modifications are discussed in the respective models.

Table 3.3 Summary of three experiments conducted at SITL.

Experiment	Period	Semester	Course name	Class	Total no. of students in class
E_1	Feb 2012-May 2012)	Second	Theory of Machines -I	Second Year	97
E_2	June 2012-December 2012	First	Applied Thermodynamics	Second Year	126
E_3	Jan-2013-May 2013	Second	Theory of Machines -I	Second Year	126 + 26* =152
					375

From the highlighted portions in table 3.3, it may be noted that, E_2 and E_3 were conducted in one academic year 2012-13 (June 2012-December 2012 and Jan-2013 to May-2013). E_2 was conducted for an *Applied Thermodynamics* course and $E_{3,}$ as discussed, was conducted for a *Theory of Machines- I* course for the same students. In E_2, 126 students participated; in E_3 26* more students participated than E_2. This way most of the students had two project experiences. By implementing two PBL models for the same cohort, I intended to determine the usefulness of the first PBL experience in helping students to manage the second PBL course. My intention was to examine students' responses to the more complex projects of E_3. In this way, I continuously refine the designs and variation for my research purpose. In this research, three experiments were carried out sequentially one after another. A total of 375 students participated in these experiments and their responses were collected, analysed and discussed in the coming chapters. With this short introduction to PBL models and the context of the research, I invite you to read further to know more about the data collection strategies adopted in these three models.

3.7 The Method for Data collection

This section of chapter 3 is dedicated to discussing the strategies adopted for data collection. Another objective of this section is to elaborate on the choice of mixed method strategy. Methods are the techniques or procedures used to gather and analyse data related to the research question or hypothesis. The choice of methods is governed by the methodology. In other words, close alignment between methodology and methods ensures the validity of the research (Cresswell, 2009). In this sense, the choice of data collection strategy must be in line with DBR. Reimann (2011) described DBR as a framework that has systematic arrangement of the specific methods and techniques of data collection required for the research purpose. To show the effectiveness of the designed model, the researcher must collect the evidence using multiple techniques. To gauge the effectiveness of the experiment, the researcher must try to collect the minute details (which may be in any form like behaviour, gesture, or words, and/or measurement, numbers etc.) during conduction of the research. These details help to interpret the effectiveness of the experiment. In this way, the DBR supports a mixed methods research design approach.

3.7.1 Sequential mixed methods exploratory research design approach

In his book on research design, Cresswell identifies and elaborates on many aspects of mixed methods procedures (Cresswell, 2009). He provides alternative strategies and visual models. He also refersto the sequential and concurrent design strategies of a mixed methods approach. The following section will discuss the choice of sequential over concurrent design. In this research, a CLPBL model is designed and implemented in classrooms in which students' strength varied from 97 to 152. These classrooms consist of students with different educational and cultural backgrounds, cognitive levels, learning priorities, motivation etc.These variables are not easy to control and cannot be treated as a constant. Hence all the students received the same treatment and were considered as a treatment group. In this research, students' response to this treatment is investigated. It was perceived that each student would have a different response and learning experience in the PBL model. The responses and experiences were collected from each individual during and after the implementation, providing critical qualitative data. In the later part of the research, the students' views on various aspects of the PBL model, and their perceptions about their achievement of learning outcomes were collected through an end of semester survey.

In the current research design, qualitative methods were used during the implementation phase, followed by quantitative methods used after implementation. According to Cresswell (2009) this type of design follows *sequential mixed methods exploratory research design approach* **(**figure 3.4). Usually, this design is used to explore the phenomenon at the beginning and to later generalise the findings by using quantitative data. In figure 3.4, 'qual' means qualitative approach and 'quan' means quantitative approach. An arrow indicates a sequential form of data collection, with one form building on another.

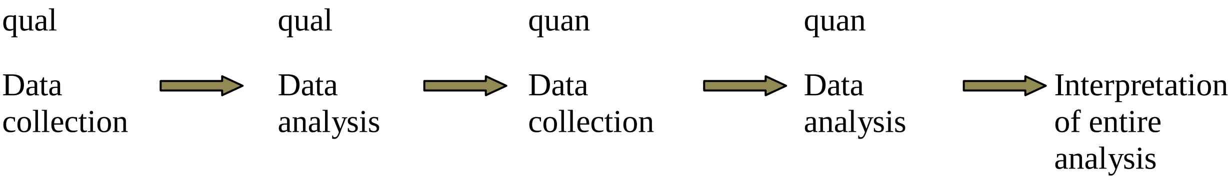

Figure 3.4 Sequential mixed methods research design approach (Cresswell, 2009, p. 209)

The proceeding sections discuss the instruments used to collect research data and the data analysis procedure.

3.8 Qualitative methods

The qualitative method is characterised as the method in which the researcher collects the data in the form of words (written and verbal), images or observations (Cresswell, 2009). In the literature, many qualitative methods were used to evaluate the effectiveness of the PBL and achieve the research purpose. For example, feedback may be used to gather data at the end of the course (Raucent, 2001). In another example, the data was collected from classroom observations (Luis et al., 2005). To assess the effectiveness of a PBL initiative, interviews of staff and students have been used to collect the data (Oliveira, 2006, Zainal & Nurzakiah, 2007). In two cases from India, the experiences of engineering students over a period of years were collected (Singh et al., 2008, Abhonkar, Sawant, & Horade, 2011).

From the above discussion it can be concluded that, to evaluate the effectiveness of the PBL initiative in the referred cases, the research included qualitative data collection strategies including the collection of students' experiences, feedback on questionnaire, interviews, and observation. Usually such data is collected in the natural setting in which the participants were exposed to or experienced the treatment. In my capacity as teacher and supervisor, I was always available in close vicinity to the students. This position allowed me to observe theirbehaviour, and to conduct formal and informal discussions with the participants. I chose the qualitative data collection instruments accordingly. These are summarised in table 3.4.

Table 3.4 Summary of qualitative methods used in the research

Technique	Tools	Data analysis
Observation	Field notes	
Essay writing	Essay	Content analysis
Semi-structured interviews	Interview guide	
Document analysis	Students' project reports	
Survey	Open ended questions	

3.8.1 Observations

Students groups were observed throughout the semester, during the project work and in final presentations. My observations were noted as field notes. Different opinions and points that arose from informal discussions with students were also noted. These notes have been included in the discussion whenever I deemed it fit. No special scheme was prepared for taking notes.

3.8.2 Essay writing

In the middle of the semester, the students were asked to write an essay on 'their experiences of different aspects of the PBL model'. These essays provided deep insight into the students' experiences of the project work and teamwork, and the learning and difficulties faced by them in this model. These essays were collected from individual students. The detailed process for essay analysis is discussed in the qualitative data analysis section of this paper. Pleas refer to the sample essays in the Appendix A_4.

3.8.3 Semi-structured interviews

At the end of the semester, the student groups presented their project work. These presentations were evaluated by the subject teacher and teachers from the institute. At the end of the presentation, each group was asked questions (see Appendix A_5) related to the project work, team work and their learning experiences in the PBL model. These sessions were video recorded for the purpose of analysis. The short interviews were conducted for 10 minutes per group, on average. For sample short interview please refer to appendix A_6

During the research, three CLPBL models were implemented for three consecutive semesters at the SITL. During the data analysis phase of each model, critical observations and interesting trends were found. To investigate these trends, an interview protocol was prepared (refer to appendix A_5). These interviews were conducted at the end of model 3. Each interview lasted for half an hour. The purpose of these long interviews was to assess or confirm the reasons behind the observed trends. Due to other commitments, only eight students came forward for these interviews. This data is included in the PBL model 3.

3.8.4 Document analysis- project reports

In the ABET criteria (from table 1.1), the learning outcome (LO) ‘g’ is defined as ‘an ability to communicate effectively’. To provide the opportunity to achieve this LO, all groups were asked to prepare and submit the project report. These project reports were part of students’ written communication skills. Hence, they form part of learning outcome ‘g’. These reports were analysed to assess the LO and to understand the students’ learning about their project. In general, a good project report means partial achievement of learning outcome ‘g’.

3.8.5 The end semester survey- open ended questions

In the first model, through students’ feedback I learned that a few of the groups were slow to start the project. This also became evident during the essay analysis. Furthermore, during short interviews, I observed that some students spokewhile others simply didn’t. There may be several reasons for this. To give the students the opportunity to write about their experiences, a few open ended questions were included in the end semester survey (refer Appendix A_7 and A_8). These questions were focused on obtaining students’ suggestions for improvements in the PBL model design and onidentifying challenges faced by the students during project work.

In the essays and project reports, the data was in written form; however, the interviews generated visual and audio data. In this way, each method discussed above contributed to the generation of a large amount and variety of qualitative data. This variety posed considerable challenges for analysis, which will be discussed in the next section.

3.9 Qualitative data analysis

The content analysis technique is used to structure data into themes and categories. My theoretical understanding and decision to use the content analysis technique can be attributed to the book *Research Methods on Education* (Cohen, Manion, & Morrison, 2007) in which Krippendorff (2004) defined,

> ***“Content analysis as a research technique for making replicable and valid inferences from the text to the context of their use” (p. 18)***

He also outlined the process for analysing qualitative data. It is important to keep the research questions in mind during analysis in order to find the evidence that supports research question in a pool of qualitative data. The analysis starts with the collection, organisation of data, reading (if it is text) or hearing (if it is interviews) and then coding the response of individual students or groups into themes. The text with the same or similar meanings is used for category generation (Krippendorff, 2004).

3.9.1 Analysis of students’ essays and interviews

I prepared the step model for category development (see Figure 3.5) for the data analysis. This model is influenced by an inductive category development model (Mayring, 2000) It shows the process adopted to analyse the qualitative data. In figure 3.5, each block in a horizontal line represents one step. In the following paragraphs each step is explained.

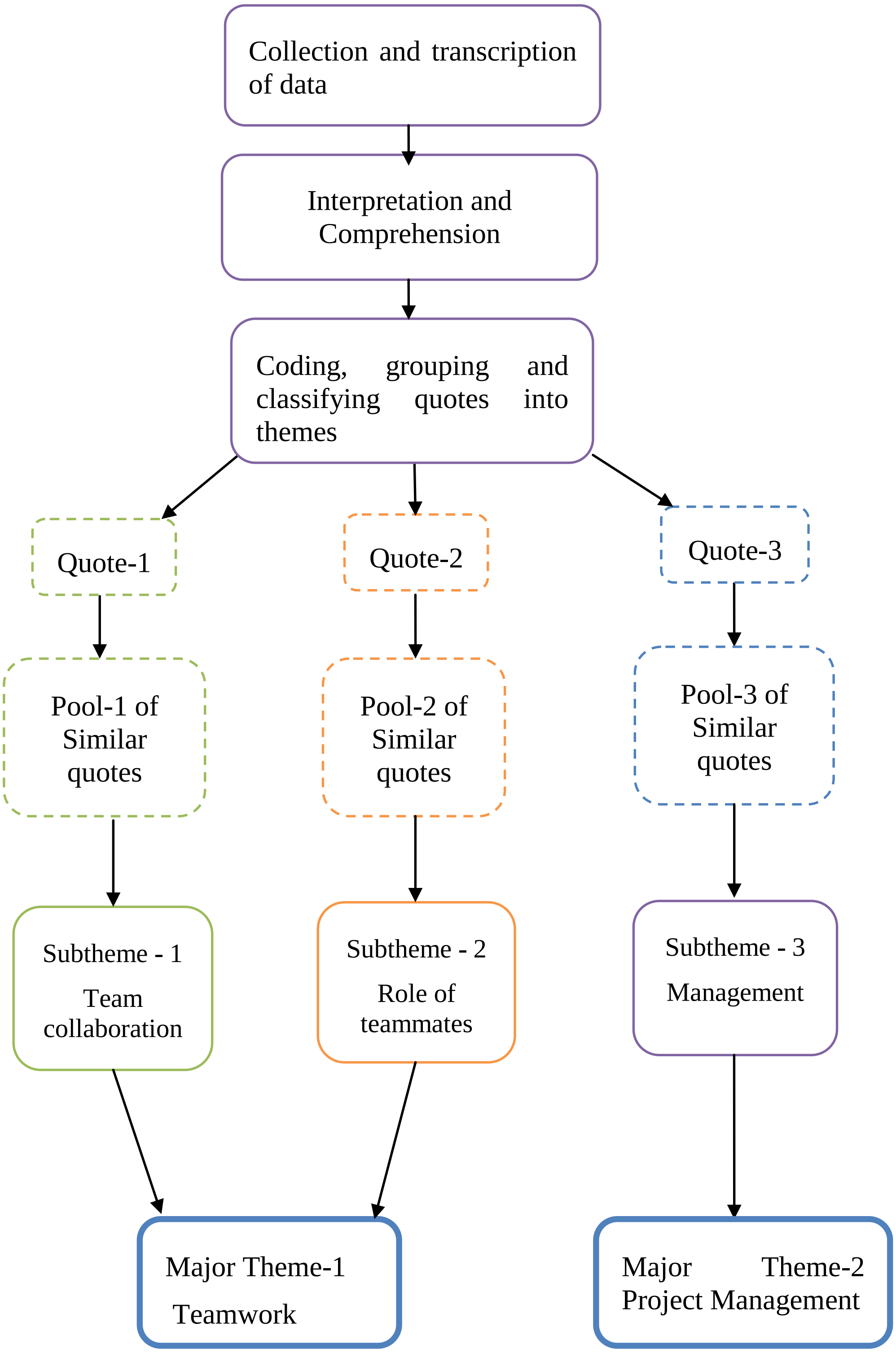

Figure 3.5 Process followed for theme generation

Step-1 Collection and transcription

The qualitative data analysis process started with collection of the data: essays, interviews, reports and documents. The available data was then organised properly. The interviews were converted into text form by listening repeatedly (a sample interview is attached as Appendix A_6). In this way, all qualitative data was converted into text form.

Step-2 Interpretation or comprehension

The text had varying length of paragraphs and was written in unstructured form. To structure this text each quote was read and understood. The relevant quote was entered into the grid as shown in table 3.5. In the grid, sample quotes from two students are shown for the purpose of understanding.

Step-3 Coding and generation of subthemes

During preliminary essay reading, it was observed that most of the students had written about their experiences of teamwork and project work, and of any difficulties and suggestions. Accordingly, four major categories emerged. ‘T’ is used to represent ‘Teamwork’. ‘P’, ‘D’and ‘S’ are used for themes related to the project, difficulties and suggestions, respectively. These major themes were finalised during the primary stage. With further reading, subthemes were generated from the data. To generate a subtheme, the grid was prepared by using quotes, with each quote (see table 3.5) being marked with the relevant code. Each subtheme is coded appropriately. For example, subthemes related to teamwork are given numbers as T_1 T_2 T_3 T_4 $T_{5.}$ This is extremely iterative process characterised by frequent moving back and forth into the data. Many times, I had to modify, readjust or create new subthemes to fit the quotes. One of the models of this iterative process is shown below in figure 3.6. In this model, the main theme and codes given to subthemes can be seen.

Table 3.5 Sample grid used in the essay analysis

Quote No	Student-1	Student-2
Q_1	We are engaged in doing in such a way that we feel like working for company	Our group work is excellent and all the group members are excellent
Q_2	Group work is very enjoyable	-
Q_3	Helpful for getting many ideas.	Everyone has a logic due to which new ideas are innovated.
Q_4	I learned basic function of motor	How to get solutions of problems and start project work
Q_5	I understood and applied my physics knowledge	How to work on field work How to do practical work

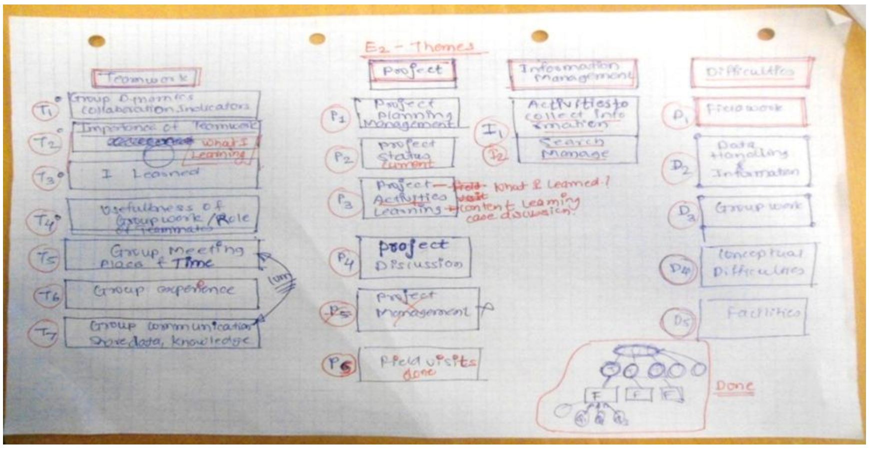

Figure 3.6 Iterative process of theme generation

This type of coding helped to classify quotes into different subthemes. These codes were handwritten along side the quote. The manual process (coding by hand) was used to code the quotes. Only the most relevant and useful quotes were categorised into themes. This way each quote is coded and entered in a sub-theme. The second essay was entered into the grid and the same process was followed. One of these handwritten papers is shown in figure 3.7. In the figure, quotes entered in the grid and coding are done with red pen so that they can be seen.

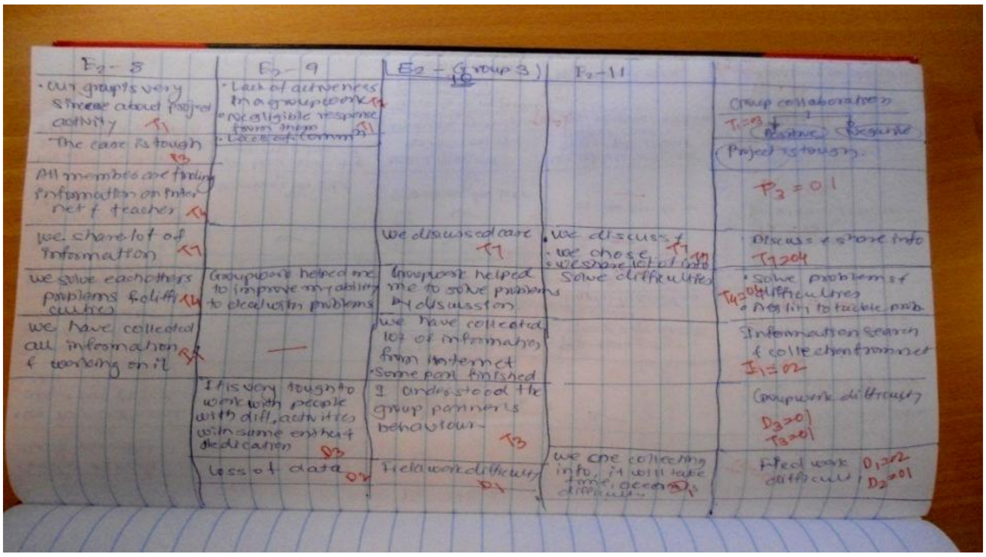

Figure 3.7 Iterative process of tabulating quotes and theme generation

Codes were summarised and entered into subthemes. This way each subtheme contained a collection of quotes. For example, in figure 3.5, pool-1 contains the quotes related to team collaboration. The total number of quotes in the pool is calculated and shown in the form of a frequency table. A sample frequency table (table 3.6) is shown below. This frequency table is used for the purpose of discussion.

Table 3.6 Frequency of the Quotes

Major Theme	Subtheme	Code	Frequency
Teamwork	Collaboration	T_1	31
	Importance and usefulness	T_2	23
	Role of teammates	T_3	15
	Communication	T_4	24
	Experience	T_5	35
Project	Management	P_1	02
	Current status	P_2	13
	Learning	P_3	2
	Activities	P_4	5
Information Management	Search, collect and manage	I_1	10
Difficulty	Fieldwork	D_1	17
	Information handling	D_2	5
	Teamwork	D_3	19
	Conceptual	D_4	27
	Total quotes		228

3.9.2 Analysis of project reports

For the project report analysis, a special scheme was used. It may be noted that the project reports were not included in the regular curriculum. In the project reports, students reported their project related findings. They were given guidelines of the expected content and the format of the report. For the preliminary analysis, the report organisation was included as a parameter by which to compare the reports. In the following table 3.7, a summary of the report analysis on the basis of organisation is shown:

Table 3.7 Project report analysis from PBL Model-1

Sr. No.	**Parameter**	**Group Nos.**									**Total out of 9**
		G_1	**G_2**	**G_3**	**G_4**	**G_5**	**G_6**	**G_7**	**G_8**	**G_9**	
1.	**Problem statement**	*	*	*	*	*	*	*	*		**8**
2.	**Names of members**	*	*	*	*	*	*	*	*		**8**
3.	**Team photo**	*	*	*	*	*	*	*	*		**8**
4.	**Abstract**	*	*	*	*	*	*	*	*	*	**9**
5.	**Introduction**	*	*	*	*	*	*	*	*	*	**9**
6.	**Types**	*	*	*	*	*	*	*	*	*	**9**
7.	**Technical details**						*	*	*		**3**
8.	**Kinematic Diagram**	*	*				*	*	*		**5**
9.	**Links**	*	*			*	*	*	*	*	**7**
10.	**Joints**	*	*			*	*	*	*	*	**7**
11.	**Pairs**	*	*			*	*	*	*	*	**7**
12.	**DOF**	*	*			*	*	*	*	*	**7**
13.	**Conclusions**	*				*	*	*		*	**5**
14.	**Advantages**	*				*	*	*	*		**5**
15.	**Disadvantages**	*				*	*	*	*		**5**
16.	**Applications**	*				*	*	*	*		**5**
17.	**References**	**3**	**3**	**-**	**-**	**9**	**-**	**4**	**4**	**5**	
18.	**No. of Pages**	**10**	**7**	**8**	**9**	**12**	**10**	**6**	**13**	**10**	
19.	**Fieldwork Photos**	*	*	*	*	*	*	*	*	*	**9**

3.9.2.1 Parameters for grading the reports

Once all the reports were analysed for the organisational framework, each report was visually examined and graded on the basis of four parameters discussed below.

Format and the organisation of data

This parameter considered effort committed by students in writing the reports and how well students have written the report. The evaluation criterion included consistency in writing and formatting aspects. The report writing included the organisation of data and visible spelling errors. The formatting aspect included the consistent use of font size, use of proper captions to data tables and figures, page numbering etc. The reports were graded as *A- Good, B-Average and C-poor* depending on the above-mentioned criterion.

Technical content

This criterion covers the amount of relevant technical information provided by the group in their report and its fitness to the purpose. The criterion generally includes scientific principles, figures and tables related to their case. The reports were graded as *A- High, B-Medium and C-Low* depending on the above-mentioned criterion.

Coverage of project activities

This was one of the important factors analysed in the report, because the students were asked to write and discuss their project activities in this report. First of all, it was determined whether or not all the desired technical activities were covered in the report. Secondly, reports were analysed for depth of coverage, which includes justification, evaluation and discussion of the project activities from the students' point of view. It was expected that these activities would cover 40-50% of the report. Better discussion on the project activities indicatedwhether or not the students understood the topics and performed the project activities with passion and zeal. These reports were graded based on the evidence found directly in relation to the project activities. The reports were graded as *A for full coverage, B- for partial coverage, and C- for poor coverage of designated project activities.*

Plagiarism

The fourth and final factor in the report analysis was plagiarism. This factor related to the amount of material copied and pasted, or paraphrased, in the report without mentioning the source. An amount of plagiarism is decided based on the visual examination. In the visual examination, the total number of pages of copied text and data were examined. The amount of plagiarism was decided based on the presence of copied pages with respect to total no of pages in the report. Only three categories were made. If the report contained less than 25% copied pages it was given an 'A' grade. The grade 'B'was given if the report contained less than 50% plagiarised pages and a grade 'C'was given when the report exceeded 50% plagiarised pages. Table 3.8 shows sample analysis of the project reports based on the above four factors.

Table 3.8 Analysis of reports and grades

Group no	Group composition			Mechanism	Format	Technical content	Coverage of project activities	Plagiarism	Overall impression
	M	F	Total						
G_1	5		5	Excavator and crane	C	C	B	C	C
G_2	4	1	5	Roller shutter	B	B	B	A	B
G_3	5		5	Steering gear	C	B	C	C	C
G_4	5		5	Grippers in robot	C	B	C	C	C
G_5	4	1	5	Foot pump	B	A	A	A	A
G_6	5		5	Toggle clamp	A	A	A	A	A
G_7	5		5	Two wheeler brake	A	A	A	A	A
G_8	1	4	5	Sewing machine	A	A	A	C	A
G_9	4	1	5	Shaper machine	B	A	A	C	B

The last column (overall impression) shows ‘A’ grade, ‘B’ grade and ‘C’ grade for the project report. In general, the higher grade in the report indicateda better ability to write technical reports. Also, the technical report can be a good indicator of students’ content learning. Hence, an analysis of technical reportswas carried out for all models.

3.9.3 Validity and reliability of qualitative data and its analysis

The process adopted for qualitative data collection was kept transparent and each student got the opportunity to share their experience. The data was collected when the students were receiving the treatment, which helped to capture most of their experiences. In this way, the chance of losing important data was minimised. Students were given sufficient time and liberty to write and share their experiences. It can be believed, then, that the data provided by the students was a true reflection of their experiences, minimising the issue of validity. To maintain the richness of the data and the text, each category was generated based on the original sentences or statements used by the participants. All themes were generated from the data and were not pre-conceptualised. The results of this process are presented in the form of themes or calculation of frequency of occurrences. During the category generation process, several revisions were made to finalise the theme and frequency of occurrences. This process helped to extend the reliability of the data and results. Themes related to the objectives of the research were included in the results.

3.10 Quantitative methods

This method deals with the numbers. In the previously discussed cases (Luis et al., 2005, Javier & Perez , 2009, Oliveira, 2006, Mohd Yusof et al., 2005, Mantry et al., 2008), an end-of-semester survey was conducted for which a questionnaire was designed. In this questionnaire, the students were asked to evaluate their impressions of the usefulness of PBL for knowledge, skills and attitudes. Suggestions were also collected for how to improve the design (Luis et al., 2005). In another example, students were asked to maintain a portfolio, and a questionnaire containing 16 questions was divided into four thematic blocks (Javier & Perez, 2009). Usually, a five point Likert scale was used in these questionnaires (Javier & Perez, 2009, Mohd Yusof et al., 2005). In my research, the quantitative analysis included the end-of-semester survey, students' grades in the project and the end-of-semester examination.

3.10.1 Survey

The intent of the survey was to record students' views about elements of the PBL model and to give a numeric description of the perceptions of the participating students on their achievement of learning outcomes. Since the objective was to observe the impact of PBL on students' attitudes and perceptions, a cross-sectional survey was conducted at the end of the experiment and used to reinforce the data collected by qualitative methods. This survey method was found suitable, convenient, and economical in terms of time, as the student population was high (at 375) and they were available in close proximity.

3.10.1.1 Population and sample size

In this research, a class of second-year mechanical engineering students was selected for the study purpose (Cresswell, 2009). Single stage convenience sampling was done, as all the students were available in close vicinity and accessible. All participants belonged to the same age group (19-21 years) and had the same level of education (all were second year students). In three models, 375 students participated (refer table 3.3).

3.10.1.2 Instrument

During the early stages of the research in 2011, I conducted a case study of the 'Aalborg PBL model'. For this research, the survey instrument (the first questionnaire) was designed. At initial stage, an existing literature (Sinclair, 1975, Nederhof, 1988, Murray, 1999, Marshall, 2005) was consulted to determine the design of the questionnaire. Qualitative data from the case study was used to frame the questions. This first questionnaire had 87 questions divided into seven categories. The pilot of this questionnaire was conducted in Denmark on fifteen international students. These students expressed that the questions were understandable and clear; however they found the questionnaire to be too long. Students also stated that some of the questions had similar meanings and suggested eliminating redundant questions. My supervisor and peers provided useful input on the construction of this instrument, especially in terms of aligning of the questions to suit the research objectives. All of this input helped to shorten the questionnaire. The modified instrument had 34 questions divided into four categories (refer Appendix A_7). In the following section, the process followed for the groupings will be discussed.

3.10.1.3 Grouping of the questions

In the designed questionnaire, four sets of questions were made. The questions were grouped according to the research intentions, with the aim ofexploring students' responses on the design aspects of PBL model and its impact on students' learning experiences. The PBL learning principles and ABET learning outcomes were used to group the questions. The questions were also grouped by finding internal consistency, via the Cronbach alpha coefficient, for each group.

Group A - Students' perceptionsof various elements in the PBL model

In the PBL environment, the project design is critical to providing an authentic learning experience to the students. Accordingly, four questions were included the questionnaire related to design aspects of the project. In table 3.9, AQ_1 AQ_2 AQ_3 and AQ_4 relate to the design aspects of the project. To complete this project, students were supported through classroom instruction and provided enough time to complete the project. To measure student response to this, two questions were included to assess students' satisfaction with the time provided for completion of the project (AQ_5) and the effectiveness of classroom instruction (AQ_6). In the last question (AQ_7), students were asked whether or not they would recommend the application of PBL in other courses. This question was added to assess the students' overall acceptance of the PBL model.

Table 3.9 Students' responses on various elements of the CLPBL model

Question no.	Question
AQ_1	Assigned project work was challenging
AQ_2	The project was well integrated into the curriculum
AQ_3	The project was relevant to my profession
AQ_4	Assigned project was enjoyable
AQ_5	I feel the time provided for the project was sufficient
AQ_6	I found classroom instructions helpful
AQ_7	I recommend to apply PBL to other courses

Group B - Students' perceptions about the usefulness of the PBL model for learning

One of the intentions of the PBL model is to help students learn. This learning may be achieved through various modes such as self-directed learning, cooperative and collaborative learning (learning in a group). These aspects of the project needed to be assessed so BQ_3 BQ_4 and BQ_6 was included (table 3.10 below). To understand the effectiveness of the project in motivating and engaging students in the learning process BQ_1 BQ_2 and BQ_5 were included. To understand the effect of the PBL environment on students, BQ_7 to BQ_{10} were included. BQ_{11} was included to assess students' satisfaction with their learning.

Table 3.10 Students' perceptions about their learning in the CLPBL model

Question no.	Question
BQ_1	The project motivated me to learn
BQ_2	This project stimulated to learn the material outside the class
BQ_3	I took responsibility of my own learning
BQ_4	I become self-directed learner
BQ_5	The project engaged me throughout the semester
BQ_6	I learned through the collaborative and co-operative approaches
BQ_7	It helped me to increase my understanding of the subject
BQ_8	It laid the strong foundation of the subject
BQ_9	I feel confident to appear in the examination
BQ_{10}	I expect improvements in my grades
BQ_{11}	Overall I am satisfied of my learning

Group C - Students' perceptions of the usefulness of the PBL model for the achievement of learning outcomes

The questions in group C were framed to assess the usefulness of the PBL environment to promote the achievement of ABET learning outcomes.

Table 3.11 Students' perception on achievement of learning outcomes

Question no.	Question
CQ_1	I learned to think deeply
CQ_2	It helped me to improve my ability to work in a team
CQ_3	I learned about the problem solving process
CQ_4	I learned how to write the report
CQ_5	I learned critical presentation skills due to the project work
CQ_6	I learned to asses and manage variety of resources
CQ_7	I applied project management principles
CQ_8	Assigned project helped me to improve my skills

Group D – Students’ experience of teamwork

To understand students’ experiences about teamwork, the last group of questions was designed. The items in the questionnaire (table 3.12) asked about students’ experiences of teamwork during the project (DQ_1). The question (DQ_2) relate to the usefulness of teamwork for completing the project and learning (DQ_4 and DQ_5). A question (DQ_3) relates to the role played by teammates during project work and the questions (DQ_6 and DQ_7) relate to the students’ satisfaction with the team performance. In the question DQ_8, students were asked to comment on their readiness to tackle the complex project.

Table 3.12 Students’ perception about teamwork

Question no	Question
DQ_1	I feel group work is a challenging task
DQ_2	Teamwork was critical for completion of this project
DQ_3	My teammates helped me to understand the concepts
DQ_4	I learned to take different perspectives and opinions
DQ_5	I learned how to lead the project through teamwork
DQ_6	I feel we could have done better in teamwork
DQ_7	I am satisfied with my group’s performance in this semester
DQ_8	I am looking forward to work on more complex projects

The table 3.13 shows how the question groups cohere with the research questions.

Table 3.13 Coherence of research questions and groups

The research questions	Group
A. Design of CLPBL Model	A.Students’ perceptions of the characteristics of the CLPBL model D. Experiences about teamwork
B. Impact of CLPBL Model	B. Students’ perceptions about an usefulness of the CLPBL model for learning C. Students’ perceptions about an usefulness of the CLPBL model for the achievement of learning outcomes

3.10.1.4 Scale

This survey used a five point Likert (continuous) scale, with responses including strongly disagree (assigned value is '1'), disagree (assigned value is '2'), no opinion (assigned value is '3'), agree (assigned value is '4') and strongly agree (assigned value is '5'). This questionnaire was administered for two weeks, with the first reminder given after the first week. Responses received after two weeks' time was not considered in the final assessment.

3.10.1.5 Validity and reliability of the survey instrument

Cronbach's alpha coefficient (α) is a tool for measuring the internal consistency of the instrument. For academic research, a minimum value of alpha equal to 0.7 is considered to be acceptable. In this research, the internal consistency for 34 questions was found to be 0.87. For each item within a question group the internal coherence was also checked using Cronbach's alpha coefficient and found to be in the range of 0.38 to 0.85. The following table 3.14 shows Cronbach's alpha coefficient for each group.

Table 3.14 Summary of Cronbach's alpha coefficient (α) for three models

Model no.	**Group A**	**Group B**	**Group C**	**Group D**
CLPBL-1	0.53	0.75	0.73	0.50
CLPBL-2	0.74	0.76	0.72	0.38
CLPBL-3	0.74	0.85	0.81	0.52

This instrument was used three times in this research. It was observed that the scores were stable when the instrument was administered the second time, which further indicated the internal consistency of the instrument. As can be seen in the above table, the lower value of 0.38 is observed for CLPBL-2 in group D. This lower value was obtained because the mean for DQ_2 and DQ_3 of D group questions was close to 3 and the standard deviation was more than 1. The survey instrument is attached as Appendix A_7 for reference.

3.11 Quantitative data analysis

In the analysis of the quantitative data, the following steps suggested by Cresswell (2009) were followed for each model.

Step 1-In this step**,** information about the number of students who responded and who did not respond is presented, as shown in the following table 3.15. In general, for these three models, the survey response rate was above 85%.

Step 2 - Descriptive analysis

As mentioned earlier, a 5-point Likert scale was used in the questionnaire. The students answered the questionnaire by ticking an appropriate option. These responses were assigned a value from 1 to 5. The descriptive analysis was then carried out to present the data in terms of mean, variance and standard deviation, as shown in table 3.16 below. This table is a piece of the final data made available after analysis. The students answered a question (column no. 1) by ticking the appropriate response (column no. 3,5,7,9 and 11). Each response was assigned a value (column no. 4, 6, 8, 10 and 12), as discussed earlier. For example, in E_1, “agree” (column 9) was assigned a value 4 (column 10). All the responses in this category would thenbe multiplied by 4, e.g. 63 x 4 = 252 (Column10). Hence, for E_1, we have 63 ‘agree’ responses with a combined value of 252. Similarly, for other responses, we got combined valuesof 1, 22, 6, and 40. In column 14, all these values (columns no. 4, 6, 8, 10 and 12) are added together to give a total of 321. Column 14 (321) is then divided by 85 (column no. 13) to get a mean of 3.777 (column 15). In this way the mean iscalculated for each group in the questionnaire, for all three experiments (E_1, E_2 and E_3). This data was used to compare the results from each experiment and to support the qualitative findings. The data was presented in the form of a percentage of students agreeing or disagreeing on the particular items.

Table 3.15 Summary of response rate in three models

Model no.	**CLPBL-1**		**CLPBL-2**		**CLPBL-3**	
Category	**Number of students**	**Response rate in %**	**Number of students**	**Response rate in %**	**Number of students**	**Response rate in %**
Respondents	86	88	106	84.13	133	87.5
Non-respondents	11	12	20	15.87	19	12.5
Total Participants	97	100	126	100	152	100

Table 3.16 Calculation of mean and standard deviation

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Question	Model	Strongly disagree	Value 1	Dis-agree	Value 2	No opinion	Value 3	Agree	Value 4	Strongly agree	Value 5	Total responses	Total	Mean	Standard deviation
AQ1- Assigned project was challenging	**CLPBL-1**	1	1	11	22	2	6	63	252	8	40	85	321	3.787	0.84

Step 3 Data presentation

In this step, the data collected from in step 2 was presented in the form of tables and graphs. In the following table 3.17, the same data for AQ_1 is represented in terms of a percentage of students agreeing and disagreeing.

Table 3.17 Data presentation in the form of percentage of students

Question no.	Question	Strongly disagree	Disagree	No opinion	Agree	Strongly agree	Total %
AQ1	Assigned project was challenging	1	13	2	75	9	**100**

The data from table 3.16 is shown in following table 3.18 for final analysis.

Table 3.18 Final quantitative analysis

Question	Model	Mean out of five	Standard deviation
AQ1 Assigned project was challenging	**CLPBL-1**	3.787	0.84
	CLPBL-2	4.104	0.63
	CLPBL-3	4.397	0.57

In this way the mean and standard deviation for each question were calculated. The mean value was used to compare responses between any two models. From the above table, it is clear that the mean value for model 3 was greater than for model 2. This shows that, according to the students, the project in the third model was more challenging than the project in models 1 and 2. This is how the mean was used to compare the data. The data from table 3.17 was converted into a graph for better visualisation of the results. The tables and graphs, along with qualitative analysis, were used to interpret the effectiveness of the designed CLPBL models by addressing the research questions outlined at the start of this chapter. In general, both types of data were used interchangeably to reinforce one other.

Step-04 Test of significance - two way ANOVA test

The first PBL model helped to carry out the pilot research work. In model 3, systematic variation was created by designing the complex project in comparison to model 2. The intention was to understand the effect of the complex project on students' responses. For models 2 and 3, 106 and 133 students responded to the survey, respectively. To compare the responses of the two cohorts involved in PBL models 2 and 3, the following procedure was used. The first step was to identify the number of students who participated in both models and also responded to the questionnaire. During the comparison, I found that 91 students had participated in these two experiments. To analyse the responses of these 91 students, a two way Analysis of Variance (ANOVA) method was used, with the aid of Microsoft Excel programme. For the analysis, responses to each question were considered separately.

Assumptions for calculation purposes:

X_1, X_2 = Mean of sample 1 and 2.

S_1, S_2 = Variance of sample 1 and 2.

n_1, n_2 = Sample in experiment 1 and 2.

F = Calculated F value

F_α = Critical F value for $\alpha = 0.1$ (90% reliability) = 2.77

We defined:

Null Hypothesis as

Ho: There is no difference between responses of two groups

Alternative Hypothesis as

Ha: There is significant difference between responses of two groups

If, $F > F_{\alpha,}$ then there is a significant difference between the two samples and we reject the null hypothesis.

If, $F < F_{\alpha,}$ then there is no significant difference between the two samples, and we accept the null hypothesis.

Sample calculation

The following table 3.19 shows a sample ANOVA table:

AQ_1: Assigned project work was challenging

Ho: There is no difference between responses of the two groups for this question

Ha: There is significant difference between responses of the two groups for this question

Table 3.19 Sample ANOVA Table

	D.f	Sum of squares	Mean sum of squares	F statistic	Critical value
k-1	1	1.59	1.59	3.32	2.77
nk-k	180	86.18	0.48		
nk-1	181				

Since, the calculated value of the F statistic was (3.32) which are greater than the critical value (2.77), we rejected the null hypothesis. We concluded that there exists a significant difference between responses of the two samples. In other words, the project in CLPBL model 3 was more challenging than in CLPBL model 2. Along similar lines, the ANOVA tables for all groups in questionnaire were prepared. A finalANOVA result table with comment is included as appendix A_9.

3.12 Ethical considerations in the research

The need and purpose of the research was communicated to the head of the institution, head of the department and students. The appropriate permission was sought from the head of the institution and head of the department. Students were requested to participate and ensured utmost secrecy for their responses. They were also told of the perceived benefits to them that the research might have. All the students in the study were asked to participate and allowed to withdraw at any time. The responses of the participants were collected individually using the instruments supplied by us.

3.13 Concluding remarks

In this chapter, I have discussed how DBR emerged as a suitable methodology for the research. Case study and action research methodologies were also considered for this research. However, the characteristics of DBR were found to be in close alignment with the research objectives stated in the third chapter. DBR goals and outcomes have been discussed, along with the challenges associated with conductingthe DBR model. These challenges included the large amount of data, research team and integration of technology. The objectives of the DBR were to improve educational practices by suitably modifying or designing a learning environment and to conduct the research. The important outcomes of the DBR were improved practice or designed context itself and the generation of theory. The assessment schemes, students’ artefacts and large amount of data were a few of the important outcomes of DBR. In this chapter, three phases of DBR were discussed: design formulation, implementation and analysis leading to re-design. The importance of prior research and contextual understanding is also outlined as an important element. One more phase was added to the existing three phases of DBR and named the pre-design stage. Finally, a research framework was developed with which to conduct the research, depictinga holistic view of the research work.

In this chapter, the instruments used for data collection were discussed. Also, the methods used for analysing both forms of data (qualitative and quantitative) were elaborated. The qualitative data was generated mainly using students’ essays, interviews and documents. The quantitative data was obtained through the survey and students’ grades. The qualitative data was analysed by a content analysis technique and the quantitative data was analysed by using simple descriptive statistical analysis. To compare between responses of the two cohorts, a two way ANOVA was conducted. Based on discussions of theoretical perspective, methodology and strategies of data collection and analysis, this research can be characterised as using a mixed method research design.

Chapter 4

Pre-design phase

In the DBR framework (refer to figure 3.2, in chapter 3), pre-design is the first phase. This phase includes the preliminary research, contextual understanding and conceptual design of the first CLPBL model. I carried out these pre-design activities at Aalborg University, Denmark.

4.1 Preliminary research

A design-based researcher prepares his design based on previous research experience gained from different disciplines. For the research side, he draws on experiences from learning and cognitive science, psychology and other social science research disciplines. For the design side of DBR, researchers build upon prior research from curriculum design, instructional design, education and computing (Sandoval & Bell, 2004). It is thus necessary for the researcher to have knowledge of methods used in educational research and curriculum design. The use of previous research is also required to specify a design (Cobb et al., 2003). The design can be developed with the aid of empirical and theoretical results from previous research done by the researcher. In order to acquire the necessary information, research experience and skills to develop the design, prior research is required. Especially for a novice researcher like me, such prior experience proved necessary to making workable designs and conducting research at the Indian institute.

During the initial period of my research (September 2010 to February 2011), I conducted a case study of the PBL model at Aalborg University. This case study was important work for me because this was the first time I conducted educational research and designed instruments to collect data. In this case study, I observed the PBL practices of fifteen postgraduate students in the mechanical engineering department. These students were studying in the first year of the programme. This research helped me to:

a. Understand and evaluate the Aalborg PBL model specifically related to the organisation of the project and courses, PBL practice and the supporting facilities. This experience provided insight into the Aalborg PBL model, and reflecting on the practice helped me to visualise a PBL model for India. Furthermore, from this research I was able to compare the academic settings of Aalborg and SITL. This helped me to understand the challenges or constraints to PBL implementation in India.

b. During this research, I encountered various data collection strategies including observation, field notes, interviews and surveys. In fact, the design of the first survey instrument was carried out for use in this case study. These data collection strategies later proved important for collecting data in the Indian context. The outcomes of this case study have been published. The published paper is attached in Appendix A_{13}. The complete reference for the publication is:

Vikas V. Shinde, Anette Kolmos, ‘Students’ experience of Aalborg PBL Model: A case study, European society for engineering education’, *SEFI Annual International Conference*, Lisbon, Portugal *WEE2011*, September 27-30, 2011.

4.2 Contextual understanding

Cobb et al. (2003) conceptualised a learning environment as a complex interacting system in which many factors, like teachers, students, resources, tools, tasks and means for supporting learning, interact and are dependent on each other. The means for supporting learning encompasses the availability and cost of equipment, the teaching and learning methods, and policy levers (Kelly & Lesh, 2000). The nature of these elements changes from context to context. For example, the educational background the teachers and students in Europe and India is different. Therefore, contextual understanding is useful at the beginning of designing learning environments or educational environments. Contextual understanding is also important in clarifying the rationale or objectives of the design; the focus of the study and what needs to be improved can only be known from the contextual understanding. Having prior understanding of the context makes researchers aware of issues in the system, context strengths and limitations, current methods etc. If the context is sidelined, it will lead to incomplete understanding and may raise questions about the usefulness of the design (Brown, 1992). Above remarks by pioneering researchers in the field clearly emphasise the role of contextual understanding in the DBR process.

The context for the current research is the Sinhgad Institute of Technology, Lonavala (SITL). This institute is governed by policies from the University of Pune’s (UoP) top management and administrators. SITL also consists of teachers, students and the supporting staff. It was necessary to identify the current student capabilities, practices, and other resources on which design might be developed. To design an effective, useful, workable PBL model for SITL, proper understanding of these elements was necessary. Since I worked at this institute for the past eight years, I was already aware of most of the above aspects. However, manipulating these variables to design the PBL model was the biggest challenge for me.

The main steps taken to develop my contextual understanding were aimed to develop my understanding of the relevance, drivers and challenges for the PBL model design in an Indian context. Additionally, a conceptual design of the first CLPBL model was developed in this phase. This design mainly included project design to suit the existing curriculum and the design of assessment norms. In this chapter, these design activities are discussed in detail.

In the beginning, I spent considerable time referring to the literature related to Indian engineering education and PBL. During this process, I spent time developing my understanding of PBL and its implementation for the Indian context. Many questions came to my mind. For example, what are the drivers and challenges of PBL implementation in India? Is PBL relevant to Indian engineering education? What are possible ways of implementing PBL in India? Addressing such question helped me to assess the needs and build a foundation for my PBL model. During this process, I published two important papers described below.

4.2.1 Relevance of PBL for Indian engineering education

The main objective of this paper was to establish or understand the relevance of PBL for engineering education. The relevance of PBL for Indian engineering education is established with the help of a mapping exercise. In this paper, effects of PBL on students’ knowledge and skills were elaborated with the help of different examples of PBL implementation from around the world. Later on, these effects were summarised and mapped with the desired set of skills demanded from Indian graduate engineers as deduced from the national survey conducted by FICCI in association with World Bank (Blom & Saeki, 2011). In this exercise, it was demonstrated that the skills required from Indian graduates could be developed by using PBL practice. However, to make this possible there was a need to design a PBL model that would be suitable for Indian institutes. This paper is attached in the appendix A_{13}.

Vikas V. Shinde, 'Relevance of the problem and project-based learning (PBL) to the Indian engineering education', *3rdInternational Research Symposium on PBL* 2011, 28-29 November 2011

4.2.2 Problem-based learning in Indian engineering education: drivers and challenges

Most of the data used in the paper described here was referenced from the Indian literature. From this literature review, it could be understood that there were far fewer cases of PBL implementation in India. The Indian engineering student community, although very large, had never even experienced PBL in a structured manner. To develop a structured and scalable change in the pedagogy, efforts were required in the area of curriculum design. In the paper described above, PBL was found to be relevant for India. However, it remained undetermined how to design a PBL model for the Indian context, in which academic settings and practices are different from in the western world where PBL is originated. The Indian context may offer resistance or there could be favourable factors for PBL implementation. This paper illustrated the drivers and challenges of PBL implementation in India.

This paper described the skill and employability of Indian engineers, the need for innovative teaching-learning practices and the demand for a skilled work force as major drivers for PBL in India. However, the diversity in educational culture resulting from India's huge population posed significant challenges for PBL implementation. Other major issues in PBL implementation in India include the academic culture and cultural diversity, lack of awareness and PBL resources, shortage of trained faculty and lack of legislation and jurisdiction relating to PBL. For further details, please refer to appendix A_{10}.

Vikas V. Shinde, Anette Kolmos, 'Problem-Based Learning in Indian Engineering Education: Drivers and Challenge, Proceedings of Wireless VITAE 2011', Chennai, India, *2nd International Conference on Wireless Communication*, Vehicular Technology, Information & Theory and Aerospace & Electronic System Technology, 28-02-11 - 03-03-11.

4.2.3 Analysis of local level requirements

In the previous sections, it is shown that there is a need to design a PBL model for Indian institutes. However, I was uncertain whether to use an institute-level model or small-scale experiment at the course level. To make this decision, I critically analysed SITL culture and constraints. The existing curriculum was analysed to determine possible methods of PBL implementation. These aspects are discussed in the next section.

4.2.3.1 Existing administrative and institutional setting

The Indian educational system uses hierarchical approach in which ownership of decision-making lies with top management. SITL is no exception to this. SITL is governed by the rules and regulations set out by UoP. The principal heads the SITL. Each department has a department head. Each department also has a sufficient number of teaching and non-teaching staff to support the curriculum structure (I am a teaching staff). The last human element of the system is the student. The SITL has classrooms, a laboratory, a computer centre and central library to support the existing curriculum. Apart from this, the institute has sports, recreational, mess and canteen facilities. The finances for running the institute are managed out of students' tuition fees.

Perspectives for PBL implementation

In the literature review chapter of this thesis, I argued that all of the elements of the curriculum (curriculum structure, evaluation and teaching learning strategy) and SITL (physical and human resource) must be aligned in order to achieve institution level change (from traditional to PBL). An institutional level change appeared to be impossible for SITL at this stage. The staff at the institute were not trained, the students were not aware of PBL and the curriculum would require significant reorientation to be suited for PBL practice. Considering the time frame of the research, this option appeared unmanageable. Also, as discussed, there were many institutional constraints. It was apparent that the PBL model needed to be designed by tackling these constraints. Some of them were beyond my control, for example, curriculum design or staff recruitment. As a result, I started to look for alternative options that would be within my reach.

I began to look for an approach that would enable me to initiate changes at the programme or course level. I researched top down and bottom up strategies for change in the literature (Kolmos, Gynnild, & Roxa, 2004). In the top down approach, top management makes a decision to implement PBL and initiates the change process. This was not possible in my case as the top management was not directly involved in my research. My position as a teacher at the institute held the lowest authority in terms of governing the institute. To implement PBL in the SITL in a top down approach, consent from top management is very much essential. Top management advised that I experiment on a single course without disturbing other courses. I found this bottom up approach to be more suitable and manageable for my research as it allowed the possibility of initiating the change process myself while conducting my research. The relevant literature also recommended experimenting first at the course level and then applying the methods to the institution (Cawley, 1991). I found that the course-level approach was typically used in the traditional system where there are other parallel courses taking place at the same time (Woods, 1991, Mantry et al., 2008). In the course level PBL implementation, the lecturer would generally decide nature of PBL activities and the learning objectives. Since, PBL is implementation in a single course in the traditional system where there are other parallel courses taking place at the same time, students would participate in a mix of traditional and PBL course (Kolmos, Graaff, & Du, 2009).

The advice from top management and my own self-reflection helped me in the decision-making process. I chose to focus on course level PBL implementation and decided to implement PBL into my course. As a teacher at SITL, I usually oversaw the subject 'Theory of Machines-I' (TOM-I). This course is for second year mechanical engineering students in their second semester. In the next section, the curriculum structure of the second semester is discussed. Including the whole semester curriculum here will also illustrate curriculum practices followed at SITL.

4.2.3.2 Existing curriculum structure

The table 4.1 shows the complete curriculum structure of the second year, second semester mechanical engineering undergraduate course. The structure and syllabus is provided by UoP and can be found on the UoP website at www.unipune.edu.in (UoP, 2012).

Table 4.1 Existing teaching and examination scheme (UoP, 2012)

Course code	Course	Teaching scheme		Examination scheme				Total marks
		Lect.	Pract/Dwg	Paper	Term work	Oral	Practical	
202047	**Theory of Machines-I**	**4**	**2**	**100**	**50**	**-**	**-**	**150**
202048	IC Engines	4	2	100	25	-	50	175
202049	Geometric Modelling	-	4	-	25	-	50	75
203050	Electrical Technology	4	2	100	25	-	-	125
202051	Strength of M/c. Element	4	-	100	-	-	-	100
202052	Production Technology	3	-	100	-	-	-	100
215053	Workshop Practice	-	2		25			25
	Total Of Second Term	**19**	**12**	**500**	**150**	**-**	**100**	**750**

From table 4.1, it can be seen that there are seven courses in the curriculum, five of which are theory courses. I decided to implement PBL in one of the courses (see highlighted course) because I was given the responsibility of teaching this course. Other courses were allotted to other teachers. Table 4.1 also provides a summary of the teaching and evaluation schemes for the chosen course. Four hours per week were provided for lectures and two hours per week for laboratory work. At the end of the semester, there was a written examination for 100 marks. This examination was based on the content outlined in the syllabus. A sample copy of the syllabus for the highlighted course is attached in appendix A_2. This syllabus was divided into six units and the topics to be covered were listed under each unit. In the final examination, each unit carries equal marks.

The highlighted course also included 50 marks for term work. Term work refers to work that needed to be carried out by individual students in the given term. This work essentially included conducting laboratory experiments (lab work), drawing and writing an assignment. The items under the heading of term work were also listed in the university syllabus. Term work marks were allotted to individual students based on performance in the listed work. For the laboratory work, the whole class was divided into four batches. Each batch had to visit the TOM laboratory for two hours every week to conduct the listed experiments. UoP conducts practical and oral examinations for the courses listed in the curriculum structure. The university appoints external examiners for these examinations.

It should be noted that there was no project head in this semester of the curriculum. UoP plays a pivotal role in designing courses, detailing the syllabus and conducting various examinations for the overall evaluation of individual students in the institute. I had no flexibility to change the course content, experiments and examination scheme. All of these elements put constraints on the project design; the challenge was to see what could be done within these constraints.

Teaching and assessment Strategy

As the teacher, it was my responsibility to prepare students for the final examination for the 'Theory of Machines- I' course. The institute's role was to provide the infrastructure and facilities to support this preparation process. The course result (passing percentage) was one of the important parameters for evaluating students' performance. The course results depended on many factors, one of which was the effectiveness of the instructions for dealing with the course content. Accordingly, each course was assigned to an expert teacher. Once the teacher had been assigned to a particular subject, his timetable was prepared. My timetable has been reproduced here for reference (figure 4.1). The timetable includes the schedule of lectures and laboratory hours. Generally, for the lab practice whole class is divided in four equal batches. Accordingly, in the timetable, S_1, S_2, S_3 and S_4 show the four batches of the second year class that would visit the Theory of Machines (TOM) laboratory.

Class Room (D-106) Time Table : SE Mechanical Engineering						
Prof. V.V.Shinde		**Sem - II**		**A.Y. 2011-12**		
					w.e.f. 02/01/2012	
Time/day	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**
08.05 - 09.00 am						
09.00 - 09.55 am						
09.55 -10.50 am	**TOM- I**				**TOM-I**	
10.50 - 11.50 am	**LUNCH BREAK**					
11.50 am-12.45 pm	S-1 TOM (VVS)	**TOM- I**	S-4 TOM (VVS)	**TOM-I (VVS)**	S-3 TOM (VVS)	
12.45 - 1.40 pm						
01.40 - 01.50 pm	**Short Break**					
01.50 - 02.45 pm		S-2 TOM (VVS)				
02.45 - 03.40 pm						

Figure 4.1 Sample timetable for the course

As can be seen, my timetable included 4 hours of lecturing time and 8 hours (2 hours X four batches = 8 hours) of lab work per week. In total, I had 12 contact hours per week with the students. From the timetable above, it can also be seen that the students are in the institute from morning until afternoon, up to 4 pm. In this time, students must attend a number of other courses (as listed in table 4.1) in addition to my course. The blank spaces in the timetable were allotted to other courses in which other teachers instructed the students. Apart from teaching my course, my role was also to design and conduct various written tests, to assess the students' knowledge and understanding gained from classroom instructions and to provide timely feedback on their performance. The sole objective of these written tests was to prepare students for the final written examination. Accordingly, the questions in the tests were designed to align with the final university examination.

Students' activities in the traditional setting

The students' main activity was to attend the lectures and laboratory hours as outlined in the timetable. Classroom activities mainly included listening and participating in the discussion, if there were any. For the laboratory work, each batch (refer timetable S_1, S_2, S_3, and S_4) was required to visit the laboratory for two hours in accordance with the timetable given to them. In the lab, students were required to perform an experiment as per a list that was given to them. They recorded their observations and wrote the experiments in a journal. This journal had to be certified by the teacher and was very important for the oral or practical tests. This was how the two hours of lab work were utilised by the students.

Examination

Students' evaluation was based on:

1. Performance on the written test
2. Performance on the oral/practical test.

Both written and oral examinations evaluate individual students and were conducted at the end of the semester; by the university. The focus of the written test was to assess the candidates' ability to remember and reproduce knowledge derived from lectures and from self-directed study. The written examination was solely based on the syllabus/content provided by the university. As a result, most of the students were aware of which content could appear in questions asked in this examination. Writing the test merely required the students to prepare the content and reproduce it in the test. The role of UoP was to design a question paper for this examination. UoP also provided a marking scheme and model answers to the teachers for evaluation purposes. The course teacher evaluated students' answer sheets and course grades were prepared. For each course in the curriculum, this procedure was followed. Please note that, as per the UoP rules, I was not allowed to evaluate the final examination answer sheets for my students. This was done instead by teachers from other institutes affiliated with UoP who taught the same course in the semester. As a result, I was not in a position to judge what students had written in the main examinations. The only indicator by which I could judge the students was the marks they achieved in this examination. I used these marks for the analysis of my research.

The oral examination was based on content from the journal. The journal was brought with at the time of the oral examination. Students were evaluated by an external evaluator appointed by the university. Most examinations were in the form of viva-voce. An external examiner allotted marks based on the students' performance in the oral examinations.

4.3 Reflections on the current academic practice

For effective learning in a curriculum there should be a close alignment between the content, the teaching–learning methodologies, and the assessment and evaluation schemes (Biggs, 1996). These three elements of the existing curriculum and educational practices at instituteswere analysed and the following observations were made:

1. The institute and teachers do not have the authority to change the content and curriculum structure. The university determines the curriculum and affiliated institute must follow it. The institute also does not have any part in the evaluation process. The institute's role is limited to preparing students for the written examination at the end of the semester. This places restrictions on the teachers in terms of adding or deducting any curricular activity.

2. The institute practices a traditional instruction-based pedagogy in order to prepare students for the final evaluation. The students' learning takes place mainly in the classroom and laboratory. They are confined to the classroom and laboratory and do not get sufficient opportunities to apply their knowledge in real life situations.

3. Because of the end semester written test, students tend to focus on obtaining better grades over learning. The current assessment and evaluation scheme assesses students' abilities to remember and reproduce content. These abilities are considered to be lower order thinking abilities (Krathwohl, 2002). The existing curriculum and educational practices are likely to promote rote learning. Students tend to be active listeners and passive learners in the classroom.

These issues are important and need to be addressed. In my opinion, the institute is doing well as far as facilities are concerned including teachers, classrooms, and labs. However, the institute's practices focus only on promoting the transmission and acquisition of knowledge. They do not promote application of the acquired knowledge to real-life situations, which is very important for engineers. Also, these educational practices do not provide an opportunity for active learning or for the development of the skills that are needed in the national requirements discussed in chapter 1. Hence, there is a need to make the appropriate changes in the institutional and curriculum practices in order to increase the application of knowledge, and the active learning and skill development of graduate engineers.

To this end, PBL is important. A proposed PBL model was designed to satisfy the following objectives or criteria, which were derived from local academic conditions:

1. The model should enable content learning, which is required for the final examination

2. The model should encourage students' active learning and provide an opportunity for the application of knowledge

3. The model should be able to promote the achievement of ABET learning outcomes

The challenge for my research was to design and implement PBL that would satisfy the above criterion within the existing academic and administrative settings of SITL. With this criterion in mind, I began the theoretical design of the first PBL model.

4.4 Course level PBL model

The course level PBL model design process started with the need for a guiding framework, to give an idea of the curriculum change. Kolmos, Graaff & Du (2009) proposed a PBL alignment model for curriculum change from traditional pedagogy to PBL. According to this model, for institutional change to occur, the curriculum philosophy must change and resources must be aligned to support the curriculum change. They asserted that the elements of the curriculum, such as type of project, teaching-learning strategy and evaluation, must be aligned for effective learning. It is also important to align the existing facilities, such as laboratory, meeting spaces and time-tables, for effective PBL implementation. In the context of the current research Kolmos, Graaff & Du’s alignment model was used as a point of departure. However, this model was developed for institutional change; I have modified it for course level implementation at the Indian institute, as shown in figure 4.2. The parameters for the PBL curriculum design have already been discussed in chapter 2.

It gives me immense pleasure to introduce my first ‘**CLPBL model’**. Based on the content of the present research, the CLPBL model includes the project design, design of assessment norms, teaching-learning strategy and supervision. It also includes the innovative use of existing facilities and time management for its effective implementation. These elements are put together in a closed loop to form a course level PBL (CLPBL) model. In the following sections, the detailed design of CLPBL-1 will be explained. I will begin with project design, which will be discussed in the next section.

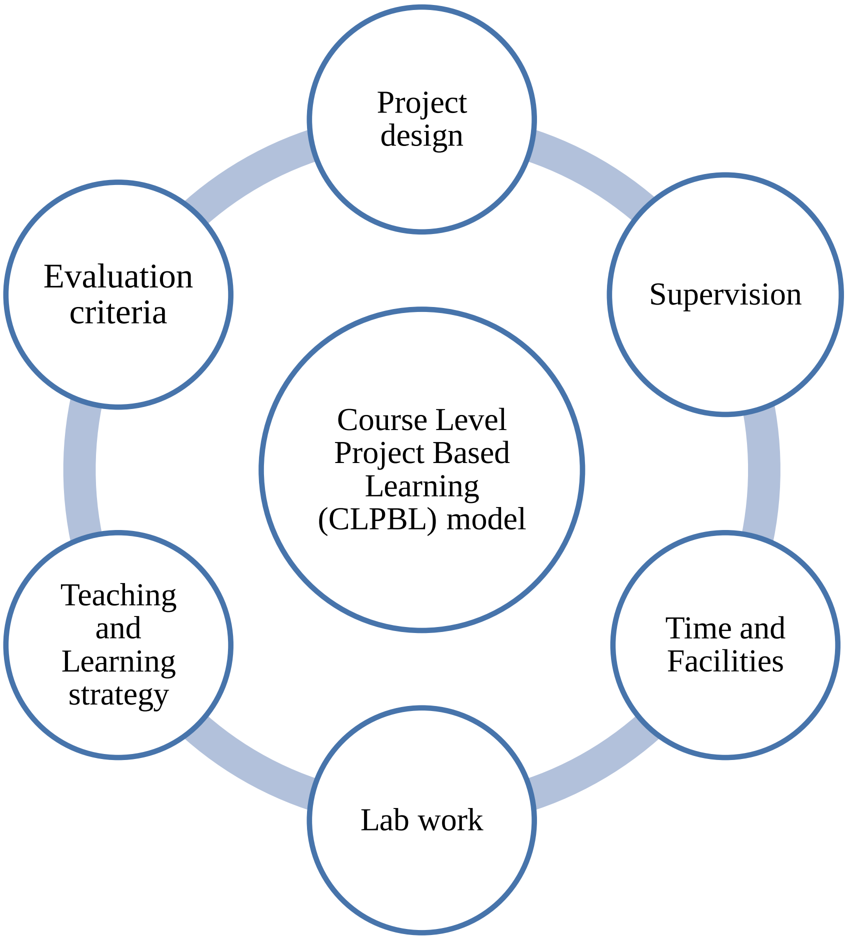

Figure 4.2 Course level PBL (CLPBL) model

4.4.1 Development of the project

In chapter 2, I discussed project design as one of the most important elements for the PBL curriculum. In his definition of problem-based learning, Barrows (1986) provided useful guidelines about the nature of the problems or tasks in PBL:

1. The project should be relevant to the profession and must replicate real life professional situations

2. Problems must be complex enough to challenge students

3. Problems must be ill defined and can have multiple solutions.

These guidelines were used in the initial stages of the design. As discussed in chapter 2, there could be three types of projects, namely task, discipline and problem projects (Graaff & Kolmos, 2003). I found that the discipline project could serve the objectives of the course and also lead to achievement of the desired learning outcomes. In the discipline type of projects, tasks are predefined by the teacher to suit the course objectives as pertaining to a specific discipline. The students' role is to perform the project tasks given by the teacher. With these guidelines in mind, I started developing the project activities.

4.4.1.1 Factors considered for development of the project

1. Curriculum structure

As discussed in the earlier sections, there was no possibility for making changes in the curriculum structure, course content or the examination pattern. This meant that I had to find an opportunity to embed the project into the existing curriculum. After careful study of the curriculum, I found an opportunity in the form of term work. The term 'term work' refers work that must to be carried out by the individual students in a given term. There was an element of flexibility involved in the term work. As a teacher, I could assign or design any activity related to the course. Accordingly, I decided to embed the project work within the term work. Consequently, I divided the 50 marks for the term work into two parts, assigning 25 marks for laboratory activities (as per the UoP syllabus) and 25 marks for a project, as shown in Table 4.2. This decision was based on the belief that allotting 25 marks for the project work would be enough to motivate students to engage in the project. Accordingly, the course structure was modified as shown in table 4.2.

Table 4.2 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 highlighted portion show the project was added into the term work. The total of 150 marks for the course remained the same as in the earlier structure shown in table 4.1. This way an opportunity was created to embed the project into the course. This adjustment, however, introduced a new constraint on the project work. The project work should be such that it justifies 25 marks.

2. Duration of the project

Generally, a single semester consists of 14 weeks of academic work, including teaching and laboratory work. This meant that the project should be completed within the time frame of 14 weeks. A semester also includes six more courses according to the curriculum structure (table 4.1). Students also have significant workloads for these courses. The students must manage the project work in addition to their regular academic schedule. Therefore, care had to be taken in designing the project so that it should not place undue stress on the students.

3. University requirements

For the given semester, the students had to appear for the end term examinations for all courses. For the oral examinations, it was mandatory for students to complete the laboratory work for all courses. Students' laboratory work, then, must also not be hampered by the project work.

4. Relevance to discipline and content

While designing the project, it had to be ensured that the given project was closely relevant to the profession. This meant that students' projects must have been suited to the requirements of the engineering major. For the current research, the project relate to mechanical engineering.

In PBL principles, content learning is one of the principles which elaborate an importance of the content to be learned. This point signifies that the chosen problem must be in line with the content to be learned. Hence, in order to properly choose the project, it was essential to understand what the students were going to learn in the given course and what they could achieve while working on a project. To develop the project, it was important to understand the course objectives and the relative worth of the course within the curriculum structure. It is my belief that such an understanding lead to the proper choice of activities for the project. With this belief, I started analysis of the course.

The TOM course is a foundation course for mechanical engineers and is closely associated with the design aspects of machines. It is expected that students will learn the basics of this course and understand the importance of the subject for a design purpose. The course contains important concepts like links, joints, mechanisms and inversions in the first unit. The second and third units comprise of various graphical methods for determining the velocity and acceleration of links. The first three units cover 50% of the syllabus and 50 marks in the main written examination.

The last three units cover the remaining 50% syllabus and 50 marks of the examination. In these units, students are expected to learn analytical methods for determining velocity and acceleration of links. The fifth unit is related to the synthesis of mechanisms, and the last unit is focussed on static and dynamic force analysis. In the last unit, the focus is on understanding the various methods for determining the radius of gyration and force analysis of an engine.

Over the course of my teaching profession, I dealt with this course many times. I observed that students made mistakes in calculating the degree of freedom (DOF) of a mechanism and in drawing velocity and acceleration polygons. The reason for these mistakes was generally a lack of understanding of the basics of a machine such as links, pairs and joints. It may be noted that the correct calculation of number of links, joints and pairs leads to the correct DOF. Students also made mistakes in identifying and classifying types of motion (turning, sliding, rolling or oscillating) in their drawings. Based on the frequent occurrence of such errors, I decided to focus on important concepts like DOF, calculation of velocity and accelerations of links of a mechanism, which are essential for building foundational knowledge of the subject. These concepts cover the first three units of the course, which is almost 50% of the TOM syllabus. I carefully studied the content of the first three units to be covered in the project. For these three units, the important objectives that students would need to achieve by the end of the project were:

1. The student should be able to understand, identify, and classify different types of mechanisms
2. The student should be able to calculate the DOF of mechanisms
3. The student should be able to apply graphical and analytical methods to determine the velocity and acceleration of various links of mechanisms.

Classroom instruction was used to deliver theoretical knowledge about the above concepts. However, for the application of these learned concepts, the project needed to be designed.

5. ABET learning outcomes

Another criterion for the project design was to promote the achievement of learning outcomes through project activity. In traditional instruction based pedagogy students received limited opportunity to achieve the learning outcomes defined by ABET (please refer to chapter 1, table 1.1). In my judgement for this course, only three of the LOs (a, b and e) listed in the ABET criteria were able to be fully or partially achieved through the traditional teaching and learning practice. The traditional practice promotes students to ***apply knowledge*** (*LO- a*)***, solve textbook engineering problems*** (*LO- e*)***,*** *and to* ***conduct, interpret and analyse data*** (*LO- b*)***) collected from laboratory experiments listed in the syllabus***. However, this method falls short of the ABET criteria in the following ways:

1. The course does not promote the application of knowledge on real engineering mechanisms (LO- a) or the analysis and interpretation of data gathered from field experiments (LO- b). These elements are essential for the design of mechanisms.

2. The course does not allow students to work in a team (*LO- d*), which is essential for professional practice.

3. The course does not promote the development of process competences such as communication (*LO- g*) and project management (*LO- k*) or the lifelong learning (*LO- i*) skills desired by ABET criteria.

The objective of a project would be to achieve these additional learning outcomes (d, g, k and i) and to strengthen the already achieved learning outcomes (a, b, and e). Thus the designed project will cover seven out of 11 ABET criterion.

6. Students

According to Ozansoy & Stojcevski, (2009), the nature of the problems (ill-defined) discussed by Barrows does not always work. There are many other parameters that need to be considered in project design. One such important parameter is the ‘level of students’, which means the students’ abilities, the level of undergraduate studies they are in and their prerequisites knowledge about the subject. Many researchers echoed this view, including Ellis et al. (1998) and Wu (2006) (both cited in Ozansoy & Stojcevski, 2009).

The students involved in my experiment were second year mechanical engineering students who had followed a traditional way of learning since childhood. They had never experienced PBL, nor had experience working in a team. Working on a complex problem could be very difficult for them. For this reason, I decided to design a less complex problem which they would be able to complete.

The class strength for this semester was 97. These students came from different parts of the country, resulting in a huge variation in educational experience among the students. Their grades in the qualifying examination reflected the variation in their intellectual ability. The prerequisite knowledge required for the subject may also have been limited as the students did not study any course related to the course content prior to the current semester. Hence, students may be required to acquire knowledge first before being able toapply that knowledge.

7. Available and required resources

It is expected that the project should not cause any financial burden on the participants. The students should be able to complete the set of activities with minimal travel and with material resources available at the institute. The project should be able to be completed within the existing infrastructural facilities at the institute. All of these factors were taken into account to create a project design.

4.4.1.2 Characteristics of TOM project

The problem choice or project design is considered to be a very important and challenging task in PBL model design. To start the development process of the project, I needed to find a way to design a project suitable for the course. Savin-Baden & Major (2004) defined different curriculum modes in problem-based learning. I found the first two modes they described to be relevant to my research. When the PBL is applied for a single course it is called as Mode 1. When PBL is implemented in a module run by teachers interested in implementing PBL and other teachers do not participate it is called as Mode-2. In my case, PBL is to be implemented in one course of the curriculum (Mode-1) and implemented by me (Mode-2). Hence, the model could be in line with Modes 1 and 2. The model could also be characterised by Models I and II as described by Savin-Baden (2000). Model –I is characterised in which students are expected to become competent at applying preceding knowledge to solve the given problem. In Model II, the emphasis is given on actions to enable the students to become competent in practice. In my model, students are getting both opportunities i.e. to apply knowledge and to practice.

4.4.1.3 Project

The project design process was guided by the case study conducted at Aalborg University (Shinde & Kolmos, 2011) and a review on PBL models (please refer to chapter 2) and the 3C3R model of problem design (Hung, 2009). This design was also directed by curriculum design principles such as Bigg’s constructive alignment (1996), Bloom’s Taxonomy (Krathwohl, 2002) and the ABET learning outcomes (see table 1.1, chapter 1). The project activities were selected to suit the students' abilities, the course content and the institutes' existing academic culture and infrastructure. Ross (1991) elaborated different ways to present the problem to the students. The problem could be presented as an event, set of questions or a statement and desired set of activities (Ross, 1991). Accordingly, the problem was presented in the form of a statement (see below) and a set of activities, as shown in table 4.3.

Problem statement- Analyse any real life engineering mechanism to evaluate its Degree of Freedom (DOF).

Table 4.3 shows the coherence of project activities and intended ABET learning outcomes (refer to table 1.1, chapter 1). The project was designed to cover the defined course objectives and seven out of 11 graduate LOs as defined by ABET.

Table 4.3 Mapping of the project activities and intended learning outcomes

Activity No.	Project activities	Intended ABET Learning Outcome (LO)
1.	The team formation	d
2.	Problem solving and drawing sheets in a group.	b,d, i
3.	Laboratory work in a group	d,e,a
4.	Identify the mechanism, submit and justify it.	a,i
5.	Undertake the field work.	a,k,i
6.	Explain the working of the mechanism.	a
7.	Find types of links, pairs and joints used in the mechanism.	a
8.	Classify, specify and calculate them.	a
9.	Apply Grubler's criteria.	a
10.	Find the DOF and justify your answer.	a
11.	Prepare a project report.	g,k
12.	Present to an audience.	g,k
13.	Questions and answers	g

Short description of the project

In this section, the project is explained to enable readers to understand it. In the PBL setting, students deal with the problem in a team. So, the team formation process acted as the first activity. By forming a team at the beginning of the semester, it was ensured that the participants would get at least three months to work together on the project. As discussed earlier, a whole class is divided in the four equal batches. Thus, each batch would visit TOM lab once in a week. Hence, to manage students group and to get enough time for guidance/ supervision, I asked students to form a team of five members from their batch only. The second activity had students work in a team and apply their knowledge to solve engineering problems from the textbook. Each group was assigned two different problems for drawing velocity and acceleration diagrams. This activity was intended to help students settle in and adjust to their groups. In addition, this activity was intended to improve students' content learning.

The third activity was laboratory work. In this activity, the group was asked to conduct the experiments in the TOM laboratory. This helped students to complete their assigned laboratory work and to work in a team to analyse and interpret data. By the time the fourth activity began, the students would likely have settled into their groups. At this point, students were asked to submit the name of the real life engineering mechanism that they were going to analyse. The intention was to make the students think and discuss the real life engineering mechanism and research it through various sources.

Activities 5 to 10 mainly comprised fieldwork activities. In fieldwork, students were expected to visit the place where the mechanism is used. They needed to understand how it works and identify important links, joints and pairs. It was hoped that these field visits would generate interest and curiosity to learn more about the machines. It was also anticipated that the students would try to find the relevance of the classroom instructions and actual engineering. It was hoped that their knowledge and understanding of the subject would be increased as a result of the fieldwork.

Only once the fieldwork was completed, students could apply the criteria to calculate the DOF. In the project, activities 4 to 10 required the students to search information from various sources, apply knowledge, discuss with their team, decide on a mechanism, find a real life application and place, visit that place, understand and collect the data and come back to calculate the DOF. These activities formed the core of the project and were intended to achieve higher order thinking skills such as analysis and evaluation. These activities were in line with the cognitive learning principle of PBL.

Once the students finished calculation of the DOF, they needed to prepare a project report and present their work in front of the class. After the presentation, the team had to answer questions asked by evaluators. This segment was intended to improve the students' communication skills (report writing, presentation and discussion). There was considerable autonomy given to the students to choose a mechanism according to their interest. This method could provide intrinsic motivation to the students. Students also selected their teammates and set up their project plan for the entire semester. Additionally, acquiring additional information to achieve the desired output was directed by the students. These activities would prepare them for the achievement of the lifelong learning skill.

In the designed project, the series of activities were designed to get disciplinary knowledge, making ita discipline project. It was hoped that the students would be able to learn and achieve learning outcomes what would otherwise not be obtained by traditional teaching and learning practices.

4.4.2 Teaching strategy

In the TOM course there are six units (refer to appendix A_2) divided into two sections: section-I and section-II. Dividing the syllabus into six units is a strategy of University of Pune. All courses in the curriculum have six units. The project activities were designed to address the content in the first section, which includes the first three units. These three units of section-I, were called ‘project units’, as they were directly related to the project activities. I planned to prioritise the teaching of these project units in order to provide the basic propositional knowledge that students would require for starting the project. Students were also given a list of reference books and handwritten notes. It could take around 6 weeks’ time to complete the project units in class. The other three units were covered using the traditional teaching-learning practice.

4.4.3 Plan for students’ Learning

Figure 4.3 (below) shows the envisioned learning process for the students. In the first block, the traditional instructional strategy is shown in which students acquire the knowledge through individual learning. They receive the basic fundamental knowledge required for the project from the teacher, as shown in block II. While the students were learning the fundamental concepts in the classroom, they were doing the initial project activities in the laboratory. In the laboratory work, students were working with their teams to solve the complex drawing problems and conduct experiments together. This process appears parallel to the first two blocks below.

In the third block of figure 4.3, it was anticipated that the students were ready to tackle the core activities of the project. They were likely to apply already acquired knowledge to the project activities. It was predictable that the students would learn through team-based learning processes (co-operative and collaborative learning), active and experiential learning. It was anticipated that the students would take the lead and assume responsibility for completion of the project. Concepts like self-directed learning and project management would play a crucial role here. In this phase, it was envisioned that the students would commence fieldwork with the team. They would observe the real life mechanism and analyse it to identify and calculate the number of links, pairs and joints in the mechanism. The data collected from the fieldwork was necessary for getting the DOF of the mechanism. Once they had finished their core project work, it was probable that their subject knowledge would improve and a deeper understanding of the core ideas of the subject would develop. In the last block IV, students were expected to prepare a project report and defend their work in the form of an oral presentation.

Figure 4.3 illustrates my perception of the students’ learning in this model. Whether or not they learned according to it will be investigated. The experience of working on the project might have led to confidence building, the refinement of concepts and increased knowledge. It was likely that project would build the confidence to sit the examination with a positive mind-set and may assist them in scoring good grades (this is not investigated here).

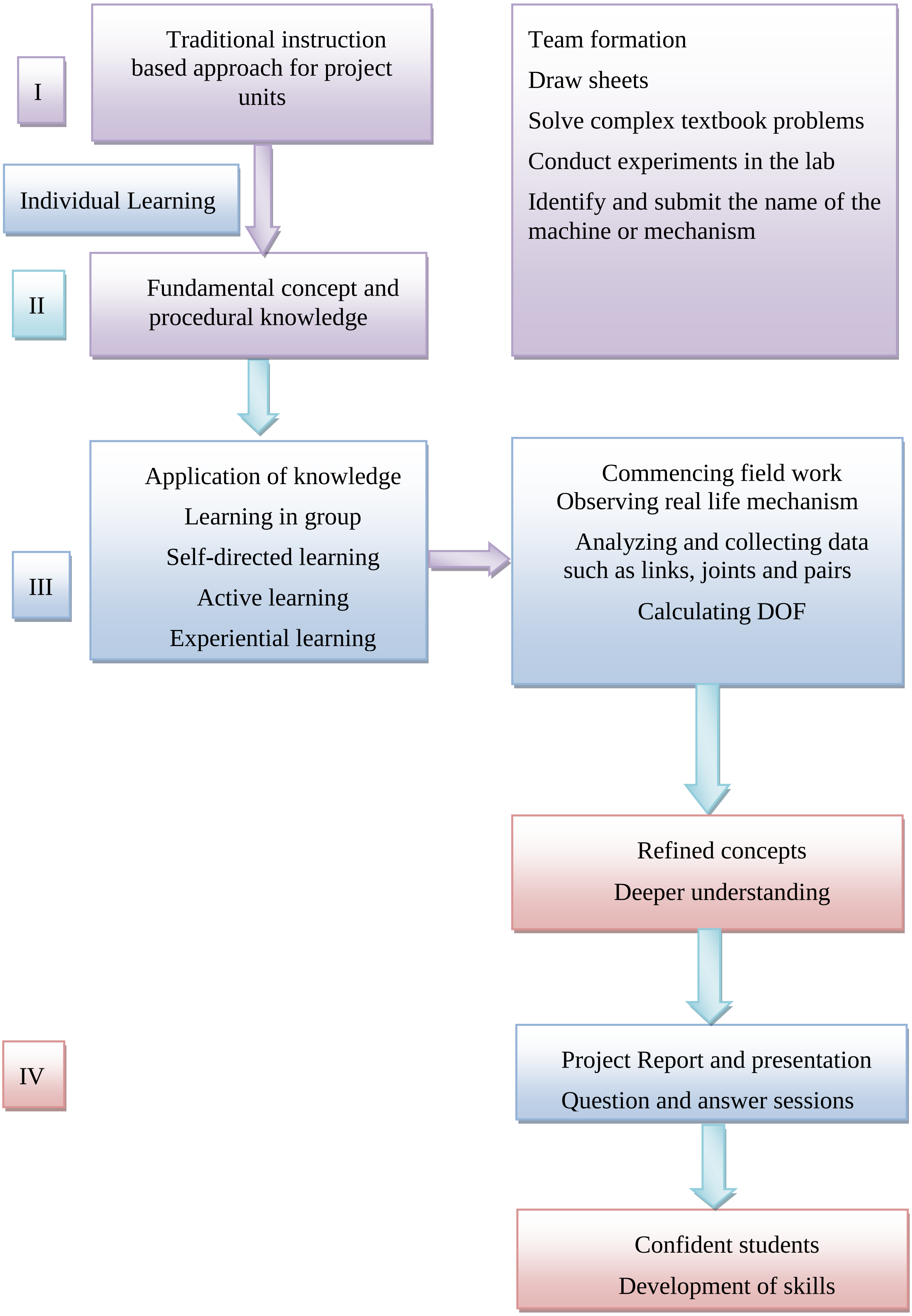

Figure 4.3 Learning strategies in a CLPBL model

4.4.4 Laboratory work

The laboratory work and classroom instructions were conducted simultaneously. At the start of the semester, the first week of laboratory time was utilised for the team formation process and followed by the laboratory activities. This arrangement was deliberately made so that students could get acquainted with their teammates. The class was comprised of 97 students. For the laboratory sessions, the class was divided into four batches of 25 students each. This meant that each batch had 2 hours of laboratory work and had to visit the Theory of Machines lab on a weekly basis. This provided a good opportunity to divide the batch into groups. Students were asked to form groups of 5 members each, from their batch only. It was strategic decision to opt for five members per group. Since the batch strength was 25, I thought five groups could be easily formed. Furthermore, if the teams had four members, the class would have had almost 25 groups. I was concerned that so many groups might be unmanageable in the given time. Instead, 17 teams of five members each and two teams of six members each were formed. In total, 19 groups were formed.

Two complex drawing sheet problems on the velocity and acceleration determination of various mechanisms were given to each group. Team members were allowed to work together on sheet problems for the first three to four weeks. This arrangement helped the students to settle into their groups and understand each other. By the time I finished the first three units; the students had completed the first few experiments and drawn sheets. They also utilised this time to find the appropriate mechanism for analysis. By this time, approximately half of the semester was over. The status of students looked like this:

1. Students were supplied with the necessary information and prerequisite knowledge
2. Students had formed their teams and worked together to finish lab work

In addition, by this time, I had finished half of the semester’s workload and was relatively free for supervision. This allowed the laboratory time to be utilised and work to be aligned to suit the project activities.

4.4.5 Time management

In the first model, from both my and the students perspective, time management was crucial. There were 19 groups and I was the only supervisor for all of them. Also, the designed project activities needed to be supported through various supporting activities. These activities included regular lecturing, self directed learning, laboratory work and supervision. Each activity required time and I had only six contact hours with the students per week (four hours in the classroom and two hours in the laboratory). I needed to utilise these six hours to facilitate regular teaching, lab activities and project activities. Table 4.4 summarises the time allotted for various supporting activities in the model.

The six hours per week allotted for the subject (shown in timetable, refer to figure 4.1) were utilised effectively to cover the curricular as well as project activities. No special timetable for this course was prepared. The project work was embedded into the existing curricular and institutional structure, and within the specified time. It may be noted that, in this model, the students needed to work beyond their contact hours to complete the project activities. However, supervision and evaluation was planned within contact hours.

Table 4.4 Time management of various activities.

Activity	**Hours per week**	**Utilisation of allotted time**
Teaching	04	Regular university curriculum is taught in the class during these four hours.
Laboratory work	01	This hour is used to conduct the experiments on the list given in the syllabus. In later phases of the semester, this hour is used for presentation and evaluation purposes.
Supervision	01	This hour is utilised for supervision purposes. The students were asked about the progress of their work. Also, if needed, they were extended necessary help to overcome difficulties experienced during their project work. In later phases of the semester, this one hour was also used for presentation and evaluation purposes.
Total no. of hours per week	06	

4.4.6 Supervision

During project work, students may require help on various aspects. In this sense, the supervisor plays a crucial role. For this reason, I assumed the role of supervisor. In the literature review (chapter 2), I elaborated on the role of the supervisor in the PBL environment. The role of the supervisor could be:

1. To motivate students to complete the project
2. To extend help as and when demanded by the students
3. To provide guidance or input on subject or content related difficulties
4. To monitor the progress of each group and take appropriate action to ensure all groups are performing the projects

As mentioned earlier, supervision for most of the time was managed during one hour of lab sessions.

4.4.7 Assessment and examination criteria for the project work

The project work undertaken by the students needed to be assessed and evaluated. Accordingly, I designed an assessment and evaluation scheme for the 25 marks, as shown in table 4.5. The 25 marks were important and were included in the term work marks (refer to table 4.2). The focus was to assess the field work, teamwork, presentation, question and answer sessions and the project report. Each item was allotted marks, as shown in table 4.5. Also, criteria for evaluation and the evaluators of the project are mentioned in the table 4.5. Detailed explanation is provided in the following text.

Table 4.5 Assessment and evaluation scheme for a project activity

Evaluation for	Allotted marks	Evaluators
Fieldwork	5	Teacher and Peers
Teamwork	5	Peers
Presentation and question and answer session	10	Teacher and Peers
Quality of project report	5	Teacher
Total marks	**25**	

4.4.7.1 Field work assessment

In the project, fieldwork was a very important activity. In fact, the outcome of the project largely depended on the quality of the fieldwork. Hence, five marks were allotted for the fieldwork. These five marks were provided in order to motivate the students to move outside of the classroom and see the machine and mechanism from a close distance. Students were asked to include proof of their fieldwork (photos of group work done at the site and communication letters, if any) in the report.

4.4.7.2 Teamwork assessment

This assessment was to be done by the students themselves (peer assessment). In the chapter 2 it is discussed that many authors (Luis et al., 2005, Raucent, 2001, Esche, 2002, Cawley, 1991) used peer assessment methods to find individual contribution in the project work. Also, it made sense to include this method because the students were the ones who worked with their teammates and knew their performance during project work. In addition, it would give them a tool to control and evaluate the non-performing students from their group. Table 4.6 shows a scheme for teamwork assessment. This scheme was developed by taking inspiration from Bellman and Ryan (2010), who have developed and written about eight collaboration indicators. Teamwork was assessed through observation and feedback from team members on a five-point scale. A sample teamwork assessment form is included below for reference. In this assessment scheme, each student was asked to rate their peers on a five-point scale from zero (min.) to five (max.).

As an example, imagine I am one of the members of a group comprising of Nitin, Payal and Vyas. I would rate my teammates, as shown in the table 4.6. Using this table, readers can see that, according to me, Nitin, Payal and Vyas would get 3.2, 3.4 and 3.8 marks respectively. Each group member would similarly rate each of their teammates. In this way; a total of 4 sheets would be generated. At the end, all of the marks earned out of five would be added and divided by the total number of assessors. Final marks out of five would be calculated this way. For example, if Nitin and Payal thought Vyas should get 3.2 and 3.5

respectively,then Vyas would get (3.8+3.2+3.5) / 3 = 3.5. Through this method, each student would be awarded marks out of five for teamwork, as determined by their teammates.

Table 4.6 Teamwork assessment sheet

Sr. No.	**Collaboration indicator**	**Name**	**Name**	**Name**
		Nitin	**Payal**	**Vyas**
1.	Involvement in the project work	3	4	3
2.	Attendance and punctuality in group meetings	4	4	4
3.	Participation in group activity and learning	3	2	4
4.	Contribution in presentation and report preparation	4	5	4
5.	Leadership qualities	2	2	4
	Total out of 25	16	17	19
	Total/5	16/5= 3.2	17/5=3.4	19/5=3.8

4.4.7.3 Assessment of presentation and question-answer session

Ten marks were allotted for the students' performance in a presentation and a question-answer session. Student groups were allowed to present their work for 20 minutes. Afterwards, presentation evaluation would be done on the basis of presentation quality and responses given to questions asked by the evaluators. Presentations would be assessed by both the teacher and the students. Students' involvement in the assessment was included with the intention of improving students' ability to critically question and evaluate other groups and their work. This would also form part of their learning process. Students and the teacher were expected to evaluate the student groups. Finally, all of these marks were added and average marks for each individual would be calculated, as shown in the following sample calculation table 4.7.

Table 4.7 Sample evaluation for presentation and question answer sessions

Sr. No.	Collaboration indicator	Name	Name	Name
		Nitin	Payal	Vyas
1.	Teacher	7	8	6
2.	Student 1	5	5	4
3.	Student 2	8	5	4
4.	Student 3	8	6	6
	Total out of 10	28/4=7	24/4=6	20/4=5

4.4.7.4 Assessment of technical report

At the end of the project activity, each group had to submit the project report according to the format already given to them. The quality of this report was assessed for technical content, plagiarism and adherence to the given format, as discussed in chapter 3. Because it was difficult to predict individual contribution to the report, each member was given equal marks for the report. In summary, the marks earned by the students in each activity would be added together to generate the final mark sheet for that group. A sample final mark sheet for a group is provided in table 4.8. The marks for all of the sub-items would get added in order to grade the individual students' project work out of 25. In this model, the students would be assessed in a group and graded individually. The individual grades of the students would be added into the other 25 marks that the students earned in the regular assigned laboratory work. Each student would be awarded a total of 50 marks for term work, as shown in table 4.1.

Table 4.8 Example of final mark sheet for a group

Student's name	Fieldwork 5	Teamwork 5	Presentation and question-answer session 10	Project report 5	Total out of 25
Vikas	4	3.2	6	3	16.2
Nitin	4	3.5	7	3	17.5
Payal	4	3.9	6	3	16.9
Vyas	4	3.5	5	3	15.5

4.5 Concluding remarks on the CLPBL model

At the start of my research, I intended to design a PBL model for SITL. I later realised that this was not possible within the specified time and I instead developed the idea of a course level PBL (CLPBL) model design. Designing the first PBL model took me three to four months. In the beginning, I thought designing the PBL Model meant design of the project only. Gradually, numerous other parameters came into the picture, such as teaching strategy, lab work, project assessment norms, supervision, and time management. All of these parameters were modified for effective implementation. A combination of all of these elements forming a closed loop is called as course level PBL (CLPBL) model.

It took me considerable time to design the CLPBL. I spent due time on the project design and its assessment norms in order to avoid deficiencies in the design. The project was designed to suit the institutional and curricular requirements. High emphasis was placed on the content learning and on promoting the achievement of learning outcomes. Other elements, like teaching and learning strategy, supervision, and time management, were equally crucial to reducing implementation deficiencies. In this way, the CLPBL model was designed for undergraduate students of mechanical engineering. This design met the objectives mentioned earlier in this chapter. Referring back to the research questions discussed in chapter 3, this section has addressed part A of the research question.

Chapter 5

Students'experiences in CLPBL-1

The conceptual design of CLPBL-1 for the TOM course was prepared in the pre-design stage. I designed this model when I was in Denmark. In February 2012, I returned to India. My immediate task was to implement the model at SITL. This chapter presents the implementation process and my analysis of the data and the impact on Indian engineering students. Referring back to the research questions outlined in chapter 3, this chapter intends to address the research question *'what is the impact of the course level PBL model on students' learning?*

5.1 Design enactment

Designing a theoretical model was only half the work required for my research; the model also needed to be implementedand evaluated for its effectiveness. Accordingly, I prepared a week by week implementation plan (refer to figure 5.1) beforehand. This plan shows a comprehensive view and the main steps of the implementation process. Some minor level modifications were made according to the situation as the experiment progressed. These changes are mentioned, with explanations, in this text. Assessment and evaluation points were also marked on an implementation plan.The project activities were intended to guide students through the project process, while the research activities related to the research data collection. I used this plan to monitor both activities.

Figure 5.1 shows a comprehensive view of the implementation process. The designed project activities and assessment norms were told to the students in the first week of the semester. The students were then asked to form groups of five or six. In the following weeks (weeks 5-12), the groups were asked to choose any engineering mechanism that could fit all of the designated project activities. Groups were allowed to draw sheets and work in the lab for the first three weeks of this period. Mid-semester feedback was collected in week 8 in the form of an essay submitted by each group. Towards the end of the semester (weeks 12-14), groups were asked to prepare a project report and present their project in front of the class. Project work was evaluated on the basis of the evaluation norms outlined in the first two weeks of the semester. Each group was evaluated; however, grades were assigned individually. The research data (here after this refers to the data collected by me for the research purpose) was collected by various means throughout this entire period, as discussed in the previous chapter. In this way, the designed CLPBL-1 was implemented at SITL.

This was my first experience of implementing PBL with Indian students. In the beginning, I was uncertain and concerned about the success of the designed model. I was worried about the reactions of the students and staff. It was also a challenge to collect the research data. Gradually, these issues and concerns were resolved. Students eventually responded to and completed the project in the semester. Moreover, the students provided useful feedback that generated my research data. This data was analysed and presented in the form of the results discussed in the next section.

Week number	Project Activities	Research Activities
Week 1-2	Students were informed about the requirements of the project. Students were asked to form groups. The problem statement, project activities, assessment and evaluation norms were discussed with all groups.	Initial contact was established with the students and an agreement was made for the purpose of the research.
Weeks 3-4	The textbook problems for drawing sheets were given to the groups, to be solved during laboratory hours.	Student groups were observed and supervised.
Weeks 5–12	Student groups were allowed to work autonomously.	Mid-semester feedback was collected, in which each student was asked to write an essay about his experience of the project and group work. Student groups were observed and supervised.
Weeks 12–14	The final evaluation of the project was performed Presentations and question-answer sessions were held.	End of semester feedback was collected -survey and interviews. Evaluation sheets and project reports were collected.
Weeks 15–16	Final grades for project work were prepared.	Reflection & data analysis was performed.

Figure 5.1 Implementation plan

5.2 Results

In chapter 4, I discussed the data collection methods used in this research. At the mid-semester point, qualitative data was collected via periodic observation and student essays. Qualitative data was also generated from group interviews and open-ended questions in the survey. At the end of the semester, students' responses were recorded in a questionnaire to generate quantitative data.The data collected by these various instruments was analysed in view of the research questions. This section will be dedicated to elaborating on these results.

5.3 Results from the qualitative data

5.3.1 Student essays

As determined in the implementation plan, the student's feedback was taken at the mid-point of the project work. All the students were asked to write an essay on the PBL model. Students enquired as to what they should write. I replied by asking them to write their experience of the group work, project, fieldwork etc. Out of 97 students, 82 submitted this essay. These essays were collected, read and interpreted. An inductive category development technique, which is described in chapter 3, was used to create different categories.The overall results of the essay analysis are shown below in table 5.1.

Table 5.1 Results of essay analysis

Major Theme	**Subtheme**		**Total no. of quotes**	**Percentage**
Teamwork (T)	Experience	-	36	86
	Collaboration	Positive	40	
		Lack	19	
	Usefulness for	Skill	28	
		Learning	55	
	Role of teammates	-	28	
	Communication	-	39	
Project (P)	Management	-	10	4
Information Management(I)	Information search and collection	-	08	3
Difficulty(D)	Teamwork	-	10	4
Suggestions (S)	-		09	3
			282	100

From table 5.1, it can be observed that 86% of quotes in the essays were about group work related aspects of the project. With the remaining 14%, students wrote about the project and its management (4%), information management (3%), their difficulties during group work (4%) and suggestions (3%). Each of these categories is discussed in the next section. Please note that, in the next section, there are many instances when a number will appear in brackets after the word; this denotes, the number of times the word or quote appeared in the essays. For example, if (4) appears in the text, it means that, the word or quote was repeated 4 times in the essays. The students have written very interesting quotes and stories. I have included a few of them in the discussion.

5.3.1.1 Teamwork (T)

In reading the essays I found that most of the students discussed different aspects of group work. From table 5.1, it canbe observed that 86% of the quotes in the essays were about group work related aspects. The CLPBL model provided the participating students with their first opportunity to work in the team. In writing about this experience, students discussed the nature (good or bad) of their group work experience. Students commented on their collaboration and communication patterns in the group. They also discussed the role of their teammates and how group work was useful for skill development and learning purposes. In table 5.1, I created sub-themes in the teamwork category to illustrate this. The subthemes will be discussed one by one in the coming section. The first sub-theme is about the experience of working in the group.

Teamwork experience

I found 36 quotes in the essays that mentioning the group work experience. The vocabulary used by students in these essays was very diverse. Students mentioned that the group work experience was good (7), innovative (5), excellent (1), fantastic (2), pleasant (2), and nice (8). These comments indicate that the students enjoyed working in a group. In my opinion, this is because most of the students were working in a group for the first time.

Collaboration in a team

In their essays, I found that students shared their views about the nature of collaboration in a team. I observed that these comments could be divided into two categories; some students indicated positive collaboration and some indicated lack of collaboration. I have included few of the statements that indicated good collaboration among members of the group:

> ***“We cooperate and help each other.”***
>
> ***“Everyone participated in the group work.”***
>
> ***“We have a lot of cooperation, coordination and interactions.”***
>
> ***“All members are working, active and cooperative.”***
>
> ***“We study together and learn together.”***
>
> ***“We are working as a team; participation is good and progressively improving.”***

In the essays, I found 40 comments along these lines. Most of the statements in this theme indicated cooperation, active participation and togetherness of the group members. These comments indicate that these groups were working cohesively. However, not all groups enjoyed the same collaboration and cooperation between members. I found 19 quotes that suggested some group members had issues and problems working in a team. The members of these groups stated:

> ***"Only selected people in our group work sincerely".***
>
> ***"We have misunderstanding in my group."***
>
> ***"We lack coordination."***
>
> ***"Not so good partners."***

The above remarks indicate that the group members were having issues withworking in a group. These issues mainly related to personal traits of the members and non-cooperation in teamwork. During data analysis, I found that 9 groups had better collaboration and 10 groups were having few issues withthe group work. In the groups that had difficulty collaborating, the issues were largely due to the behaviour of team members (11) and working with the opposite gender (1). The problematic behavioural aspects of team member included a preference for working individually, not participating in the discussion and slow learning.

From the above analysis, it seems that the students had difficulty working in a team. This was to be expected, as the students were working with each otherfor the first time. I can say that they are learning teamwork. In this view, I believe that they should be given more opportunities to work in teams so that they can become more effective at teamwork.

Usefulness of teamwork

During my analysis, I found that many essays began with statements like the following:

> ***"The group work was very helpful/useful/beneficial for me to................................"***

In total, I found 83 quotes indicating the usefulness of group work. I found it difficult to merge them into a single category. As a result, I decided to divide them into two sub-categories.

Skill development

The students understood the value of teamwork (4). They stated that teamwork was very important for understanding differences (2), building team spirit (2) and for 'polishing/ nurturing' their skills (2). One student commented on learning about the "challenges of teamwork" (1). Others found that theylearned "to listen and value other's opinions" (7). One student mentioned learning to work with different people (1) with different sets of beliefs and ideas. Many students (10) mentioned that their "communication skills were improved" due to group work and three students stated that group work was useful "improving leadership qualities."

From the above analysis, it can be understood that the students valued abilities like understanding differences and listening to the opinions of people with a different set of beliefs and ideas. These abilities are very important forworking in a team. It is evident that the students were making good progress in attaining the learning outcome (d), which is related to the ability to work in a team. A few students mentioned that their communication and leadership skill were enhanced, which are also essential skills for teamwork. In their essays, students stated that the group work was not only useful for improving teamwork abilities but also for learning. The group work's positive impact on learning will be described below.

Learning

Students found that learning in a group was far better and more efficient than individual and classroom learning. In this context, the term ‘efficient’ signifies that the students learned many things in a short span of time. Students also stated that they took responsibility for learning (2) and started using self-directed study (5). Moreover, they found that concepts became clearer (10) and understanding was increased (15) due to working in a group. There was an increase in knowledge (10) and confidence (2) about the subject. In the group setting, students learned from each other by sharing knowledge to help them understand the concepts and gain confidence. The following quote from one of the essays summarises the responses discussed above:

> ***“It is quite a good experience to study and learn in a group. It gives more understanding of a particular topic and it also covers a lot of ideas. The work is finished quite easily and quickly as compared to individual work.”***

In this sense, the role of teammates was very important. The next sub-theme will examine the role of teammates in the learning process.

Role of teammates

This theme addresses the role played by teammates in the learning process. Many students wrote that their teammates helped them in solving problems and difficulties (20), clearing doubts (20) and drawing complex sheets (7). Teammates also contributed by sharing their ideas and opinions. The following quotes provide some insight into how the students felt about their teammates:

> “***We work together with very good coordination and help each other by solving problems by discussion.”***
>
> “***It’s good to work in a group because any problems are easily solved and many brains are always better than one.”***

In summary, it was evident from the essays that the students helped each other in the learning process. Teammates cleared each other’s doubts, solved each other’s problems and helped each other to draw sheets. In designing this CLPBL model, I envisioned that the students would learn from each other. At this stage, it can be concluded that the team setting helped these students to learn and that the designed model was effective for content learning.

Communication

Communication between group members is a very important aspect of teamwork. This sub-theme indicated how the students responded to each other’s problems and queries and which modes of communication were used in group work. Whenever group meetings were held, it was apparent that the group members would talk about the project. Many students feltthat they learned from each other through various modes of communication such as discussing project ideas and opinions (18), sharing (10), interacting (5), explaining to each other (2), guiding, debating and asking questions (3). These many aspects of communication indicate that the students had good opportunitiesto improve their communication skills. In fact, as mentioned earlier, 10 students directly stated that their communication skills were improved by working in a group. An example statement from this category is included below:

> *“Due to group working, the communication with group members is improved”.*

5.3.1.2 Project work

When feedback was taken, most of the groups had completed the drawing problems and had not yet started the fieldwork activity. Students responded that they had started preparation for the fieldwork activity (4) by distributing the work equally within the group (5). A few admitted to not having started yet (3) and to needing more time to finalise the mechanism (1). The following quote indicates the status of the project for one of the groups:

> *“About our project work, we haven’t started it. But ideas are discussed and very soon we will start it.”*

Nine groups stated that they had started the analysis part of the project by gathering (searching, downloading and collecting) information (text, pictures and videos) from the internet (8).

> *“Our project under Theory of Machine course is started and we have collected some data and photos.”*

In a few of the essays, students wrote suggestions for the formation and composition of the groups. Three students said that they should be given more time and freedom in choosing their team members. One student mentioned the awards for best groups, and four students suggested implementing PBL into other courses.

Summing up

Overall these essays were helpful in gaining insight into the students’ experience of group work. It can be understood from the essay analysis that the students enjoyed the group setting, although a few groups struggled to move forward. The students learned from each other by solving, discussing and explaining to each other. Based on these essays, it is evident that newly designed CLPBL environment is effective to promote student’s for teamwork. It can also be concluded that the group setting helped the students’ learning, promoted teamwork and developed communication skills. These were important objectives of the CLPBL-1. It can be said that the students had many reasons to find group work helpful.

Experiences from the project presentation

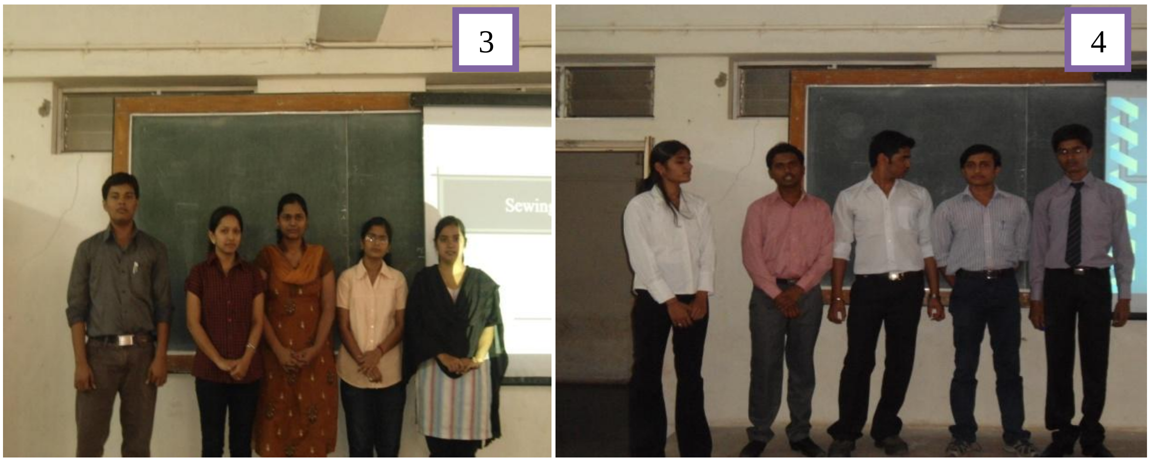

Figure 5.2 Action images fromCLPBL-1

At the end of the semester, each group presented their project work. The above action images show the procedure adopted during presentations. In the beginning, each group presented their work. Photo 1 shows a student presenting his part of the project; Photo 2 shows the class listening to the presentation. One teaching staff (I) evaluated each presentation with the help of three students. The three student evaluators can be seen sitting in the first row in photo 2. In the third and fourth photos, the students are lined up for the question-answer session. These images also show the group composition: four girls and one boy (G-8, photo 3) and the reverse in the next group (G-13, photo 4). During these presentations, students showed enthusiasm and positive body language. I was thrilled to see the excellent project work done by the groups, including a shutter, an excavator and grippers in robots. From these presentations, it was evident that the students had learned about the mechanisms, leading to the desired content learning. During the question-answer sessions, I observed that one or two students from the group tended to come forward to answer the questions posed by the evaluators. This suggested that the groups relied heavily on a few members, with the other members supporting them. During the presentations, I observed that the group leaders spoke most and answered most of the questions. This raises the question of whether the other students from the groups really learned from the project or not. I was worried about a few students who did not contribute enough in the presentation and question-answer sessions.

5.3.2 Results of semi structured interviews

At the end of the semester, 18 out of 19 groups had completed the project work. To get insight into students' experiences, 16 out of 18 groups were interviewed for ten minutes each. The questions asked in these interviews are listed in the appendix A_5. The interviews were video recorded for further analysis. The same coding process was used to analyse the interviews as had been used for the essay analysis. During the interview analysis, I found that not all members of the teams answered questions. Hence, the total number of quotes in interviews (170) was much less than in the essays (282). Still, this data was important because the essays were written at the middle of semester and the interviews were held at the end of the project. Table 5.2 shows a summary of the interview analysis.

Table 5.2 Result of Interview analysis

Major theme	Subtheme		Total no. of quotes
PBL	PBL experience	-	14
	Recommendations	-	11
Teamwork	Collaboration	Positive	07
		Negative	02
	Usefulness	Importance	27
	Role of teammates	-	16
	Communication	-	16
Project	Management	-	10
	Learning	-	25
	Challenging projects		05
Information management	Search and collection	-	01
Difficulty	Teamwork	-	03
	Data handling		04
	Fieldwork		06
	Conceptual difficulties		04
	Time		07
Suggestions	-	-	12
			170

The interviews were helpful for strengthening the essay and survey data. In most of the interviews, the groups shared their experiences about project work, teamwork and their learning. A few more themes emerged, like PBL and difficulties, and have been added to the existing themes from the essay analysis. During the interviews, most groups stated that they liked the new model because it gave them the opportunity to learn something new (14) and recommended it for use in other courses (11). Under the teamwork theme, the students claimed that they understood the importance of teamwork for successful completion of the project (27). Students felt that the role of teammates was also important for completion of the project (16). They further elaborated by saying that the major asset of teamwork was in the collection of the relevant data and sharing that with other members of the team. Sharing and explaining to each other were modes of communication used during teamwork (16). I observed that members of some of the groups showed good coordination amongst each other (7) while members of a few of the groups showed low levels of coordination between members (2).

Under the project theme, students claimed that they learned from the project activity (25). From the presentations and question-answer sessions, I found that the students' learning of basic concepts was enhanced. It was evident that the students learned in detail about their chosen mechanism. When asked how they managed the project work, ten members shared their project management strategy (10), remarking that they divided the work among the members and later shared their individual work with each other. Some members informed me that they would like to work on a more challenging project (5).

It can be observed from tables 5.1 and 5.2 that the students faced a variety of difficulties while completing the project work. The students' difficulties related to teamwork (3), information management (4), fieldwork (6), conceptual difficulties (4) and time (7). The students suggested that the project activity and its requirements should be explained to students at the start of the semester (9) and that the final presentations should be conducted well before the end of the semester. It was also suggested that the team composition should ensure that at least one student in each group be intelligent (3). The students felt that this would aid in the completion of the work. In the following paragraphs, I have shared interesting thoughts and quotes from interviews.

The students mentioned that the project activity was good (G-2) and useful (G-6) for learning many things. They helped each other in the learning process. They found the project activity was useful for gaining practical knowledge (G-5) and helpful for applying the knowledge gained in class. The group who worked on the flywheel mechanism (G-11) said that they learned to write a technical report and prepare a presentation. Members of group G-16 said,

> ***"The project activity was helpful for gaining confidence and we learn how to handle members."***

When I asked about the challenge posed by the project activity, the students gave a mixed response. Some groups said the project was challenging (G-7, automobile brakes) and some said they would like to work on more challenging project (G-16, wiper mechanism).

Most of the groups used the same type of project management technique. They gave everyone the initial responsibility of collecting the data and later each shared what they had collected. The collected data was then synthesised to create usable data. This usable data was used for the presentation and in the project report. One group (G-16) informed me that they had divided the project work depending on the individual abilities of their group members. This group met 2-3 times a week.

Some group members had a horrible experience (G-15, G-1). One member complained that he had to work alone even though he was in a group of five. None of his group membersappeared for the project work and he had to take the burden of project. This was evidenced, too, by the fact that only three members of his group appeared for the final presentation. The one member who made the complaint said,

> ***"I will not work with these members again and would like to have cooperative team members."***

Many groups experienced conflict within their group (G-15, G-1, G-12) that generally influenced the quality of their project work. The influence of conflict on project work was evident from the quality of the presentations and project reports for these groups. The comments about this matter demonstrated that working with team members, and managing them in order to complete the project in time, was the most challenging aspect of this model.

One group (G-12), who worked on a hand pump, stated the following regarding their view of the conflict:

> ***"We had a conflicts mentioning that everyone has point of view and opinion. Sometimes, these conflicts help and sometime it does not. It worked in favor for us".***

Another group (G-16), who worked on an excavator, had a great experience and recommended the project activity for the next semester. They said that they managed to complete the project work over five group meetings. One member of the team claimed,

> ***"The project work was not challenging enough but we learned a lot out of it."***

This outcome may have been the result of good collaboration and proper management of the project work. The group who worked on a pendulum clock (G-17) did not find a working model of clock to conduct their fieldwork. However, they said that all group members collected information from the internet and helped in arranging their findings. These students enjoyed working in a group and promised to do fieldwork next time. The group working on a pantograph (G-19) said,

> ***"We could not complete the project as we could not find relevant information about our project. We did not get proper guidance and could not do well".***

This group explained that they initially had found three similar mechanisms and were confused in deciding on one for the project. They eventually decided mutually and started working. They felt that this was a good learning experience. They now knew each other's strengths and learned from the experience.

In general, most of the students said that they feel confident in the subject and they mostly attributed this feeling to the group activity. Many of the average students (those with lower examination scores and demonstrated lower cognitive abilities) asserted that they benefitted fromthe group setting because the more intelligent students from the group helped them to understand the concepts (in case of G-3, &G-7). As a result, they (weak students) felt confident on the subject. The student in a group-14 said that the classroom instructions helped them to understand the concepts and were helpful for calculation purposes.

Summing up

From the interview data, it can be concluded thatthe students liked the new model becauseit gave them the opportunity to work in a team and to learn outside the classroom. It is evident that the students would recommend this model for use in other courses. The students understood the role and importance of teamwork for the successful completion of the project. The students found that collecting and sharing relevant data and solving each other's problems was an important aspect of the group work. Some groups had clear team leaders and the other members followed them. In this way, PBL helped to promote leadership behaviour in some of the students. The project was useful for content learning and understanding basic concepts. It was evident that the students learned in detail about their chosen mechanisms. Overall, it can be said that the students liked the PBL environment. Students remarked that, although project was useful, they would like to work on more challenging projects. During the project work, students faced difficulties in the areas of teamwork (3), information management (4), fieldwork (6), conceptual difficulties (4) and time (7).

5.3.3 Results of technical report analysis

At the end of the semester, 18 groups submitted their reports. The reports were analysed to determine whether or not the students completed the desired project objectives. This analysis also revealed aspects of student's skill development process in the technical report writing. Each submitted report was evaluated on the basis of four parameters, format of the report, technical content and its explanation, coverage of project activities and plagiarism which refers to the amount of copied material, as discussed in the chapter 3. Table 5.3 shows that six groups obtained an 'A' grade for their project report, eight groups obtained a 'B' grade and four groups received a'C' grade. Out of the 18 groups, 14 groups received high grades (A and B). This shows that the students made reasonably good efforts in writing the project reports. The 4 'C' grades show that there is room for improvement among these students. Furthermore, 11 out of 18 got C grade in plagiarism in reports which showed atendency to copy and paste material without proper referencing and paraphrasing. Still, this is part of the learning related to report writing and the students had to quickly learn various aspects of report writing.

It was observed that the same format was followed in most of the reports. The project reports revealed the students' ability to manage and properly organise technical information in the form of a report. Although the students put reasonable effort into writing the report, I found that there was still significant scope for improvement in the areas of technical writing and avoiding plagiarism. Table 5.3 shows the group composition (i.e. number of male and female students per group). There were 19 groups out, of which seven had at least one girl in the team. Out of the seven groups, one group (G_8) had four girls. All groups had five members, with the exception of two groups that had six (G_{17} and G_{18}). All 19 groups analysed engineering mechanisms for the project; the mechanism chosen is listed under the heading 'Name of mechanism' in table 5.3. One group (G_{10}) did not submit the project report.

Table 5.3 Analysis of project reports and its grades

Group no	**Group composition**			**Name of mechanism**	**Format**	**Technical content**	**Coverage of project activities**	**Plagiarism**	**Overall impression**
	M	**F**	**Total**						
G_1	5		5	Excavator and crane	C	C	B	C	C
G_2	4	1	5	Roller shutter	B	B	B	A	B
G_3	5		5	Steering gear	C	B	C	C	C
G_4	5		5	Grippers in robot	C	B	C	C	C
G_5	4	1	5	Foot pump	B	A	A	A	A
G_6	5		5	Toggle clamp	A	A	A	A	A
G_7	5		5	Two wheeler brake	A	A	A	A	A
G_8	1	4	5	Sewing machine	A	A	A	C	A
G_9	5	-	5	Shaper machine	B	A	A	C	B
G_{10}	5	-	5	Hooke’s Joint	Did not submit report.				
G_{11}	5		5	Flywheel	C	A	B	C	C
G_{12}	5		5	Hand pump	A	A	A	A	A
G_{13}	4	1	5	Bulldozer	A	A	B	C	B
G_{14}	4	1	5	Wiper	B	A	B	C	B
G_{15}	4	1	5	Door closure	B	A	B	A	B
G_{16}	5		5	Excavator	A	A	A	A	A
G_{17}	5	1	6	Pendulum clock	C	B	B	C	B
G_{18}	6		6	Pneumatic brakes	B	B	B	C	B
G_{19}	5		5	Pantograph	B	B	B	C	B
	87	10	97						

Table 5.4 Student report’s analysis of CLPBL-1

Sr. No.	Parameter	Group No.																			Total out of 18
		G_1	G_2	G_3	G_4	G_5	G_6	G_7	G_8	G_9	G_{10}	G_{11}	G_{12}	G_{13}	G_{14}	G_{15}	G_{16}	G_{17}	G_{18}	G_{19}	
1.	**Problem statement**	*	*	*	*	*	*	*	*			*	*	*	*	*	*	*	*	*	**17**
2.	**Team members’ names**	*	*	*	*	*	*	*	*			*	*	*	*	*		*	*	*	**16**
3.	**Team Photo**	*	*	*	*	*	*	*	*			*	*		*	*	*				**13**
4.	**Abstract**	*	*	*	*	*	*	*	*	*				*	*	*	*	*	*	*	**16**
5.	**Introduction**	*	*	*	*	*	*	*	*	*			*	*	*	*	*	*	*	*	**17**
6.	**Types**	*	*	*	*	*	*	*	*	*			*		*		*		*	*	**14**
7.	**Technical details**						*	*	*			*	*		*	*	*	*			**9**
8.	**Kinematic Diagram**	*	*				*	*	*			*		*		*	*		*		**10**
9.	**Links**	*	*			*	*	*	*	*		*	*	*	*	*	*	*	*	*	**16**
10.	**Joints**	*	*			*	*	*	*	*			*	*	*	*	*	*	*	*	**15**
11.	**Pairs**	*	*			*	*	*	*	*		*	*	*	*	*	*	*	*	*	**16**
12.	**DOF**	*	*			*	*	*	*	*		*	*	*	*	*	*	*	*	*	**16**
13.	**Conclusions**	*				*	*	*		*					*			*			**07**
14.	**Advantages**	*				*	*	*	*				*	*			*				**08**

15.	**Disadvantages**	*				*	*	*	*					*			*				07
16.	**Applications**	*				*	*	*	*			*	*	*		*			*	*	11
17.	**References**	3	3			9		4	4	5		3	5		3	7	6	5	6	5	
18.	**No. of Pages**	10	7	8	9	12	10	6	13	10		10	16		13	6	7	13	13	12	
19.	**Fieldwork Photos**	*	*	*	*	*	*	*	*	*			*						*	*	12

In table 5.4, the highlighted items (5 to 16) form the core activities of the project. The students were expected to carry out in-depth analysis of these points and towrite about these activities in detail. This detailed writing would reveal the depth of their content learning and understanding. Table 5.4 showsthat 85% of the groups covered most of the project activities in their reports (except G_3 and G_4). This suggests that most of the groups understood the mechanism and studied it in detail. It was found that the report length varied from 6 to 13 pages. It is worth noting that 12 out of 18 groups added fieldwork photos to their reports. These photos proved that the students had actually visited the various places for their fieldwork activity. The students' ability to write a project report was assessed through the technical report analysis. It should be noted that report writing was not part of the regular curriculum. This was the first time that the students had the opportunity to write a report. With this in mind, I feelthat the students made a reasonably good effort inwriting their reports.

5.3.4 Results of survey: Open-ended questions

At the end of the semester, the students' responses were recorded on a questionnaire. The questionnaire included a few open-ended questions relating to the location of the project work, the difficulties experienced and suggestions for future models (refer Appendix A_7). The students' responses to these questions are analysed here by using the content analysis technique.

5.3.4.1 Location of the projectwork

In the questionnaire, the students were asked to discuss the locations of their fieldwork and group work (Appendix A_7 question a, b). From table 5.5 it can be seen that the students held their meetings in the reading hall (23) and hostel rooms (9). Students completed their fieldwork in college laboratories (20) and at various outside locations such as construction sites, shops etc. (22). Two important considerations can be drawn from this information. First, even though the SITL did not have group rooms to facilitate the group work, the students still managed to find suitable locations in which to hold their team meetings. Secondly, students made deliberate efforts to move outside the class, visiting laboratories and other sites for fieldwork. Students do not get this kind of opportunity in the traditional curriculum structure. CLPBL-1 provides an opportunity for students to manage their work with available resources and to relate classroom learning toreal engineering mechanisms.

Table 5.5 Location for the project work

Location	Frequency
Reading hall	23
Hostel room	09
Laboratory	20
Outside	22
Campus	05
Total	79

5.3.4.2 Difficulties

Students were asked to share the difficulties (Appendix A_7 question d). They experienced during the project work. This information was needed to improve the next design. The students' responses are analysed and summarised in table 5.6.

Table 5.6 Summary of difficulties experienced in project work

Difficulties	Frequency
Teamwork	10
Data handling	Information management (19) and reports (5) = 24
Fieldwork	22
Conceptual difficulty	5
Time	Time management (4), Time limitation(7) = 11
No difficulties	7
No response	14
Total	93

In general, each group had their share of difficulties. Table 5.6 shows the range of difficulties experienced by the students. The major difficulties related to fieldwork, teamwork, time management, data handling and conceptual difficulties. Difficulties in fieldwork included travelling to the site and getting permission to see the mechanism in operation. These difficulties affected the analysis part of the project but the students generally managed by gathering the information from multiple places. Below are examples of the students' impressions around these challenges.

> ***"Actually the difficulties are technical. We had seen manually operated shutter. But, we were not able to see the motor operated shutter."***

> ***"It is difficult to see the mechanism by opening of hand pump so we have seen in videos."***

Another set of challenges revolved around handling the data, including getting the right information, limited or overwhelming availability of information, and compiling information into the report. This set of difficulties affected the analysis and report writing aspect of the project. Below are quotes that exemplify the students' experiences in this category.

> ***"Gripping mechanisms are of many types. Analysis of all the types wasn't possible. Hence, we were in dilemma about which mechanism we will actually present."***

> ***"Difficulty experienced while making technical report but we saw many technical reports on internet and solved the problem."***

> ***"Writing technical report was a challenging task also to obtain information related to topic was a challenging work."***

Difficulties in teamwork included managing teammates and making them work on the project. Students expressed that individual preferences and attitudes towards the project influenced their teamwork. Some team members did not turn up for the fieldwork. Students complained that managing everybody's time in order to do teamwork was a significant difficulty for them. Below are some examples of the students' impressions on this matter.

> "***Sometime some members are engaged in different work. So due to this we have to fix the time for meeting."***

> "***Working in a team in which individual comes with different ideas was a challenge."***

Conceptual difficulties were those in which students struggled to understand the information and to apply known information tothe actual mechanism. Team members experienced most of these difficulties during the analysis phase. The groups struggled to manage in the given time and sometimes had to work more intensively, especially closer to deadlines. In addition, due to departmental issues, presentations had to be postponed into the students' exam preparation leave. Many groups were unhappy with this decision and mentioned time was not managed well for the presentation period. Below are some examples of the students' impressions on this issue.

> ***"Time is not very good managed during the projects. If this project is taken before the prelim then we could have made good projects."***

> ***"Timing for presentation was not good."***

From the above analysis, it is evident that the students faced various types of difficulties during their project work. In spite of these difficulties, the students managed to complete the project in time, with the exception of one group. In light of the challenges they encountered, the studentsoffered somesuggestions for the next design.

5.3.4.3 Suggestions for improvement

The students were asked to suggest improvements (Appendix A_7 question e) for the CLPBL model. Students put forward 102 comments on various aspects of the model. Table 5.7 shows a summary of the students' comments.

Table 5.7 Summary of suggestions for the next model

Suggestions	Code	Frequency
Teammates	Teammates	17
More time	Time	14
Timing		10
Project at start		22
Challenging projects	Projects	11
Project presentation		04
Availability of Net lab		02
Ideas from Guide		02
No response		20
Total		102

The students suggested that more time be given for the project (14) and asked that the process of project work be initiated earlier in the semester (22). They also suggested finishing the project evaluation before the semester's end so that the timing of each activity could be improved (10). In terms of teammates, the students offered suggestions on two aspects: team composition (8) and the number of members per team (9). It was suggested that the teams should have fewer than five students and all teams should include at least one intelligent student. The respondents felt that reducing the team numbers would ensure that each member got some work and could contribute to teamwork. The students believed that presence of one intelligent student on each team would improve the understanding of the weaker students in the group.

In terms of the project itself, the students suggested that they be given more challenging projects, like industry or design projects, and a prototype model of the mechanism (11).The students felt that the project presentation should be done with a prototype model and not on Power Point (4). The students also offered suggestions regarding the teachers' involvement. They suggested that the teacher should give ideas to struggling groups so that they can complete the project work properly (2). It was also suggested that the Internet lab be made available even after college hours (2). Unfortunately, this is not possible for security reasons. Otherwise, all other suggestions were welcomed and will be used to improve the next model.

5.4 Results from quantitative data

5.4.1 Socio-demographicanalysis of students' profile

There were 97 (n = 97) participants, of which only ten (n = 10) were female. All participants were aged between 19 and 21 years. All participants spoke three languages. Out of the 97 students, a total of 19 groups were formed. The group compositions were shown in table 5.3. In terms of gender, the group compositions were as follows: 12 groups had all male members; seven groups had mixed gender (that is, having at least one female member in the group). Of the seven mixed-gender groups, only one group had four female members and one male member. No group had all female members.

5.4.2 Results from the survey

A survey was conducted at the end of the semester. For the survey instrument, refer to appendix A_7. For the quantitative data analysis procedure, refer to chapter 3. Out of 97 students, 86 recorded responses in the survey and returned the questionnaire in time. The response rate was 88%. Table 5.8 shows the summary of respondents and non-respondents.

Table 5.8 Summary of respondents and non-respondents

	Number	**%**
Respondents	86	88
Non-respondents	11	12
Total no. of participants	97	100

The survey instrument had four clusters, as discussed in the methodology section of this thesis. In the next section, each cluster will be discussed individually and compared with the qualitative data discussed so far. For data analysis, the Microsoft Office Excel programme was used. The mean and standard deviation were calculated for all items in the questionnaire. Graphs were then plotted to obtain a visual representation of the results.

5.4.2.1 Students' responses on various elements of CLPBL-1

Table 5.9 presents a summary of student responses relating to various aspects of the CLPBL model. In this table, the mean score obtained out of five is shown, along with standard deviation.

Table 5.9 Students' responses on various elements of CLPBL-1

Question no.	**Question**	**Meanscore out of five**	**Standard deviation**
AQ1	Assigned project work was challenging	3.74	0.85
AQ2	The project was well integrated into the curriculum	3.79	0.94
AQ3	The project was relevant to my profession	4.12	0.62
AQ4	I found classroom instructions helpful	4.02	0.81
AQ5	I feel the time provided for the project was sufficient	3.64	0.90
AQ6	Assigned project was enjoyable	4.14	0.61
AQ7	I recommend to apply PBL to other courses	4.44	0.32

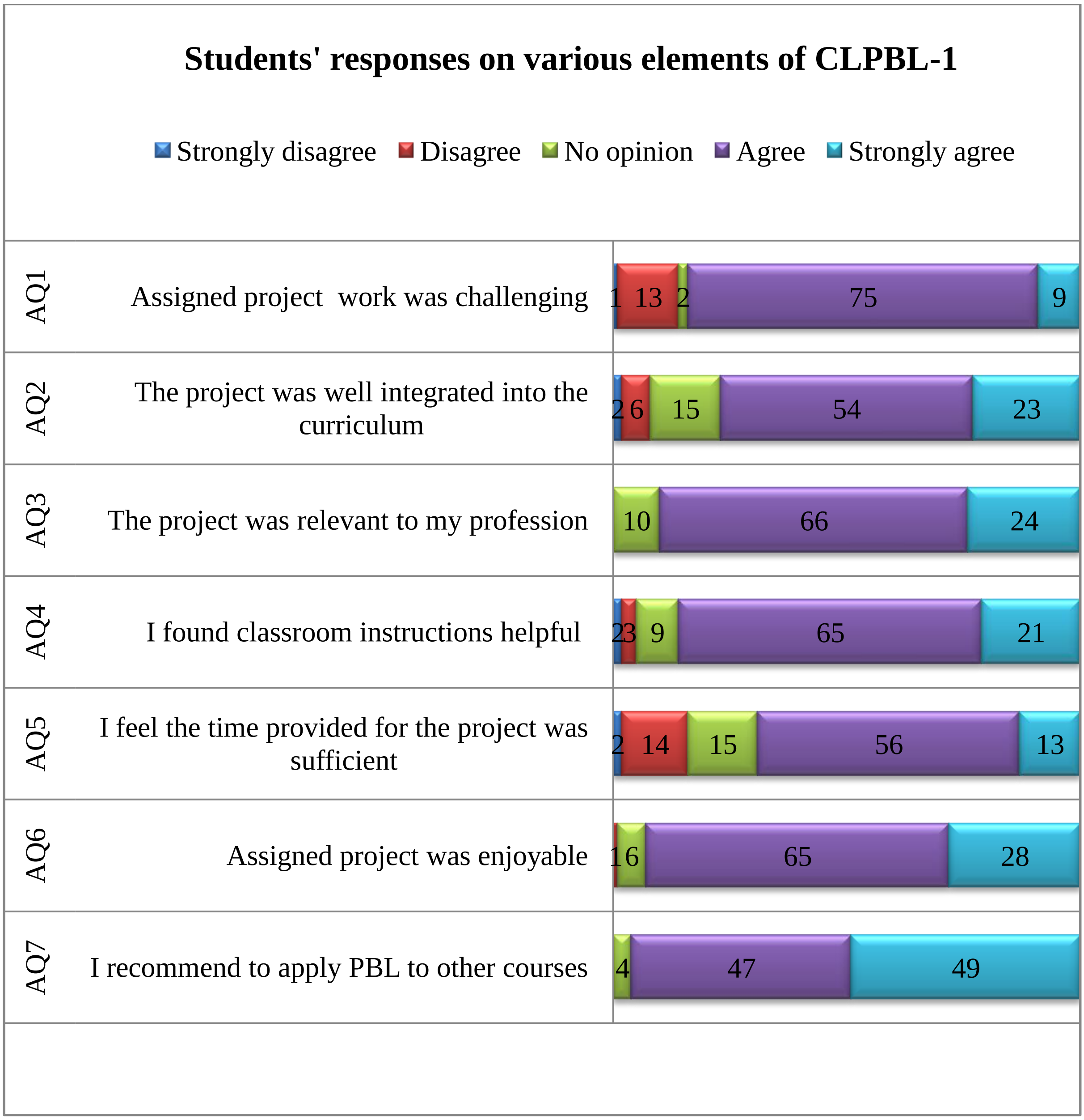

Figure 5.3 Students' responses to various elements of CLPBL-1 in percentages.

In the PBL approach, the problem or project is very important for challenging and motivating students to learn. To assess the approach's effectiveness in fulfilling these objectives, AQ1 asked whether the project was challenging (figure 5.3). I found that 84% (75+9) of students felt that the project was challenging. Of the remaining 16%, 14 % (13+1) did not agree with this statement and 2% did not have an opinion on the statement.

In the design stage, I made an effort to design the project to suit the engineering profession and, more importantly, the course. It was therefore important to know the students' reactions to the project. I asked students whether the project was relevant to their profession (AQ3) and whether it had relevance to the course (AQ2). I found that 90% (66+24) of the students believed that the project was relevant to the engineering profession. However, only 77% (54+23) thought that it was well integrated into the curriculum. Of the remaining 23%, 8 % (2+6) did not agree with the statement and 15% did not have an opinion on the statement. From table 5.3 it can be seen that the mean value of responses for AQ2 and AQ3 were 3.79

and 4.12, which are close to 4. This means that most of the students agreed that the project was relevant and in line with the course. From the responses to AQ1, AQ2 and AQ3, it can be concluded that the project was challenging and relevant to the course and profession.

In addition to working on the project, students also had to attend lectures. To provide prerequisite knowledge relating to project, three units were taught at the beginning of the course. It was thought that this move would help students to apply their knowledge in the project work. It was important to evaluate the role that classroom instructions played by in the project work (AQ4). From figure 5.3 it can be seen that 86% (65+21) of the students felt that the instruction was useful. However, the remaining 14% felt otherwise. The mean was close to 4, with low standard deviation (0.81), suggesting that classroom instruction helped students in the project work. This confirmed my decision to give the instruction before the start of the project activities.

The project was designed with consideration to the limited available time in the semester. For this reason, it was essential to get feedback on the time provided to complete the project activities (AQ5). I found that only 69% (56+13) agreed that the time given was sufficient. The remaining 31% either had no opinion (15) or did not agree (16). This means that 31% of students had some issue related to time. They were not happy with the time provided. This aspect is elaborated in the discussion section of this paper.

I was interested to know whether or not the students enjoyed the new learning environment (AQ6). I was not surprised to findthat 93% (65+28) of the students enjoyed the project; I was very sure that they were going to enjoy it. Since 93% of the students enjoyed it, it was logical to guess that they wouldrecommend the PBL model for future courses. As expected, we found that 96% (47+49) of the students recommended PBL (AQ7) for future courses.

5.4.2.2. Students' experiences oftheir learning

In this section, a discussion is held to understand the students' learning experiences. This includes examining why, how and what the students learned in CLPBL-l?

Table 5.10 Students' responses on their learning experiences

Question no.	Question	Mean score out of five	Standard deviation
BQ1	The project motivated me to learn	4.43	0.66
BQ2	This project stimulated to learn the material outside the class	4.34	0.64
BQ3	I took responsibility of my own learning	4.27	0.80
BQ4	I become self directed learner	3.84	0.81
BQ5	The project engaged me throughout the semester	3.48	1.04
BQ6	I learned through the collaborative and co-operative approaches.	4.13	0.44

BQ7	It helped me to increase my understanding of the subject	4.33	0.43
BQ8	It laid the strong foundation of the subject	4.17	0.49
BQ9	I feel confident to appear in the examination	4.10	0.63
BQ10	I expect improvements in my grades	4.19	0.69
BQ11	Overall I am satisfied of my learning	4.47	0.39

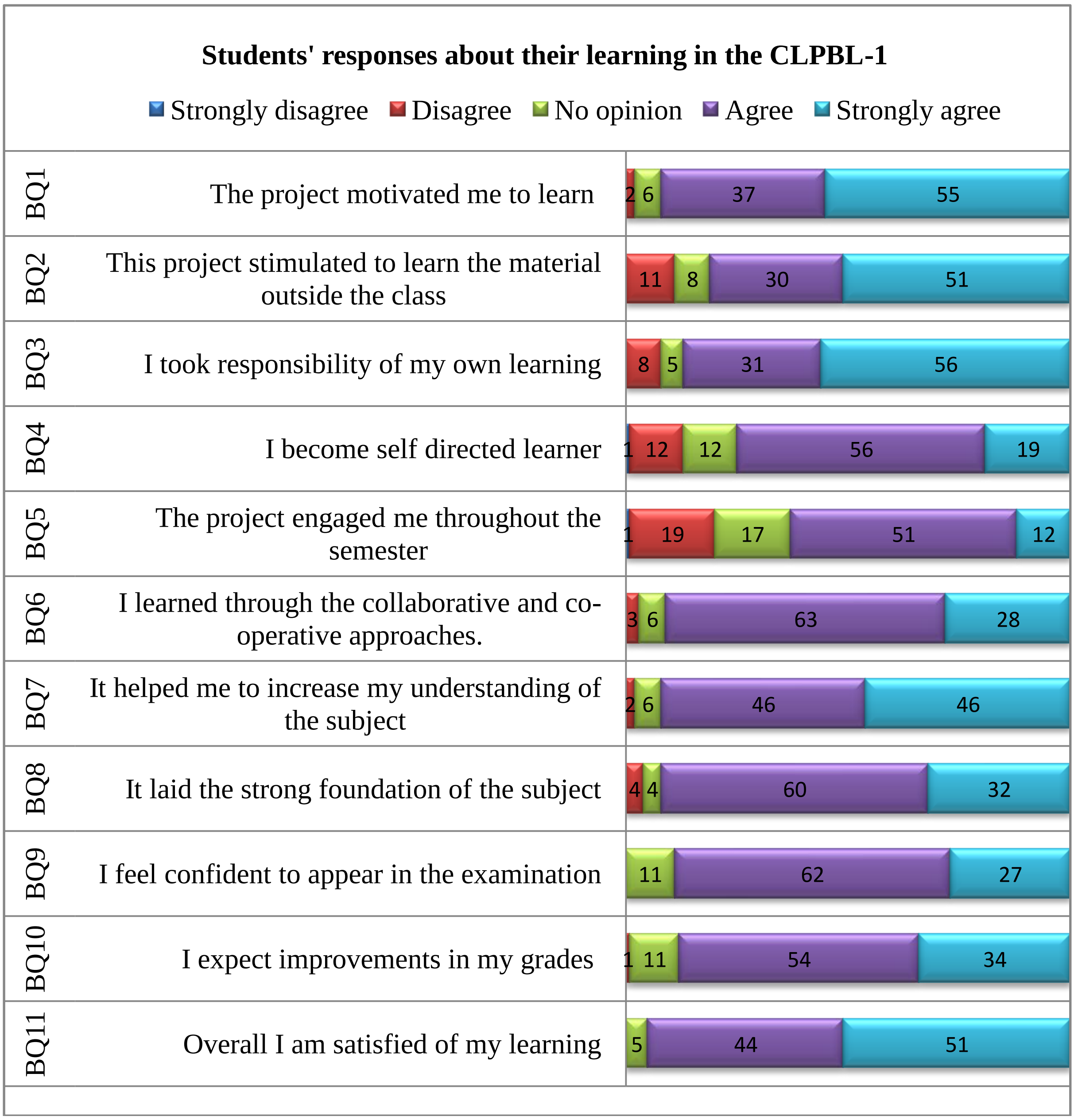

Figure 5.4 Students'responses regarding their learning in CLPBL model-1 in percentages.

The effectiveness of the project in motivating students to learn was evaluated on the basis of the responses to BQ1 and BQ2. BQ1 asked students whether the project could motivate them to learn; responses showed that the project motivated 92% (37+55) of students to learn. In this model, a substantial part of the students' learning was expected to occur outside of the classroom. We asked whether the project stimulated students to learn outside of class (BQ2). In response, 81% (30+51) of students claimed that they learned something beyond the traditional curriculum. This response showed that the project was effective motivating students to learn material outside the classroom boundaries. However, it was less effective in engaging students for the complete semester (BQ5). Only63% (51+12) students said that the project engaged them in the semester. The remaining 37% disagreed (20) with the statement or had no opinion (17) on it. The low mean (3.48) and high SD (1.04) show that the responses were widely dispersed around the mean. This will be discussed later.

In BQ3, I assessed whether the students took responsibility for their learning in the project work. The responses showed that 87% (31+56) of students felt they took responsibility for their learning. There could be two possible meanings for this response. First, the students learned independently, without taking the help of the course teacher. Second, the students took responsibility to learn the material that was assigned to them as part of their teamwork.

Almost 75% (56+19) of students felt that the project helped them to learn independently (BQ4). In contrast, 25% did not agree nor had no opinion. A total of 91% (63+28) of respondents claimed that they learned through the collaborative approach by sharing and learning from each other (BQ6). The contrast in results for the questions regarding independent learning versus those regarding group learning showed that students learned better with a group than individually in the PBL model. This could be explained in a number of ways. Students stated, in the essays and interviews, that they had distributed the work among the members of their teams. This means that they learned individually first and then shared their learning with their teammates. Through students' responses it is evidentthat learning in the team was more than the individual learning. This shows the importance of group work in the CLPBL model.

On average, 92% (46+46) of the students felt that the project helped them to acquire knowledge related to their engineering major and helped them to understand the subject content (see figure 5.4, BQ7 and BQ8). As a result of this knowledge, 89% (62+27) of the students felt confident to appear in the course examination (BQ9) and 88% (54+34) believed that their grades would improve (BQ10). Overall, 95% (44+51) of students were satisfied with their learning in the semester (BQ11).

Summing up

From the above analysis it can be summarised that the students responded positively to the project and felt that the project was useful for learning. It is evident from the feedback that the majority of students felt that their learning and understanding had improved in CLPBL. Furthermore, most of the students indicated that they learned better working in a team than learning independently. It was observed that students applied their knowledge to real life engineering mechanisms. This experience is directly related to LO 'a' ('an ability to apply knowledge of mathematics, science, and engineering'). CLPBL offered students ample opportunity to apply their knowledge to real life engineering mechanisms; such experience is limited in the traditional curriculum. The given project design related closely to the course content. Hence, working on the project and working in a team resulted in improved understanding and knowledge of the subject. As a result, 89% of students felt confident in the subject and confident about sitting the examination. The end-of-semester results confirmed that 87% of the students appear to have passed this course. This validated the claims made by students in response to the questionnaire. Furthermore, I witnessed the students' enthusiasm, commitment, stress, frustration, engagement and arguments, all of which were evidence to the effect of PBL on students' behavioural aspects. These observations were, however, rather difficult to express quantitatively.

5.4.2.3. Students' perceptions towards achievement of learning outcomes

In this CLPBL, the project activities were designed with the intention ofpromoting achievement of the ABET learning outcomes. In this section, the CLPBL model is evaluated based on students' responses regarding the achievement of learning outcomes.

Table 5.11 Students' perceptions towards achievement of learning outcomes

Question no.	**Question**	**Meanscore out of five**	**Standard deviation**
CQ1	I learned to think deeply	4.24	0.66
CQ2	It helped me to improve my ability to work in a team	4.22	0.8
CQ3	I learned about the problem-solving process	4.04	0.68
CQ4	I learned how to write the report	4.29	0.59
CQ5	I learned critical presentation skills due to the project work	4.27	0.62
CQ6	I learned to asses and manage variety of resources	4.20	0.55
CQ7	I applied project management principles	3.85	0.72
CQ8	Assigned project helped me to improve my skills	4.37	0.61

Figure 5.5 and table 5.11 show students' perceptions about the achievement of various learning outcomes (LOs). In CQ1, 88% (52+36) of students agreed that their ability for reflective thinking was improved and 83% (64+19) of students felt that they had learned about the problem-solving process (CQ3). Both responses were closely associated with the ABET LO 'e' ('an ability to identify, formulate and solve engineering problems') and can be attributed to the project work. In the project work, students analysed a real life mechanism to obtain its various parameters. To conduct this analysis, students needed to exercise application, as well as reflective skills. They needed to establish the relationship between classroom learning and a real life context. In order to do this, they needed to compare, evaluate and critically examine their chosen mechanism. This should result in an improvement in the thinking and problem-solving abilities of the students.

In the CLPBL model, students were challenged to complete the project. To do this, students worked independently and also were assisted by their teammates. They worked with each other for an entire semester. This opportunity was provided in order to improve the students' ability to work effectively in a team (ABET LO'd'). When surveyed, 89% (46+43) of the students said that their ability to work in a team was improved (CQ2). I will provide a detailed discussion of this in the next section on teamwork.

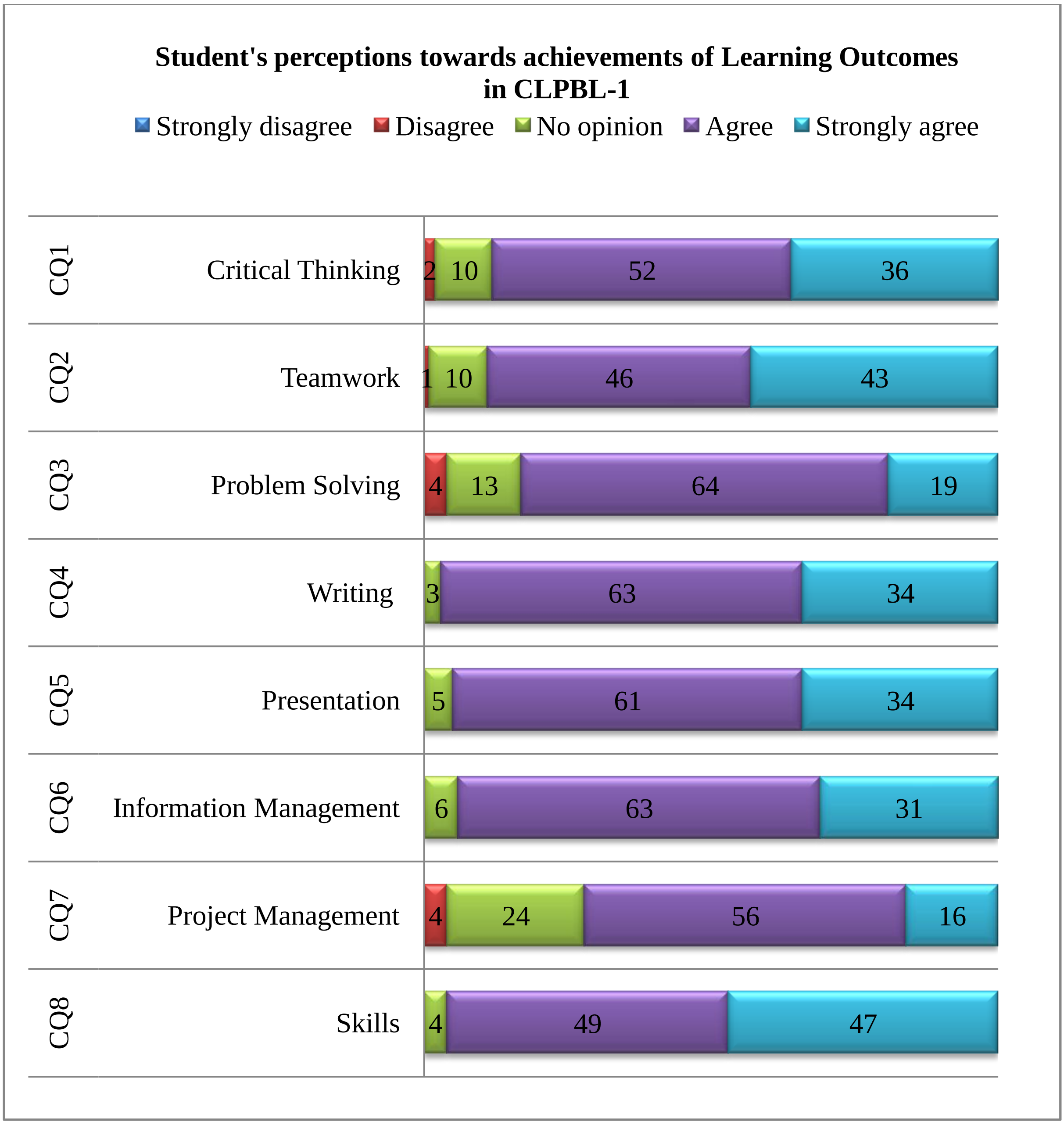

Figure 5.5 Students' perceptions towards achievement of learning outcomes in percentages

In this model, students were asked to write a project report and to deliver a Point presentation in front of the class. These activities were found to be critical in developing the students' abilities to manage and arrange information in the proper manner. These two activities were designed in view of ABET LOs 'g' ('an ability to communicate effectively'), 'i' (an ability to engage in life-long learning) and 'k' (An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice). It was found that the students used Microsoft Office, Microsoft Excel and Microsoft Power Point programmes to manage the data and prepare their presentations. Some groups demonstrated the ability to integrate video clips and audio data into their presentations. Overall, this activity helped the students to analyse, interpret (LOs 'b') and manage the data (LOs'i') by using modern tools and techniques (LO 'k'). The students' impressions of this skill development were illustrated in their responses to CQ4 (97%) (63+34), CQ5 (95%) (61+34), and CQ6 (94%) (63+31); respectively indicate writing, presentation and information management skills. In general, this CLPBL model offered a favourable environment for students to improve their communication ('g') and information management skills ('i'). It may be noted that the skill 'information management' was included as one of the important sub-skills in the definition of life-long learning.

In response to CQ7, 72% (56+16) of students said that they used project management principles. This was an acceptable response because the students were not instructed about project management techniques and would not have learned themin any prior courses. However, students did manage to complete the projects in time so they must have found ways to manage the projects. In the essays and interviews students discussed the application of simple project management techniques. These included dividing the work equally among members, managing periodic meetings to report progress and individual allotments of work to be shared later. These are a few examples of the project management techniques adopted by the groups. In my opinion, 72% was a good response.

In the last question (CQ8) students were asked to comment on the improvement of their skill levels. In response, 96% (49+47) students perceived that their skills were improved in the PBL model. It can be concluded that this designed CLPBL model helped students to advance in the ABET LOs and to nurture the intended skills.

5.4.2.4 Students' experiences about teamwork in CLPBL-1

This section focuses on explaining the students' teamwork experiences. A summary of the students' responses about teamwork is shown in table 5.12.

Table 5.12 Students' experiences about teamwork

Question no.	Question	Mean score out of five	Standard deviation
DQ1	I feel group work is a challenging task	3.64	1.16
DQ2	Teamwork was critical for completion of this project	3.17	1.22
DQ3	My teammates helped me to understand the concepts	4.07	0.79
DQ4	I learned to take different perspectives and opinions	4.19	0.60
DQ5	I learned how to lead the project through teamwork	4.20	0.70
DQ6	I feel we could have done better in teamwork	3.98	0.88
DQ7	I am satisfied with group's performance in this semester	4.17	0.89
DQ8	I am looking forward to work on more complex projects	4.41	0.56

Teamwork is an important aspect of the PBL approach. Accordingly, the student cohort was divided into 19 groups and allowed to work in these groups for the entire semester. In this section of my thesis, the students' responses about teamwork are discussed (see table 5.12 and figure 5.6). The students faced many difficulties as this was the first time that they had worked together in groups. These difficulties have already been discussed at length in the qualitative data analysis section. The students had conflicts and misunderstandings among group members. Because of these difficulties 70% (43+27) of respondents felt that group work was a challenging task (DQ1). I received unexpected responses to DQ2, in which students were asked to respond on the importance of teamwork for this project. Only 51% (36+15) students said that the teamwork was important to the project and 41% (36+5) said it was not important. In my opinion, this could be because of the project itself. In the discussion section, I elaborate on how the project may be cause of this response.

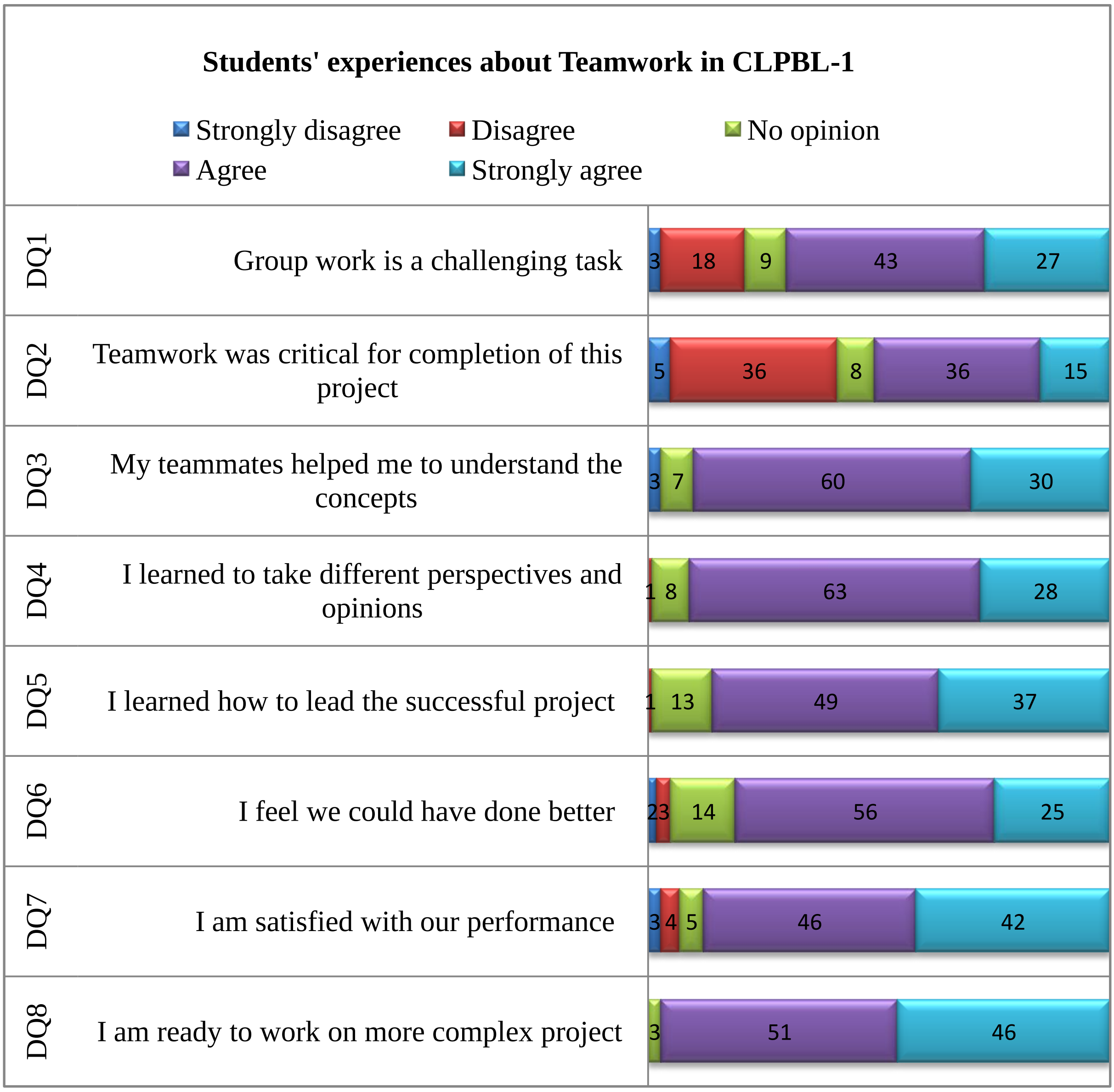

Figure 5.6 Students' experiences about teamwork in CLPBL-1 in percentage

In DQ3 students were asked to respond regarding the role of teammates. In response, 90% (60+30) of students agreed that their teammates helped them to understand the important concepts and helped in the learning process. In response to DQ4, 91% (63+28) of students perceived that they had learned to take different perspectives and value other's opinions. In response to DQ5, 86% (49+37) of students agreed that they had completed the project with the help of the team. Overall, 81% (56+25) of the respondents felt that they could have contributed better to the teamwork (DQ6), indicating there is room for improvement in this area. Considering this was a first experience, 88% (46+42) of students were satisfied with the team's performance in this semester (DQ7). Having worked in a team once this semester students gained confidence and understood the pros and cons of teamwork. As a result, 97% (51+46) of students felt that they were ready to face more challenging and complex projects (DQ8).

5.4.3Projectgrades

Table 5.13 below shows the grades received by students for the project. The project in the PBL model was evaluated for 25 marks, as discussed in the previous chapter. The table shows that 11 ('D' and 'E' grades) out of 97 students were unable to achieve marks above 40% in the project. Of the remaining 86 students, 25 scored more than 80% marks ('A' grade), and 50 secured marks from 60% to 80% ('B') grade in the project. These 75 (77.31%) students who received more than 60% marks for the project can be considered as students who have done the project seriously and have an excellent chance at securing good grades in the main examination. Almost 12% of the students failed to score more than 40% marks (passing percentage). In the final written examination conducted by University of Pune (UoP), 87% of students passed this course (shown in table 5.14), which is almost the same as the passing percentage of the project (87.65). This comparative statement indicates that project success is reflecting on the overall achievement of grades and success in the course, suggesting the effect of the project on students' overall success.

Table 5.13 Summary of project grades

Grade	Marks out of 25	Range of marks in %	Frequency	Percentage
A	more than 20	81-100	25	25.77
B	16-20	61-80	50	51.54
C	11-15	41-60	11	11.34
D	6-10	21-40	01	1.03
E	0-5	0-20	10	10.31
			97	100

5.4.4 Grades in the final exams

Table 5.14 below shows asummary of the students' grades in the final examination for this course. UoP conducted the final examination. An external evaluator assessed the answer sheets of the students. The norm for passing was 40%. In this course, 12 students (13%) failed and the remaining 82 students (87 %) passed the course. This value is very close to the 87.65% of students who had secured good grades in the project, as discussed above. This very interesting trend can be investigated to establish the correlation between project grades and final examination grades. Such analysis is recommended for future work. It should be noted that three* students were absent fromthe final examination.

Table 5.14 Summary of written examinationgrades

Grade	Range of marks in %	Frequency
A	61-80	22
B	51-60	33
C	40-50	27
D	21-39	9
E	0-20	3
		94*

5.5 Discussion of the results

In this section, key results are discussed and a few areas are identified where the existing design could be improved.

5.5.1 About CLPBL model design and its outcomes

The development and implementation of CLPBL for the SITL was a first attempt. National and institute-level requirements were considered in the design process of CLPBL (refer to chapter 4). The national level requirements included the graduate learning outcomes outlined in the ABET criteria. In this design, the local conditions for offering the propositional knowledge essential for content learning have been fulfilled. The design of the course was grounded in the PBL principles and practice. The approach adopted motivated students to be self-directed learners. Cooperative-collaborative approaches of learning were promoted as students worked in groups to complete the project. Students were challenged in working on the project. To achieve completion of the project, students were required to apply knowledge, higher order thinking and communication skills.

This CLPBL model was implemented for the period of one semester in the year 2012. The first cohort welcomed this initiative with positive feedback. They considered it highly relevant to the needs of their profession and recommended that it be applied to future courses. Multiple objectives were achieved through the implementation of this model. A blend of traditional teaching with PBL was exercised.

At the end of the semester, 18 out of 19 teams were able to complete the project. Through out the project, the groups used team-based and self-directed learning techniques to tackle a project. They collected information, carried out analysis of a problem and found the final desired outcomes. The students completed the entire project without taking much help from a teacher, which showed their ability to learn and apply the concepts independently. As the students' first time working in a PBL environment, they enjoyed the group work and learned from each other by exchanging ideas and knowledge. Thus, a very good environment for collaborative and cooperative learning was created. The students valued teamwork and understood its importance in building team spirit and accomplishing the given task in due time with comparatively less effort than when done individually. Students' learning capabilities were enhanced through teamwork and they learned new things from each other.

Each team developed their own strategy of doing things or managing project activities. The teams completed the desired set of activities in time, which showed their successful time management and project management skills. In the following section, I will discuss a few areas where improvement is needed.

5.5.2 Complexity of project

Three interesting and contradictory results emerged from the questionnaire responses**.** Firstly, the questionnaire produced mixed response relating to the level of challenge posed by the problem design or project. Eighty-four per cent of the students felt that the project work was challenging and provided various sets of difficulties (AQ1, see figure 5.3). However, 14% of group members thought the problem did not pose difficult enough challenges. Secondly, interesting responses were given by the students about the importance of teamwork for the project (DQ2, see figure 5.6). Forty-one per cent of students felt that teamwork was not critical for the project activity, while 51% felt that it was. Thirdly, responses regarding the capacity of the project to engage students in learning were also of interest for potential future improvements (BQ5, see figure 5.4). Only 63% of students felt that the project engaged them throughout the semester. The remaining37% did not agree with this statement.

After reflecting on these three sets of responses, I found that they were interlinked. There are two major reasons for these responses. First is the project design and second is the team composition. I will explain this further in the following paragraph. Problem design is a very important aspect of PBL. The nature of the problem should be such that it should challenge the students' abilities to solve it and make them confront tasks involved in the problem-solving process. In the current research, the problem was designed with the students'current cognitive abilities in mind. I designed the project activity withconsideration to the fact that the students had never worked on this type of project and to their inexperience withgroup work. As a researcher this was my first experience of implementing PBL at SITL; I was unsure whether or not the students would be able to do it. Perhaps I under estimated the students' capabilities and designed a less complex project than necessary.

Another aspect that played a crucial role was team composition, specifically the number of members per team. In this model, each team had five members, with the exception of a few groups that had six members. In the students' opinions, this was a large number of members for a less complex project like my CLPBL model. The project was not challenging enough to engage 5-6 members of a team. Even during interviews, students suggested reducing this number to 3 students per group. For this reason, students might have felt that the teamwork was not critical for the project. In the survey, 63% students agreed that they were engaged in a semester, which indicates that only three members per group worked seriously on the project. Hence, the project design and team composition were closely interlinked. These responses suggest an opportunity to increase the complexity of the project work in the next cycle and to reduce the number of students per team. Taking these measures in the next design would ensure that students were engaged in learning and felt the importance of teamwork.

Although the participants suggested that the project was not challenging enough, it still had enough potential to bring the students out of the classroom and make them think about material outside the classroom. The project also made the students struggle at various phases of the project work, such as in finding suitable information, doing fieldwork or writing technical reports. Thus, it can be concluded that the project was very effective in nurturing the students' ability to handle the activities independently and to take responsibility for their own learning. From the reports and student presentations, it was also evident that this project was very effective in improving students' technical knowledge. The project helped students to gain in their knowledge and confidence. Students showed commitment to complete the projects in time, and a great desire to engage in the self-directed learning process.

5.5.3 Team composition

Considerable flexibility was given to the students in choosing their team members and the mechanism to be analysed. This way, they had ownership of the project and followed their interests. The students found their own ways of managing the team and project work. Team composition included the number of team members, their genders and their abilities. In this experiment, the project teams comprised of five or six members. As the project activity was insufficiently complex to give each member in the team a significant workload (discussed earlier), this created a divide in some groups. As a result, a few groups had issues with the group divide and sub-groups were formed within. These sub-groups worked independently without much communication between them.

Another factor that played a crucial role in group divisions was residential location (hostel groups, local groups) and demographic differences. In the essays and interviews, students said that they could not meet each other because they were staying at different locations. For example, if a group had three members staying in the hostel and two members outside in the other locality. Then, the hostel students worked separately and two members worked separately from home. This could delay in the work and create group divide. The student essays reported that most of the groups had group leaders whom the others followed. In such cases, the group leader was the one who knew and understood the subject content better than the others. Also, the leader was someone who was sincere and dedicated to the project work. The other students relied heavily on the group leader to do the assigned work. While this might have improved peer learning, this improvement was not evident during presentations because the group leaders would step forward to answer most of the question. This raises questions as to whether or not peer learning was improved and raises the issue of learning for the weaker students.

During the feedback and informal discussions, only a few of the weaker students reported that their learning and understanding of the subject content had improved due to group work. Out of 19 groups, two had all average and weak students. These groups suggested that the group's composition should be a mixture of good, average and weak students. These groups struggled to cope with the expectations of the project. Hence, in future designs, team composition of bright and weak students may be encouraged, with groups comprising of four members.

5.5.3.1 Problems in the groups with mixed genders

The mixed gender groups were those with both boys and girls. There were seven such groups. This was the first time these students had worked together. It was not the usual for them. As a result, students felt some discomfort working together. I highlight the problem of one of the mixed groups in which the boys and the one girl foundit difficult to work together. The boys generally preferred to work in the hostels where the girl was not allowed to enter. The same problem was applicable when girls had a majority in the group. Four girls who were resistant to working with boys formed their own group with only one boy (G8). This group had difficulty managing time to work together. The girls would work in the hostel where boys were not permitted to enter. The group managed to meet during and after college hours but most of the work of this group was done by the girls.

I deliberately encouraged the arrangement of at least one girl member in each team. During the professional life of an engineer; he has to work with people of different ages, genders and cultures. Thus it made sense to have a girl and boy in every group to give students the opportunity to experience working with the opposite gender. This was much closer to the real world job experience. It was anticipated that the boys and girls would face some difficulties in working with each other. I expected that they would find ways to manage working together in due time. I would like to maintain this aspect of the model, as some students learned to work with the opposite gender and accepted the situation.

5.5.4 Time management and timing of activities

In the mid-semester essays, 10 groups informed me that they had not yet started the project, suggesting that these groups were very slow to choose and start their projects. A few groups reported that they were unable to find a project in time. In these cases, I had to push them for a selection or sometimes had to suggest projects to the group. Later, these groups found themselves lagging behind the other groups and working hard to meet the deadlines. There was a serious time management issue for many of the students in this semester.

In the survey (refer to figure 5.3, AQ2 and AQ5), students discussed their dissatisfaction with the timing and integration of the project into the curriculum. During interviews, the students also complained about time and timing of the project activities. I believe, this was a legitimate complaint, to some extent. Due to my late arrival in India (the semester started on January 2nd, 2012 and I arrived in India on February 12, 2012), I started project implementation when the semester was half over. Naturally, students found that the time was not sufficient. The second issue was integration of the project activities into the curriculum. This issue was also related to the timing of activities. Due to the overlap of an international conference at the institute, students' project presentations had to be postponed. The students were not happy with this. To complete the project presentations, I called them in during their preparation leave. Preparation leave is a period in which the students are free from all departmental and institutional activities so that they can study for the main examination. Naturally, the students felt inconvenienced. Hence, the students said the time and timing was not good. In the next cycle, care must be taken to have all project activities finished before preparation leave or within the academic period.

5.5.5 Project management

The students' essays and interviews illustrated that the students managed the project by dividing and distributing the work equally to each member. Later, this individual work was shared and combined in the report. This was a logical way for students to manage the project work. Although the groups reported using project management principles in the survey (see figure 5.5, CQ7), the tools and techniques used for project management were not discussed in the report or in the presentations. This gave me an indication that the students might need input on the principles of project management. In future designs, some input on project management may be given.

5.5.6 Project reports

From the project report analysis, it has been found that 90% of the groups followed the format given to them and included all the steps needed in the project work. This is a very good sign of their learning to write a project report. However, the quality of the reports was not up to the desired standard. Most of the students copied and pasted material from the

Internet into their reports and failed to write proper references. In general, the students paid little attention to the report preparation. This may be attributed to lack of time and improper time management. This indicated the need to train students in report writing and referencing. For future designs, clear instructions on how to write a project report will be necessary. Although the students were given a project format to use in writing their technical report, there was generally a gap between the format and the actual reports.

5.5.7 Learning in PBL model and achievement of learning outcomes

In general, all of the students responded positively to the project and explained how the project was helpful to their learning. They also reported positively on the knowledge sharing and peer learning aspects. It is evident from the feedback that the majority of students felt that their learning and understanding had improved in CLPBL. Furthermore, most of them hinted that they learned better from working in a team than in the classroom. Overall, 95% of the students were satisfied with their learning during the semester.

Referring to the LOs defined in the first chapter and the project design in the fourth chapter, it is concluded that the current PBL model proved effective in directly advancing LOs ‘a’, ‘b’, ‘d’, ‘e’, ‘g’ and ‘k’. The project helped students to learn and apply knowledge to real life engineering mechanisms (LO-‘a’). For the achievement of learning outcome ‘b’ (conducting experiements and data analysis) both traditional and PBL approach were useful. The traditional approach helped the students to conduct experiments in the laboratory and the PBL approach helped students to gather data from the field experiment. In both cases, students used data for calculation purposes.

Students were not expected to work in a team in the regular curriculum for the course. In the CLPBL model, students were provided the opportunity to work in a group, with the opposite gender, throughout the semester. This provided them useful experiences from which to learn from each other and get used to working in a team, advancing students towards achievement of LO‘d’. In the survey, 89% of students mentioned that their ability to work in a team had improved. Regarding LO ‘e’, students were not asked to solve areal life engineering problem but were instead asked to analyse a real life machine for the content learning aspect. Students were asked to solve the problem of finding the DOF of a real mechanism. In this sense, students were given an opportunity to solve an engineering problem.

In the CLPBL model, students got the opportunity to communicate with their group mates in various modes such as discussion, explaining to each other and sharing ideas and perspectives. In the presentation, they had the opportunity to communicate in front of their peers. In the project report, they had the opportunity to write and manage technical information. All of these activities would help them to improve their verbal and written communication skills. In the survey, 97% of the students mentioned that their ability to write a report had improved. This is not an opportunity that they would have got early in the engineering curriculumin a traditional setting. In the process of working on the project, students needed to find relevant information from various sources and to understand and apply that information to a relatively challenging problem. They managed their work fairly independently, showing their ability to engage in lifelong learning (LO ‘i’). The students used Microsoft Power Point and Word software to prepare presentations and reports, exhibiting their ability to use the tools needed for engineering practice (LO ‘k’).

The LOs ‘c’, ‘f’, ‘h’ and ‘j’ remain untouched. This is because the design activity was not included in the project work. In future designs, efforts could be made to add a few design activities to ensure that this deficiency is addressed. It should be noted here that these LOs were not considered in the design of my CLPBL model. Overall, it can be concluded that this CLPBL design helped students towards achievement of the intended LOs and better nurtured their abilities incomparison to the traditional setting.

5.5.8 Role of supervisor

My role in this model was twofold. At the beginning, my role was to pass on the basic information and propositional knowledge of the project units. My intention was to make the students ready to apply their knowledge and tackle the project activities independently. In the later phases of the model, I acted as a supervisor for the 19 groups, providing advice when needed. I provided feedback on the students' work and evaluated all the projects. Since the students managed the project work in their own capacity, not as much of supervision was required. Only a few groups demanded advice; for those groups, timely advice from the supervisor helped them to complete the projects.

5.6 Conclusions

Referring back to the first research question,'what characteristics of the course level PBL model are needed to fulfil students' learning requirements?' relating to PBL model design, this research has created a model for PBL implementation in the Indian academic setting. This experiment has increased the possibility of PBL implementation in other courses at SITL and of other institutes having a similar set-up. My understanding of the local context and academic culture and requirements helped me tremendously in designing an implementable design. It is recommended that future researchers place due importance on these factors in the design and actual PBL implementation. This understanding was useful in building the implementable theoretical design and will ensure effective PBL practice. Without this understanding implementation deficiencies may lead to failure of the experiment.

The students responded positively to the CLPBL and expressed satisfaction with their experiences. Almost all of the respondents (96%) found the project activity well integrated into the curriculum and recommended the activities be continued in forthcoming semesters. Students' improved confidence levels could be ascertained by the fact that 97% of the students were looking forward to working on complex and challenging projects. For this experiment, 5 was the minimum number of students per team. I advocate that, for less complex projects, 3-4 members may work better than 5-6. This could be investigated further. Although the students felt that teamwork was not sufficiently critical to the project work, they realised the challenges posed by teamwork. The statements from the students indicated that they struggled with the group work aspect. Although students tasted the bitter experiences of group work, there was a sweet side also. Many weak students reported that the group work helped them to attain improved knowledge, understanding and confidence. In general, it can be concluded that the group work was useful in increasing understanding, confidence and knowledge. Collaboration and sharing knowledge played a major role in the group aspect of the project.

After reflecting on the responses, I found that the project design and team composition could be closely related and were major reasons for implementation deficiencies in the current design. This creates an opportunity to increase the complexity of the project work in the next cycle. The importance of project design and its relation to teamwork is understood and will be refined further in the next cycle. In general, student responses suggested that they were eager to break the barriers of the traditional instruction-based setting and to learn something beyond the curriculum. Overall, PBL has been found to be a useful way to engage students in learning and to achieve LOs. In the literature, it has been quoted that one of the important outcomes of DBR is changed practice. We could achieve improved academic practice and stimulate change in the academic setting. Hence, from the methodological point of view, DBR as a framework has proved to be effective in this research. Furthermore, this experiment confirmed the usefulness of instruments and data collection strategies and created a framework for data analysis for future experiments.

Asa first experiment in implementing PBL at an institute that was built for and, for decades, has practised traditional teaching, I am satisfied and feel encouraged by the model’s successful implementation and the responses of the students. For more concrete conclusions, a few more experiments need to be conducted. I look forward to designing the next CLPBL with more assurance while keeping in mind my experiences with this model.

Chapter 6

Stundent's experiences in CLPBL - 2

This chapter focuses on presenting the design process and results of the second CLPBL model, which was implemented from June 2012 to September 2012.

6.1 Changes in the plan

In the last chapter, we discussed findings that showed that students from the first CLPBL model enjoyed the PBL environment and were eager to work on a more complex project. With the successful implementation of CLPBL-I, I was confident about experimenting with the same cohort who had worked on the first project to complete a more complex assignment. I was planning to design a complex project for the course *Theory of Machines –II* (TOM-II), which is the sequel to the course for which the students had completed the project in CLPBL-1 (Theory of Machines –I). Then the situation changed.

Despite my having insisted for a long time, the head of department did not offer to let me teach this course. Instead, he offered me a new course called Applied Thermodynamics (ATD). The TOM-II course was offered to another staff member. This change left me with two choices regarding my experiment. I could either implement PBL in my course (Applied Thermodynamics), or I could have it implemented in the Theory of Machines –II course taught by a different teacher. Both choices offered opportunities and challenges. Implementing PBL in the TOM-II course could have given me the chance to design and implement PBL in someone else's course, without my presence as a teacher. I could then collect data for research. However, there was the issue of staff training and administration of the project. I was not sure whether the new staff could satisfy the requirements of the PBL model. Furthermore, I had to teach the ATD course. I was confident about myself and unsure about others, so I finally decided to design a project for the ATD course. This meant that I was forced to change my previous plan and had to deal with a new course and a new cohort. However, based on my experience of the first model, I was confident that I could do it.

6.2 Introduction to new cohort

In June 2012, the new cohort (referred as a second cohort) entered the department for the first semester of their second year. These students had just finished their first year,in which the curriculum structure is the same for all programmes. In this curriculum structure, there is no project work included in the first year. Hence, the new cohort was completely inexperienced at project work. The challenge, then, was to design a project for a relatively inexperienced cohort. The course itself was very challenging; the average number of students that achieved a passing percentage for the course in the last five years was less than 50%. I was confronted with the situation where I needed to teach the new course so that the students could achieve good grades, and I needed to make them work on a project, something they had never done before. With this dual challenge, I started the process of designing the CLPBL Model-2.

6.2.1 Reflections on the first model-1

From the first model, I had learnt that the students could execute a simple discipline project. In the first model, the project covered three units of the TOM course. The students indicated that there was a considerable increase in knowledge and understanding of the course content due to the first project. This was reflected in the results. This feedback from the first model helped me to make the decision to design a similar kind of project for the ATD course. Furthermore, the new cohort was inexperienced and, like the first cohort, did not have the depth of knowledge required to execute a complex project. Therefore, it made sense for me to design a similar kind of project for the new cohort.

From the first model, I had also learnt that the group composition was very critical in ensuring students' engagement in learning and indetermining the challenges faced during the group work. In the first model, there were 5-6 members per group, something which contributed to collaboration issues in many groups. The first cohort suggested bringing down this number to three. There were 130 students in the new (second) cohort. If I made groups of three students, then the total number of groups would be around 42. This many groups would be unmanageable. The first cohort did not recommend five students per group. Therefore, I made the decision to make groups of four members per team, in hopes of improving collaboration while keeping to a manageable number of groups. Even with four students per team, 33 groups were formed. Hence, in this design, team members were reduced to four, from six in CLPBL-1. The type of project was kept similar to the first model. The total groups in this model were 33, compared to 19 in the first cohort.

It may be noted that, since, all other strategies remained the same as in the first experiment, repetitive information is avoided in this chapter.

6.3 The ATD course structure and syllabus

In table 6.1, a course structure for ATD is given. The complete curriculum structure and syllabus is available on the UoP website (UoP, 2012). For reference, the syllabus for this course is attached in appendix A_3.

Table 6.1 Existing course structure

Course name	Teaching scheme per week		Examination scheme			Total marks
	Lecture	Practical	Theory exam marks	Oral	Term work marks	
Applied Thermodynamics	4	2	100	50	25	175

From table 6.1, it can be seen that the ATD course has 25 marks for term work and 50 marks for oral examination. Similar to the first model, I embedded project activities into the term work. Accordingly, 25 marks are divided into two parts (12.5 marks each). The modified course structure that includes the project is as shown in table 6.2.

Table 6.2 Modified coursestructure with the project

Course name	Teaching scheme per week		Examination scheme			Total marks
	Lecture	Practical	Theory exam marks	Oral	Term work marks	
Applied thermodynamics	4	2	100	50	12.5	162.5
Project Work	**-**	**-**	**-**		**12.5**	**12.5**
	4	2	100	50	25	175

From table 6.2, it can be seen that the lecture and practical hours remained at six hours per week. I utilised these six hours for teaching: learning, lab work and supervision (similar to the first model). It may be noted that, in this model, the course level requirements have changed. Also in this model, the project needed to be designed for the 12.5 marks, as compared to 25 marks in the first model.

6.4 Introduction to a course requirement

The ATD course is a basic course for mechanical engineers and is closely associated with the thermal engineering field. Knowledge gained in this course is useful to understanding other subjects like heat transfer, energy conversion systems and courses relating to energy in the later years of the programme. The course is also useful for understanding thermal considerations in the design of any engineering product in which principles of work and heat or energy transfer are used.

The course contains important concepts like temperature, heat and work in the first unit, along with an in-depth study of various statements of thermodynamic laws. The second unit focuses on defining ideal gas and related equations. Basic gas laws such as Boyle’s law, Charle’s law, Avagadro’s Law and their applications are also covered in this unit. The second unit also contains concepts like thermodynamic processes, which is a very important concept for designing thermal equipment. The concept of availability also needs to be studied in the second unit. The third unit is comprised of vapour power cycles and an introduction to properties of steam. Students are expected to become competent in using steam tables to calculate various properties of steam, such as dryness fraction and enthalpy. These three units covered 50% of the syllabus and 50 marks in the main written examination.

The final three units covered the remaining 50% of the syllabus and 50 marks of the examination. In the fourth unit, students are expected to learn different types of fuels, their calorific values and its determination. The combustion of various types of fuels is also to be studied in the third unit. The fifth and sixth units cover compressors and boilers respectively.The compressors and boiler are important thermodynamic systems through which the basics from the above four units are considered for design purposes.

From observation of the course syllabus, I understood that the first four units cover basic information required to understand final two units. Also, the syllabus is fragmented which covers many concepts that may or may not be used in a single application. For instance, the concept of fuel and its combustion is important in the case of boilers, whereas an understanding of thermodynamic work and processes is critical in compressors. The concepts of steam are useful in the case of boilers, whereas concepts of ideal gas (air) are important for air compressors. This fragmentation of the syllabus put me in a confused state of mind. I was unsure for which section of the syllabus I should design a project. After reflecting for quite some time, an idea came into my mind to focus on the application side. The reason was simple. The equipment we use in day today life is applications of thermodynamic concepts, like heaters, refrigerators, air coolers and conditioners, electric irons, heating rods etc. These are also easily available in the market. So, the idea was generated to ask students to study these products and to justify how thermodynamic laws and concepts were applied in these products.

In my opinion, this type of project was suitable because it would help students to get the relevance of the theory and the actual application of theory in real life. The students would also, then, understand the related concepts and workings of each application. Since these products are available in large variety, there was a wide scope for each group to choose their product. There would be less financial burden on the students and they may not need to travel to find their application. In spite of the many advantages of this project design, it had disadvantages as well. Unlike the first project, this project may not cover the first three units of the course or have the same overarching concepts from the first three units, although it would cover 50% of the syllabus from all the different units. This meant that students needed to wait until the corresponding unit was taught in the class before proceeding with the project. For example, if the group chose to work on the boiler, the applicable concepts are only covered in the final unit of the course. The same applies for the compressor. However, I was confident that the students could do this type of project and I continued the process of designing the project.

6.4.1 Course objectives

It may be noted that the course objectives are not mentioned in the syllabus. Accordingly, the course objectives and unit objectives are defined here. At the end of the course, the students should be able to:

1. Understand and apply various statements of thermodynamic and gas laws
2. Understand basic forms of energy like heat and work, their conversions and application
3. Apply gas and vapour cycles to evaluate thermodynamic properties such as work, enthalpy, entropy for compressors and boilers
4. Evaluate calorific value of different types of fuels
5. Use steam table to analyse performance of the boiler
6. Conduct experiments on various experimental set-ups

To achieve the above course objectives, students are supported with classroom instruction and laboratory work. Assessment and evaluation of course objectives is based on the written tests conducted by the institute and university. Students' learning requirement is to study for the examination point of view.

6.4.2 Opportunity for improvement

Traditionally, this course is taught by using conventional teaching-learning practices. I critically evaluated the course content and gathered opinions from subject experts on the achievement of ABET learning outcomes referred in table 1.1. From this analysis, it was concluded that the current academic practice promotes students to *apply knowledge to solve textbook engineering problems, and to conduct, interpret and analyse data collected from laboratory experiments, listed in the syllabus*. However:

1. The course does not promote the application of knowledge to real engineering products or the analysis and interpretation of data gathered from field experiments.

2. The course does not allow students to work in a team, which is essential for professional practice. In the ABET learning outcomes, it is expected that the students should be able to work in multidisciplinary teams. In the project I designed, students would work in disciplinary teams. The intention was to give them the experience of teamwork. This experience may help them to work in multidisciplinary teams later in their professions.

3. The course does not promote the development of process competences such as communication, project management and lifelong learning skills that are desired by the ABET criteria.

The objective of the CLPBL model 2 would be to achieve the above-mentioned criteria. Since I was designing a project for the second time, the project design process of this model took less time than the first model. After careful study of the syllabus and content requirements, I designed a project. The project design was accomplished by following the same procedure as in the first model. This project is intended to achieve 7 out of 11 ABET learning outcomes, as outlined in table 6.3 (next page). The problem statement is shown below and project activities are shown in table 6.3. In the last column of table 6.3, the intended ABET learning outcome is shown.

Problem statement – Perform thermodynamic analysis of real life engineering product

6.4.3 Assessment and evaluation criteria for project work

The project work undertaken by the students needed to be assessed and evaluated. I designed an assessment and evaluation scheme for the 12.5 marks, as shown in table 6.4. In the first model, each item was assigned five marks. In the second model, each item receives two point five (2.5) marks.

Table 6.4 Assessment and Evaluation Scheme for a Project Activity

Teamwork	Field work	Quality of technical report	Presentation and question answer session	Total Marks
2.5	2.5	2.5	5	12.5

It may be noted that an evaluation procedure similar to that of the first model is followed for this project also. Students are assessed in a group and graded individually.

Table 6.3 Mapping of project activities with intended ABET learning outcomes

Sr. No	Major project activities	Intended ABET learning outcome
1.	Teamwork	d
2.	Identify and justify the product	a
3.	Conduct experiments in the lab with your team	b, d
4.	Text book problem solving in a team	d, e
5.	Carry out field work	a, d, e
6.	Explain working of a product	a, g
7.	Classify type of system and processes used	a
8.	Justify, how the first and the second law of thermodynamics are satisfied in this product	a
9.	Calculate energy transfer if any	a, b
10.	Identify important components and their functions	a, e, i
11.	Identify and justify the material used for these components	a, e, i
12.	Identify the manufacturing process used for these components	a, e, i
13.	Prepare project report.	g, i, k
14.	Prepare PowerPoint presentation	g, i, k
15.	Defend your analysis in front of the class	g

6.5 Design enactment

The designed project was implemented in the first semester of the academic year 2012-2013, starting from June 2012 and ending in September 2012. The implementation strategy remained similar to that of the first model. This time, I started implementation in the first week of the semester. During the first week, I explained all the listed project activities to the students. This was done to communicate my expectations from them. I told them the importance of the project and what they could gain from it. I informed them of my research and asked them to cooperate. I also shared some experiences from the previous model. The students unanimously agreed to participate in the project work and assured me that they would give honest feedback.

As expected, the second cohort completed the project work. Some groups were slow; I had to push them to complete the project in the stipulated time. At the end of the semester, I was burdened with lot of work and had to deal with evaluating 32 groups. To collect and analyse data, the same strategy and instruments were used as in the first model. I collected a lot of data: data on 32 groups and 126 students.

6.6 Results of qualitative data

6.6.1 Students' essays

In their essays, students wrote about their experiences of the project and teamwork. A total of 105 essays were collected and analysed using the content analysis technique described earlier. The overall results of essay analysis are shown below in table 6.5. From the essays it was evident that almost all groups had started working on their analysis of the thermodynamic case, which is a core activity of the project, when the feedback was taken. At this time, most of the students stated that they had started distributing the work amongst group members and that the preliminary data collection for the project was completed.

From table 6.5, it can be observed that 47.24% of the quotes in the essays related to group work aspects; this is approximately 45% less than the 86% quotes from the previous model.There were 30.17% quotes related to the project, as compared to 4% from the previous model. This is 7.5 times more. This data reflects that the timing of the essay writing in this model was better than in the first model. In the first model, students groups were just starting their project when the feedback was taken; as a result, their quotes in the project category were less than for the second model. The same trend was seen in all other categories. For example, in the information management category percentages of the quotes increased from 3% to 9.59%. In the case of comments about difficulties faced, this number increased from 4% to 12.83%. This confirms that these students faced more difficulties in the project than the previous cohort. Also, in the earlier model students had difficulties relating to teamwork only. In this model, however, students faced challenges in fieldwork, data handling and conceptual difficulties. In comparison to CLPBL-1, in which the total number of quotes was 282, this number increased to 708 in the second model. This may be for two reasons. The number of participating students was 97 in the first model, out of which 82 essays were collected. In this model, 126 students participated, out of which 105 essays were collected. In terms of percentage, the response rate in the two cases was similar, 84.54 and 83.33 respectively. In this model, I observed that the students wrote longer essays than in the first model. This may be also because the second cohort students were given more time to work on the project than the first cohort.

Table 6.5 Results of essay analysis

Major Theme	**Subtheme**		**CLPBL-1**		**CLPBL-2**	
			Total no. of quotes	**%**	**Total no. of quotes**	**%**
Teamwork(T)	Group experience	-	36	86	50	47.24
	Collaboration	Positive	40		54	
		Negative	19		8	
	Usefulness	Importance	28		27	
		Learning	55		69	
	Role of teammates		28		81	
	Communication		39		46	
Project (P)	Management		10	4	73	30.17
	Learning				109	
	Activities				32	
Information Management(I)	Information search and collection		08	3	68	9.59
Difficulty(D)	Fieldwork			4	38	12.83
	Data Handling				19	
	Teamwork		10		18	
	Conceptual				12	
	Time				04	
Suggestions (S)	-		09	3		
		Total	282	100	708	100

In the coming section, each category is discussed one by one. Please note that the number in the brackets denotes the number of times the word or quote appeared in the text.

6.6.1.1 Teamwork

Teamwork is one of the important aspects of the PBL approach. In this model, students were made to work in a group for the first time. I found that, in their essays, students talked about many aspects of teamwork such as their experience of working in a team, collaboration, the role of teammates, the usefulness of teamwork and communication. Each aspect is discussed below, with support from the students' quotes.

Group experience

In this subtheme, the students' experiences while working in a group are summarised. In the essays, I found 50 quotes discussing these experiences. The vocabulary used by the students was very diverse. Students' feelings could be judged from following examples:

> ***"It was a nice experience."***
>
> ***"I experienced something which I never did before."***
>
> ***"It is a good experience to work in a group as some new things we are learning."***

These quotes indicated that the students had a nice experience while working with a group. This may be because most of the students were being exposed to group work for the first time. In the next theme, students elaborated on collaboration in the group.

Collaboration

This category was created to illustrate the nature of collaboration in the group and how well the students worked with each other. The students' quotes (54) indicated that they worked well with each other and very few (8) mentioned issues in the group. The following statements indicate that the groups had positive collaboration among their members.

> ***"Our group is working sincerely, properly to complete the project. Our project is not a one man project." (Group-04)***
>
> ***"Everyone in a group is contributing in a project work." (Group-07)***

We also found eight quotes indicating that the group was having issues of time management and lack of interaction and cooperation from team members. A few sample quotes can illustrate these complaints:

> ***"In my group only two students are active, others are not paying attention." (Group 6)***
>
> ***"There is a lack of interaction as my group mates are busy in some other work." (Group 13)***
>
> ***"In group work only three members work, one member does not take part at all." (Group 19)***

Group 22 has two boys and two girls and is working on an electric kettle. One of the girls commented,

> ***"We do not manage time together and there are some problems to work on electric kettle, because we are two girls in a group"***

Very often during essay analysis, I observed that there were definite issues in the groups containing boys and girls (mixed gender groups). It may be because of the challenges arising from meeting places, as described in model 1, or it might be that boys are dominant in the group. This needs to be further investigated. From the students' quotes, it can be understood that members of the groups are working together or trying to find solutions to overcome any issues. In a sense, they are learning how to work in the group.

Usefulness of teamwork

Students mentioned that the group work was helpful to them in many ways. In total, there were 96 quotes of this nature, which are divided into the two subcategories of importance and learning.

Importance of teamwork

I found 27 quotes indicating that students understood the importance of the group work. Students felt group work was important for understanding each other's ideas and to development of the skills necessary to work in a team. One student (Group 16) said,

> ***"I listen carefully when someone speaks, it gives us many ideas." (Group 16)***

> ***"Group work is important to develop group working skill." (Group 20)***

Learning within team

A student from group 23 (E_2-70) elaborated on the usefulness of group work in three areas:

> ***"Doing work in a group helps me in lot many ways like i) it helps me to understand lots of practical concepts, ii) it gives me experience that how to face difficulties in a teamwork, and iii) it helps me to develop my practical skills and my ability to work in a team.".***

The above comment gives insight into the students' perception and experience of the group work. In all, I found 69 such comments discussing group work as useful for understanding concepts and learning to learn in a team. Another comment, from a student from group 24 (E2-73), stated,

> ***"I think working in a group improves my knowledge and study. However, it causes problem when other members are not listening what I want to say."***

This student indicated that listening was a very important dimension of the group work. From his words, it appears that his team members were not bothered to value his opinions. This can give rise to conflicts in a group.

Role of teammates

Please refer to the following comment from student (E2-97):

> ***"I learn how to work in a team. Whenever I faced any difficulty my group mates guided me. It was a nice experience." (Group31)***

The above student mentioned the role played by teammates in group work. He explained that his team members helped him to overcome difficulties. I found 81 quotes indicating the role played by teammates in group work. Depending on the status of the project, the role of the group members changed. For instance, at the beginning of the project, the role of each team member is to gather as much information as they can about the project and to suggest project ideas. The following quote (from Group 2) highlights this aspect:

> ***"Teamwork is always helpful because four members have four different ideas which when combined together gives better idea." (E2-6)***

One girl from Group 3 shared her views as follows:

> ***"Group work idea is too much good. We all discussed about thermodynamic case and finalised topic of ocean energy." (E2-11)***

Many students wrote that their teammates helped them solve problems and difficulties, clear doubts, and collect information.

Communication

In group work, communication between group members is vital for communicating ideas, solving each other's problems, discussing and deciding future work. Communication is also important for group collaboration. In the essays, I found 46 quotes indicating the importance of communication. The following are a few examples:

> ***"We shared the data with each other and discussed ideas." (Group 5, E2-16)***
>
> ***"We all sat together and discussed about the points to be covered in the main working." (Group 8, E2-28)***

One student (E2-31) remarked,

> ***"Due to group work, I am doing well in the group discussions." (Group 9)***

This shows that, for some students, group work helped to improve their ability to communicate in a group. In general, it can be said that the group settings of CLPBL-2 provided students an opportunity to work and learn together. In doing so, the students learnt about collaboration, contributing ideas and communication. In short, they are learning how to work with a team.

6.6.1.2 Project work

Project management

In the last experiment, I made a mistake by collecting essays before the students had started working on the project. In the second model, I first took feedback from different groups about their project status. As the majority of groups informed me that they had started their work, I asked the students to write an essay. Because of this adjustment, the students wrote more quotes relating to project work than in the first cohort. In the project category, students discussed the current status of the project and their project management techniques. I found 73 quotes addressing project status and the project management principles used by the students. One student elaborated on their management style in the following way:

> ***"We divided the content of the project in ourselves. We sit together and discuss. We edit the content and information brought and done by each member." (Group 11, E2 39)***

One group member (Group 15, E2- 42) explained more precisely.

> ***"As per work distribution we all are working. Two are working on information collection and other two are observing the oven."***

A leader of Group 21 (E2-64) mentioned,

> ***"We have given each member particular work. Roll no. 31 handled material part used in the cooler. Roll no. 27 and 45, handling the working process in the air cooler and also the thermodynamic part. Roll no 33 is given manufacturing process part of air cooler."***

He further explained, "This work management is done by recognising the person for which work he fits the best." A member of Group 24 (E2- 72) claimed,

> ***"We were bit slow in our work. We have started by collecting information"***

From the above quotes, it can be understood that the students applied project and work management techniques to manage their project work. In this way, the project provided an opportunity to improve their project management skills.

Learning from the project

I found 109 comments mentioning the importance of the project for learning. Students mentioned that the given project was useful for gaining knowledge and learning practical things and concepts. Students stated that they learned about the case which they were investigating.

> ***"Project helped me to understand practical knowledge." (Group 23, E2-70)***

> ***“We are getting practical experience. I learned about radiator and heat transfer.” (Group 7, E2-24)***

The above student described the usefulness of the project for content learning and illuminating the concepts. Since the cases, like radiator, kettle etc. are not in the syllabus, students were getting knowledge over and above the curriculum. As part of the project work, the students needed to conduct fieldwork and, by doing this, they gained practical knowledge as well.

Project activities

Students’ activities in the project work mainly included visiting various places such as shops (air cooler, refrigerator, and water heater), garages (radiator and compressor), and canteens (oven, refrigerator and induction heating) to conduct fieldwork. A few groups did their fieldwork in the hostel (kettle, geyser and heating rod). Also, a few groups conducted their fieldwork during an industrial visit (cooling tower and condenser). In summary, the students’ activities in the project included visits to various places, observation and understanding the working of all this equipment. I found 32 quotes in this category for evidence.

6.6.1.3 Difficulties

In the essays, students shared their difficulties in the project work. Most of the difficulties they mentioned were about the fieldwork (38). These challenges included getting permission and access to the product, inability to dis-assemble the product and see from inside, and finding a place to conduct fieldwork. Other types of difficulties were: data management (19), teamwork (18), conceptual difficulties (12) and time related (4). In this experiment, students had more conceptual difficulties than in the first experiment. The reason for this was the nature of the product. Most of the groups were working on products that work on the principle of electrical heating (geyser, oven, heating rod, water heater, kettle, electric motor etc.). The students were not familiar with the electrical appliances. As a result, they found it difficult to understand the system and the conversion of electrical energy into work.

Summing up

The essays were useful for collecting the students’ experiences relating to teamwork and project work, and to getting insight into difficulties faced by the students as they worked on the projects. From the essay analysis, it was understood that the students enjoyed the group setting. Their quotes indicated that the students had a nice experience working with a group. The place of meeting or the boys’ dominance created issues in the mixed gender groups and members of these groups were trying to find ways to overcome these issues. This needs to be investigated further. Students mentioned that team members helped to overcome difficulties, solve problems, clear up doubts and collect information. The group members learned from each other by solving, discussing and explaining to each other. In doing so, the students learnt about collaboration, contributing ideas and communication. In short, they were learning how to work with a team. In general, it can be said that the group setting for CLPBL-2 provided students with an opportunity to work and learn together.

Students applied project and work management techniques to manage their project work. In this way, the project provided an opportunity to improve their project management skills. Students also mentioned the usefulness of the project for content learning, illustrating the concepts, and improving practical knowledge. Students visited various places to conduct fieldwork. In summary, the students' activities on the project included visits to various places, observation and understanding the workings of various equipment. This student cohort had difficulties in the fieldwork, data management and teamwork, and experienced conceptual difficulties. In this experiment, students had conceptual difficulties in understanding the equipment that worked on an electrical heating principle. As a result, they found it difficult to understand the state of the system and conversion of electrical energy into work. From the essay data, it can be concluded that the CLPBL-2 was effective for content learning, promoting teamwork and communication skills, which were important objectives of the model.

Experiences from the project presentation

Out of 33 groups, 32 completed the project in time and presented their work. From the project presentations, it was observed that students were able to prepare a presentation to a reasonably good level. The presentation slides were mainly focused on the workings of the engineering product or application, its parts and function. Students mainly discussed technical content and governing laws for that engineering application. The project presentation helped me to get a sense of the depth of the students' project work.

During the presentations and question-answer sessions, I saw the groups rely heavily on a leader. The active students were more talkative and sometimes consumed all the time given for the question-answer sessions. The intelligent, talkative and active students were leading the groups and the weaker, less active, more introverted students were either in a supporting role or sidelined.

Figure 6.1 Active students answering questions

In the two images above, it can be seen that the active students were standing in front to defend their project work. The other members leaned back and avoided answering the questions. In my opinion, it is not a good situation for the PBL approach to activate already active students and exclude already more passive students. Some practical arrangements must be done to change this situation.

During the presentations, I observed that the girls (from all groups) were seldom active and the boys were in command of the group. Having said so, this may also depend on the girls' enthusiasm and motivation to get involved in the project work. The boys in the mixed gender groups reported that the girls did not respond quickly enough and took their time, delaying the project work. In the first picture from the left (see figure 6.2), the leader of the group (the person on the right) was answering the question. In the second picture, the girl got a chance to talk because I stopped the leader (the person on the right) from talking. In the second picture, the leader is standing at the end and kept quiet after that.

During the presentations, I saw heated technical debates among the groups (induction heating, electric kettle, refrigerator) and student evaluators (students who also acted as evaluators). This gave me the impression that the student evaluators critically examined the group and that the groups tried their best to convince the evaluators about their work. I was pleasantly surprised to see the student debate over technical content, which is a skill often required of engineers to convince people in professional life. I was not, however, satisfied with the quality of project work from five of the groups (heating rod, internal combustion engine, solar panel, water heater and fans). These groups did not complete the project activity at level of my expectations.

Figure 6.2 Groups having girl members in a team

6.6.2 Results of semi-structured interviews

In the 10-minute group interviews, groups were asked to share their views and experiences of the CLPBL model (refer A_5). Out of 32 groups, 28 were interviewed.This section will discuss the results of the interview analysis. Interviews were analysed in the same manner as was used for the essay analysis. During the interview analysis, I found that not all team members answered questions. Hence, the total number of quotes (174) was much less than in the essay (708) analysis. However, this data was still important because the essays were written at the middle of the semester and the interviews were held at the end of the activity. The interview information, then, was helpful for reinforcing the essay data. Table 6.6 summarises the group interviews.

In the second model, 28 interviews were conducted versus 16 from the first model. From table 6.6, it can be seen that the total number of quotes in both models are almost the same. This is because the leaders of the groups answered the questions most of the time in the second model. From table 6.6, it can be seen that the interview data followed a similar trend to that of the essay data. In general, students in the second model had a larger number of quotes in the project category and the trend was reversed in the teamwork category. The reason for these trends has already been discussed in the essay analysis. The students in the second model had more teamwork and fieldwork difficulties. It can be noted that students in the second model had less issues regarding time; this was to be expected as they were given more time than the first cohort.

Table 6.6 Results of interview analysis

Major Theme	Subtheme		CLPBL-1		CLPBL-2	
			Total no. of quotes	%	Total no. of quotes	%
Teamwork	Group experience		25	54.70	-	20.03
	Collaboration	Positive	07		5	
		Negative	02		-	
	Usefulness	Importance	27		16	
		Abilities	-		4	
		Learning	-		2	
	Role of teammates	-	16		6	
	Communication	-	16		2	
Project	Management	-	10	23.6	8	44.66
	Learning	-	25		43	
	Challenging projects		05		26	
Information Management	Information search and collection	-	01		10	
Difficulty	Teamwork	-	03	14.16	11	20.3
	Data handling		04		5	
	Field work		06		11	
	Conceptual difficulties		04		06	
	Time		07		02	
Suggestions	-	-	12	7.08	04	2.32
		Total	170	100	174	100

As in the first experiment, students in the second experiment did not talk much about their experience in the project work (although they wrote long essays on the subject). In the following paragraphs, I highlighted a few interesting comments from the students. I asked a few groups about what challenges were posed by the project. I found 26 quotes where students mentioned that they would like to work on more challenging projects. A group working on an engine said,

“We chose this project because we are interested. It is not a challenging project as we are familiar about these things.”The group working on ‘ocean energy’ said,

> ***“The project was challenging to understand.”***

The leader of the above group took a lot of opportunities to answer the questions and gave me the impression that he had worked alone. Other members from this group did not take the initiative.

The group working on the air conditioner said,

> ***“It was very challenging for us. Because many difficulties, we came across. Due to our combined work we were able to complete this work.”***

Group who worked on a hair drier said,

> ***“It was challenging for us, because it is hard to call all people. To some people we have to call 3-4 times. Then they will come and work. Very few people are giving response to the work and few are not given any response.”***

It is quite reasonable to accept that the difficulty level of the project would vary from group to group. This was mainly because each group analysed different equipment. Some equipment was easy to understand and a few were very difficult. However, each group tried their best to understand the project item. As a result, their content learning was improved. Students mentioned in the interview that their content learning was improved due to the project (43). I asked a group of students what they learned in the project. One of the members (gas geyser group) said,

> ***“In this project, we learned how the thermodynamic laws are applied and how it is used. It was very difficult to calculate weight of the gas.”***

One of the members from the air cooler group said,

> ***“We learned about air cooler and personally, I learned patience.”***

I asked students in the gas geyser group what skills they thought had improved. They responded,

> ***“Logical thinking, how to start and do the project.”***

One of the team members said,

> ***“My communication is improved.”***
>
> ***“Confidence in working in a team is increased”***

The students experienced difficulties in conducting fieldwork (11).One group said,

> ***“It is not actually possible to see the engine from inside.”***

I asked one girl member about how difficult it was to work with boys. She said,

> ***"It was 25% simple and 75% difficult."***

Summing up

From these quotes and the analysis in table 6.6, it has been found that the project affected different groups and members differently. Some members learned about the content and for some members their abilities were enhanced. A few members gained confidence while others faced difficulties. In conclusion, the designed project was effective in engaging students in the learning process and had varying effects on the students' learning and abilities. Overall, it can be said that the students liked the PBL environment. Students remarked that, although project was useful, they would like to work on more challenging assignments.

6.6.3 Results of technical report analysis

At the end of the semester, 32 groups submitted the report and one group did not. These reports were analysed to determine whether the students completed the desired project activities or not. This analysis also revealed many important aspects of technical report writing. The reports were analysed by following the same procedure discussed in chapter 3. Tables 6.7 and 6.8 below show the results of the project report analysis. Activities 3 to 13 (highlighted area in Tables 6.7a and 6.7b) formed the core project activities. It was anticipated that the students would write about these activities in their reports to indicate that they had learned the content and the depth of their understanding. From table 6.7, it could be seen that 70% of the groups covered all of the project activities in their report. The report lengths varied from 6 pages to 21 pages. To my surprise, only four out of 32 groups included the calculations of heat and work transfer. It is significant to note that, out of 32 groups, 20 added fieldwork photos to their reports. These photos showed that the students had actually visited the various places for fieldwork activity. Other groups did not produce photos.

Table 6.8 shows that 13 groups obtained an 'A' grade, 12 groups obtained a 'B' grade and 7 groups received a 'C' grade for their project report. Out of the 32 groups, 25 received good grades (A and B). This shows that the students made reasonably good efforts to write the project report. Seven groups got a 'C' grade, which shows that the students' ability to write technical content needs to be improved. From the table it can be seen that in the plagiarism, seven reports got 'C'grade and 21 groups got 'B' grade. These 28 out of 32 reports showed the students' tendency to copy and paste material without proper referencing and paraphrasing. This is a very high percentage. This may be because it was the first time the students had prepared a project report. The students might need to be given guidance on aspects of report writing. Report writing is an important part of their learning and must be addressed in the next design. It was observed that the similar format was followed in most of the reports. The technical reports revealed the students' ability to manage technical information and to properly organise that information in the form of a report. Although students made efforts to write good reports, they need to improve significantly in the areas of technical writing and avoiding plagiarism.

From column five in table 6.8, it can be observed that each group selected a different domestic product for thermodynamic analysis. Students said that they had never thought that these products used thermodynamic principles and laws in their operations. While applying thermodynamics to these products, I believe that the group members understood the workings of these products and thereal life application of thermodynamic laws. This leads to the conclusion that the students' content learning was improved in this model.

Table 6.7a Student reports analysis for CLPBL Model-2

Sr. No.	Parameter	Group No.																Totalout of 16
		G_1	G_2	G_3	G_4	G_5	G_6	G_7	G_8	G_9	G_{10}	G_{11}	G_{12}	G_{13}	G_{14}	G_{15}	G_{16}	
1.	**Problem statement**	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	**16**
2.	**Name of Team members**	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	**16**
3.	**Abstract**		*		*		*	*	*	*	*			*	*	*	*	**11**
4.	**Introduction**	*	*	*	*	*		*		*	*	*	*	*	*	*	*	**14**
5.	**Types**	*	*		*		*	*		*			*					**7**
6.	**Technical/ component details**	*	*	*	*	*	*	*	*	*	*		*	*	*	*	*	**15**
7.	**Working**	*	*	*	*	*		*	*	*	*	*	*	*	*	*	*	**15**
8.	**Justification of the Ist law**	*	*	*	*	*	*	*	*	*	*	*		*	*	*	*	**15**

9.	**Justification of the IInd law**	*	*		*	*	*	*	*	*	*	*		*		*	*	**13**
10.	**Heat and work calculations**				*					*		*	*					**4**
11.	**Materials used**	*	*	*	*	*	*	*	*	*				*	*	*	*	**13**
12.	**Manufacturing process**	*	*	*	*	*	*	*	*					*	*	*	*	**12**
13.	**Conclusions**	*		*	*	*		*	*	*		*	*	*	*	*	*	**13**
14.	**Advantages, disadvantages, applications**										*							**1**
15.	**References**	**3**	**2**	**3**	**4**	**5**	**5**	**5**	**4**	**5**	**5**	**5**	**4**		**4**	**6**	**6**	
16.	**No. of Pages**	**9**	**9**	**12**	**10**	**17**	**11**	**14**	**11**	**17**	**11**	**9**	**6**	**8**	**6**	**15**	**14**	
17.	**Field work photos**	*	*	*		*	*		*	*	*	*				*	*	**11**

Table 6.7 b. Student reports analysis for CLPBL Model-2

Sr. No.	Parameter	Group No.																Totalout of 16
		G_{17}	G_{18}	G_{19}	G_{20}	G_{21}	G_{22}	G_{23}	G_{24}	G_{25}	G_{26}	G_{27}	G_{28}	G_{29}	G_{30}	G_{31}	G_{32}	
1.	**Problem statement**	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	**16**
2.	**Name of team members**	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	**16**
3.	**Abstract**	*		*		*	*	*	*	*	*	*		*		*		**11**
4.	**Introduction**	*	*	*	*	*			*	*	*	*	*	*	*		*	**13**
5.	**Types**	*				*								*		*	*	**5**
6.	**Technical/ component details**	*	*	*	*	*	*	*	*	*	*		*	*	*	*	*	**15**
7.	**Working**	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	**16**
8.	**Justification of Ist law**	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	**16**
9.	**Justification of IInd law**	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	**16**

10.	**Heat and work calculations**																	**00**
11.	**Materials used**	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	**16**
12.	**Manufacturing process**	*	*	*	*	*				*	*	*	*	*	*	*	*	**13**
13.	**Conclusions**						*					*				*	*	**4**
14.	**Advantages, disadvantages, applications**					*		*			*	*			*			**5**
15.	**References**	**5**	**6**	**4**		**12**	**5**			**4**	**6**	**3**	**5**	**3**	**3**	**3**	**3**	
16.	**No. of Pages**	**15**	**9**	**15**	**12**	**21**	**8**	**10**	**13**	**10**	**9**	**8**	**10**	**8**	**10**	**12**	**13**	
17.	**Field work photos**	*	*		*	*	*	*	*	*						*		**9**

Table 6.8 Analysis of the reports and report grades

Group no.	Group composition			Name of the product	Format	Technical content	Coverage of project activities	Plagiarism	Overall impression
	M	F	Total						
G_1	4		4	Cooling tower	B	B	B	B	B
G_2	4		4	Refrigerator	B	B	B	C	B
G_3	3	1	4	Tidal power plant	B	B	A	B	B
G_4	4		4	Gas geyser	A	B	A	B	A
G_5	3	1	4	Electric motor	C	C	C	C	C
G_6	3		3	Fans and blower	C	B	C	C	C
G_7	4		4	Radiator	A	B	A	B	A
G_8	4		4	Spray painting gun	A	A	A	A	A
G_9	4		4	Solar panel	B	A	B	A	A
G_{10}	4		4	Four stroke engine	C	C	C	C	C
G_{11}	4		4	Electric water heater	C	C	C	C	C
G_{12}	3		3	Heat exchangers	C	C	C	C	C
G_{13}	3		3	Motor cycle engines	C	C	B	B	C
G_{14}	3		3	Solar cooker	B	B	B	B	B
G_{15}	4		4	Microwave oven	A	B	A	B	A
G_{16}	4		4	Hair dryer	A	B	A	B	A
G_{17}	4		4	Room heater	A	A	A	B	A
G_{18}	3	1	4	Electric iron	A	B	A	B	A
G_{19}	4		4	Water cooler	B	B	B	B	B
G_{20}	4		4	Refrigerator	A	A	A	B	A
G_{21}	4		4	Air cooler	B	A	B	C	B
G_{22}	2	2	4	Electric kettle	B	B	B	B	B

G_{23}	4		4	Reciprocating compressor	B	B	C	B	B
G_{24}	4		4	Air conditioner	B	B		B	B
G_{25}	4		4	Water heating rod	B	B	B	B	B
G_{26}	4		4	Geysers	B	C	B	B	B
G_{27}	3	1	4	Induction heating	B	B	A	A	A
G_{28}	3		3	Jet turbines	B	A	A	B	A
G_{29}	4		4	Wind turbines	A	B	A	A	A
G_{30}	4		4	Solar water heaters	A	B	B	B	B
G_{31}	4		4	Internal combustion engine	A	B	A	A	A
G_{32}	1	2	3	Air conditioner	C	C	C	C	C
G_{33}	4		4	Not available					
Total	118	8	126						

6.6.4 Results of survey- open-ended questions

At the end of the course, students' responses were recorded on the questionnaire (refer A_7). This questionnaire included a few open-ended questions relating to the location of the project work, difficulties and suggestions for future models. Students' responses to these questions are analysed and discussed below.

6.6.4.1 Group meetings

Table 6.9 shows the students response about group meetings per week (refer A_7 question c). Thirty five students commented that they met two times per week. Twenty-six students outlined that they met once a week and 25 groups met three times per week. I observed that the students' meeting frequency increased closer to the deadline. Especially for the groups who worked closer to the deadline, the frequency of meeting went up to four (10 students) or almost every day (10 students) in the closing weeks. From table 6.9 it is clear that students conducted group meetings, the frequency of which varied from group to group. This variation could be attributed to the group composition and the project stage. In general, the data in the table suggests that students met each other often to discuss the project. We have already seen that such discussion lead to content understanding, doubt and difficulty solving. It may be noted that the frequency of meetings was not collected for the first model.

Table 6.9 Frequency of group meetings per week

Meetings/week	Students
One	26
Two	35
Three	25
Four	10
Everyday	10
Total	106

6.6.4.2 Location of the project work

In the questionnaire, the participants were asked to mention the location of the field work and group work (refer A_7 question a, b). Table 6.10 summarises the locations of the project work for the two models. This table shows that the locations of the project meetings remained the same but the frequency changed. As compared to the first model, from table 6.10 it can be seen that the students in the second model preferred to meet in hostel rooms (83) and the reading hall (34). Students also mentioned that they met in the college laboratories (9) and outside at different places (4), depending on the requirement.

Table 6.10 Location for the project work

Model	CLPBL-1	CLPBL-2
Location	**Frequency**	**Frequency**
Reading hall	23	34
Hostel room	09	83
Lab/Classroom	20	9
Outside	22	4
Campus	05	3
Total	79	133

6.6.4.3 Difficulties

Students were asked to share the difficulties they experienced during the project work. This information could be useful for making changes or improvement for the next design. It was also worth developing awareness of the difficulties experienced by the groups so that efforts could be made to minimise them. In the final analysis, I grouped the expressed difficulties into five main categories, as was done for the essay analysis. Table 6.11 shows a summary of the difficulties experienced by participants in the project work.

Table 6.11 Summary of difficulties experienced in project work

Difficulties	**CLPBL-1** **Frequency**	**CLPBL-2** **Frequency**
Teamwork	10	Managing team members (17) + Girl in a group (04) + lack of coordination (04) = 25
Data handling	Information management (19) and reports (5) = 24	Internet access (04), Information collection (03) and reports (05) = 12
Field work	22	place of fieldwork (27)+ unable to see from inside (04) = 31
Conceptual difficulty	5	04
Time	Time management (4), Time limitation (7) = 11	Time management (07), Time limitation (08)=15
Total	72	87

Table 6.11 summarises and compares the difficulties experienced by the students in both models. It can be seen that mentioned similar set of difficulties in both models students; these mainly included fieldwork, teamwork, time management, information management and conceptual difficulties. In general, the students in the second model faced more difficulties than those in the first model, except in difficulties relating to the data handling. The difficulties in teamwork included managing teammates (17), working with the other gender (4) and lack of coordination (4). In the first model, students had experienced a similar set of difficulties but with less frequency (10). This may be because of individual preferences and attitudes toward teammates. In mixed gender groups, working with the opposite gender (04) was difficult for some members and a few (4) participants felt that they did not get much cooperation from their team members.

The difficulties in data handling included Internet access (4), getting the right information (3), and compiling the information into reports (5). The first cohort had more difficulty in data handling category, possibly because there is more information available about the mechanisms compared to thermodynamic products. Difficulties in the fieldwork category (31) included getting to the fieldwork site and getting permission to conduct fieldwork (27). A few of the groups that got the permission could not see the product from inside (4). In the first model, students experienced fewer difficulties in this category,possibly because the machines were available in close vicinity.

The conceptual difficulties (4) were the difficulties in which students struggled to understand the information and apply known information to the actual product. Most of the difficulties experienced by team members were due to the nature of the product (principle of electrical heating). Although project activities were started at the start of the semester for the second model, some students still had difficulty managing their time (7) or felt that there was a shortage of time (8). The participants faced a similar set of difficulties during the project in both models. In spite of these difficulties, 32 groups in the second model completed the project work in time. The student got the experience of overcoming difficulties to achieve the final desired outcomes. This set of skills is part of the project management, which is related to ABET learning outcome (k).

6.6.4.4 Suggestions for improvement

The students were also asked to suggest possible improvements to the existing model. The students provided many areas where improvement could be done to CLPBL-2. Table 6.12 shows a summary and comparison of the suggestions given by the participants for the two models. From the table 6.12, it can be seen that, in both models, students offered similar suggestions. The total number of suggestions for the first model was greater (82) than the second model (69). This difference was mainly because the students in the first model had more suggestions relating to time (46) than the students in the second model (26). This was understandable because the project in the first model the project was started in the middle of the semester, whereas the project in the second model was given at the beginning of the semester. In other categories, the difference between models was marginal.

Regarding teammates, the students offered suggestions on team composition (11) and the number of members per team (6). The students suggested that the teams should have fewer students (less than four) (06) and must include at least one intelligent student (5). The students felt that doing so would allow each member to contribute to teamwork and, due to the presence of intelligent person on the team, would improve their learning. Regarding time, the students in the second model suggested initiating the process of project work early in the semester (19). They suggested finishing the project evaluation before the semester end so that the timing of each activity could be improved (1). One acceptable suggestion was that a detailed timetablebe displayed outlining a week-by-week plan for the project activities.

Regarding project work, the students suggested giving more challenging, practical projects (6) and raised issue of assessment (2). They also suggested that the Internet lab be made available even after college hours (6). As has already been discussed, the Internet lab could not be kept open for security reasons. All other suggestions were already considered in this design. A few students raised important points about the supervisor and guidance provided by him. They suggested providing or deputing one supervisor per group. This would surely help students to get out of difficulties that arise throughout the project. This suggestion could be taken up by incorporating more teachers into the project work. From the above discussion, it can be said that CLPBL-2 could be improved further in the areas of time management and providing guides to each group. There is also scope for improvement in the areas relating to team composition.

Table 6.12 Summary of suggestions for future models

Code	Suggestions	CLPBL-1 Frequency	CLPBL-2 Frequency
Teammates	Teammates	17	Group of less members (6) +Meeting of group (3) + one groups containing one good member(5) + group should be with new members(6) + early group formation(2) = 22
Time	More time	14	display timetable (2) and proper time management (04) = 6
	Timing	10	Finish before exam (01)
	Project at start	22	19
Projects	Practical / challenging projects	11	06
	Proper / project assessment	4	02
	Availability of Net lab	02	6
	Proper Guide	02	7
	Total	82	69

Summing up

In this section, qualitative data collection and analysis methodology are discussed. The essays, project presentations, short interviews, project reports and responses to the open ended questions provided the qualitative data, which was analysed by using content analysis technique. From the data analysis, it is understood that the CLPBL-2 model proved to be effective for improving students' motivation, engagement towards learning and application of knowledge on real life engineering products. This resulted in improved understanding, and content learning. Moreover, students claimed that their practical knowledge was improved. In terms of skills, students' responses showed that CLPBL-2 was effective in improving teamwork, time and project management abilities. The project reports and project presentations provided an opportunity to improve written and verbal communication. There is a scope to improve this model in the areas of project assessment, time management and providing guides to each group. In the coming sections, the survey, project grades and grades in the final examination will be used to reinforce this data.

6.7 Results from quantitative data analysis

6.7.1 Survey

The survey was conducted at the end of the semester. In this survey, 106 out of 126 students recorded their responses and returned the questionnaire in time. Twenty students did not respond. Table 6.13 below shows a summary of respondents and non-respondents. The response rate of the second cohort (84%) was close to the response rate of the first cohort (88%).

Table 6.13 Summary of respondents and non-respondents in CLPBL-2

Total students	Number of students	%
Respondents	106	84.13
Non-respondents	20	15.87
Total no. of participants	126	100

In the following section, the results from the survey are discussed. It can be noted that the project for the second cohort was of a similar nature to that of the first cohort; only the course has been changed.

6.7.1.1 Socio-demographic analysis or participating students' profiles

There were 126 (n = 126) participants, of which only eight were (n = 8) female (refer to table 6.8). In terms of age, all participants were between 19 and 21 years old. In terms of language, all spoke three languages. Out of the 126 students, a total of 33 groups were formed. In terms of gender, the group compositions were as follows: 27 groups had all male members, 6 groups had mixed gender (that is, having at least one female member in their group). Out of 33 groups, 27 had 4 members per team and 6 groups had 3 members per team.

6.7.1.2 Students' experiences in PBL and related aspects

Table 6.14 provides a summary of the student's overall experience relating to various aspects of CLPBL-2. In response to AQ1, (see figure 6.3), 93% of students claimed that the project was challenging. Compared to the first cohort's response, this value is increased by 9%. From the table, the mean value of responses here was 4.10, as compared to 3.74 from the first cohort. This means that the students in the second cohort felt that the project was more challenging than those in the first cohort. I then asked whether the given project was relevant to their profession (AQ3) and had any significance to the course (AQ2). I found that 95% of students believed that the project was relevant to their engineering profession and 87% felt that it was well integrated into the curriculum. This is unlike the results from the first cohort, in which 90 % and only 77%, respectively, gave favourable responses to these questions. This means that more, or most of the students from the second cohort agreed that the project was relevant and in line with the course.

Table 6.14 Students' responses on various elements of CLPBL-2

Question no.	Question	Mean out of five	Standard deviation
AQ1	Assigned project work was challenging	4.10	0.62
AQ2	The project was well integrated into the curriculum	4.08	0.58
AQ3	The project was relevant to my profession	4.36	0.64
AQ4	I found classroom instructions helpful	4.17	0.70
AQ5	I feel the time provided for the project was sufficient	4.07	0.78
AQ6	Assigned project was enjoyable	4.19	0.82
AQ7	I recommend to apply PBL to other courses	4.44	0.66

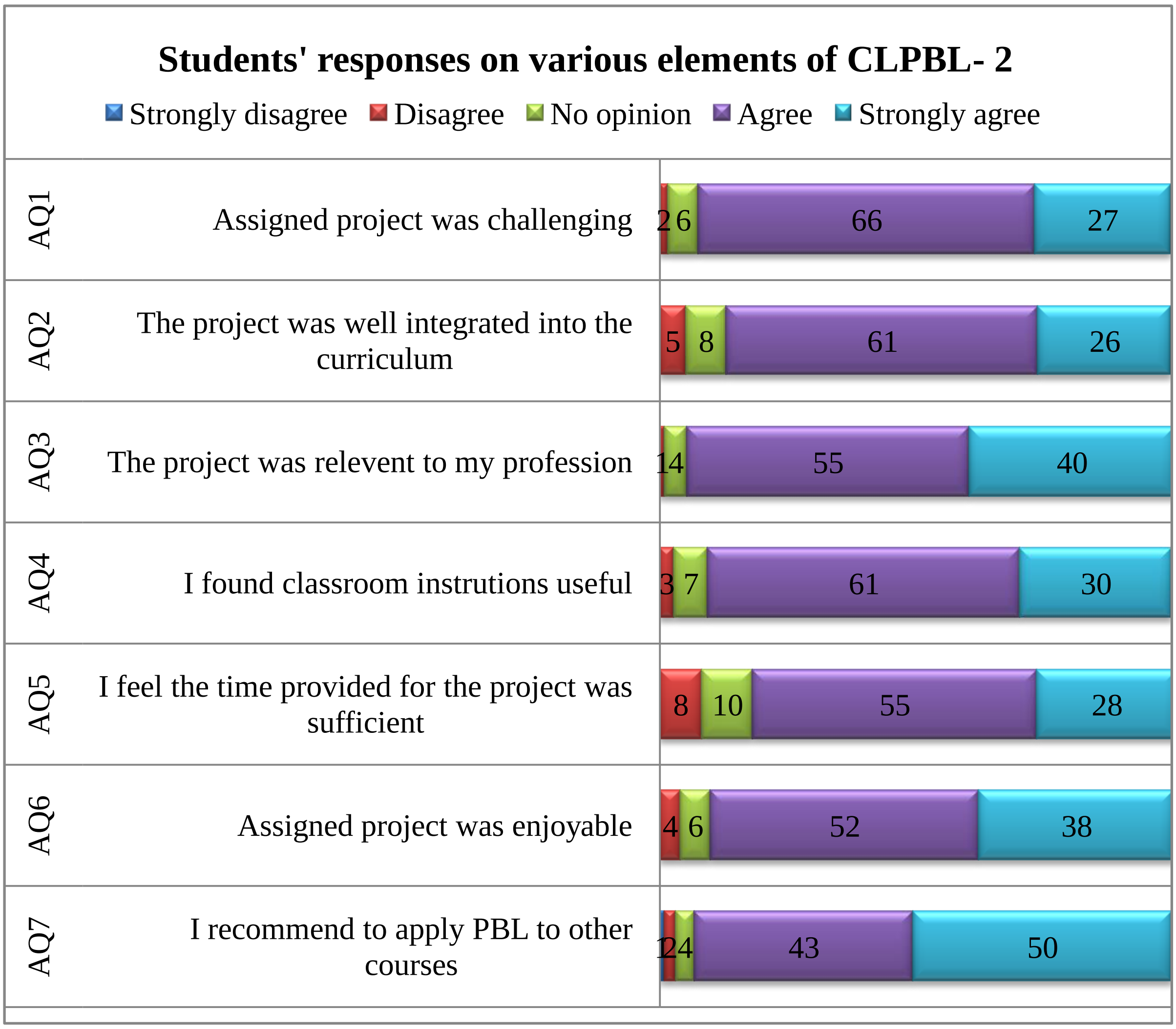

Figure 6.3 Students' responses on various elements of CLPBL-2 in percentages.

In both designs, a propositional knowledge was important for the project work. Accordingly, propositional knowledge and important information related to project were provided to the students through classroom teaching during the semester. Students were asked to assess the effectiveness of the instructions for the project in AQ4. From figure 6.3, it can be seen that 91% of the students felt that the instructions were useful. This value was 86% in the first cohort. The first cohort was not satisfied with the timing of the project activities (31%). Based on their feedback in the previous semester, I started the project activity at the beginning of the semester and completed it before the end of the semester. I wanted to know whether the students in the second cohort found the time provided sufficient for completing the project activities in time (AQ5). 83% agrees with it. The remaining 17 % either had no opinion or did not agree. Compared to the first cohort, there was a rise of 14 % of students who found that the time was sufficient for the project. Still, 17% of students had some issue relating to time. This may be because of individual's time management problems or other difficulties that groups faced during the project. The time management problem was also evident in responses to the open-ended questions. Overall, from the students' responses it can be seen that they were happy about the project and instructions. In summary, 90% of the students enjoyed the project (AQ6), which is 3% less than in the first cohort. Also, 93% of the students recommended PBL for future courses (AQ7), which is also marginally (3%) less than in the first cohort.

6.7.1.3. Students' experiences about their learning

Table 6.15 Students' learning experiences in CLPBL-2

Question no.	Question	Mean score out of five	Standard deviation
BQ1	The project motivated me to learn	4.46	0.68
BQ2	The project stimulated to learn the material outside the class	4.58	0.52
BQ3	I took responsibility of my own learning	4.46	0.60
BQ4	I become self-directed learner	4.18	0.85
BQ5	The project engaged me throughout the semester	3.50	1.10
BQ6	I learned through the collaborative and co-operative approaches.	4.11	0.76
BQ7	It helped me to increase my understanding of the subject	4.43	0.59
BQ8	It laid the strong foundation of the subject	3.96	0.82
BQ9	I feel confident to appear in the examination	4.22	0.85
BQ10	I expect improvements in my grades	4.24	0.75
BQ11	Overall I am satisfied of my learning	4.37	0.61

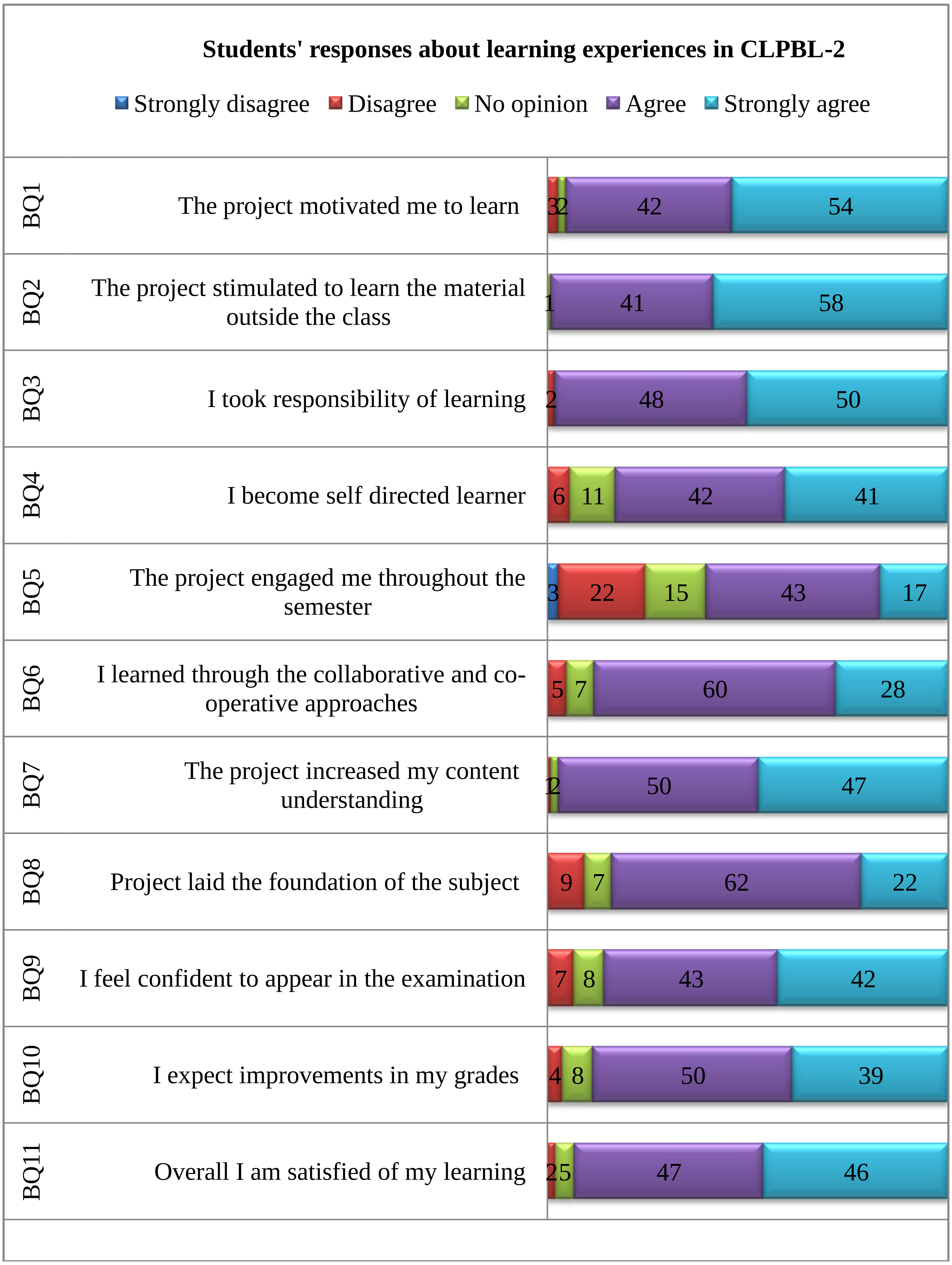

Figure 6.4 Students'responses about learning experience in CLPBL- 2 in percentage

In this section, the focus is to investigate why, how and what students learned in this model. I intend to assess the effectiveness of the project for learning. The students were asked to respond (see figure 6.4) whether the project could motivate them to learn (BQ1) and stimulate learning outside of the classroom (BQ2). The project motivated 96% of the students to learn, which is marginally higher than the first cohort (4%). I found that 99% of the students felt that they learned something above the curriculum, which is 17% higher than the first cohort. This response shows that the project was equally effective in motivating students to learn for both cohorts. However, the second cohort enjoyed learning beyond the classroom more than the first one. This may be because they were not given such an opportunity in their first year.

With similar trends as in the first cohort, the second cohort claimed that the project was insufficiently complex to engage the students for a complete semester (BQ5). Only 60% of students in the second cohort felt that the project engaged them in the semester. This was a marginal drop from the responses of the first cohort (3%). Responses from the two cohorts suggested that this type of project was not sufficiently complex to engage the remaining 40% of the students. There is a need to increase the complexity of the project to better engage the students.

In BQ3, 98% of the students felt they took responsibility for their learning, which was 17% higher than in the first cohort. Almost 83% of students responded that the project helped them to learn independently (BQ4), which is again higher than in the previous cohort by 8%. Similarly, 88% of respondents felt that they learned more through sharing and learning from each other (BQ6). The contradictory results of independent learning versus group learning show that, in the PBL model, students had opportunity to learn independently, and learnedslightly more with a group (5%) compared to individual learning. A similar trend was noted during the essay analysis. The students mentioned that they learned from their peers and shared material and knowledge.

As shown in figure 6.4, 97% of students stated that the project helped them to acquire knowledge related to their engineering major (BQ7), which was marginally higher than the first model response (5%). However, only 84% felt that the project activities helped them to understand the subject better (see figure 6.4, BQ8), which was 8% lower than that of the first model. This difference may be because of the syllabus and project design. In the first model, the project was in line with the first three units. However, in the second model, the course syllabus was staggered and the project activities may not cover three units of the syllabus. Still, 84% students felt that the project laid a strong foundation (BQ8) for their engineering major. This could be because the students understood the basic concepts and gained practical know-how, as mentioned in the essays and interviews. As a result, 85% of students felt confident to appear in the course examination (BQ9) and 89% of respondents believed that their grades would improve (BQ10). Overall, 93% of students felt satisfied with their learning in the semester (BQ11).

6.7.1.4. Students perceptions towards achievement of Learning Outcomes

The focus of CLPBL-2 was to promote achievement of the ABET learning outcomes. This section is dedicated to discussing the model's effectiveness in achieving the intended learning outcomes. Figure 6.5 and table 6.16 show the results regarding students' perception of the achievement of Learning Outcomes (LOs). In CQ1, 94% of students perceived that their ability to think deeply was improved. There was a 6% increase in these responses as compared to the first cohort. I found that 82% of students stated they learned more about the problem-solving process (CQ3), which was 1% more than in the previous cohort. In response to (CQ2), 94% of the respondents said that their ability to work in a team was improved.

Table 6.16 Students’ perception towards achievement of learning outcomes

Question no.	Question	Mean out of five	Standard deviation
CQ1	I learned to think deeply	4.38	0.68
CQ2	It helped me to improve my ability to work in a team	4.44	0.62
CQ3	I learned about the problem solving process	3.95	0.83
CQ4	I learned how to write the report	4.49	0.54
CQ5	I learned critical presentation skills due to the project work	4.26	0.68
CQ6	I learned to asses and manage variety of resources	4.30	0.65
CQ7	I applied project management principles	3.94	0.85
CQ8	Assigned project helped me to improve my skills	4.44	0.63

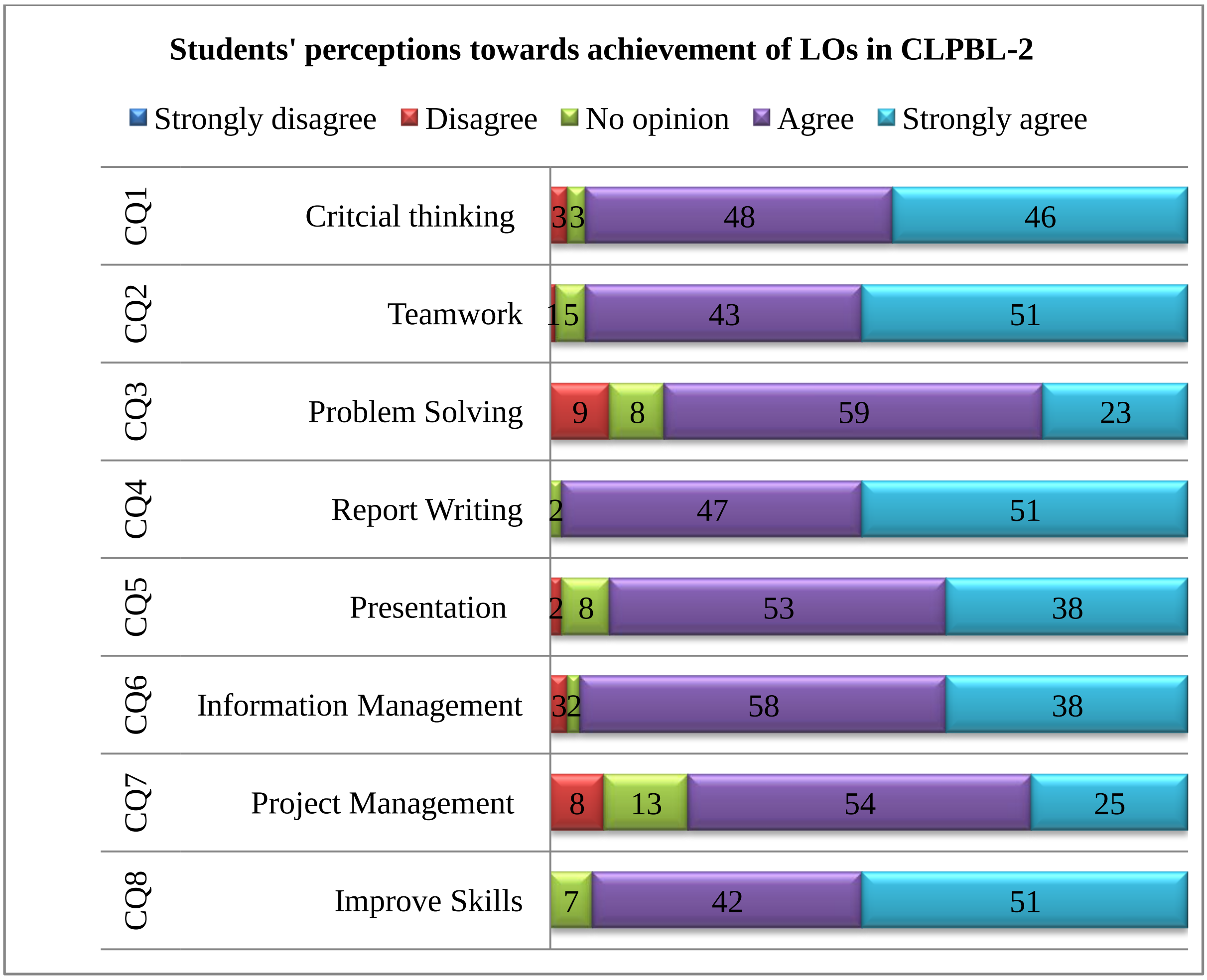

Figure 6.5 Students’ perception towards achievement of learning outcomes in CLPBL-2 in percentage

In this model, students were asked to write a project report and to deliver a Power Point presentation in front of the whole class. It was evident from the responses to CQ4 (98%), CQ5 (91%), and CQ6 (96%), respectively about writing, presentation and information management skills, that the students felt the project had given them the opportunity to develop skills in these areas. This response was very similar to that of the first cohort, with a difference of around 1-2% in each case. In response to CQ7, 79% of students said that they used project management principles. This response was 7% higher than in the first cohort. It was also evident from the essay analysis, that the second cohort used better project management techniques than the first cohort. Overall, 3% less (i.e. 93%) of students from the second cohort perceived that their skills were being improved by the PBL model (CQ8). Detailed discussion on these results will be provided in the discussion section.

6.7.1.5. Students' experiences about teamwork

The focus of this section is to explain the students' experiences of teamwork. Table 6.17 provides a summary of students' responses about teamwork.

Table 6.17 Students' experiences about teamwork in CLPBL-2

Question no.	Question	Mean out of five	Standard deviation
DQ1	I feel group work is a challenging task	4.02	1.02
DQ2	Teamwork was critical for completion of this project	3.42	1.23
DQ3	My teammates helped me to understand the concepts	4.02	0.83
DQ4	I learned to take different perspectives and opinions	4.25	0.58
DQ5	I learned how to lead the project through teamwork	4.33	0.67
DQ6	I feel we could have done better in teamwork	4.15	0.79
DQ7	I am satisfied with my group's performance in this semester	3.92	1.03
DQ8	I am looking forward to work on more complex projects	4.51	0.64

Figure 6.6, shows the responses to DQ1, in which 82% of respondents found the group work to be a challenging task, whichwas 12% higher than the in first cohort. This may be attributed to the various difficulties related to teamwork that were experienced by these students. These difficulties have already been mentioned in the essay analysis. The first modelreceived one of the most unexpected responses for DQ2, in which 51% of students felt that teamwork was important and 49% said it was not so important. In the second model, also, 59% of students felt that teamwork was important and 31% said teamwork was not so important. These similar results may have similar reasons, i.e. the complexity level of the project. In the discussion section, I attempt to elaborate on this response. Almost 82% of students agreed about the role of teammates in the learning process (DQ3). In response to

DQ4, 92% perceived that they had learned to take different perspectives and value other's opinions, which was only 1% higher than in the first cohort. In response to DQ5, 96% of students agreed that they knew how to conduct a project with a team. This response was 10% higher than in the first cohort.

Overall, 89% of the respondents felt that they could have done better with the teamwork (DQ6); this was 8% more than in the first cohort. The second cohort strongly felt that there was scope for improvement in the teamwork aspect. As a result, only 79% of students were satisfied with their team's performance in this semester (DQ7); this was 9% less than in the first cohort. Having worked in a team once, students had gained confidence and understood the pros and cons of teamwork. As a result, 95% of students felt that they were ready to face more challenging and complex projects; this was only 2% less than in the first cohort.

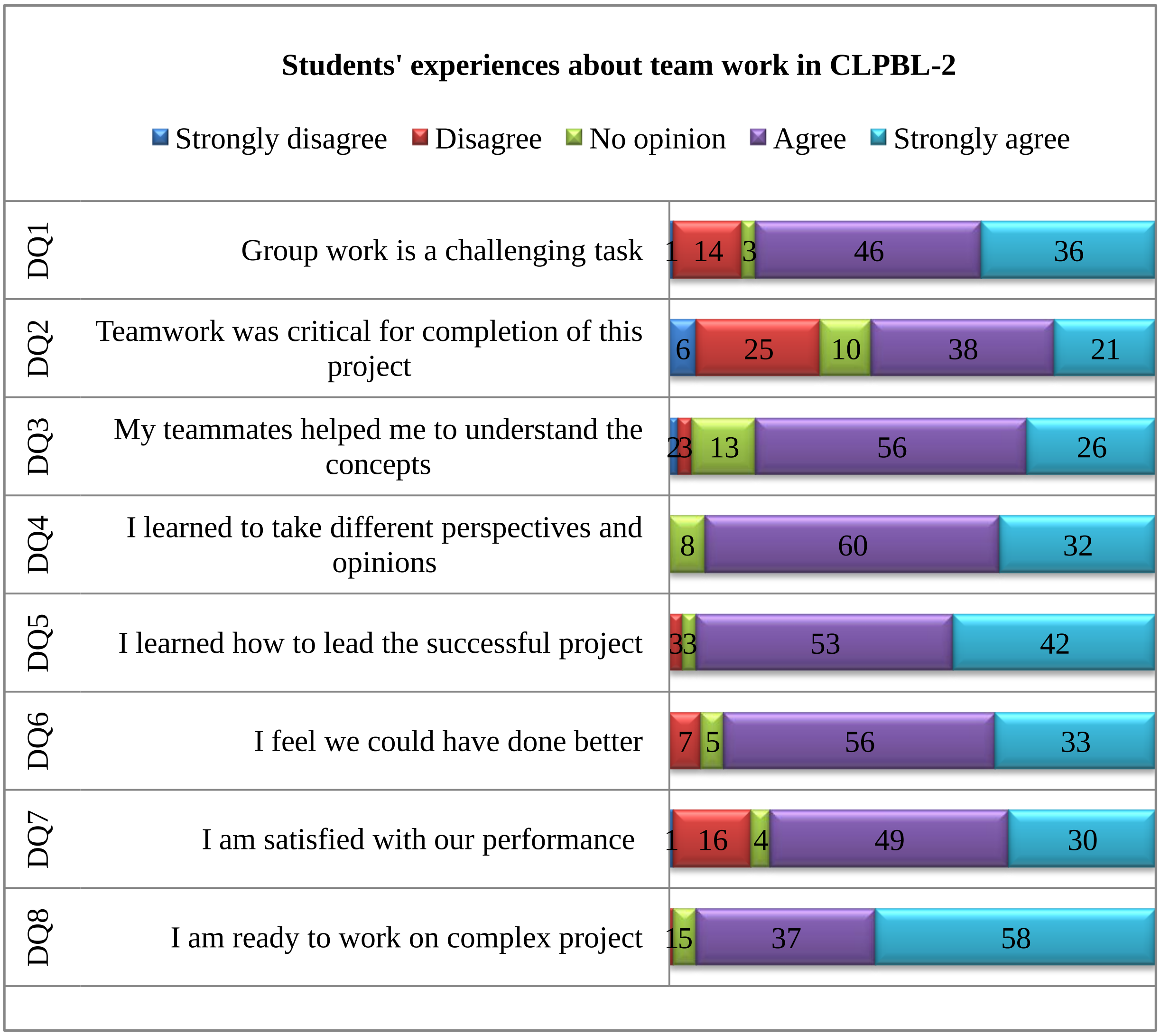

Figure 6.6 Students'experiences about teamwork in CLPBL- 2 in percentage

6.7.2 Project grades

Table 6.18 below shows the project grades received by the students. The project in CLPBL-2 was evaluated for 12.5 marks. It can be seen that, out of 126 students, 11 students (grade D & E) were unable to achieve 40% marks or higher on the project. Of the remaining 115 students, 58 scored more than an 80% marks (A grade) and 34 students scored in the range from 60% to 80% marks (B grade) in the project. In total, the 92 students (73.1% of the total students) who received more than 60% on the project can be considered as students who did the project seriously and had an excellent chance to secure good grades or pass in the main written examination.

Table 6.18 Summary of project grades

Grade	Marks out of 12.5	Range Of marks in %	Frequency	Percentages
A	more than 10	81-100	58	45.82
B	7.5-10	61-80	34	26.86
C	5-7.5	41-60	23	18.17
D	2.5-5	21-40	05	3.95
E	0-2.5	0-20	06	4.74
			126	100

6.7.3 Grades in the final exams

Table 6.19 below shows a summary of the students' grades in the final examination for the course. This examination was conducted by UoP. The answer sheets for my students were assessed by an external evaluator. According to the university norms, students must score 40% marks to pass the course. In my course, 41 students (34.5%) failed and the remaining 78 (65.5) passed the course. This value is close to the 92 students (72.68%) who secured good (A & B) grades in the project, as discussed. It may be noted that the 65.5% result for this course was the best in the institute so far. Previously, the average passing percentage for the course was below 50%. This increase in passing results could be related to the students' project and teamwork. In short, I have seen that the projects in the first two CLPBL designs had an effect on students' learning.

Table 6.19 Summary of written examination grades

Grade	Range of Marks in %	Frequency
A	61-80	05
B	51-60	22
C	40-60	51
D	21-39	24
E	0-20	17
	Total	119*

*for seven students, resultswere withheld by UoP

6.8 Discussion of the results

In this section, important results of the model are discussed. During the discussion both forms of data (qualitative and quantitative) are used to reinforce each other. Referring to chapter 3, in DBR each design is refined through successive iterations. Accordingly, based on reflections from the first PBL model, CLPBL-2 was prepared for a new course, called Applied Thermodynamics, and a new cohort. The development of the project for theApplied Thermodynamics course was the first attempt at SITL. However, this was the second time PBL had been applied to a single course in the department (first one being the TOM-1 course). The CLPBL-2 was implemented for the period of one semester, from June 2012 to September 2012.

The objectives of this model remained the same as in the first model: to promote active learning and enable students to achieve the graduate learning outcomes outlined in the ABET criteria. The elements of the PBL model mainly included the project and its evaluation, teaching-learning strategy and other supporting elements such as time, supervision and lab work. Each element played a significant role in the outcome of this model. In the coming section, each element of the model will be discussed one by one.

6.8.1 Project

Chapter 2 discussed how relevance and complexity are two important elements for the PBL project. In CLPBL-2, the project was designed keeping in view there levance to the students' major and profession. The success of the model can be judged from the fact that, at the end of semester, 32 teams were able to complete the project and 106 participated in the end-semester survey. In the survey, 95% of students perceived that the project was relevant to their profession. In this model, emphasis was placed on covering the course objectives and learning outcomes. The nature of the project activities invited students to understand basic thermodynamic concepts and laws, and to apply them on real-life engineering products. These activities were not a regular part of the course. Furthermore, efforts were made to integrate the project into the routine academic practices of the students. No special timetable was prepared and care was taken not to disturb the other courses of the semester. In response to these efforts, 87% of students felt that the project was well integrated in the curriculum.

In the survey, 96% of students stated that the project motivated them to learn. There could be multiple reasons for getting motivation for learning. The first reason may be that working beyond the classroom walls created interest in the students to do something over and above the curriculum. In the qualitative section, students' quotes and experiences indicated that the students felt the project motivated them to learn outside classroom boundaries and to get practical knowledge. The extrinsic motivation also came from the fact that the students got 12.5 marks for the project work. Furthermore, they were challenged to do something they had never done, which stimulated them to learn. Almost all of the students (93%) agreed that the project was challenging (figure 6.3, AQ1), it motivated 96% of students to learn (figure 6.4, BQ1), and it stimulated 99% of students to learn material outside class (figure 6.4, BQ2).

The complexity of the project could be judged from the students' engagement in the project work and an account of the difficulties faced by them. Regarding engagement in the project, there seems to be two streams. Sixty percent of the students felt that the project engaged them (figure 6.4, BQ5). Of the remaining 40%, 25% did not agree. This disagreement might be true, and could be understood from the fact (as per my observation) that, most of the groups completed the project work towards the end of the semester. The semester lasted three months and it was expected that the project would keep the students engaged for the entire semester. However, I observed that most of the groups left the project work towards the end of the semester and managed most of their project in the last two weeks. In the essays (collected at the middle of the semester), student groups mentioned that they had started collecting data and had distributed the work between members. This indicates that the students had planned to complete the project towards the end of the semester. This may be because students knew that the project presentations were at the end of the semester. I found the students were intensely focused on the project work towards the end of the semester or closer to deadlines.

The complexity of the project could also be judged by the difficulties experienced by the students while completing it (refer to table 6.11). The students mentioned that they faced conceptual difficulties and found it difficult to understand the various engineering products working on the electrical energy principle. Hence, it can be concluded that the project was relevant to the course content and complex enough to engage the students in the activities.

6.8.2 Use and role of the instructions

In a PBL environment, instructions are important to provide prerequisite knowledge and background information to the students. However, the placement of the instructions depends on the how the instructions are to be used in the context of the project, whether alongside the project or before the project. In my case, I placed the instructional period before the project, as I believed this would create a base for the project work. The classroom instruction proved to be helpful for the project work for 91% of the students. Teacher instructions are part of the SITL learning culture that the students are accustomed to, and they rely on it. It would be very interesting to investigate whether or not students could complete the project if such instructions were not given. The Applied Thermodynamics course is one of the toughest courses in the mechanical engineeringprogramme. It is my opinion that propositional knowledge in this course was required by students for the analysis purpose.

6.8.3 Content learning in the project

As discussed in the previous section, the project played an important part in this PBL model in motivating and stimulating students to learn. It is also important to know what students learned and how they learned from the project. Firstly, I will consider what they learned and then I will reflect on which mode of learning (individual or team based) was accountable for their learning. In the survey, 97% of students said that the project helped them to understand the subject matter and 84% stated that the project a laid strong foundation for the subject (see figure 6.4, BQ7 and BQ8). In addition, during the interviews and essays students mentioned that their understanding of the subject was enhanced. In the project presentations, it was seen that students carried out thermodynamic analysis of the engineering product. Such analysis would be possible only when the relevant content was understood and that knowledge was applied for analysis purpose. In the project reports, the content learning was evident. This result could be attributed to the effectiveness of the project design and related activities.

These results showed that the PBL approach was conducive to learning. For the students' learning point of view, there could be three modes of learning: classroom instructions, individual study and collaborative approach. Each mode played an important role in this CLPBL environment. The instructions provided the pre-requisite knowledge required to start the project. To complete the project, the students needed to apply this knowledge. In doing so, they needed to collect relevant information from different sources. In the essays, students mentioned the collection of information from theInternet and from books. In the essays and interviews, student mentioned distributing work between them, collecting information from various sources and trying to understand that information. Through this method, individual learning could also come into the picture. Later, the collected information and knowledge was shared with team members to carry out the analysis of a problem and to find a final desired outcome. This way the project provided space for individual and team-based learning. This was confirmed by the survey responses, in which 83% of students said that they learned independently and 88% said that they learned through the collaborative approach (see figure 6.4, BQ4 and BQ6). Observing these two responses, there is a fair chance that same students might have (83% and 88%) indicated both approaches was important. From the essays I found that the collaborative learning (team-based approach) was dominant. Students claimed that the role of teammates was critical for sharing knowledge, solving problems and resolving doubts during the learning process. However, in the presentations I observed the strong influence of individual learning, as only 2 out of 4 students could answer the questions asked during project evaluation. In the project presentations, group leaders generally dominated the question-answer sessions, which showed glimpses of individual learning. This would lead to the conclusion that the CLPBL-2 model provided the multiple occasions (classroom, team or individual) for everyone to learn.

Irrespective of individual preferences, it was good to see that the students themselves completed the entire project without taking much help from a teacher; this showed their ability to learn and apply the concepts independently. As this was their first experience working in a PBL environment, the students enjoyed the group work and learned from each other by exchanging ideas and knowledge. Thus, the PBL model created a very good environment for collaborative and cooperative learning. Still, in the team-based approach the students faced many difficulties and had to manage their teammates by considering their time, behaviour and attitude.

Owing to their understanding of the subject content developed from their individual and team-based learning, the students felt confident about the course. In the survey, 85% of the students described feeling confident to appear in the examination and 89% said they expected an improvement in their grades. However, only 65.5% of students ultimately passed the course. There is a difference of 20% between the survey response and the percentage of students who passed the course. This could be explained further. In the survey, only 106 out of 126 students responded. For calculation of the end of semester result, 119 students were considered. This may lead to further investigations to find which students passed the course whoalso said in the survey that he or she was confident to appear in the examination.

6.8.4 Teamwork

In the traditional set-up for this course, students were not expected to work in a team. In the CLPBL model, the students were provided an opportunity to work in a group with the opposite gender. These groups worked for almost three months and completed the project work satisfactorily. The team composition consisted of members per team and gender distribution of the team. In this model (CLPBL-2), groups had 3-4 members. There were 33 teams. Out of 33 groups, 27 groups had 4 members and 6 groups had 3 members. Gender-wise, the group compositions were as follows; 27 groups had all male members, 6 groups had mixed gender (that is, having at least a female member in their group).

In the survey, respondents stated that they found the group work to be a challenging task that produced various difficulties (see figure 6.6 DQ1). These difficulties mainly comprised managing teammates and working with the opposite gender. Although they faced difficulties, most of the students understood the importance of teamwork. They found their teammates' cooperation to be important for the completion of the project and for the learning process. Students mentioned that they were learning to work in a team by taking different perspectives and opinions. Students stated in the essays and interviews that they valued teamwork and understood its importance for accomplishing the given task in the due time with comparatively less effort than working individually. Students appreciated the efforts put forth by individuals in the project. Responses in the survey indicated that the students were satisfied with their team's performance in this semester (DQ7). It seems that 3-4 students per team were the optimal number for the course level project. Students experienced teamwork in this semester. They gained confidence and understood the pros and cons of teamwork. As a result, 95% of students felt that they wereready to face more challenging and complex projects.

In the survey, 89% of respondents felt that they could have done better with the teamwork and strongly felt that there was scope for improvement in the teamwork (Q6). I observed that the team composition played a very important role in the outcome of the project. In both experiments, I observed two trends. The intelligent, talkative and active students were leading the groups and the weaker, less active, more introvert students were either in supporting roles or sidelined. In my opinion, it is not a good situation for the PBL approach to be effective only in activating the already active students and excluding the already passive students. Some practical arrangements must be done to change this situation. The girl member in a team was given a soft role or faced a problem while working with boys. The boys in the mixed gender groups reported that the girls in their group did not respond quickly enough and that they took their time, delaying the project work. The female students found it difficult to adjust to the group. It would take some time to change this situation, as this was their first experience of working with males.

6.8.5 Time management

The first cohort students were largely unsatisfied with the time and timing of the project activities (31% felt the time given was not sufficient). Based onthis feedback, I started the second cohort's project activity at the beginning of the semester and completed it before the end of the semester. As a result, I found that 83% of students in the second cohort agreed that the time was sufficient for the project work. This was a rise of 14 % of students who found that time was sufficient for the project work in the CLPBL-2. Hence, it is very important to announce the project at the beginning of the semester.

Still, 17% of students had some issue related to time. This may be because the students left the project work towards the end of the semester or they might have faced difficulties in the project work. Otherwise, it can be concluded from the students' responses that the time provided for the project was sufficient. In this model, 32 student groups completed their work in the given time, which showed their ability to respect the deadlines and complete the task in the given time. In relation to time, students suggested that a detailed timetable of the activities could be prepared and displayed on the notice board. This would help the students in their time management.

As far as my time management was concerned, at the beginning I was comfortable and carried out regular academic activity at a normal pace. In this model, most of the critical project activities, such as project evaluation and grade preparation, occurred at the end of the semester. As a result, I was stressed towards the end of the semester. The survey and short interviews were also conducted in this period. The project reports and data analysis, were at the end of the academic and project activities. I managed the data analysis activities during the vacation period.

6.8.6 Project management

In the survey, 79% of students said that they applied project management principles in their project work (see figure 6.5, CQ7). This was an acceptable response because students were not instructed about the project management techniques, nor had they learned them in any of the courses prior. Still, students did manage to complete the projects in time; therefore there must have been a method by which the student managed their projects. In the feedback sessions, students discussed the application of simple project management techniques. These included dividing the work equally among members, managing periodic meetings for reporting the progress or individual allotments of work and sharing that work later. These were a few of the examples of project management techniques adopted by the groups. It has been observed that each team developed their own strategy of doing the things or managing the project activities. The teams completed the desired set of activities in time, which showed their time management and project management skills. In my opinion, 79% was a good response. I have already discussed the project management techniques adopted by students during my essay analysis.

6.8.7 Project reports

From the project report analysis (see tables 6.7 and 6.8), it has been found that only 70% of the groups included all the major activities of the project in their report. This was a modest sign of learning to write the project report. However, it was observed that the quality of the reports was not up to expectations. Most of the students copied and pasted material from the Internet into their reports. They also failed to write proper references. In general, the students paid little attention to the report preparation. This was their first instance of writing a report, so it is possible that the report quality will improve in the next project.

6.8.8 Achievement of learning outcomes

Overall, 93% of the students felt satisfied with their learning during the semester and recommended the PBL approach for the next semester. The project helped students to learn and apply knowledge to real life engineering products (LO-‘a’). This was especially evident from students’ essays and presentations, in which they talked about their cases. Heated debates and arguments during the question-answer sessions of the presentations signalled the depth of knowledge gained by students about the topics under study. For the achievement of learning outcome ‘b’ (conducting experiment and data analysis), in my opinion, both traditional and PBL approaches were useful. The traditional approach helped students to conduct experiments in the laboratory and the PBL approach helped students to gather data from field experiments. In both cases, students used data for calculation purposes.

LO- e relates to the solution of real-life engineering problem. In this project, students were not actually asked to solve a real-life engineering problem, but they were asked to analyse a real-life product in the content learning perspective. In the project work, students analysed the real-life product for its various thermodynamic parameters and application of the laws. To conduct this analysis, students needed to exercise their application as well as reflective skills. They needed to establish relationships between classroom learning and real-life context. To do this, they needed to compare, evaluate and critically examine their choices. Hence, there ought to have been improvement in the thinking and problem solving abilities of the students.In the survey, students stated that their thinking and problem solving abilities were enhanced.

In the traditional set-up for this course, students were not expected to work in a team. In this model, students were provided an opportunity to work in a group with the opposite gender. These groups worked for almost three months and completed the project work satisfactorily. This provided them with useful experiences of learning from each other and getting used to working in a team, advancing them towards the achievement of LO-‘d’. Because of the group work, the students’ understanding levels and confidence in problem solving improved. In the survey, 94% of students felt that their ability to work in a team was improved (see figure 6.5, CQ2).

In this PBL model, students got opportunities to communicate with their group mates in various modes such as discussion, explaining to each other and sharing ideas and perspectives. In the presentations, the students had the opportunity to communicate in front of their peers. In the project report, they had the opportunity to write and manage technical information. All of these activities would help them to improve their written and verbal communication skills. In the survey, 97% of students claimed that their ability to write reportswas improved. In the process of working on the project, students needed to find relevant information from various sources, and to understand and apply that information to a posed problem. The students managed their work independently, showing their ability to engage in lifelong learning (LO- ‘i’).

The students used Microsoft Office, Excel and Power Point programmes to manage the data and prepare their presentations. Some groups demonstrated the ability to integrate video clips and audio data into their presentations. Overall, this activity helped them to analyse, interpret and manage the data (LOs ‘b’ and ‘i’) by using modern tools and techniques (LO ‘k’). This was evidenced by their responses to CQ4 (98%), CQ5 (91%), and CQ6 (96%) about writing, presentation and information management skills respectively. In general, this PBL model offered a favourable environment for improving students’ communication (‘g’) and information management skills (‘i’). Since the project in this model was similar to in the first model, the LOs ‘c’, ‘f’, ‘h’ and ‘j’ remain untouched.

6.8.9 Role of supervisor

In this model, there were 33 groups and I was the only supervisor for all groups. Not only did this create a huge workload for me, but the students faced problems related to guidance. During the essay analysis, I found that students complained about the lack of guidance. I agree with the students’ point of view on this. There is a need to include a few more staff members and to allocate each of them only a few groups. This is not impossible but seems to be difficult, as we have limited staff to support the courses and university curriculum. In addition, other staff members have their own priorities for their courses. I need to think further on this aspect, as both cohorts mentioned the need for a guide for every group.

6.9 Conclusions

In the first PBL model, a framework for CLPBL for the SITL was developed. This created the possibility of PBL implementation in other courses. The same framework was implemented to develop CLPBL-2. The framework was equally effective for the purposes of my research. So far, I have designed two models for two different courses. In both models, I designed and implemented a course level project of virtually the same level of difficulty. In the implementation process for the second model, a class of 126 students was divided into 33 groups having 3-4 students per group. I found that, for the course level projects, 3-4 members worked better than 5-6 members (as were included in the first model). This could be investigated further.

During essay analysis the students wrote that the PBL model helped them to learn independently and from their peers. During this process, students faced many difficulties, mainly related to fieldwork and teamwork. In the end, 32 out of 33 groups were able to complete the project in time and submit the report. During project presentations, most of the groups exhibited their knowledge about the topic under investigation. In this project, students showed the ability to apply the knowledge leading to content learning and demonstrated a deeper understanding and enhanced practical knowledge. Though they were satisfied with their learning experience, the role of weaker and female students in the PBL environment could be further investigated. Students perceived that the PBL environment provided them the opportunity to learn and improve their skills, which will be useful for professional practice. In the end of semester survey, 93% of students recommended PBL for the next semester and suggested that they would like to work on more complex projects.

After reflecting on the responses from this model, I concluded that the course level project design could be used as a starting point for implementing PBL in an institute that uses the traditional academic set-up. The experiments and trials like the models in this research would help to develop experience in designing a PBL course and in refining the design. These designs could then be replicated for other courses in the programme. Overall, PBL has been found to be a useful way to engage students in learning and to achieve LOs. Furthermore, for the second time in this research, the data collection instruments demonstrated their consistency for the purpose. The data analysis in this experiment was also much quicker because the framework for data analysis had already been created in the first model. Encouraged by students' responses in two consecutivelysuccessful PBL implementations, I designed a third CLPBL model. This model provided me with an opportunity to investigate the students' experiences in two consecutive PBL models working with a complex project. The next chapter is dedicated to CLPBL-3.

Chapter 7

Students' Experiences in CLPBL - 3

7.1 Purpose of the third model

In this section, I refer to the outcomes of the first and second models. In the first model, there were 97 students in 19 groups, with 5-6 students per group. The name of the course was *Theory of Machines- I.* In the second model, there were 126 students in 33 groups, with 3-4 members per group. The name of the course was *Applied Thermodynamics.* It may be noted that the courses and students in these two models were different. However, the two cohorts in the first two models worked on low complexity projects. In both projects, the students carried out analyses of real-life engineering products. In this sense, the first two projects were similar.

The student cohorts from both models recommended the PBL approach for future courses. The students had the opportunity to work on a project, during which time they had their first experience of teamwork and expressed the desire to work on a more complex project in the coming semester. The students' responses to the second model indicated that:

1. The project in the third model must be complex enough to challenge and engage the students.

2. The students should have project groups of 4-5 students, with a mixture of genders and a mixture of intelligent (active), average, and weak students.

I decided to implement a more complex project with the same cohort (named as the third cohort), in order *to investigate the difference in students'responses compared to the first two more narrow projects*.

In the previous semester, the second cohort gained the first experience in project management and teamwork. It can be anticipated that this experience would help them to perform better in the next project. I was interested *in investigating in what ways the first experience would help students perform in the second project*. In addition, CLPBL-3 was prepared to allow further investigation of the trends observed in CLPBL-1 and 2. The focus of this chapter is to present the design of CLPBL-3 and its outcomes. Concisely, this chapter is positioned *to report and compare students' experiences in the third CLPBL model.*

7.1.1 Introduction to the third cohort

At the time of implementation, the cohort (second) from the second model was in the first semester of their second year. This cohort had 126 students. When the cohort moved on to the second semester of their second year, 26 more students were added to the cohort.

It is important to note that the additional 26 students had completed 3-year diplomas in the mechanical engineering field. According to the university's rules, students holding a diploma can be admitted to the second year of the programme. Due to a delay in the admission process, the 26 students were admitted late in the first semester. By the time they were admitted, almost half of the semester was over. For this reason, I did not allow them to participate in the second model project. However, these students attended the project presentations of their classmates and had an idea of the project work done by them. In addition, the students were assigned group projects in the final year of their diploma curriculum. This means that the 26 new students already had experience working on a group project. The third cohort was comprised of 152 students in total. The 152 students each had one project experience behind them already. Detailed demographic analysis of the cohort is provided in later sections.

7.1.2 The experiment –a systematic variation

The third cohort provided the following research opportunities:

1. To design and implement a complex project for the 'Theory of Machine-I' course.

It may be noted that the first cohort worked on a simple project for the course '*Theory of Machines-I*'. To create systematic variation in the experiment, this simple project was modified to make it complex. This modified project will be discussed in the next section. The experiences of the first and the third cohorts can be compared as they both occurred in the same course.

2. The results from the third model can be compared with those of the second model as they both involved the same cohort. In addition, when the same cohort works on a project for two different courses in consecutive semesters, the variation in experiences can be investigated.

3. I observed some interesting trends in the last two models. This third cohort experiment gave me an opportunity to investigate these trends further.

7.2 Developing the complex project

In this semester (second semester, Jan- 2013 to June 2013), once again, I was given the opportunity to teach *Theory of Machines- I.* The course, course structure and course requirements remained the same and can be referred from the first model. For the TOM course, previously I implemented the project in CLPBL-1. I decided to make suitable modifications in this project to make it more complex. To develop this project, I reflected on the existing project design from the first model.

During earlier project presentations and in the project reports, I observed that some groups had drawn a kinematic diagram of the real-life mechanism but had not included further analysis of it. *A kinematic diagram is a representation of the real-life mechanism in the form of a drawing on a sheet of paper.* From a kinematic diagram, the velocity and acceleration analysis of the mechanism can be obtained. This type of analysis was not included in the first project. This inspired me to modify the existing project. I thought the third cohort could be asked to determine velocity and acceleration of a real-life engineering mechanisms. This would add to the complexity of the project and would cover the subject content required for the syllabus. Accordingly, a modified problem statement was created:

Problem statement- Analyse any real-life engineering mechanism to evaluate the Degree of Freedom (DoF), velocity and acceleration of its links.

In the modified problem statement, *'velocity and acceleration of its links'* is added. In line with this modified statement, the project activities were modified to develop a complex project. Table 7.1 shows a modified project and intended learning outcomes that could be achieved at the end of the project (for complete learning outcomes, refer to table 1.1). It was assumed that this project design would be challenging and improve students’engagement in the learning process.

Table 7.1 Mapping of the project activities and intended ABET learning outcomes

Activity No.	Project activities	Intended ABET LO
1.	The team formation	d
2.	Problem solving and drawing with teammates	b,d, i
3.	Laboratory work in a group	d,e,a
4.	Identify the mechanism, submit and justify it	a,i
5.	Undertake the field work	a,k,i
6.	Explain the working of the mechanism	a
7.	Find types of links, pairs and joints used in the mechanism	a
8.	Classify, specify and calculate them	a
9.	Draw a kinematic diagram showing all joints and pairs	a
10.	Apply Grubler’s criteria	a
11.	Find the DOF and justify your answer	a
12.	Calculate total no. of ICRs and classify them	a
13.	Draw relative velocity and acceleration diagram for the mechanism	a
14.	Calculate velocity and acceleration of each link by using relative velocity method	a
15.	Calculate velocity and acceleration of each link by ICR Method	a
16.	Prepare a project report	g,k
17.	Present to an audience	g,k
18.	Question and answers	g

In table 7.1, the newly added activities have been highlighted. The non-highlighted activities have already been discussed in CLPBL-1. The rationale behind the highlighted activities is discussed below.

Activity number 9 is critical for completion of the project. A kinematic, line or configuration diagram shows the configuration of any machine at a particular instant. It shows the length and angular positions of each link in the machine relative to each other. The diagram also shows the type of motion between each pair of links (two links joined together form a pair). For a machine to do useful work, it is very important to have relative motion between each of the pairs in the mechanism. Above information can be obtained from the kinematic diagram.

The kinematic diagram is the first step in getting the velocity and acceleration of any mechanism. These diagrams are readily available in textbooks. In the main written examination for the course, configuration diagrams are given and students are asked to get the DOF (activity 11), velocity and acceleration of each link. The students are required to apply different methods such as relative velocity and acceleration method (activities 13 and 14) and instantaneous centre of rotation method (ICR) (activities 12 and 15). In the modified project, I asked students to prepare or draw a line diagram of the real-life engineering mechanism. They were asked to use this drawing to get the velocity and acceleration of each link in the mechanism by applying the two methods mentioned above. As a subject teacher I can confirm that this would be a difficult task for the students.

It is important to note that prerequisite knowledge of types of links, joints and pairs is essential in order to draw this line diagram. Without a clear understanding of these concepts, students are unlikely to be able to draw or understand a configuration diagram. Students also need to understand and measure the relative linear and angular positions of links at the instant captured by the diagram. In this sense, students' knowledge of the basic concepts, along with measurement and drawing skills, are likely to improve by the end of the project.

To complete the project, students needed to do a series of activities, outlined here. The students needed to initially form the groups and find a suitable mechanism for the analysis purpose. Then the groups had to find an actual place where the machine was in operation. They needed to visit this place with measuring instruments. They had to measure all the major dimensions; this required observing the relative motion and types of link, joints and pairs while the machine is in operation. The students would probably need to visit the machine many times to finalise their kinematic diagram. Once this was done, the students would need to calculate the DOF and draw a velocity and acceleration diagram in order to get the final values of velocity and acceleration of each link. This process could take a long time if the kinematic diagram is complex and, hence, the project could engage the students for a longer period of time than the earlier project models.

The newest project design was worth 25 marks of the term's final evaluation. Since, the project design was based on the same course structure and requirements, I followed the teaching-learning and project evaluation strategies adopted in CLPBL-1.

7.3 Design implementation

The designed project was implemented from December 2012 to March 2013. The implementation strategy remained much the same as that of the first model. During the first week of the course, I explained the entire project activities listed above to students. This was done in order to communicate my expectations from students over the course of the semester.

I shared some experiences from the first model and showed the students the type of mechanisms that the previous cohort had investigated. In this way, the third model was introduced.

7.4 Results of qualitative data

During the semester, I found that the groups had to really stretch themselves to accomplish the assigned activities. This was especially true at the end of the semester as the students strove to complete the project. During this model, many of the groups approached me with doubts and concerns. Three groups especially (working on a door closure, car window and hacksaw) came to visit me frequently. Other groups also experienced doubts and problems. In the process of solving their doubts and understanding their difficulties, I was also stretched to my limits. This was a very challenging project for the students and for me. I sometimes had to refer to books to help the students resolve the project challenges. My knowledge and ability as a teacher and supervisor were tested in this project. However, after all the trouble and effort put in during the semester, the end outcome was ultimately sweet and memorable. At the end of the semester, all 30 groups completed their project and submitted the report, and most of them provided feedback about their experiences. In the following section, I have shared the results of the qualitative data.

7.4.1 Open-ended questions

In the earlier two models, an essay was used to collect the mid-semester data. Although these essays were helpful for collecting data, I used open-ended questions (refer Appendix A_8) instead for the third model. There were two reasons for this change.

1. The essays were unstructured and sometimes did not provide the relevant experiences feedback needed for my research. Furthermore, some students wrote very few little and some wrote long essays, resulting in unequal distribution of the quotes in each category.

2. I wanted to know the answers to very specific questions and in a very specific way. Hence, I used open-ended questions to gather more structured data.

These questions were typed and printed on a sheet of a paper. Space was left between questions for students to write and fill in their experiences. This page was given to each student in the class to write about their experiences. Out of 152 students, 117 students returned this form and I analysed them using the content analysis technique described in earlier chapters. This review was conducted at the closing period of the semester, before the project presentations.

7.4.1.1 Comparison of two experiences

In the previous semester, this cohort worked on the first project for the course Applied Thermodynamics. I wanted to understand the students' experience of the second project in the new course TOM-1. I also wanted to investigate in what ways the first project experience would be useful for completion of the second project. Accordingly, in the first question (see A_8) of the open-ended question form, I asked the students to compare their experiences in the two consecutive projects. Table 7.2 shows a summary of the students' experiences as compared to the first project. I found 165 relevant quotes, which were grouped into eight categories and arranged in descending order of frequency.

Table 7.2 Summary of comparison between two project experiences

Sr. no.	Experience	Frequency of Quotes	Percentage
1.	Difficult	38	23
2.	Better	29	18
3.	Challenging	26	16
4.	Felt easy	21	13
5.	Feel confident	20	12
6.	Better management	15	9
7.	Good teamwork	10	6
8.	Same	6	4
	Total	165	100

I found 23% of the quotes claimed that the second project was more difficult and 16% of the quotes reported the second project was more challenging than the first. In the remaining 61% of the quotes, respondents described the benefits of the first experience. In 13% of the quotes, students indicated that they experienced trouble-free work in the second project. Many of the students elaborated on areas where the first experience had helped them. Students wrote that, in the second project, they had a better experience (18%) and were confident to manage the work (12%). They stated that they experienced better teamwork (6%) and project management (9%) in the second project. Only 4% students claimed to have had same experience with both projects. In summary, it can be concluded that the students' prior experience helped them to manage the project work and teamwork effectively.

7.4.1.2 Relevance of project

In the second question, I asked students to explain if they found the project relevant to the course content and the final examination. From table 7.3 it can be seen that 35% of the students' quotes mentioned expecting to find the project useful for the main examination. Furthermore, 28% said that the project helped to increase their subject knowledge and was helpful for understanding the basics. Only 9% of the quotes claimed that the project was well integrated into the curriculum. Most of the students felt that the project covered only two or three units from the first section of the course. From this data, it is apparent that the designed project was effective in improving students'practical knowledge, clarifying basic concepts and improving understanding of the course content. As a result, the students felt that the experience would help them in the final examination.

Table 7.3 Students' response about relevance of the project

Relevance of project	Frequency	Percentage
Useful for final exams	76	35
Useful for clearing basics	61	28
Increased practical knowledge	60	28
Well integrated	19	9
Total	216	100

7.4.1.3 Role of teammates

In the next question, students were asked to elaborate the role of teammates in the project work. Out of 117 students, 105 students agreed that the role of teammates was critical for completion of the project. The respondents also elaborated on the role played by teammates in the project. I found 152 comments, from which five categories were created, as shown in table 7.4. In total, 27% of students claimed that the total workload of the project was reduced to a manageable level for an individual because of their teammates. This signifies the importance of the teammates for sharing the responsibility of the project work. As a result, the number of students on a team may be a critical factor in the overall project experience.

Table 7.4 Students' response on the role of teammates

Importance of teammate	Frequency	Percentage
Reduces workload	41	27
Doubt clearing	38	25
Project completion	33	22
Support and help each other	27	18
Different qualities	13	9
Total	152	100

In addition to sharing the workload, 25% of students mentioned that the role of teammates was important for understanding subject-related concepts. This indicates the effectiveness of team or cooperative learning in the CLPBL. Also, total 40% of responses indicated that the students helped each other (18%) and were useful for a timely completion of the project (22%). It was clear that it would be difficult for the students to cope with the project workload in the absence of teammates. Finally, 9% of the quotes indicated that each teammate has different qualities, bringing different values in teamwork. In summary, it can be concluded that the role of teammates was to reduce the workload and to help each other to complete the project in time.

7.4.1.4 Most challenging activities

During the project development stage, I perceived that students would face many challenges in this project. I was interested to know the types of difficulties experienced by them. Therefore, in the survey, I asked students to write about the three most challenging activities during the project work. As expected, students faced an incredible variety of challenges, as shown in table 7.5. I found 359 quotes in this category. Seventeen percent of the quotes indicated that conducting the fieldwork was challenging. Students explained that they faced difficulties in measuring the dimensions of the links (measurement, 9%). The dimensions of the links were very important for drawing the configuration diagram. It may be noted that, without understanding the mechanism properly, the configuration diagram could not be drawn. Sixteen percent of students faced difficulties in understanding the mechanism.

Table 7.5 Account of the most challenging activities in the model-3

Challenging activity	Frequency	Percentage
Conducting fieldwork	60	17
Velocity and acceleration	59	16
Understanding mechanism	56	16
Drawing kinematic diagram	51	14
Measurement	32	9
Teamwork	31	9
Report preparation	19	5
Information management	15	4
Time management	13	4
Application of knowledge	13	4
Presentation preparation	10	3
Total	359	100

From table 7.5 it can be seen that other challenging activities included drawing the kinematic diagram (14%) and calculating velocity and acceleration of the various links in the mechanism (16%). It is worth mentioning that the first four challenges mentioned in the table formed the core activities for content learning and were very important activities for improving the cognitive or thinking abilities of the students. Their response confirmed that the project was complex enough to challenge the students' abilities to apply the knowledge. Other challenges included teamwork (9%), report preparation (5%) and presentation preparation (3%). Students also faced some difficulties in managing the information (4%) and time (4%) for the project. It can be noted that the students' conceptual difficulties (conducting fieldwork, understanding mechanisms, measurement and drawing, application of knowledge) were greater than the other difficulties such as teamwork and report preparation.

This could have been because they had prior experience in dealing with teamwork and project reports.

7.4.1.5 Learning through project

The main intention of the project was to provide students with an authentic learning experience. Therefore, I asked the students to write about *any three important learning outcomes*. Students wrote about their most valued learning experiences from the project work. Table 7.6 shows a summary of this. In total, I found 261 quotes; from these, eight categories were generated.

Table 7.6 Students' responses on three important learning outcomes in the project

Learning Outcomes	Frequency	Percentages
Content	86	33
Teamwork	70	27
Project management	30	11
Presentation	24	9
Skills (General term)	19	7
Time management	12	5
Leadership	12	5
Report	8	3
Total	261	100

From table 7.6, it can be seen that 33% of the quotes related to the content learning. This response indicated the effectiveness of the project in promoting content learning. In the teamwork category, 27% of students mentioned that their teamwork ability was improved due to the project work. This shows the effectiveness of the PBL environment for improving teamwork abilities. In the project management category, students claimed that their management skills, such as project management (11%) and time management (5%), were improved. The students' information management skills, which included presentation (9%) and report preparation (3%), also improved. The project was found useful for improving students' leadership skills (5%) and skills (7%). According to the students' own perceptions, they learnt content and improved in teamwork, leadership and management abilities. The content learning aspect was important for achievement of the grades, whereas skills were important for professional practice.

7.4.1.6 Summing up

The decision to use open-ended questions proved useful compared to the essay writing, as it was effective in gathering more structured data. From the responses, it is evident that the first project experience helped the students to manage the second project properly, especially in the areas of time, team and project management. The second project proved to be complex for the students. They faced difficulties in drawing the kinematic diagram and calculating the velocity and acceleration of the mechanism. Students valued the role of teammates in reducing the workload and improving their understanding of the concepts. Students felt that their content learning was improved, along with teamwork and project management skills.

7.4.2 Results of semi-structured interviews

Unlike the 10-minute interviews used in the first two models, for the third model I conducted two focus group interviews. One member from each group was asked to appear for the interviews. Accordingly, eight students came forward to represent eight groups. The questions asked in the interviews focused on confirming observations made in the previous two models and gaining insight into the students'experiences in this model. The interview questions selected are included in appendix A_5.

7.4.2.1 Project related experience

During the interview, students mentioned that they had enjoyed working on the project because it gave them the opportunity to learn practical things during the fieldwork. I was curious to know which aspect of the project made them to enjoy. The students explained,

> ***"In the book configuration diagram is already given. But, in our project, we have to select a mechanism and then we have to redraw on the paper. We have to draw configuration diagram ourselves. It was live project. It was helping us in studies also and completing our project. In that sense we enjoyed."***
>
> ***"Actually sir, we are mechanical engineers and for the first time we worked on any mechanical device. Therefore, the excitement was there. In our life, we are doing live project. Because of curiosity we enjoyed it."***
>
> ***"In my opinion it was enjoyable to learn something out of the class."***

From the above quotes, it is evident that the project created an interest and curiosity among students to learn material outside of the class. Interest was also created because the project was relevant to the mechanical engineering profession. One student commented on his project experience:

> ***"My first opinion is that PBL is a good activity. Due to this project, I used velocity formula practically. I used known formula to apply on the project. I am sure that I will solve Corioli's problem in the main examination. Now, I know various parameters and how to draw velocity diagram. Before project, I was not that much confident about the drawing but after project I can do that."***

Another student explained,

> ***"We can apply our knowledge, whatever we have done in a class. It will be helpful for our future to apply our knowledge on mechanisms etc."***

A third student stated,

> ***“It was a positive move. We worked in a group and it is useful for our future. Therefore, it is very positive for us. We also developed our skills, which are required in future.”***

In general, students agreed in the focus group interview that the project work was useful for applying the knowledge learned in a class to real-life mechanisms. Also, students felt that working in a group was useful for building skills needed for the future. Students explained that the project gave them an opportunity to work outside the classroom and created an interest in the work. One of the students elaborated on his experience by saying that,

> ***“The first project was more theoretical, however second project was more practical oriented. Therefore, we got the interest. The first task was to find the links. We do not know how to do it. By discussion, we found it. After having seen the mechanism practically we got the interest. We enjoyed this activity in actual. We came to know important concepts like ternary link.”***

Another student said,

> ***“We are actually getting the knowledge. By comparing theoretical and practical knowledge, we are getting opportunity to develop knowledge.”***

Students claimed that the project provided an opportunity to get practical knowledge and that it challenged them to do something they had never done before. In terms of the challenges posed by the project work, one student said,

> ***“It was challenging. In the second project, while drawing velocity and acceleration diagram we faced lot of difficulties. But, due to group work, we could complete this task.”***

Another student discussed the difficulty level of the project work:

> ***“In the first project it was difficult because we have not done this type of project. We have done only paper work. But, practically live project we have done first time. We faced difficulty. The project case was not near to us. So, we had only one chance to visit that place and to implement it. Second time it was easier as we have done one project. It was easier to complete this project. Group work was challenging because we had five members. So it was difficult for time management.”***

Another student recalled his memories from the last semester project:

> ***“In thermodynamics it was difficult to understand how heat and mass transfer takes place.”***

Another candidate compared the two project experiences by saying,

> ***“In the second project there were many activities. Because we have to draw velocity, acceleration and ICR diagram. But, in first project***

> ***there was nothing like that. Only we have to visit for the fieldwork and presentation is given. But, this time we have to do the paper work also. So this was challenging.”***

The students’ responses show that compared, to the first project, they found the second project more challenging. They also found that they were able to demonstrate better time and project management in the second project. Although the students agreed that the project was challenging, they had different opinions on the time required for completion of the project. One student mentioned,

> ***“Last time it took around three weeks for our group. As our group planning was better this time, only two weeks were sufficient. The task was divided among all members and it was explained to them. So, it was better.”***

Other student said that the time needed depended on the group and how they managed their time. One student said that two months would be more than enough. Regarding time required for the project work, students had different opinions. It seems to me that the students were largely confident in their ability to finish the project work in two to three weeks. Possibly because of this**,** the students have shown a tendency to work closer to the deadlines in all three models. It interested me to understand why the students worked towards the end of the semester. One student explained by saying,

> ***“If we draw or start our activity early, we will face many difficulties like drawing. You have not taught us to draw acceleration diagram. So, we are not able to draw it. So, that is why, as syllabus was going on, we continued our work.”***

One student’s reasons for working late on the project were as follows:

> ***“Sir, if we have a pressure, we can work. We thought we have lot of time from December to March, because you told us the final evaluation would be in March. We also thought that the project was easy. When we started our work, we found the project work is complex. Now I know, if you want to do well, start from the start.”***

Another student reiterated this response:

> ***“We have done the project at the end of the semester; it does not mean that the project was not difficult. It was so difficult that when we started work, we have to spend lot of time for that. Now, we understood that the project was so difficult compared to first one. We have to work regularly so that we should not face the problem.”***

From the above quotes, it is evident that the project was challenging. It has been confirmed that the students waited until close to the deadlines for two reasons. The first reason was that most of the students expected the project to be easy. Later, they discovered that the project was complex. They explained that they had to engage themselves intensely towards the end of the semester, due to the pressure of approaching deadlines. The second reason was that the students wanted to complete the related syllabus in class before starting the project. In this sense, the instructions were helpful to the students for getting fundamental knowledge to complete the project.

7.4.2.2 Role of classroom instructions and supervisor

In the interview, students mentioned the need for classroom instructions to start the project work. I asked them how important classroom instructions were. Below are some responses from the students.

> ***"Yes, it was most important."***
>
> ***"Teacher taught us TOM in a class. We have to implement in the project. So unless and until teacher covers the syllabus in a class, we cannot go for project activity. So teaching was most important for our project."***
>
> ***"It works simultaneously. We need to understand the concepts first. Then we can apply in actual practice. If the classroom instruction was not provided, then it is difficult."***
>
> ***"It is difficult to get knowledge from books by reading only. From classroom concepts are clear. Easily, we can find solutions then."***

From these quotes, it is evident that the students valued the classroom instructions. They expressed the necessity of prerequisite knowledge of important concepts for completing the project work. Therefore the students reinforced the usefulness of my strategy of providing instructions on the project units at the beginning of the semester. A few students described needing a supervisor in the absence of instructions:

> ***"Sir, I am sure that even though the classroom instruction was not given then also we can do the project. Then we will learn. Then we will need someone to help us. If we do not know, we will approach you, search on internet, and refer books. When we do such things, concepts become much clear by asking more people. When we work independently concept are clearer that instructions."***

Another student in the same interview stated:

> ***"In that case we will need supporter, who can help us. If he clears a doubt, then and then only we can do it. We need someone to guide and help us."***

However, one student insisted on the necessity of classroom instruction;

> ***"For me classroom instruction was very important for this project activity. If we do not know anything about the subject, how can we do the project?"***

From the students'conversation, I got the impression that the classroom instructions were useful for the project. This need varied from student to student. Some students may not have required instructions to start the project, while for others instruction was important to kickstart the project. In either case, students felt that there was a need to have someone to guide, support or help them. Students said that they approached the teacher for help when they faced any difficulties.

7.4.2.3 Learning in the project work

Two important objectives of the project were to promote active learning and to promote the application of knowledge learned in the class to a real-life situation. The project could be said to be effective when these two objectives were fulfilled. The following quotes indicate the effectiveness of the project for these objectives:

> ***"By applying theoretical knowledge our concepts are more cleared than a book."***

> ***"Yes, sir, to find velocity and acceleration, we actually calculated the dimensions. We learned how practically mechanism works."***

> ***"Our practical and theoretical knowledge is very different. It is important to get both. It was very important to assemble these two to get more knowledge about that system."***

From above quotes it is evident that the students applied their knowledge. Since they have seen the machines and realized the usefulness of the theoretical knowledge for construction of the machine, their practical knowledge has also been improved by the project work. The students explained that they had practiced important concepts many times, which led to increased self-confidence. They predicted that this practice and exposure would be helpful in the final examination. In the earlier models, students complained that the project did not engage them sufficiently throughout the semester. Accordingly, the third project was designed to improve students'engagement. The quotes discuss this aspect.

> ***"We did in two weeks. During these weeks we were engaged in project work completely."***

> ***"During that period, we were fully engaged. Many decisions took place about project."***

> ***"This project helped us to find the solution other than the book. It engaged us to do the work other than curriculum."***

It is clear that the students were intensely engaged in the project work towards the end of the semester. I have already discussed reasons for this in the previous section. The students'engagement towards the end of the semester could be seen through two perspectives. First, it could be argued that it was good that the students were not engaged for the whole semester. In the process of doing this project, if it engaged them all semester, there was a risk that they might have ignored, and even failed, their other courses. Secondly, the majority of the groups started the project late because they required prerequisite knowledge from the class. As mentioned earlier, at least half a semester was required to complete the project units in the class. Hence, it may not be necessary for the project to engage students for a semester. Students stated that they were engaged in doing the project work over the final two to three weeks. This timing could be beneficial for the students because they need to appear for the final examination at the end of the semester. Their memories and learning from project would still be fresh then, which may help them to succeed in the final examination.

7.4.2.4 Choice of roles –leader and supporting role

Students from the previous models mentioned that their teammates helped to share the workload of the project and clarify the concepts. Students also claimed that they shared their work with each other and that everyone in the group had definite role to play. During the interview, students discussed two roles: leader and supporting role. I was curious to know more about the students' roles in the project and how decisions surrounding roles were made. During the interview, each student elaborated on his role; a few of these quotes have been included below.

> ***"I played a supporting role in a project. I drew velocity and acceleration diagram and all the concepts related to it were up to me. I explained that to other group members. Akshay, was leading the group and other members were supporting him. In the first project, I was a leader and I have distributed work amongst members."***

I interrupted, this student to ask what he meant by 'supporting role'? Another student explained,

> ***"These students were making Power Point presentations, project report and helping to draw velocity and acceleration diagrams. Intelligent students were doing calculation part. They were studying hard."***

The students further explained how they choose the leaders of their groups. The leader of one of the group said,

> ***"It comes naturally. No one takes responsibility, so from our group someone has to take responsibility."***

Other students said their groups had no leader. There was some disagreement on this opinion. One group leader said,

> ***"According to me every group has one leader. He motivates and pushes other guys to work. Since there is no one to take initiative, someone has to take initiative. His job is to take initiative. Because of him, other guys start the work."***

I then asked the students how they decided roles within the group. One student replied,

> ***"Based on how the concepts are clear of that candidate. Somebody is good at some work, and then the work is given to him. He will do that work and check it from sir. Then he will explain that to other members. All of us seat together and explain each other."***

From the interview excerpts, three main points emerged.

1. Students shared their responsibilities in the project. They were given a role based on their abilities.

2. The leader’s role was to initiate, distribute the work among the members and motivate and organize them to complete the work.

3. Students in the supporting role helped with the report preparation and presentation. However, the core activities (calculation or problem solving) were done by intelligent students. This suggests that the intelligent students emerged as a leader of the group.

7.4.3 Results of technical report analysis

At the end of the semester, 30 groups submitted their reports. These reports were analysed to understand whether the students had completed the desired project activities or not. This analysis also revealed many important aspects of technical report writing. Reports were analysed by following the procedure discussed in chapter 3. Tables 7.7 and 7.8 below show the results of the project report analysis. Activities 3 to 15 in table 7.7 formed the core project activities. It was expected that the students would discuss and write about these activities properly in their reports to indicate that they had learned the content and the depth of their understanding. From the table, it can be seen that 90% of the groups covered all the project activities in the report. The report lengths varied from 10 pages to 28 pages. The increase in report length compared to the first two models may have been due to there being a greater number of activities in this project. It is worth noting that, out of 30 groups, 29 added field work photos in the report. These photos showed that the students had actually visited the various places for fieldwork activities.

Table 7.7a Students' reports analysis for CLPBL-3

Sr. No.	Parameter	Group No																Total out of 16
		G_1	G_2	G_3	G_4	G_5	G_6	G_7	G_8	G_9	G_{10}	G_{11}	G_{12}	G_{13}	G_{14}	G_{15}	G_{16}	
1.	**Problem statement**	*	*	*	*	*		*	*	*	*	*	*	*	*	*	*	**15**
2.	**Name of team members**	*	*	*	*	*		*	*	*	*	*	*	*	*	*	*	**15**
3.	**Abstract**	*	*	*	*	*	*	*					*	*	*	*	*	**12**
4.	**Introduction**	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	**16**
5.	**Types**	*			*			*				*	*				*	**5**
6.	**Working**	*	*	*	*	*	*	*	*		*		*	*	*	*	*	**14**
7.	**Technical details**	*	*	*	*	*	*	*	*	*	*		*	*	*	*	*	**15**
8.	**Kinematic diagram**	*	*	*	*	*	*	*	*	*	*		*	*	*	*	*	**15**
9.	**Types of links**	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	**15**
10.	**Types of joints**	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	**15**

11.	**Types of pairs**	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	**15**
12.	**DOF**	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	**15**
13.	**ICR**	*	*		*	*			*	*			*	*			*	**9**
14.	**Velocity and acceleration**	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	**16**
15.	**Calculations**	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	**16**
16.	**Advantages, disadvantages, applications**			*			*				*	*		*			*	**6**
17.	**Conclusions**		*	*			*					*	*			*	*	**7**
18.	**References**	**3**	**7**	**3**	**10**		**4**					**4**		**9**	**8**	**2**	**3**	
19.	**No. of Pages**	**21**	**17**	**28**	**24**	**14**	**15**	**28**	**19**	**18**	**24**	**13**	**13**	**21**	**16**	**11**	**18**	
20.	**Fieldwork photos**	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	**16**

Table 7.7b Students' report's analysis of CLPBL -3

Sr. No.	**Parameter**	**Group No.**														**Total out of 16**
		G_{17}	**G_{18}**	**G_{19}**	**G_{20}**	**G_{21}**	**G_{22}**	**G_{23}**	**G_{24}**	**G_{25}**	**G_{26}**	**G_{27}**	**G_{28}**	**G_{29}**	**G_{30}**	
1.	Problem statement	*	*	*	*	*	*	*	*	*	*	*	*	*	*	14
2.	Name of team members	*	*	*	*	*	*	*	*	*	*	*	*	*	*	14
3.	Abstract	*		*	*	*		*	*	*	*	*			*	10
4.	Introduction	*	*	*	*	*	*	*	*	*	*	*	*	*	*	14
5.	Types				*	*		*				*			*	5
6.	Working	*	*	*	*	*	*	*		*	*	*	*	*	*	13
7.	Technical/ component details	*	*	*	*	*	*	*	*	*	*	*	*		*	13
8.	Kinematic diagram	*	*	*		*	*	*		*		*	*	*		10
9.	Types of links	*	*	*	*		*	*	*	*	*	*	*	*	*	13
10.	Types of joints	*	*	*	*		*	*	*	*	*	*	*	*	*	13

11.	Types of pairs	*	*	*	*		*	*	*	*	*	*	*	*	*	13
12.	DOF	*	*	*	*		*	*	*	*	*	*	*	*	*	13
13.	ICR	*	*	*	*		*					*				6
14.	Velocity and acceleration	*	*	*	*	*	*	*	*	*	*	*	*	*		14
15.	Calculations	*	*	*		*	*	*	*	*	*	*	*		*	12
16.	Advantages, disadvantages, applications				*				*					*		3
17.	Conclusions	*	*	*			*	*			*			*		7
18.	References		4	4	7	5	2	3			4			5	5	
19.	No. of Pages	14	16	19	23	14	14	17	14	17	18	20	19	12	10	
20.	Fieldwork photos		*	*	*	*	*	*	*	*	*	*	*	*	*	13

Table 7.8 Analysis of project reports of CLPBL-3

Group no.	**Group composition**			**Name of the Product**	**Format**	**Technical content**	**Coverage of project activities**	**Plagiarism**	**Overall impression**
	Male	**Female**	**Total**						
G_1	4		4	Railway braking	A	A	A	A	A
G_2	5		5	Jcb bucket and dipper	A	A	A	A	A
G_3	4		4	Oscillating cylinder	B	C	B	A	B
G_4	5		5	Wiper	A	B	A	A	A
G_5	5		5	Link between bogies	A	B	A	A	A
G_6	5		5	Rocker arm	B	C	C	B	C
G_7	5		5	Crane	B	A	B	B	B
G_8	5		5	Synchronisation gear box	A	A	A	A	A
G_9	5		5	Sewing machine	A	B	A	A	A
G_{10}	3	2	5	Jig saw, reciprocating compressor	A	B	A	A	A
G_{11}	4	1	5	Steering	B	B	B	A	B
G_{12}	5		5	Elevators	B	B	A	A	B
G_{13}	5		5	Hand pump	B	B	A	A	B
G_{14}	4	1	5	Jcb front loader	B	B	A	B	B
G_{15}	5		5	Pantograph	B	C	B	C	C
G_{16}	5		5	Tower crane	B	B	B	B	B
G_{17}	5		5	Chilly grinding	C	B	B	A	B

G_{18}	5		5	Power hack saw	A	B	A	A	A
G_{19}	4	1	5	Excavator	A	B	A	A	A
G_{20}	5		5	Chain and sprocket	B	B	B	B	B
G_{21}	4	1	5	Door closure	B	B	A	B	B
G_{22}	5		5	Sugar cane crusher	B	B	A	A	B
G_{23}	5		5	Railway crossing barrier	A	A	B	A	A
G_{24}	4	1	5	Sewing machine	C	B	B	C	C
G_{25}	4	1	5	Two wheeler braking	A	B	A	B	B
G_{26}	4		4	Flour mill	B	B	B	B	B
G_{27}	5		5	Steering	B	A	A	A	A
G_{28}	3	1	4	Car window regulator	C	C	B	A	B
G_{29}	5		5	Hammering mechanism	B	B	B	B	B
G_{30}	5		5	Shaper mechanism	C	B	C	A	C
	137	09	146[$]						

[$] Please note that six students were absent for the presentations. As a result, their names do not appear in the total.

Table 7.9 shows (see column of grades A, B, C) the number of reports with percentage in the brackets. In the second column, the total number of reports in the each model is mentioned. For the CLPBL-3, from the table 7.9, it can be seen that 10 groups obtained an ‘A’grade, 15 groups obtained a ‘B’grade and 5 groups got a ‘C’grade for their project report. In table 7.9, a comparison of the report quality from all three models is shown. After comparing CLPBL-2 and 3, it is evident that the quality of the reports did not improve.

Technical report writing remains an issue for the participants. In my opinion, this is due to the students’ tendency to complete the project work towards the end of the allotted time. Working closer to the deadline meant that the students did not have enough time to write the report. It is my belief that students did not put as much effort into the project reports as they put into completing the project work. I feel they needed to devote more time to the report writing, especially at the end of the semester.

Table 7.9 Comparison of reports' quality of three models

	Total Reports	Grade-A	Grade-B	Grade-C
CLPBL-1	**18**	**6 (33.33)**	**8 (44.44)**	**4 (22.20)**
CLPBL-2	**32**	**13 (40.13)**	**12 (37.56)**	**7 (21.91)**
CLPBL-3	**33**	**10 (30.3)**	**15 (45.45)**	**5 (15.15)**

From the project report analysis, it has been found that 95% of groups included all of the major activities of the project in their report. This is a very good sign of learning to write the project report. However, the quality of the reports was not up to expectations. Most of the students copied and pasted material from the Internet into a report. They also failed to write proper references. In general, the students paid little attention to the report preparation. In the next model, students' report writing progress could be reviewed periodically and lectures on academic writing could be done during the semester. This would help to improve writing and reduce plagiarism.

7.4.4 Results of the open-ended survey questions

At the end of the semester, students' responses were asked to fill out a questionnaire. This questionnaire included a few open-ended questions (refer A_7) relating to the location of project work, difficulties and suggestions for future models. Students'response to these questions are analysed and discussed below.

7.4.4.1 Group meetings

In the table 7.10, a second column shows 38 students mentioned that they met once in a week. It can be observed that most of the students (63) said they met two times a week. Some students (26) met three times per week. Similar to earlier models, I observed that the meeting frequency was increased for the groups who did the majority of the work at the end.

Table 7.10 Frequency of group meetings per week

Meetings/week	Number of students
One	38
Two	63
Three	26
Four	07
Total	134

7.4.4.2 Location of the project work

In the questionnaire, students were asked to discuss where they held their group meetings. Many students mentioned multiple locations for the project meetings. As a result, total number of students' responses increased to 233. From table 7.11, it can be seen that 100 students preferred reading halland equal number of students preferred hostel rooms for the group meetings. These results were different from the second model, in which students preferred only hostel rooms as a meeting location. Students also stated that they conducted meetings in the classroom, laboratory and canteen. However, this percentage was less than use of the reading hall and hostel rooms.

Table 7.11 Location for the project meetings

Location	Frequency
Reading hall	100
Hostel room	100
Classroom	22
Lab	03
Canteen	08
Total	233

Figure 7.1 below shows two groups conducting project meetings at the reading hall and hostel room. Another group could be seen in the background of the first picture, also using the reading hall to carry out the project work/meeting.

Figure 7.1 Meeting places- reading hall (left) and hostel room (Right)

In this project, it was expected that the group should visit different locations where the machines are used. In the questionnaire, students were asked to comment on location of their fieldwork. Students' responses are analysed and shown in table 7.12 below. From this table, it could be observed that the students visited various places to conduct the fieldwork. The groups who chose to work on brakes or steering mechanisms visited a garage. For cranes and excavators, groups visited construction sites. The place of the fieldwork varied according to the choice of mechanism. These visits added practical experience and knowledge. Students claimed that they learned about the mechanisms from the operators of the machines. In the presentations, they mentioned that their learning was improved due to fieldwork.

Table 7.12 Location for the project work

Location	Frequency
Garage	28
Near railway station	19
College lab	17
Construction site	17
Other towns	14
Workshop	13
Sewing machine	05
Juice centre	03
Flour mill	02
Other sites	02
Total	120

Following figure 7.2 shows students performing tasks at various project locations.

Figure 7.2 Project Locations (Workshop-Left, Flour Mill-Right)

7.4.4.3 Difficulties

In this section, the difficulties experienced by the students are shared. Table 7.13 shows the six categories of the difficulties experienced. Students had a similar set of difficulties as in earlier models. However, there was a significant rise in the number of conceptual difficulties experienced by students that points to the increased complexity of the project. This data also confirms withthe data collected in earlier models where students mentioned experiencing difficulties related to the application of knowledge and the relation between theory and practice. After reflecting on the data from the three models and comparing them, it could be concluded that the students faced more conceptual difficulties in the third model, due to the complexity of the project. The lower number of conceptual difficulties in the other models couldalsoindicate that the projects in these models were less complex. All other difficulties have already been discussed in the other models. As table 7.13 shows, although the students had project experience, they still faced difficulties in teamwork and data handling.

Table 7.13 Summary of difficulties experienced in project work

Difficulties	**Details**	**Frequency**
Teamwork	Managing team members(09) + Teamwork (07) + lack of co-operation from team members (14)	30
Data handling	Internet access (02), Information collection (02), lack of information (16)	20
Fieldwork	Place of fieldwork (27) + unable to see from inside (04) + travel (03)	36
Conceptual difficulty	Configuration diagram (28) + Calculation Part (22)+ To analyse problems (05) + Understanding mechanism (19) + Calculation of velocity and acceleration (29)	103
Time	Lack of time	15
Other	Lack of guidance (02) + other courses (02)	4
	Total	208

7.4.4.4 Suggestions for improvement

During the survey, students were asked for suggestions of improvements for various areas or elements of the third model. The students offered many suggestions, which are shown in table 7.14. From table 7.14, it can be observed that the students' made the most suggestions in the teamwork category. In the next project, they would like to choose their teammates from a class and not from the batch. (It may be noted that in all models students were asked to form the team from their batch only). To some extent, I agree with this suggestion. These students have now worked on two projects; they know each other's strengths and weaknesses. Accordingly, they can choose the best team for a project. From their experiences, they know who can be a good team member and who could not. An interesting suggestion was that some students (4) asked that the non-performers from the groups be penalized.

Students also suggested that the submission of the project should be taken at the middle of the semester (9) and that the project work could be included in the regular time table (8). These two suggestions could be taken up in the next project. Students strongly requested the allotment of a guide for each group (18) so that regular meetings and observations could be made. Another important suggestion was given by two students, who suggested discussing the projects in the class. This could be made possible by asking each team to present and discuss their project in the lecture hours in front of the class at the middle of the semester. This might help in overcoming students’ difficulties. However, managing time for this adjustment could be problematic.

Table 7.14 Summary of suggestions for future models

Suggestions	Code	Suggestions	Frequency
Teammates	Teammates	Choice of teammates (22) + appointment of team leaders (05) + punishment to non-performers (04) + teacher to form the group (02) + team of three (01)	34
More time	Time	Include in timetable (07) and proper schedule (01), more time (08)	30
Timing		Midterm submission (09)	
Project at start		Project at start (05)	
Practical projects	Projects	Practical projects (03), more practical work (07)	10
		Should not be there	03
Proper assessment		Proper assessment (06), more marks(01)	07
Availability of net lab		Availability of Net lab	01
Proper guide		Observation by faculty (16), industry people (01), regular meeting (01)+ topic by teacher (04)	22
Other suggestions		Financial assistance (01), compulsory visits (01), for every subject (06), problem discussion in class (02)	10
		Total	117

7.5 Results of quantitative data

7.5.1 Survey data

7.5.1.1 Socio-demographic analysis of students'profiles

There were 152 (n = 152) participants of which only nine (n = 9) were female. In terms of age, all participants were between 19 and 21 years. In terms of language, all participants spoke three languages. Out of the 152 students, a total of 30 groups were formed. Gender wise, the group compositions were as follows: 22 groups had all male members, 8 groups had at least one female member in the group. Out of the 30 groups, 26 had 5 members each and 4 groups had 4 members each. It may be noted that six students did not participate in the presentation.For details (project teams) you are refered to table 7.8.

7.5.1.2 Response rate

At the end of the semester, a survey was conducted in which 133 out of 152 students recorded their responses and returned the questionnaire in time. Nineteen students did not respond. Table 7.15 below shows a summary of respondents and non-respondents. The response rate in this model increased from 84% (for the second cohort) to 87.5% in the third cohort. This response rate is similar to that of the first cohort (88%).

Table 7.15 Summary of quantitative analysis

Total students	**Number of students**	**%**
Respondents	133	87.5
Non-respondents	19	12.5
Total no. of participants	152	100

The data of 133 students was analysed by using descriptive statistics. In the next section, the results from the second model were compared with the third model by using two-way ANOVA techniques. This statistical test was focussed on finding whether there was a statistical difference between the responses in the second and thirdmodels.

7.5.1.3 Students'experiences in PBL and related aspects

Table 7.16 provides a summary of students' responses relating to various aspects of CLPBL-3 as compared with the other two models. In table 7.16, a mean score obtained out of five for the given cohort is shown along with standard deviation values. In the table 7.16, the last column refers to ANOVA results, indicating whether or not a significant difference was found between the results from models 2 and 3. In this table, CLPBL-1, 2 and 3 denote the three models respectively. The students' responses were compared based on the mean score.

Table 7.16 A summary of students’experiences in three PBL models on design aspects

Question no	Question	PBL Model No.	Mean score	Standard Deviation	Significant difference
AQ1	Assigned project was challenging	CLPBL-1	3.78	0.84	
		CLPBL-2	4.10	0.62	Yes
		CLPBL-3	4.40	0.68	
AQ2	I feel the project work was well integrated into the curriculum	CLPBL-1	3.89	0.92	
		CLPBL-2	4.08	0.58	No
		CLPBL-3	4.16	0.80	
AQ3	I found the project relevant to the acquisition of skills and knowledge of my profession	CLPBL-1	4.14	0.57	
		CLPBL-2	4.36	0.64	No
		CLPBL-3	4.47	0.50	
AQ4	I found classroom instructions helpful at various stages of project	CLPBL-1	4.03	0.73	
		CLPBL-2	4.17	0.70	No
		CLPBL-3	4.26	0.62	
AQ5	I feel the time provided for the project work was sufficient	CLPBL-1	3.65	0.92	
		CLPBL-2	4.07	0.78	Yes
		CLPBL-3	4.17	0.79	
AQ6	Assigned project work was enjoyable	CLPBL-1	4.20	0.59	
		CLPBL-2	4.19	0.82	No
		CLPBL-3	4.30	0.75	
AQ7	I recommend applying project-based learning concepts to other courses in a next semester	CLPBL-1	4.45	0.57	
		CLPBL-2	4.44	0.66	No
		CLPBL-3	4.32	0.89	

From table 7.16 it can be observed that, for all the questions, the mean score of the students' responses in the third model was greater than in the other two models, with the exception of AQ7. This increased score suggests that the project design in this model was effective and was implemented in a better way than in the first two models. This can be attributed to the continual refinement of the PBL model over successive cycles, including modifications to the project design. The marginal dip in the mean score in AQ7 suggests that a few students from the third model did not recommend the PBL for next semester. May be they expectmore complex project in the next semester or they want permission to form the team from a class (refer table 7.14). This indicates a need to make the appropriate changes to the next model. In the PBL model, the project design is considered to be one of the important factors for challenging students, motivating them to learn and encouraging them to learn beyond the classroom walls. The three projects were designed with this intention in mind. The project in the third model was more complex than in the first two models. Hence, it was important to understand if there was any difference in the students'responses or not. Even if there was a difference, was it significant? Table 7.16 shows that there was a difference in the mean scores of model-2 and model-3. However, these differences were only found to be significant for two Questions (AQ1 and AQ5). In the other questions, the difference was found to be insignificant. These results will be discussed in the coming section.

Looking at table 7.16, if we compare the mean scores for AQ1 for all three models, the score for the third model is the highest (4.40). This value indicates that the students felt the third project was more challenging than in the second model. In AQ1 (refer figure 7.3), I asked whether the project was challenging. In response, 97% of students said that the project was challenging. This was 6% and 15% higher than in the second and first cohort, respectively. This response showed that the project in the third model was more challenging than in the other two models. Furthermore, this difference was found to be statically significant when compared with the second model. These results clearly indicate that the project in the third model was useful for challenging the participants.

It was investigated whether the students found the given project relevant to their profession (AQ3). I found that 95% of students believed that the project was relevant to their engineering profession. This was 5% higher than in the second cohort and 10% higher than in the first cohort. From table 7.16, it is evident that the mean score is close to 4.5, which shows that the students from the third model strongly agreed that the project was relevant to their profession and to the acquisition of skills. Although there was a marginal rise in the mean score (0.11), this was found to be statistically insignificant. It means that the students found the second and third project equally relevant for the profession.

From figure 7.3 (AQ2), it can be seen that 89% of students thought the project was well integrated into the curriculum. This was different from the results of in the second and first cohorts, in which we 87 % and 77% gave favourable responses to this question. The mean value of responses for AQ2 increased from 4.08 to 4.16 when compared to the second model (see table 7.16) and was higher than the 3.79 score in the first cohort. This means that most of the students from the third cohort agreed that the project was well integrated into the curriculum. However, 6% did not agree. There was a marginal rise (0.12) in the mean score for AQ2, which was found to be statistically insignificant. The given curriculum had five theory courses and other lab courses. It was a challenging job to integrate the project into the curriculum. In that sense, I would consider this as a good result.

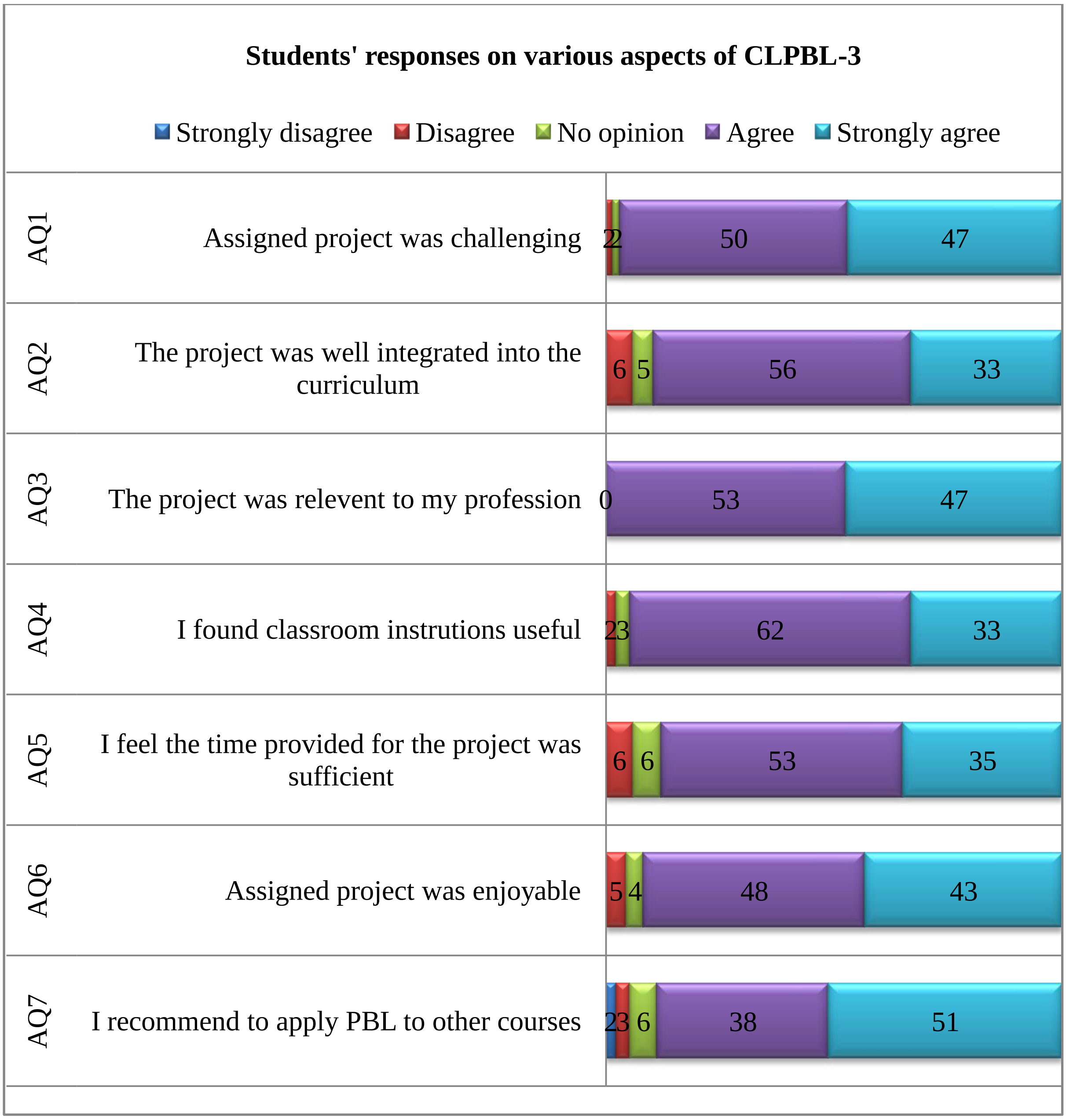

Figure 7.3 Students'responses in percentage on various aspects of CLPBL -3

In all designs, my idea was that prerequisite knowledge related to the project was important for the project work. Students' responses were collected to find the role of classroom instructions (AQ4) in the project. From figure 7.3 it can be seen that 95% of the students felt that the classroom instruction was useful. These values were 91% and 86% in the second and the first cohort respectively. The mean is increased from 4.17 to 4.26, with comparatively less standard deviation (0.62), suggesting that the classroom instructions helped students in their project work. It may be noted that, during interviews, students also stated that the instructions were useful and important for the project work.

In the third model, 88% of students felt that the time provided for the project was sufficient (refer figure 7.3, AQ5). Compared to the second cohort, this was a 5% increase. Only 12% in the third model did not agree or had no opinion. In the first cohort, this value was 31% and, in the second, this value was 17%. The drop in the students' negative responses shows that the students felt the available time was sufficient to complete the project work. The difference in these responses was found to be statistically significant when compared to the second model. This effect may be attributed to the gradual refinement of the model by incorporating changes in successive cycles. For example, the later models started project activities early in the semester, helping students to manage their time. Also, because this was the second consecutive time these students had worked on a project, their time management was better.

There was a 1% rise in the students'responses to AQ6 compared to the second cohort, and a 2% drop compared to the first cohort. In general, from the three cohorts, it can be said that 90% of the students enjoyed the project design. There was a marginal rise (0.11) in the mean score, which was found to be statistically insignificant. This shows that the students enjoyed working on the project in all three models. In the third model, 89% of students recommended PBL for the next course (AQ7). This response was 4% less than the second cohort and 7% less than the first cohort. There was a marginal drop (0.12) in the mean score, which was found to be statistically insignificant. However, this dip suggests that the students would expect appropriate changes in the project design for the next semester. They could possibly be given a more complex or a design project.

7.5.1.4. Students' experiences of their learning

In this section, I examine whether the third cohort had similar or different learning experiences compared to the other two. The focus was to investigate why, how and what the students learned in this model. Referring to table 7.17, the responses to BQ1 and BQ2 indicate that the project in each model equally motivated students to learn about mechanical engineering and material outside of theclassroom. In the ANOVA test, the difference in responses was found to be insignificant. This shows that all three projects motivated and stimulated students to learn beyond the classroom walls. Responses to BQ3 and BQ4 suggest that there was a marginal rise in the mean score for the third model. This could be because of improvements done in the project design. However, this marginal rise was found to be insignificant in the ANOVA test.

Referring to BQ5, in the table 7.17, the students'engagement showed a significant rise in mean score to 4.12 from 3.5. This suggests that the project in the third model was effective in engaging students throughout the semester. It may be noted that, in the previous two models, students felt that the project was not sufficiently challenging to keep them engaged in the work. The ANOVA test showed this difference to be significant, indicating that the project in the third model was effective in engaging students in the learning process.

In BQ8, there was a considerable rise in the mean score, which showed that the project laid a strong foundation for understanding the course. In the ANOVA test, this difference was found to be significant, indicating that the project design was relevant and in line with the course content. Hence, the project was equally effective for content learning. This was also discussed in the interviews, further validating the usefulness of the project for content learning. Students also stated in the interviews that they learned from each other. Responses to BQ6 illustrate the usefulness of the collaborative and cooperative learning approach for gaining better understanding of the subject and for content learning.

Table 7.17 Students' learning experiences in all CLPBL models

Question No.	Question	PBL Model No.	Mean Score out of five	Standard deviation	Significant difference
BQ1	The project motivated me to learn more about mechanical engineering	CLPBL-1	4.46	0.68	
		CLPBL-2	4.46	0.68	No
		CLPBL-3	4.43	0.75	
BQ2	This project stimulated me to think about the material outside the class	CLPBL-1	4.34	0.75	
		CLPBL-2	4.58	0.52	No
		CLPBL-3	4.57	0.67	
BQ3	This project helped me to take responsibility of my own learning	CLPBL-1	4.36	0.89	
		CLPBL-2	4.46	0.60	No
		CLPBL-3	4.55	0.68	
BQ4	I learned to become more independent and self-directed learner	CLPBL-1	3.81	0.93	
		CLPBL-2	4.18	0.85	No
		CLPBL-3	4.29	0.70	
BQ5	The project engaged my learning throughout the semester	CLPBL-1	3.53	0.98	
		CLPBL-2	3.50	1.10	Yes
		CLPBL-3	4.12	0.83	
BQ6	I learned through the collaborative and co-operative approaches.	CLPBL-1	4.17	0.65	
		CLPBL-2	4.11	0.76	No
		CLPBL-3	4.21	0.87	
BQ7	This project helped me to increase my understanding of the subject	CLPBL-1	4.39	0.66	
		CLPBL-2	4.43	0.59	No
		CLPBL-3	4.60	0.76	

BQ8	Project laid the strong foundation of the subject in this semester	CLPBL-1	4.21	0.69	
		CLPBL-2	3.96	0.82	Yes
		CLPBL-3	4.26	0.89	
BQ9	I feel confident to appear in the examination	CLPBL-1	4.17	0.60	
		CLPBL-2	4.22	0.85	No
		CLPBL-3	4.40	0.82	
BQ10	I expect improvements in my grades due to this project work	CLPBL-1	4.21	0.68	
		CLPBL-2	4.24	0.75	No
		CLPBL-3	4.33	0.60	
BQ11	Overall I am satisfied of my learning	CLPBL-1	4.46	0.59	
		CLPBL-2	4.37	0.71	No
		CLPBL-3	4.47	0.61	

In all other questions, the students expressed similar or better experiences for the third model than for the previous two models. These responses show the importance of good project design in the PBL model for improving students' understanding (BQ7) and confidence (BQ9). As a result, students expected improvement in their overall grades for the subject (BQ10). Similar to the first two models, students in the third model were satisfied with their own learning. The ANOVA test showed that the difference in responses to BQ6, BQ7, BQ9, BQ10, BQ11, and BQ12 were insignificant, showing that the students had similar experiences in models 2 and 3. Further analysis is shown in figure 7.4.

Figure 7.4 shows students' responses in percentage. Responses to all questions are compared here based on percentage of the responses. It may be noted that the project in the third model was more complex than in the first two models. Responses to BQ1 and BQ2 suggest that the project motivated 94% of students to learn (BQ1), which is in between the scores for the earlier two models (96% and 92%).

Ninety-seven percent of students in the third model felt that they had learned over and above the curriculum (BQ2). This response was 15% higher than the first cohort and 2% lower than the second cohort. Two conclusions can be drawn from this outcome. First, the project was equally effective in motivating students to learn in the second and third groups. However, since the first group had less time, they enjoyed the project 15% less than the third model. This variation can be attributed to the effectiveness of the project design.

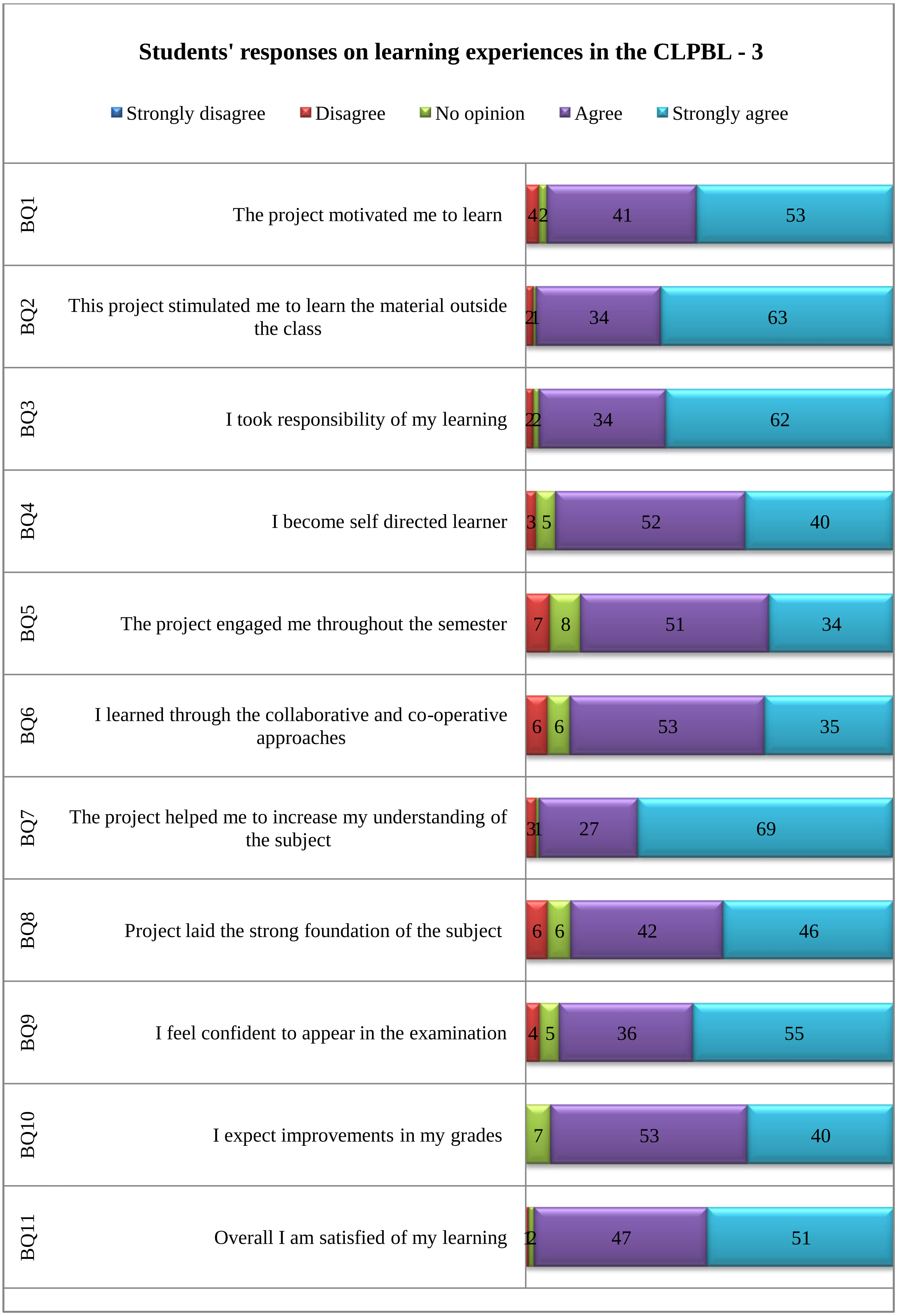

Figure 7.4 Students'responses in percentage about learning experiences in CLPBL-3

It may be recalled that, in the first cohort, only 60% of students said that the project engaged them in the semester. In the second cohort, 57% of respondents felt that the project was insufficiently complex to engage them for the entire complete semester (BQ5). Responses from the first two cohorts suggested that the type of the project assigned was not sufficiently complex. This response indicated a need to increase the complexity of the project for the third model with the intention of improving engagement of the students. Accordingly, for the third model, a more complex project was designed. The response of the students to BQ5 then increased to 85%. Hence, it can be concluded that the third project was effective in engaging most of the students.

In the third model, 96% of students said that they had taken responsibility for their own learning (BQ3); this response was similar to the 98% received in the second model. This response in the third model was 15% higher than in the first model. In BQ4, 92% of students in the third model felt that there was more scope for independent learning. This response was 9% higher than in the second model and 17% higher than in the first model. This response showed that the project in the third model provided more opportunities for self-directed and independent learning than in the first two models. Responses to BQ6 for the third model were very similar to the responses in the second model, in which 88% felt that they had learned through sharing and learning from each other. These similar results regarding independent learning versus group learning show that students got equal opportunity to learn independently across the models and slightly less (4%) with a collaborative approach.

In response to BQ7 (see figure 7.4), 96% of students felt that the project helped them to acquire knowledge relating to their engineering major. This response was marginally higher (4%) than the response in the first model response and almost equal to that of the second model (97%). In response to BQ8, 88% in the third model felt that the project activities helped them to understand the subject content better; this was 4% lower than that of the first model and 4% higher than in the second model.

In the third model, 91% of students responded that they felt confident to appear in the course examination (BQ9) and 93% believed that their exam grades would improve (BQ10). In the final examination, 88% of students passed the course. It is likely that the 88% of students who passed the course were largely among the 91% students who felt confident to appear in the examination. Overall, 98% of students in the third model felt that they were satisfied with their learning in the semester (BQ11). This response was similar to the responses from the previous two models, which shows the overall effectiveness of the PBL environment for learning purposes.

7.5.1.5 Students' perceptions towards achievement of learning outcomes

The focus of this design was to promote students' achievement of the intended ABET learning outcomes, as outlined in the previous sections. Table 7.18 shows the result of the questions regarding students' perceptions of the achievement of learning outcomes (LOs) in the CLPBL-3. Referring to the table 7.18, it can be observed that students mean score is higher for all questions than in the first two models. This shows that CLPBL-3 was effective in promoting the achievement of LOs. It is also observed that, in all three models, students reported similar experiences, with the exception of for CQ3, CQ5 and CQ7.

In CQ3, students' mean score for the third model increased to 4.36, which suggests that the students' problem solving abilities were improved from the first two models. This data also suggests that the project in the third model was complex enough to advance students' problem solving skills. The ANOVA test found this difference to be significant, confirming that the students' problem solving skills were improved in the third model.

The ANOVA test for responses to CQ5 suggested significant difference between the responses of the second and third models. This suggests that students had more opportunity to learn presentation skills in the third model. During project presentations students included a lot of information and experiences, which further validate this response. Responses to CQ7 suggest that the third model project provided ample opportunity to apply project management principles, more so than in the other models. This, again, may be attributed to the complexity of the project. The students'similar responses, across the three models, to all other questions confirm that the designed PBL models were equally effective in achieving the other learning outcomes. The ANOVA test found differences in all other questions to be insignificant, confirming that the students had similar experiences in all three models.

Table 7.18 Students'perceptions of achievement of learning outcomes in CLPBL -3

Question no.	**Question**	**PBL Model No.**	**Mean score out of five**	**Standard deviation**	**Significant difference**
CQ1	Assigned project and related work helped me to think deeply	CLPBL-1	4.24	0.68	
		CLPBL-2	4.38	0.68	No
		CLPBL-3	4.47	0.63	
CQ2	This project helped me to improve my ability to work in a team	CLPBL-1	4.30	0.70	
		CLPBL-2	4.44	0.63	No
		CLPBL-3	4.44	0.70	
CQ3	I learned much about the problem solving process	CLPBL-1	3.99	0.69	
		CLPBL-2	3.95	0.83	Yes
		CLPBL-3	4.36	0.67	
CQ4	I learned how to write and present technical information in the report	CLPBL-1	4.32	0.52	
		CLPBL-2	4.49	0.54	No
		CLPBL-3	4.55	0.61	
CQ5	I learned critical presentation skills due to the project work	CLPBL-1	4.29	0.56	
		CLPBL-2	4.26	0.68	Yes
		CLPBL-3	4.45	0.69	

CQ6	I learned to asses and manage variety of resources	CLPBL-1	4.24	0.56	
		CLPBL-2	4.30	0.65	No
		CLPBL-3	4.33	0.57	
CQ7	I applied project management principles to manage the project work	CLPBL-1	3.84	0.74	
		CLPBL-2	3.94	0.85	No
		CLPBL-3	4.11	0.81	
CQ8	Assigned project and related work helped me to improve my skills	CLPBL-1	4.43	0.57	
		CLPBL-2	4.44	0.62	No
		CLPBL-3	4.44	0.69	

Figure 7.5 shows the result of the students' perceptions on the achievement of learning outcomes (LOs). In CQ1, 97% of students perceived that their abilities in reflective thinking or thinking deeply were improved. In this case, there was a 3% and 9% rise in the responses as compared to the first and second model. In the third model, 95% of students agreed that the project improved their problem solving skills (CQ3). There was a rise of 12% positive response compared to the previous two models. In the third model, 95% of students agreed that their teamwork skills were improved, which was similar to the responses in earlier models (CQ2).

As discussed, quality of the project report remained almost at the same level of the second model. However, the quality of the project report improved compared to the first model. Similarly to models 1 and 2, students in the third model were asked to write a project report and to deliver a Power Point presentation in front of the whole class. CQ4 (96%), CQ5 (94%), and CQ6 (97%) respectively addressed the improvement of writing, presentation and information management skills. It is evident from the responses that the students felt the project provided opportunities for development in these areas. The responses to these questions in the third model were very similar to the responses from previous models, with a difference of only 1-2%.

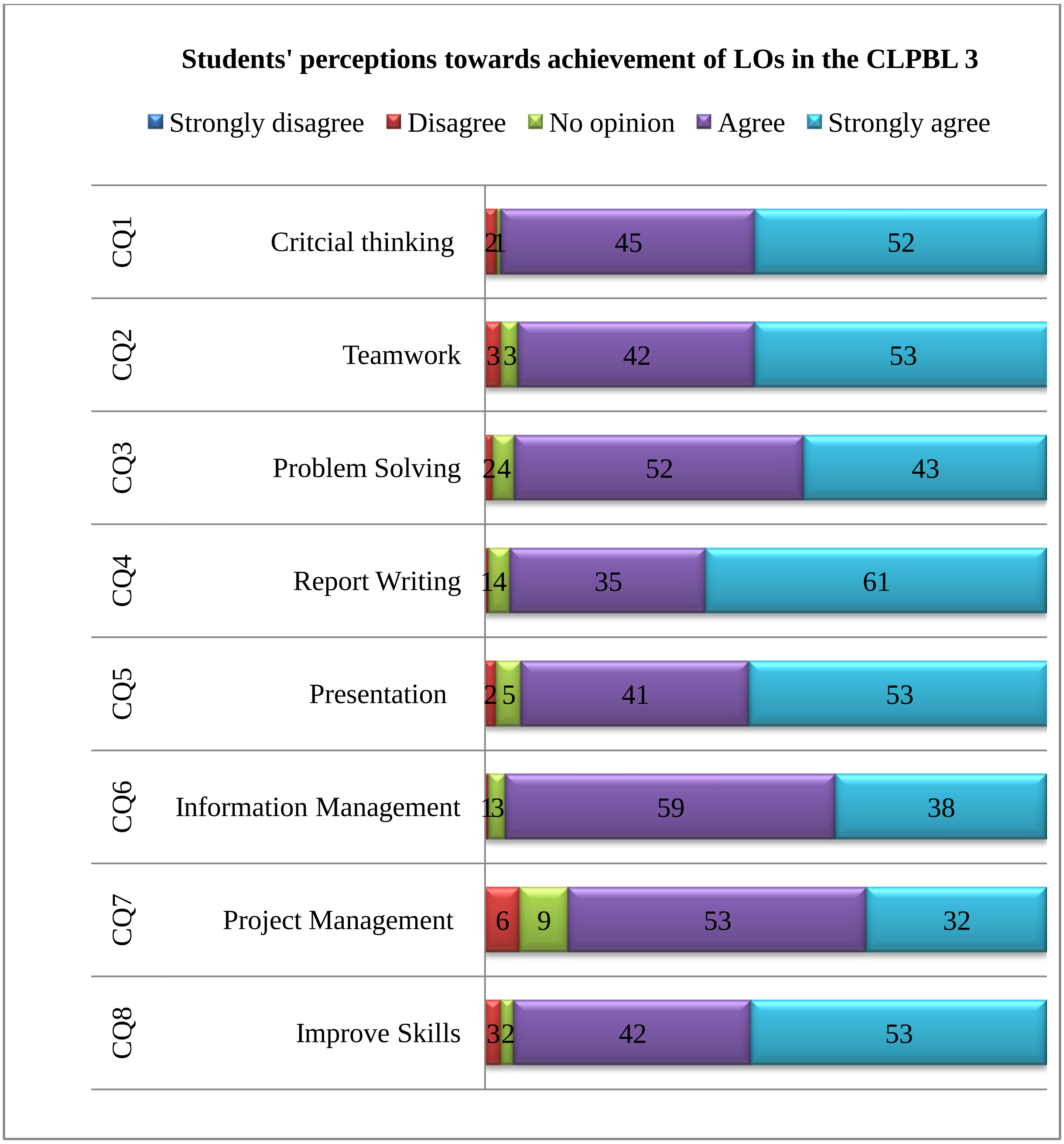

Figure 7.5 Students'responses towards achievement of learning outcomes in CLPBL-3 in percentage

In the second model, the response to CQ7 showed that 79% of students felt they used project management principles. This response was 7% higher than in the first cohort. In the third model, 85% of students said that they applied project management principle, which were 6% higher than in the second model and 13% higher than in the first model. This rise in positive responses indicates that the project in the third model provided more opportunity for applying project management principles. Overall, 95% of students from the third model agreed that their skills were improved in the PBL model (CQ8). This response was very similar to responses in previous models.

7.5.1.6. Students' experiences about teamwork

Table 7.19 Students' experiences about teamwork in CLPBL-3

Question no.	Question	PBL model no.	Mean score out of five	Standard deviation	Significant difference
DQ1	I feel group work is a challenging task	CLPBL-1	3.74	1.12	
		CLPBL-2	4.02	1.02	No
		CLPBL-3	4.08	1.05	
DQ2	Teamwork was critical for completion of this project	CLPBL-1	3.21	1.23	
		CLPBL-2	3.42	1.23	No
		CLPBL-3	3.46	1.34	
DQ3	My teammates helped me to understand the problems and the subject content	CLPBL-1	4.16	0.77	
		CLPBL-2	4.02	0.83	Yes
		CLPBL-3	4.20	0.86	
DQ4	I learned to take different perspectives and opinions	CLPBL-1	4.17	0.62	
		CLPBL-2	4.25	0.58	No
		CLPBL-3	4.23	0.64	
DQ5	I learned much about how to lead the successful project through teamwork	CLPBL-1	4.22	0.71	
		CLPBL-2	4.33	0.67	Yes
		CLPBL-3	4.41	0.63	
DQ6	I feel we could have done better in project work	CLPBL-1	3.99	0.85	
		CLPBL-2	4.15	0.79	No
		CLPBL-3	4.26	0.96	
DQ7	I am satisfied with my group's performance in this semester	CLPBL-1	4.22	0.91	
		CLPBL-2	3.92	1.03	Yes
		CLPBL-3	4.23	0.93	

DQ8	I am looking forward to work on more challenging and complex project work	CLPBL-1	4.44	0.55	
		CLPBL-2	4.51	0.64	No
		CLPBL-3	4.36	0.70	

Table 7.19 provides a summary of students' responses describing their experience of teamwork. Referring to DQ1 in the table, students' mean in the third model was almost the same as in the second model. This response was expected to increase according to the project design. The lack of increase may have been because students had experienced teamwork in the previous model. In all three models, the odd response to DQ2 was received, suggesting that teamwork was not critical for project completion. Further investigation and discussion of these responses is needed. The students' mean score for this question remained similar around 3.42. Compared to the first model, there was a rise of 0.25, which may be attributed to the complexity of the project. The similar means in the second and third models could be attributed to the larger number of students per team in the third model compared to the second model. In the third model, the students' already had experience working in a team, so they might have managed teamwork better than in their first experience. It could be investigated further in the next model, to see if the responses of the students were the same for a similarly complex project with a team of four members.

For DQ3, the difference in students'responses was found to be significant. There was a rise of 0.18 in the students'response compared to the second model. This rise can be attributed to the increased complexity of the project, which required the students understand the content properly. It has already been mentioned in the interviews that the students helped each other to learn the content.

For DQ4, responses remained the same and no statistically significant difference was found. In response to DQ5, there was a marginal rise (0.08) in the mean of the response. A similar trend was seen in the response to DQ6, with a marginal rise (0.11) in the mean of the response. In DQ7, students' mean score increased to 4.23 from 3.92 in the second model, which shows that the students' performance in the third model was much better than in the second model. The ANOVA test found this difference to be significant, indicating that the students' performance was better in the third semester. However, the increased mean score for DQ6 indicated that the students could have done better in their group work. This may be especially applicable to a few groups who struggled to work together. For DQ8, the mean decreased from 4.52 in the second model to 4.36 in the third model, which indicates that the project design was at the expected level of complexity. The reason for this marginal drop may be that the students thought they may not be able to complete the more complex project in the given time or may have wanted to work on a different type of project, for example a design or industry project.

Figure 7.6 shows the students' responses to their teamwork experience. Figure 7.6, shows the response to DQ1, in which 78% of students in the third model felt that the group work was a challenging task. This response was 4% less than in the second model and 8% more than in the first model. The 4% decrease from the second model may be attributed to students having teamwork experience from the previous model. They might have felt more comfortable working in a team the second time. Still, 78% felt the group work was challenging and that there was scope for improvement in this area. This was also evident in the open-ended questions, where students stated that they could manage their team better than in the previous semester.

In the first model, an unexpected response to DQ2 was received. In this response, 51% of students felt that the teamwork was important and 49% said it was not so important. In the second model, similarly, 59% of students found teamwork to be important and 31% said it was not important. The third model also followed a similar trend, with 60% of students said claiming that teamwork was critical for the project and 34% saying it was not important. These similar results may be influenced by similar factors, i.e. the complexity of the project and the team composition. In the discussion section, I attempt to elaborate these responses.

Almost, 90% of students in the third model agreed about the role of teammates in the learning process (DQ3). Students learned many aspects of teamwork, including learning to take a different perspective (DQ4) and learning to lead successful projects through teamwork (DQ5). In response to DQ4, 91% of students perceived that they had learned to see different perspectives and value other’s opinions, which were similar to in the previous cohorts. In response to DQ5, 95% of students agreed that they knew how to conduct a project with a team. This response was similar to in the second model and 9% higher than in the first model.

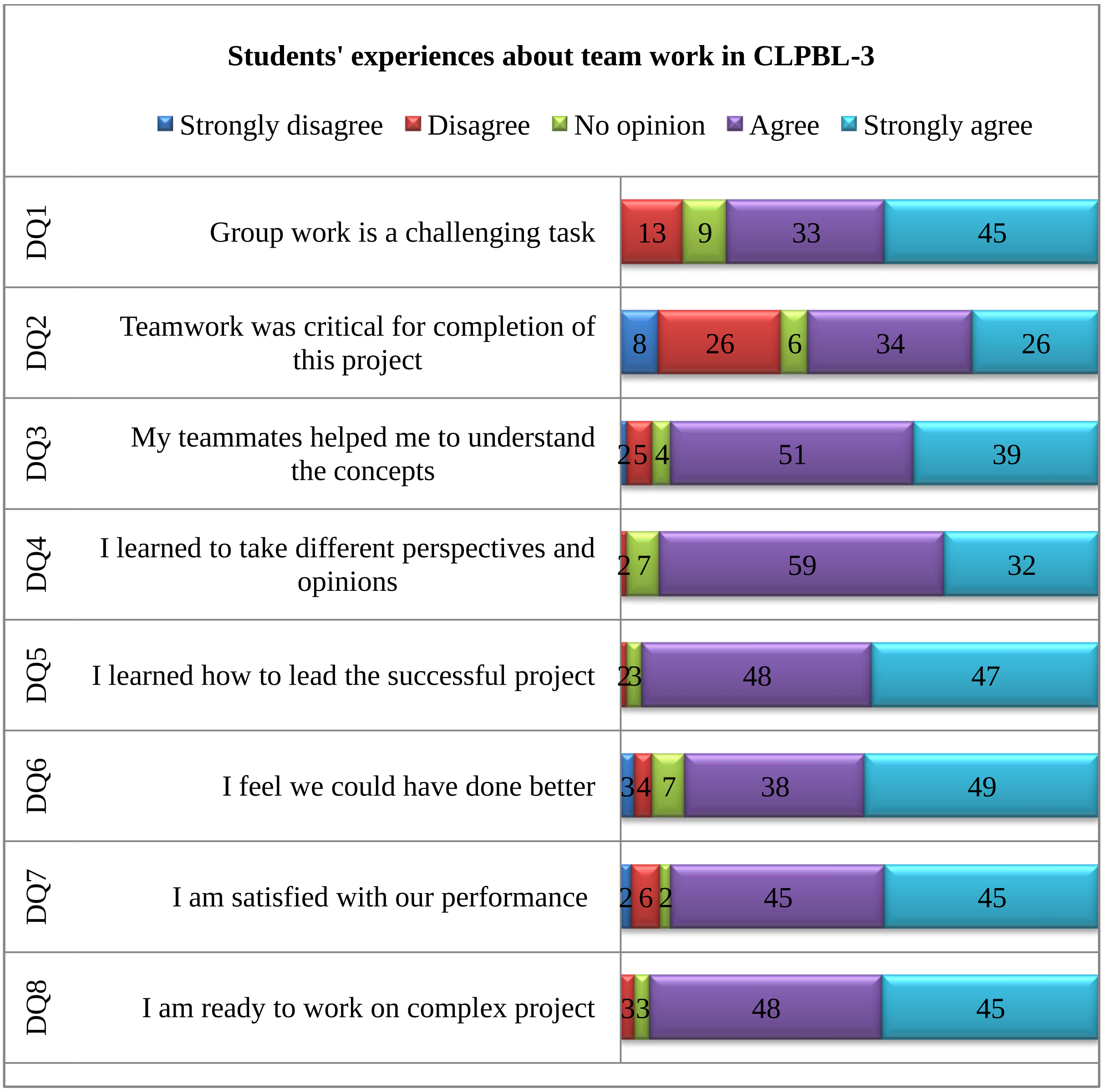

Figure 7.6 Students’ experiences about teamwork in percentage in CLPBL-3

Referring to figure 7.6, 87% of respondents in the third model indicated that there was scope for improvement in their teamwork (DQ6). Responses showed that 90% of students were satisfied with their team's performance in this semester (DQ7). This may be because the students had already worked in a team setting previously, in a consecutive semester, resulting in increased confidence. It is also possible that the students in the third model better understood the pros and cons of teamwork. As a result, 93% of students felt that they were ready to work on challenging and complex projects. This was a marginal drop of 2% compared to the second cohort.

Teamwork was important for carrying out the fieldwork activities. The following images (figure 7.7) show students'fieldwork activities during the third model. In the both images, it can be seen that the group of four students are busy measuring and noting the dimensions of the real-life mechanism at a site. A girl can be seen in the second picture. In the first picture, a group of four boys can be seen taking the dimensions of a hacksaw in a workshop. These pictures illustrate that teamwork played an important role in the learning process for the students and that the fieldwork activities enabled the students to receive practical knowledge.

Figure 7.7 Action images showing teamwork from PBL model 3

7.5.2 Project grades

Table 7.20 below shows the students' project grades. The project was worth 25 marks, as mentioned earlier. Out of 152 students, 8 students were unable to achieve marks of 40% or higher on the project. Out of the remaining 144 students, 89 scored more than an 80% grade and 43 students secured a score of between 60% and 80% on the project. The 132 students (86.84%) who received more than a 60% grade on the project can be considered as students who have done the project seriously and have an excellent chance of securing good grades in the final examination.

Table 7.20 Summary of project grades

Grade	Marks out of 25	Range of marks in %	Frequency	Percentage
A	More than 20	81-100	89	58.55
B	15-20	61-80	43	28.29
C	11-15	41-60	12	7.89
D	6-10	21-40	01	0.66
E	0-5	0-20	07	4.61
			152	100

7.5.3 Grades in the final exams

Table 7.21 below shows a summary of the students'grades in the final examination for the course. This examination was conducted by UoP. The answer sheets for my students were assessed by an external evaluator. It can be assumed, then, that there was no bias and that the results were not influenced by me. Students were required to score a minimum of 40 marks out of 100 (40%) to pass the examination. This criterion was decided by the university. In this course, 117 students (78.5%) passed the course and the remaining 21.5% of students failed. This value was very close to the 132 students who secured more than 60% grades in the project (refer to above table 7.20). It would be very interesting to see if there was any correlation between the project grades and final examination grades. In the final examination 78.5% of the students passed this course, which is close to the 86.84 % of students who scored more than 60% grades on the project. This comparison suggests the effect of project work on the achievement of grades.

Table 7.21 Summary of written examination grades

Grade	Range of marks in %	Frequency
A	61-80	34
B	51-60	46
C	40-50	37
D	21-39	28
E	0-20	4
		149*

***Three students were absent in the final examination.**

7.6 Discussion of the results

In this section, important results from the model will be discussed and compared with the first two models.

7.6.1 About PBL model design and implementation

This was the third time that PBL was applied to a single course in the department. This model was designed for the course*Theory of Machines-I*. The course level requirements remained similar to in CLPBL-1 (see chapter 5). The objectives of the PBL model remained the same, namely to promote students' active learning and enable students to achieve the intended ABET learning outcomes. This newly designed course was implemented for the period of one semester from December 2012 to April 2013.

7.6.1.1 Project

The existing CLPBL-1 project was modified by adding activities (highlighted in table 7.1) to form the more complex project for CLPBL-3. The results and reflections from earlier models influenced the new project. In the project design, two important elements were considered: relevance and complexity. A good project would have strong relevance to the students' major and profession. Accordingly, in the third PBL model, the project was designed with consideration to the first three units of the syllabus, covering almost 50% of the course objectives. The nature of the project activities required students to understand the basic concepts and principles and the application of important graphical and analytical methods to real-life mechanisms. These activities were not a regular part of the curriculum.

In the open-ended questions (refer to table 7.3), 35% of students said that the project was useful for passing their examination and 56% of students said that the project was important for clarifying basics and getting practical experience. In total, 91% of student responses in the third model indicated that the project was useful for them in this way. In the survey, 100% of students agreed that the project was relevant to their profession (figure 7.3, AQ3). Furthermore, 89% of students felt that the project was well integrated into the curriculum (figure 7.3, AQ2). Almost all of the students (97%) agreed that the project was challenging for them (figure 7.3, AQ1). It motivated 94% of students to learn (figure 7.4, BQ1) and stimulated 97% of students to learn material outside of class (figure 7.4, BQ2). The extrinsic motivation also came from the fact that the students received 25 marks for the project work. From the above results, it can be concluded that, in their second PBL experience, the project motivated students to learn relevant, conceptual and practical knowledge that they felt would be useful for passing examination and for their future professional work.

The complexity of the project could be judged from the engagement of students in the project work. In first two models, 60% of the students felt that the project engaged them and the remaining 40% did not. This prompted me to increase the complexity of the project work. Accordingly, in the third model, 85% of students agreed that the project engaged them over the semester (refer figure 7.4, BQ5). From table 7.5, it can be seen that the students mentioned encountering various conceptual difficulties in the third project. In the earlier projects, students had far fewer conceptual difficulties. The difficulties in the third model were mostly related to the application of basic concepts to draw kinematic diagrams and then draw velocity and acceleration diagrams. In the interviews, students stated that the third model project was more difficult than the second model. These responses confirmed that the third model project was complex enough to challenge the students and engage them in the learning process.

7.6.1.2 Role of instructions in the model

In the third model, students were given prerequisite knowledge required for the completion of the project at the beginning of the semester. This classroom instruction proved to be helpful in the project work for 95% of the students. In the interviews, students have stated that they started their projects late in the semester because they were waiting for the relevant units to be covered in the classroom instructions. Most of the interviewed students said that, without instructions, it would have been difficult for them to complete the project in time. This confirms the importance of classroom instructions for the students in this model.

7.6.1.3 Availability of time

The research for this study was started with the first cohort in the first half of 2012 and then moved to second cohort in the second half of 2012. The first cohort complained about a shortage of time. In the second model, I started the project activity at the beginning of the semester. In response, the students completed the project work in time. In the third model, I did the same. As a result, 88% of students in the third model agreed that the time was sufficient for the project work. This was a rise of 5% (compared to the second model) of students who found that the time was sufficient for project work in the semester. Students also mentioned in the survey (open ended questions) that they managed their time better than in their first experience. This showed that their time management skills had improved. In the interviews, students said they managed their project at the end of the semester, in the last three weeks. This showed their tendency to work close to deadlines. In the third model, 30 groups completed their work in the given time, which showed their ability to complete the work in time.

7.6.2 Students' learning experiences in the PBL model

Students'learning in CLPBL-3 was evaluated on two parameters: content learning and achievement of learning outcomes.

7.6.2.1 Content learning in the project

The project played an important part in motivating and simulating students to learn. From the open-ended questions outlined in table 7.6, students said that the project work helped them to understand the content and develop the relevant practical knowledge. Students also stated that they felt confident to appear in the examination because of the project work. In the survey, 96% students said the project helped them to understand the subject matter and 88% expressed that the project laid a strong foundation for the course subject (refer figure 7.4, BQ7 and BQ8). These results can be attributed to the project, which covered 50% of the course content. During the interviews and essays, students claimed that their understanding of the subject had been enhanced. Thus, it is concluded that the PBL environment is conducive to content learning and to gaining practical knowledge.

The students'learning can be categorized under three modes of learning: classroom instruction, individual study and collaborative approach. In my opinion, each mode was important in the PBL environment. Instructions were useful for the students to gain the prerequisite knowledge required for the project. Throughout the project, the students used team-based and self-learning techniques to tackle the project. Individual learning occurred when students collected information from various sources and tried to understand the material by themselves. Later, this information and knowledge was shared with their teammates in order to carry out an analysis of the problem together, and to find a final desired outcome. In this way, the project provided opportunities for individual and team-based learning. In the survey, 92% of students said that they learned independently and 88% said that they learned through a collaborative approach (see figure 7.4, BQ4 and BQ6). It is most likely that the same students indicated that both approaches were important. From the open-ended questions, I found that 43% of students'felt that the role of teammates was important, not only to share the workload but to resolve doubts and support each other in the learning process (see table 7.4). These are essential components of a collaborative (team-based) learning approach.

In the presentations and question-answer sessions, I observed that the group leaders dominated. I observed a strong influence of individual learning, as group leaders seemed to have learned more and to have better knowledge than the others in the team. This puts an element of doubt on the superiority of the different modes of the learning process. In my opinion, it depends on individual learning preferences. In spite of individual preferences, the students worked together to complete the entire project without taking much help from a teacher. This showed their ability to engage in self-learning and to apply the concepts independently. Since students were working in a PBL environment for the second time, 33% of the quotes in the survey (open ended questions) indicated that they felt easier more confident and better. In addition, they demonstrated better teamwork and managed their time more efficiently.

Owing to their improved understanding of the subject content as a result of individual and team-based learning, the students felt confident about the course. In the survey, 91% of students said that they felt confident to appear in the examination and 93% said they expected an improvement in their grades. However, the results from the final written examination showed that only 78.5% of students passed the course. There was a difference of 14.5% between the expectations and actual outcomes. This requires further investigation.

7.6.2.2 Achievement of learning outcomes

In the survey, students explained that they had visited various locations to conduct their fieldwork. The choice of location for the fieldwork depended on the choice of mechanism. Some groups mentioned having to travel out of town to complete the fieldwork. The fieldwork provided a practical learning experience for the students. The project helped students to learn and apply knowledge to a real-life engineering mechanism (LO-'a'). This was evident in the interviews, survey and presentations where the students discussed their mechanisms. For achievement of the learning outcome 'b', in my opinion, both traditional and PBL approaches were useful. In the PBL approach for the third model, students actually measured the length of links and angular positions of links. For calculation purposes, they needed to measure the speed of the link. Students used a tachometer for speed measurement. In the open ended questions (the survey), students said that measuring these parameters was a challenging activity. The traditional teaching approach helped the students to conduct experiments in the laboratory. In both cases, students used this data for calculation and drawing purposes.

In the survey, students said that their thinking and problem-solving abilities had been engaged in the PBL environment. Compared to the previous models, the third model showed a considerable rise in these two categories (see figure 7.5, CQ1 and CQ3). This response was closely associated with ABET LO 'e'. Regarding LO- e, the project required students to analyse a real-life engineering mechanism and calculate velocity and acceleration of the links. This was a very challenging activity. To conduct such analysis, students needed to apply knowledge, evaluate and compare real-life links, and measure and discuss the data among themselves. These are higher-order thinking skills. Hence, there ought to have been improvement in the thinking and problem-solving abilities of the students. They needed to establish relations between classroom learning and real-life context. The project provided an opportunity to link the theory to the real life situation. The students are not used to do this linking. As a result, they faced many conceptual difficulties as outlined in table 7. 5.

In the survey, 95% of students felt that their ability to work in a team had improved (see figure 7.5, CQ2). This was the second experience for this cohort of working in a team, so it was expected that their teamwork ability would have improved. The project provided them a second experience to work with different group members and get further used to working in a team. In doing so, the project advanced the students in achievement of the LO-'d'. In view of developing students'communication skills, presentation and report writing were included in the project activities. It was also perceived that working in a group would help students to improve their communication skills. In the survey, 94% of students said that their presentation skills had improved and 96% of students said their ability to write a project report had improved. In actuality, these perceived improvements appear to be a bit exaggerated. It is worth noting that this model gave students an opportunity to practice writing skills in the second year of their programme. Normally, in the traditional curriculum, they are not given this opportunity until the third and final year. In this sense, the PBL environment provided an additional opportunity to improve their communication skills.

The students'ability to engage in lifelong learning could be judged from their ability to find and manage relevant information. It could also be judged from the students'engagement in the learning process. In the third model, the students were challenged to perform complex tasks, such as drawing a kinematic diagram. In this process, the students needed to engage themselves in fieldwork, collect relevant data and calculate various dimensions of the links. They collected information from various sources to understand the given mechanism. These actions are good indicators of the students' engagement in the project. Also, as discussed earlier, students prepared project presentations and reports, which show their information management skills. In the survey, 97% of students felt that their information management skills were improved. In working on the project, students managed their work fairly independently, showing their ability to engage in lifelong learning (LO- 'i'). This way 7 out of 11 ABET learning outcomes were achieved in this model.

7.6.3 Teamwork and team composition

Students wrote in the survey that, due to the group project, their teamwork abilities had improved and they understood the importance of teamwork for completion of the project. The students found their teammates to be important for sharing the project workload and learning from each other. In their second experience of working in teams, the students felt that they demonstrated better teamwork and project management. As a result, they were able to complete the project at the end of the semester, in two to three weeks. In general, it can be understood that the students realized the importance of teamwork to accomplish the given task in due time, with comparatively less effort than working individually.

In the third model, team composition was kept at 4-5 students per team. In the three experiments done so far, I observed that the student teams demonstrated the best collaboration in the final model. Similar to the earlier models, it was observed that the most intelligent, talkative and active students lead the groups in the third model. The less intelligent, less active, more introvert students continued to either hold supporting roles or be sidelined. Furthermore, some groups had students who contributed significantly less and/or relied entirely on the work of others in the group. These students were absent in the project presentations.

7.6.4 Role of supervisor

There were 30 groups in the third model. In the earlier models, I was the only supervisor for all groups. However, in the third model, two more teachers were involved. They looked after the groups from their batch and evaluated them during presentations. I was responsible for 60% of the students from the class and the other teachers were responsible of 40% of the students. This way, the responsibility of supervision was shared. Consequently, I felt less burdened during the project evaluation period. The students in the third model suggested that each group be allotted one supervisor who would observe the groups, conduct regular meetings and help the groups whenever they needed it. This was difficult to arrange, as the project is not a part of the regular curriculum. There can be much resistance from the staff, as participating would increase their workload.

7.7 Conclusions

In the first PBL model, I implemented PBL for the first time in the “Theory of Machines-I”course. At that time, I was not sure whether the model design would work or not. During implementation of the first model, the students mentioned positive aspects and effects of PBL and suggested improvements for the project design. Many of the same observations were made in the second model. Accordingly, for the third model, project design and implementation strategy were improved. The syllabus of the course and ABET learning outcomes were considered in the project design for all three models. Field notes and a survey method were used to collect the data in all three models. Also, in-depth interviews were conducted to reinforce the survey data. Unlike the first two models, essay writing was avoided in the third model.

In the third model, 30 groups totalling 152 students participated and completed the project work in a stipulated time. In this model, 4-5 students per group worked on a relatively complex project. These students were working in the PBL environment for the second consecutive time. The student stated that, they managed the project better due to their first experience. They also mentioned that their teamwork and time management was better in this model. The students informed me that they learned better in the PBL environment than in a traditional set-up. The students’ learning mainly took place through independent and group learning. During the interview, students mentioned that the project in this model was challenging compared to the earlier model. From the data, it can be concluded that the project in this model was challenging for students and was able to engage them in the learning process. The project also helped students in content learning and getting practical knowledge. The students found that the PBL environment was useful for developing skills such as communication, teamwork, and project and time management. In this model, the effect of the project design was evident from the students’responses. The students experience and responses in this model were slightly better than in the first two models. The importance of project design and its relation to teamwork could be further understood and could be refined further in the next cycle. Overall, PBL has been found to be a useful way to engage students in active learning and to promote the achievement of LOs.

Chapter 8

Research outcomes and directions for future research

This chapter will sum up an important research outcomes and conclusions. Furthermore, directions for future work will be discussed at the end of this chapter.

In the introduction chapter, literature on Indian engineering education was discussed to outline the current status of engineering education. In this literature, it has been emphasised that the academic practices followed at Indian engineering institutes must be improved. There is a need for curriculum development that addresses the needs of the engineering profession and to inculcate innovative teaching-learning practices to improve the quality of engineering education. From this review, it was concluded that there is an urgent need to change and to look for different education strategies.

The choice of PBL as a suitable approach is reinforced by the PBL literature. My review of research done around the world regarding Project Based Learning (PBL) indicates that PBL could be a appropriate strategy for improving the quality of engineering education and graduate engineers' skills in India. It is understood that PBL is identified by different acronyms in different countries. These numerous practices have been designed to suit various local academic cultures. Furthermore, through this literature review, this research show that PBL originated in Western culture and the academic practices are different in India. Hence, the challenge for my research was to study PBL philosophy and develop a model suitable for Indian conditions.

For the development of the PBL model for this study, a review of existing Indian PBL models and related research was done. It was concluded that the Indian education system lacked practice in PBL, despite several reports clearly stating the need for reforms in the direction of PBL. It was also evident that Indian educators and administrators were not committed to accepting PBL. In this sense, my research was challenging. Modest research in the areas of PBL has shown that, there was significant scope for research in the areas of curriculum development, staff training and management of change to PBL. With both favourable and challenging conditions, I began my research in 2010.

This research was focussed on to answer two questions; first question was to decide nature of teaching and learning elements of the PBL model for the Sinhgad Institute of Technology, Lonavala (SITL). The second question was to assess its impact on students' learning experience and learning outcomes. To address these research questions, a DBR methodology was chosen over action research. DBR literature was discussed and the DBR framework was prepared to guide the flow of research.

To address the first research question the main challenge was to develop a PBL model for SITL to suit its academic and administrative settings. At the beginning, *a case study of an Aalborg PBL model* proved to be very useful for deciding nature of PBL and data collection instruments to be used at SITL. In the later half of 2011, I began developing a course-level model to initiate a small-scale experiment at the institute. To begin with, I decided to implement PBL in the *Theory of Machines- I* course. During the initial phase of model development, I perceived many drivers and challenges for PBL implementation at an Indian institute. The main motivation for PBL implementation was the need to bring an appropriate change in teaching-learning practice, to meet industry demand for skilled engineers, and newly adapted accreditation norms. These three elements were critically examined and used as the foundation of the model. The main challenges in this process included a traditional set of values and beliefs that create resistance to change, the academic setting, and the curriculum structure. The first course-level PBL model (CLPBL) was designed in 2011. This model included the project, project evaluation scheme, and teaching-learning and supervision strategies. It also included a strategic use of resources such as time and institutional infrastructure. The first CLPBL model played a very important role in the outcome of this research. The DBR methodologies proved to be an effective methodology for designing and testing the CLPBL models. It permitted me to conduct the research and could be used to improve the current academic practice at SITL. The first CLPBL model was implemented in 2012.

To address second research question i.e to assess an impact of designed CLPBL model on students' learning experience and learning outcomes, a mix of qualitative and quantitative methods was used. The essays, survey (open-ended questions) and interviews provided qualitative data. In addition, observations, project presentations and project reports proved useful to get insight into the students'experiences. Although the essays were useful for preparing the initial themes and categories of the qualitative analysis, considerable variation in the essay length was observed, which produced significant unstructured data. Short interviews at the end of the presentations proved helpful for clarifying and reinforcing the essay data from the first two models. At the end of the third model, in-depth interviews were used to verify the observations made during implementation of the three models. This qualitative data was analysed by using content analysis technique. Along with qualitative data, quantitative data was also collected by using the survey instrument with an overall Cronbach alpha in the range of 0.85. The project and course grades also provided quantitative data. The survey had four major groups, for which the Cronbach alpha value was found to be in the range of 0.7. This survey instrument was tested three times during this research and proved effective and consistent enough to generalise the findings of the research. The response rate in all three models was close to 85%. During the initial phases of the research, quantitative data was analysed using descriptive statistics. Later, a two-way ANOVA test was found to be useful for comparing the results.

The responses to the CLPBL-1 indicated that the model was successful in improving the students' learning experience and to promote achievement of learning outcomes. More detailed discussion is held in coming section. Most of the students recommended applying the CLPBL approach in the forthcoming semester. With the success of the first CLPBL, two more CLPBL models were designed for two courses. Thus, three CLPBL models were designed for two important subjects of the mechanical engineering undergraduate programme. The implementation of CLPBL was an important outcome of this research. In the three models, three innovative projects were designed, along with project evaluation strategies, which proved effective for the overall assessment of student projects and groups. These projects and its assessment strategies were other important research outcomes. In the coming section, important research outcomes and contributions are discussed from different perspectives.

8.1 Perspectives on the research

Personally, this research was fruitful for me. I gained recognition resulting in opportunities to conduct PBL workshops and lectures (refer Appendix A_{12}). For me, these are important outcomes. In the course-level PBL implementation, a course teacher is a key person, as the success of the PBL implementation lies with his or her level of motivation. In my case, I played many roles depending on the phases of the semester. For example, at the beginning, I was busy in designing project and evaluation strategies, whereas at the end, I played the role of evaluator. Throughout the semester, I needed to step into the role of teacher and supervisor. These efforts ultimately were useful for my students and for the successful implementation of CLPBL.

8.1.1 Students' perspective

The most important beneficiaries of this research were my students. Three hundred and seventy five second-year mechanical engineering undergraduate students participated in this research. The students'reactions to and experiences in the PBL environment indicated that they welcomed this innovative practice. They actively participated and completed the given projects within the stipulated time of one semester. This showed that, given an opportunity, the students can work satisfactorily on the project even in the early years of their programme. In my opinion, one of the most important research outcomes was the students' ability to work independently on the projects and engage in the learning process. The project provided an opportunity for the students to break the monotony of classroom instructions to do hands on work in the field. Also, the project provided students with the autonomy and liberty to set the pace of their own project work. This created interest and motivation among them to complete the project.

In the first two models, most of the students worked in a team setting for the first time. For the less complex projects in these models, 3-4 students per teams can work satisfactorily. If this number was increased to 5-6 members per team, then there were cases of divided groups. In the third model, for a more complex project, 4-5 members per team worked better. *So, it can be summarised that project complexity and best fit team composition were closely related.* For less complex projects, 3-4 members per team was best, and for more complex projects, 4-5 members per team worked better. In general, the correlation between project complexity and team composition could be explored further in the future. Another observation related to team composition is that the PBL environment helped active students to become even more active. However, less intelligent, introverted and female students benefitted the least. This could be investigated further. For team meetings, hostel rooms were mostly considered as the best option. The reading hall and canteen were the next most preferred locations for team meetings. This shows that, even in the absence of group rooms, students can manage team meetings at other locations.

Teamwork helped the students at many stages of the project work. In all three models, around 40% of students said that the role of team members was not critical for the project work completion. This was contradictory to their comments stating that their teammates helped to solve problems, clarify doubts and concepts. By working with teammates, many concepts were clarified that would otherwise not have been understood from the classroom instructions. Team members were also useful for sharing the project workload and knowledge. These contradictory results indicate a need for research at the individual level. This being said, my research data indicated that the project exposure helped the students to gain confidence in working with a team and their ability to work in a team was improved.

Students claimed that finding the project case and fieldwork were difficult. Students described the challenges associated with fieldwork, like getting permission from the owner of the machine and negotiating with him, understanding real machines and measuring sizes, managing the travel time to field visits and dealing with its overlap with routine academic work. Although there were many challenges, the fieldwork activities helped the students to relate their classroom learning to real-life engineering applications. In all three models, the students analysed real-life engineering products. My research data indicated that they applied classroom learning to real-life applications for the purpose of analysis. In conclusion, CLPBL provided a chance for participants to enhance their higher order thinking skills such as problem solving and critical thinking. This would not have been the case in the traditional instruction-based practice. Students experienced that the PBL environment was useful for gaining practical engineering knowledge and understanding the relationship between theory and practice. The students' improved performance in their examinations showed the positive effect of the project on their grades. However, more research would be required to draw concrete conclusions regarding the effect of projects on grades. In all three models, the percentage of students achieving more than 60% on project grades and the percentage of students passing the entire course were close to each other. This suggests that there is a relationship between learning due to projects, grades achieved by students and the passing percentage of the course. However, correlation between project work and grades was not established.

The students applied simple project management techniques. After team formation, they divided the work amongst team members. In the first quarter of the semester, most of the teams found a case for them to work on. The middle portion of the semester was used to gather information through classroom instructions and other resources. Students were intensely engaged in the project towards the end of the semester. This trend was observed in all models. This pointed to the fact that the students had a project management plan. In my research, 95% of the groups completed the project in all respects, showing their ability to complete the project. The data indicated that the CLPBL strategy helped the students to manage time and project. In the third model, students'responses indicated that the previous project experience had helped them to have better time and project management in the second project. This shows that successive PBL experiences helped the students to improve time and project management abilities. Activities such as report writing, technical presentations and question answer sessions created an opportunity to develop written and verbal communication skills. Although there was room for improvement in these abilities, the students at least began learning these skills and processes. It is concluded that the designed CLPBL environment was effective for promoting the achievement 7 out of 11 ABET learning outcomes.

8.1.2 Institutional perspective

For SITL, I was able to improve the current teaching-learning practice adopted for the *Theory of Machines- I* and *Applied Thermodynamics* courses. The dream of an institutional PBL model still remains distant. However, continuing efforts at course-level implementations in various departments of the institute could encourage further scaling. This research demonstrated the possibility of implementing PBL within the existing curriculum and institutional setting. This success could motivate others to research and design PBL models for their courses. During the process of this research, four staff members were involved in the supervision and evaluation of projects. These staff members received training on PBL practice and could help them to design models for their other courses. Thus, my research could serve as the representative model, which could be taken as a starting point for the further development of course-level models for various similar courses.

8.1.3 National perspective

In the literature review chapter, it was discussed that the Indian education system lacked practice in PBL. Modest research in the areas of PBL has shown that PBL is the under researched in India. This research can be added to the few PBL experiments that have been done in India. The CLPBL models developed in my research showed great possibilities for PBL implementation at the course-level without affecting the institutional and university routines. The research outcomes described above clearly indicate that PBL is a useful approach for improving the teaching-learning practices and skill level of under graduate students (engineers). These results indicated that PBL can fulfil the needs of Indian engineering education discussed in the first chapter. In India, private engineering institutes account for 90% of admission intake in engineering education. SITL is one such private institute. My research is a small dot compared to the country’s engineering education landscape. However, this dot can become central to forthcoming experiments in the locality.

8.1.4 International perspective

This research has an international perspective in the sense that I, as an Indian, visited Denmark to learn the PBL philosophy. Later, I came back to India and investigated PBL’s usefulness for an Indian institute. The models for SITL were designed by taking inspirations from international models, especially the Aalborg model. Internationally, researchers are investigating the role and influence of local culture on the PBL practice. The literature suggests that PBL originated in a Western culture, where academic practices are different than those in India. India being a different culture, where traditional instruction-based pedagogy is practiced, the application of PBL in this part of the world would produce a magnificent story of change for the international literature. Furthermore, such research would initiate the process of spreading the PBL philosophy to this part of the world. . Internationally, there is a growing trend towards outcome-based education. In this research, ABET learning outcomes were used to design the project. In this research, PBL is shown as a useful approach for achieving learning outcomes. There are various challenges associated with the assessment of these learning outcomes. The survey instrument and rubrics developed for teamwork assessment in my research could be further developed to contribute to the assessment of learning outcomes. DBR as a methodology for educational research is still in the developing stages. My research would provide an exceptional example of the use of DBR in PBL and engineering education

8.2 Directions for future research

Although course-level implementation provides an effective way to begin experimentation in an institute, firm conclusions cannot be drawn from a single cycle. For concrete conclusions, more research is required through successive implementations of three to four cycles. Similar CLPBL designs could be implemented in other courses at SITL, in the mechanical engineering department and in other departments of the institute. This would require the design of training programmes for staff development. In the institute, grades are valued and considered an important parameter for evaluating students. The effect of PBL implementation on grades could be investigated further. Furthermore, efforts could be made to establish correlation between project grades and course grades of the students. The designed PBL models, along with the instruments, could be tested in other affiliated institutes of UoP to investigate its effectiveness. Thus, these designed models could be tested for transferability.

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Appendices

Appendix A_1 Skill gaps of Graduate Engineers

Table 1: Importance Level by Three Factor Skills

Core Employability	Mean	Professional Skills	Mean	Communication Skills	Mean
Integrity	4.48	Use of modern tools	4.08	Communication in English	4.26
Reliability	4.42	Apply Math/Sci/Engg know.	4.07	Written Communication	4.07
Teamwork	4.41	Creativity	4.07	Reading	4.04
Willingness to learn	4.40	Problem solving	3.93	Technical Skills	4.02
Entrepreneurship	4.35	System design to needs	3.84	Experiments/data analysis	4.01
Self-discipline	4.26	Contemporary issues	3.83	Verbal Communication	4.00
Self-motivated	4.22	Customer Service	3.51	Basic computer	3.95
Flexibility	4.15			Advanced computer	3.71
Understand/take directions	4.14				
Empathy	3.92				
Average	**4.27**	**Average**	**3.91**	**Average**	**4.01**

Table 2: Satisfaction Level by Three Factors

Core Employability	Mean	Professional Skills	Mean	Communication Skills	Mean
Integrity	3.50	Apply Math/Sci/Engg know.	3.23	Communication in English	3.95
Teamwork	3.46	Use of modern tools	3.15	Basic computer	3.34
Entrepreneurship	3.44	Creativity	3.08	Written Communication	3.22
Self-discipline	3.37	System design to needs	2.95	Verbal Communication	3.17
Willingness to learn	3.37	Contemporary issues	2.95	Technical Skills	3.13
Flexibility	3.29	Problem solving	2.87	Reading	3.08
Reliability	3.20	Customer Service	2.65	Advanced computer	3.03
Empathy	3.15			Experiments/data analysis	3.02
Self-motivated	3.12				
Understand/take directions	3.12				
Average	**3.30**	**Average**	**2.98**	**Average**	**3.24**

Table 3: Skills Gaps by Three Factor Skills

Core Employability	Mean	Professional Skills	Mean	Communication Skills	Mean
Reliability	1.22	Problem solving	1.06	Experiments/data analysis	0.99
Self-motivated	1.10	Creativity	0.99	Reading	0.96
Willingness to learn	1.03	Use of modern tools	0.93	Technical Skills	0.89
Understand/take directions	1.03	System design to needs	0.89	Written Communication	0.85
Integrity	0.98	Contemporary issues	0.88	Verbal Communication	0.83
Teamwork	0.95	Apply Math/Sci/Engg know.	0.85	Advanced computer	0.68
Entrepreneurship	0.91	Customer Service	0.85	Basic computer	0.61
Self-discipline	0.90			Communication in English	0.31
Flexibility	0.86				
Empathy	0.77				
Average	**0.98**	**Average**	**0.92**	**Average**	**0.77**

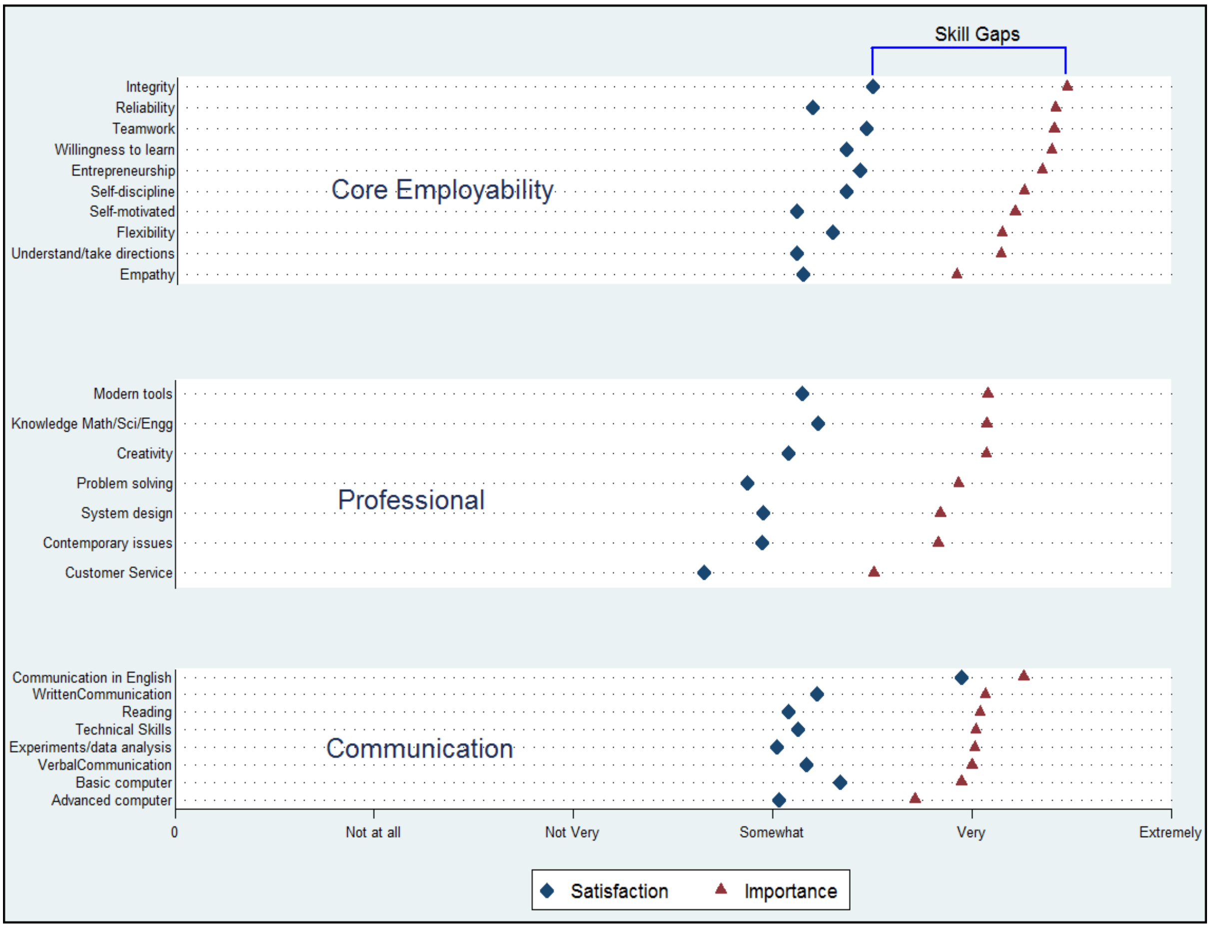

Figure A.1 Graphical representation of the skill gap of Indian graduate engineers

Appendix A_2 Syllabus of Theory of Machines-1

202047 Theory of Machines - I

Teaching Scheme:	**Examination Scheme:**
Lectures: 4Hrs/week	**Theory: 100 Marks (4Hrs)**
Pract: 2Hrs/week	**TW: 50 Marks**

UNIT 1 **(10 Hrs.)**

Fundamentals of Kinematics and Mechanisms

Kinematic link, Types of links, Kinematic pair, Types of constrained motions, Types of Kinematic pairs, Kinematic chain, Types of joints, Mechanism, Machine, Degree of freedom (Mobility), Kutzbach criterion, Grubler’s criterion. Four bar chain and its inversions, Grashoff’s law, Slider crank chain and its inversions, Double slider crank chain and its inversions. Pantograph, Swinging/Rocking mechanisms, Geneva mechanism. Equivalent linkage of mechanisms.Steering gear mechanisms : Condition for correct steering, Davis steering gear mechanism, Ackermann steering gear mechanism.

UNIT 2 **(8Hrs.)**

Velocity and Acceleration Analysis of Simple Mechanisms : Graphical Methods-I

Relative velocity method : Relative velocity of a point on a link, Angular velocity of a link, Sliding velocity, Velocity polygons for simple mechanisms. Relative acceleration method : Relative acceleration of a point on a link, Angular acceleration of a link, Acceleration polygons for simple mechanisms.

Instantaneous center of rotation (ICR) method: Definition of ICR, Types of ICRs, Methods of locating ICRs, Kennedy’s Theorem, Body and space centrode

UNIT 3 **(8Hrs.)**

Velocity and Acceleration Analysis of Mechanisms: Graphical Methods-II

Velocity and acceleration diagrams for the mechanisms involving Coriolis component ofAcceleration. Klein’s construction.

UNIT 4 **(8Hrs.)**

Kinematic Analysis of Mechanisms: Analytical Methods

Analytical method for displacement, velocity and acceleration analysis of slider crank mechanism, Position analysis of links with vector and complex algebra methods, Loop closure equation, Chace solution, Velocity and acceleration analysis of four bar and slider crank mechanisms using vector and complex algebra methods, Hooke’s joint, Double Hooke’s joint.

UNIT 5 **(7 Hrs.)**

Introduction to Synthesis of Linkages

Steps in synthesis process: Type, number and dimensional synthesis.

Tasks of Kinematic synthesis: Path, function and motion generation (Body guidance)

Precision Positions, Chebychev spacing, Mechanical and structural errors, Branch defect and order defect, Crank Rocker mechanisms.

Graphical synthesis: Two and three position synthesis using relative pole method and inversion method for single slider crank and four bar mechanism, three position motion synthesis of four bar Mechanism.

Analytical synthesis: Derivation of Freudenstein’s equation, three position function generation using Freudenstein’s equation.

UNIT 6 **(7 Hrs.)**

Static and Dynamic Force Analysis

Theory and analysis of Compound Pendulum, Concept of equivalent length of simple pendulum, bifilar suspension, Trifilar suspension

Dynamics of reciprocating engines: Two mass statically and dynamically equivalent system, correction couple, static and dynamic force analysis of reciprocating engine mechanism (analytical method only), Crank shaft torque, Introduction to T-θ diagram.

Term Work

The term work shall consist of:

[A] Laboratory Experiments:

Any four of the following experiments shall be performed and record to be submitted in the form of journal.

1. Demonstration and explanation of configuration diagram of working models based on four bar chain, single slider crank mechanism, and double slider crank mechanism for various link positions (any two models).

2. Identifying different mechanisms used for motion conversion in sewing machine.

3. To determine the mass moment of inertia of a connecting rod using a compound pendulum method.

4. To determine the mass moment of inertia of a flat bar using bifilar suspension method.

5. To determine the mass moment of inertia of a flywheel/gear/circular disc using trifilar suspension method.

6. To determine the angular displacements of input and output shafts of single Hooke's joint for different shaft angles and verification of the results using computer programme.

[B] Drawing Assignments (4 sheets of ½ imperial size) :

1. To study and draw (any four) mechanisms for practical applications such as: mechanical grippers in robot, lifting platform, foot pump, toggle clamp, folding chair etc.; straight line mechanisms such as : Peaucellier Mechanism, Scott Russell Mechanism, Grasshopper Mechanism etc., for various link positions.

2. Two problems on velocity and acceleration analysis using Graphical methods i.e., polygons or ICR (Based on Unit 2).

3. Two problems on velocity and acceleration analysis using Graphical methods i.e., polygons involving Coriolis component or Klein's construction (Based on Unit 3).

4. Two problems based on graphical three position function generation, using either relative pole method or inversion method.

[C] Assignments:

The following two assignments shall be completed and record to be submitted in the form of journal.

1. Computer programming for velocity and acceleration analysis of slider cranks mechanism.
2. One problem on velocity and acceleration analysis using:
   a) Vector algebra,
   b) Complex algebra, and comparison of results

Text Books:

1. Rattan S. S., "Theory of Machines", Tata McGraw Hill.
2. Ballaney P. L., "Theory of Machines", Khanna Publishers, Delhi.

Reference Books:

1. Thomas Bevan, "Theory of Machines", CBS Publishers & Distributors, Delhi
2. Shigley J.E. and Uicker J.J., "Theory of Machines and Mechanisms", McGraw Hill, Inc
3. Myszka D. H., "Machines and Mechanisms - Applied Kinematic Analysis", Prentice – Hall of India
4. Ghosh Amitabh and Malik A.K., "Theory of Machines and Mechanisms", East-West Press
5. Groover M.P., "Industrial Robotics", McGraw Hill International.
6. Hall A.S., "Kinematics and Linkages Design", Prentice-Hall.
7. Hartenberg and Denavit, "Kinematic Analysis and Synthesis of Mechanisms".
8. Erdman, A. G. & Sandor, G.N., "Mechanism design, Analysis and synthesis",Vol 1, Prentice –Hall of India.
9. Erdman, A. G. & Sandor, G.N., "Advance Mechanism design", Vol 2, Prentice –Hall of India.
10. Wilson, C E Sandler, J P "Kinematics and Dynamics of machinery", Pearson Education

Appendix A_3 Syllabus of Applied Thermodynamics

202041 Applied Thermodynamics

Teaching scheme:	Examination Scheme:
Lectures: 4 Hrs/week	Theory: 100marks
Practical: 2 Hrs/week	Term work: 25 marks
	Oral: 50 Marks

SECTION-I

Unit 1: **(8 Hrs)**

Laws of Thermodynamics

First Law of Thermodynamics, Second Law of Thermodynamics, Clausius statement and Kelvin-Plank statement, Equivalence of Kelvin-Plank statement and Clausius statementPerpectual Motion Machine I & II, Concept of Reversibility & reversible cycle.

Entropy Entropy as a property, Clausius inequality, principle of increase of Entropy

Unit 2: **(8 Hrs)**

Availability

Available and unavailable energy, concept of availability, availability of heat source at constant temperature and variable temperature **(Numerical)** Availability of non flow and steady flow systems, Helmholtz and Gibbs function, irreversibility and second law efficiency

Ideal Gas Properties and Processes

Ideal Gas definition, Gas Laws: Boyle's law, Charle's law, Avagadro's Law, Equation of State Specific Gas constant and Universal Gas constant Ideal gas processes- on P-V and T-S diagrams

Constant Pressure, Constant Volume, Isothermal, Adiabatic, Polytropic, Throttling Processes.

Calculations of heat transfer, work done, internal energy. Change in entropy, enthalpy **(Numerical)**

Unit 3: **(8 Hrs)**

Properties of Steam and Vapor Processes

Formation of steam, Phase changes, Properties of steam, Use of Steam Tables,

Study of P-V, T-S and Mollier diagram for steam, Dryness fraction and its determination, Study of steam calorimeters (Separating, Throttling and combined)

Non-flow and Steady flow vapour processes, Change of properties, Work and heat transfer.

Vapour Power Cycles

Carnot cycle, Rankine cycle, Comparision of Carnot cycle and Rankine cycle, Efficiency of Rankine cycle , Relative efficiency, Effect of superheat, boiler and condenser pressure on performance of Rankine cycle. Reheat & Regenerative cycle (no numerical, for reheat & regenerative)

SECTION-II

Unit 4: **(8Hrs)**

Fuels and Combustion

Types of fuels, Proximate and ultimate analysis of fuel, Combustion theory, Combustion Equations Theoretical, excess air and equivalence ratio.

Analysis of products of combustion Calorific value – HCV & LCV. Bomb and Boy's gas calorimeters (Numerical)

Unit 5: **(8Hrs)**

Air Compressors:

1) Reciprocating Air Compressor

Types of compressor valves, Single stage compressor – computation of work done, isothermal efficiency, effect of clearance volume, volumetric efficiency, Free air deliveryTheoretical and actual indicator diagram,

2) **Multistage compressors –**

Constructional details of multistage compressors, Need of multistage, Computation of work done, Volumetric efficiency, Condition for maximum efficiency, Inter cooling and after cooling (**numericals**)Theoretical and actual indicator diagram for multi stage compressors, Capacity control of compressors

3) Rotary Air Compressors: -

Classification, Difference between compressors and blowers, Working and constructional details of roots blower, Screw type and vane type compressors (Numerical)

Unit 6: (8Hrs)

1) Steam Generators: -

Classification, Constructional details of low pressure boilers, Features of high pressure (power) boilers, Location, Construction and working principle of boiler Boiler mountings and accessoriesIntroduction to IBR and non IBR boilers

2) Analysis of boilers – (numerical)

Equivalent evaporation, Boiler efficiency by direct and indirect method Energy balance,

Boiler draught (natural and artificial draught)

Text Books

1. P. K. Nag, Engineering Thermodynamics, Tata McGraw Hill Publications
2. R.K.Rajput, Engineering Thermodynamics EVSS Thermo Laxmi Publications
3. Rayner Joel, Engineering Thermodynamics ELBS Longman
4. V. P. Vasandani and D. S. Kumar Heat Engineering, Metropolitan book Company, New Delhi

List of Practicals

1. Determination of calorific value using gas calorimeter.
2. Determination of calorific value using Bomb calorimeter.
3. Flue gas analysis using Orsat apparatus or Gas analyser.
4. Trial on multi stage reciprocating air compressor.
5. Determination of dryness fraction of steam using Throttling Calorimeter or Separating and Throttling , Calorimeter.
6. Trial on boiler to determine boiler efficiency, equivalent evaporation and Energy balance.
7. Visit to any industry, which uses boiler and submission of detailed report.
8. Measurement of fuel properties such as Flash point, Pour point, Cloud Point.
9. Analysis of any thermal system using Analysis Software.

Note :

i) Sr. Number 5, 6 & 7 are compulsory Practicals.

ii) Total 8 Numbers of above listed Practicals to be performed.

Appendix A_4 Sample essays from Group No: 2 from CLPBL-1

Student-1

Sir in my group five members are there. It’s good to doing group or team work within practical time. All members are good & helpful. During sheet drawing when any problems comes we solve in teamwork or in group so any quires comes and not solving then all ask to finally sir and for project or mechanism we haven’t started yet.In team work we doing sheet or problems are nice as compared to indivisible study because any quires or problems are come to solve then u con share in our group & all group members are solving. In group or anyone who can know that problem answer that help to all group members but individually problems comes we can’t solve & it continue then teamwork or group work concept is nice. But sir i request u to continue that concept group work.

Student-2

Concept of group working is good, it helped me, but the group work will be successful when all come and work together.In our group everyone is doing individually. Only selected three members are doing, others are also doing but not in group.As we are having one girl member in our group so, we are not able to manage the time for doing our projects. We have not yet started our projects, become groups is not having time to work together. And my interaction with group is also less.

Student-3

Group work concept is an excellent innovation in our system. It works better when all members contribute. In our selected people work and due to which the progress is not upto the work. As you know due to which our group is late in checking the assignment. In our scenario selected people work together while other works individually. As observed from other groups which work together if all work together the efficiency does go up. As of the projects, the initial data has been collected but working on it has not started.In all its a great concept & learning is surely as easy work now.

Student-4

No problem faced working in groups. The entiredoubts are cleared as we work in group. The sheets are completed in time.Yet we have 5 members -4 boys and 1 girl, we have no issue of learning in a group. We contact with each other and we prepare good.

Student-5

Team work: the team has good members and we co-operate each other and difficulty is come we help other.Learning Gap: yet we have 5 members 4 boys and 1 girl, we have no case of hearing gap we concept with each other and we prepare good.Project: Our project is shutter mechanism yet we had not started but we soon start it is a team work. We can do better and we make good projects because individually has some error but group work is not having any error. Sheet working team: sheet working teams good we completed our sheet at on time and go for group checking.

Appendix A_5 An Interview protocol

1. Short Interview

Theme	Questions
Project work	1. What you think about this semester Project activity? 2. Do you feel the project given to you was challenging? 3. Did you experience any difficulty in this project activity? **4.** Do you find classroom instructions were useful for a project work? **5.** Do you recommend this activity for other courses also?
Teamwork	1. What is your comment about collaboration among the members of the team? 2. Was there any one who led the group? **3.** In future, would you like to retain the same team or would like to work with new team members? **4.** What was your contribution or a role in this project?
Learning	1. What did you learned due to this activity? 2. How this activity was helpful to you? **3.** Do you think this activity will be helpful to you to secure good grades in the course examination?

Long Interviews

Theme	Questions
Project work	1. As a second year engineering student, do you feel the project was challenging activity? 2. What motivated you to do this project work? 3. Do you feel compared to the first project, the second project was difficult? 4. How much time did you spent to complete the project? 5. In your opinion, ideally, how much time is required to complete the project activity? **6.** Which activity of the project did you enjoyed most? **7.** Do you recommend project activities for other or future courses?
Teamwork	1. What was your role in a project work? 2. How did you manage and decided the project work load among the team members? 3. What was the reaction from your teammates during teamwork? 4. Whether you found engagement of team members was sufficient in project work? 5. Why the students worked on the projects, when the deadlines are approaching? **6.** What kind of role was given to female candidates and how did they respond to it?
Learning	**1.** What did you learned in these projects? **2.** What difficulties are experienced by you in these projects?
Role of teachers and supervisors	1. Do you feel in what way classroom instructions were useful in a project work? 2. Did you get enough help or guidance from your supervisor? 3. Why do you feel confident to appear & secure good grades in the course examination?

Appendix A_6 Sample of short Interview

Interviewer	What you think about PBL activity?
Student 1	As it is being the group activity, it is really helpful because if we see in military area they have given a task they have given they have to perform in one unity group. It is not like that If he knows something which I don't know it can be shared and can be conveyed to all.
Student 2	We can share our knowledge it is beneficial for our knowledge.
Student 3	It is useful and we can learn many things from each other.
Interviewer	In what sense it was useful?
Student 5	Group work helps as we can in future also. His thinking is different; he can prepare presentation in his way. I think different way, so resultant is good.
Student 3	The data collection extend is also large and we can get better knowledge.
Student 1	In less time we cover great job. Suppose we have initially divided the work, suppose he will give the resources, then one will be working on report, then another will be working on presentation. Then all this combined together, finally we will finalise and share with each other.
Student 3	So it helped us.
Student 4	Instead of individual work we can get better output.
Student 2	Also, it will be helpful for the leadership qualities. The whole group is behind you, and you are having responsibility of leading your group.
Student 4	We were putting diagram on the slide but one was saying it should not put diagram on that slide and one was saying we should put. So we discussed with each other should we put that diagram there or not. So at last we put that diagram there. This is an advantage.
Interviewer	Who was leader of your group?
Student 1	We all
Student 2	all
Student 3	Sir, we all
Student 5	We all collected the data from various sources and involved in a presentation.
Interviewer	What you think about collaboration is this activity?
Student 1	It is quite good.
Student 2	good
Student 3	good
Student 5	Group activity can increase our speed and even it can decrease individual working speed. But for us it increased working speed.
Interviewer	Do you recommend this activity in next semester?
Student 1	Yes sir (Agrees with student 3.)
Student 2	Shook head
Student 3	Says yes sir and adds, Only thing is that this activity should be started at the start of the semester.
Student 4	Shook head
Student 5	Yes
Interviewer	Thank you very much.

Appendix A_7 The Survey Instrument

Your name:

Permanent address:

Mobile no- **e-mail-**

Project Title: Engineering analysis of __________________________

Total no of team members: Male:_____Female:______________

a. What was a source and place of analysis of an engineering application?

b. Where did you conduct group meetings?

c. What was a frequency of team meetings in a week?____________________________________

***Please tick mark in appropriate column for the following questions**

Group A Students' responses on various elements of the CLPBL model

Question no.	Question	Strongly Disagree	Disagree	No opinion	Agree	Strongly Agree
AQ_1	Assigned project work was challenging					
AQ_2	The project was well integrated into the curriculum					
AQ_3	The project was relevant to my profession					
AQ_4	Assigned project was enjoyable					
AQ_5	I feel the time provided for the project was sufficient					
AQ_6	I found classroom instructions helpful					
AQ_7	I recommend to apply PBL to other courses					

Group B Students' perceptions about their learning in the CLPBL model

Question no.	Question	Strongly Disagree	Disagree	No opinion	Agree	Strongly Agree
BQ_1	The project motivated me to learn					
BQ_2	This project stimulated to learn the material outside the class					

BQ$_3$	I took responsibility of my own learning					
BQ$_4$	I become self-directed learner					
BQ$_5$	The project engaged me throughout the semester					
BQ$_6$	I learned through the collaborative and co-operative approaches					
BQ$_7$	It helped me to increase my understanding of the subject					
BQ$_8$	It laid the strong foundation of the subject					
BQ$_9$	I feel confident to appear in the examination					
BQ$_{10}$	I expect improvements in my grades					
BQ$_{11}$	Overall I am satisfied of my learning					

Group C Students' perception on achievement of learning outcomes

Question no.	Question	Strongly Disagree	Disagree	No opinion	Agree	Strongly Agree
CQ$_1$	I learned to think deeply					
CQ$_2$	It helped me to improve my ability to work in a team					
CQ$_3$	I learned about the problem solving process					
CQ$_4$	I learned how to write the report					
CQ$_5$	I learned critical presentation skills due to the project work					
CQ$_6$	I learned to asses and manage variety of resources					
CQ$_7$	I applied project management principles					
CQ$_8$	Assigned project helped me to improve my skills					

Group D Students' experiences about teamwork

Question no	Question	Strongly Disagree	Disagree	No opinion	Agree	Strongly Agree
DQ_1	I feel group work is a challenging task					
DQ_2	Teamwork was critical for completion of this project					
DQ_3	My teammates helped me to understand the concepts					
DQ_4	I learned to take different perspectives and opinions					
DQ_5	I learned how to lead the project through teamwork					
DQ_6	I feel we could have done better in teamwork					
DQ_7	I am satisfied with my group's performance in this semester					
DQ_8	I am looking forward to work on more complex projects					

d. What difficulties did you experienced in this project work?

e. What could be done to improve the project work and group setting for the next semester? Please suggest the improvements-

Dear participant,

We would like to acknowledge your commitment towards the participation in the case study and would like to thank you for contribution and valued opinions. Also, we would like to thank you for being enthusiastic and motivated to contribute in this research. Thank you very much for sparing your time. In future we will be obliged to keep association with you.

Mr. Vikas V Shinde

Mobile no-9762051751

e-mail-vikashinde@yahoo.co.in

Appendix A_8 Open ended questions

Dear Participant, Date: 25/03/2013

You are requested to share your experiences related to recent ***Project work of the course theory of machines -1*** by addressing following questions.

Name: ____Div:______________

1. Please write your comparison of last semester and this semester experience of working on Project?

2. Do you feel the project was relevant to course content and it will be helpful to you in final examination? Explain

3. Your comments on "***the role of team member was critical or important in the current project work***?

4. List out the three most challenging activities done by and your group to complete the project
    1.
    2.
    3.

5. List out three most important learning outcomes of this project for you?
    1.
    2.
    3.

6. Any other relevant experience you would like to share with us.

Thank you very much for sparing time to answer these questions. We would be obliged to keep an association with you.

Please return your responses till 1st April 2013.

VIKAS V SHINDE

Mobile No- +919762051751

e-mail- vikas@plan.aau.dk

Appendix A_9 The sample ANOVA result table

Question 1: Assigned project work was challenging

Ho: There is no difference between responses of two groups for this question

Ha: There is significant difference between responses of two groups for this question

Sample ANOVA Table for AQ1

	D.f	**Sum of squares**	**Mean sum of squares**	**F statistic**	**Critical value**
k-1	1	1.59	1.59	3.32	2.77
nk-k	180	86.18	0.48		
nk-1	181				

Since, the calculated value of F statistic is greater than the critical value we reject null hypothesis. Then, it is conclude that there exists a significant difference between responses of two samples. In other words, project in the PBL model 3 was challenging compared to PBL model 2.On similar lines ANOVA table for each question is prepared. Important results are put into the table for the comparison purpose. Following table shows final results for all questions.

Final ANOVA Results Table

Group A Students' responses on various elements of the CLPBL model

Question no.	**Question**	**F**	**Fα**	**Does Significant difference exist**
AQ_1	Assigned project work was challenging	3.32	2.77	Yes
AQ_2	The project was well integrated into the curriculum	0.86	2.77	No
AQ_3	The project was relevant to my profession	1.66	2.77	No
AQ_4	Assigned project was enjoyable	0.144	2.77	No
AQ_5	I feel the time provided for the project was sufficient	3.31	2.77	Yes
AQ_6	I found classroom instructions helpful	0.821	2.77	No
AQ_7	I recommend to apply PBL to other courses	0.41	2.77	No

Group B Students’ perceptions about their learning in the CLPBL model

Question no.	Question	F	Fα	Does Significant difference exist
BQ_1	The project motivated me to learn	0.009	2.77	No
BQ_2	This project stimulated to learn the material outside the class	1.61	2.77	No
BQ_3	I took responsibility of my own learning	0.502	2.77	No
BQ_4	I become self-directed learner	1.424	2.77	No
BQ_5	The project engaged me throughout the semester	11.2	2.77	Yes
BQ_6	I learned through the collaborative and co-operative approaches	2.33	2.77	No
BQ_7	It helped me to increase my understanding of the subject	1.2	2.77	No
BQ_8	It laid the strong foundation of the subject	8.78	2.77	Yes
BQ_9	I feel confident to appear in the examination	1.84	2.77	No
BQ_{10}	I expect improvements in my grades	0.173	2.77	No
BQ_{11}	Overall I am satisfied of my learning	0.013	2.77	No

Group C Students’ perception on achievement of learning outcomes

Question no.	Question	F	Fα	Does Significant difference exist
CQ_1	I learned to think deeply	0.97	2.77	No
CQ_2	It helped me to improve my ability to work in a team	1.21	2.77	No
CQ_3	I learned about the problem solving process	18.3	2.77	Yes
CQ_4	I learned how to write the report	0.064	2.77	No
CQ_5	I learned critical presentation skills due to the project work	9.15	2.77	Yes

CQ_6	I learned to asses and manage variety of resources	0.24	2.77	No
CQ_7	I applied project management principles	1.544	2.77	No
CQ_8	Assigned project helped me to improve my skills	0.11	2.77	No

Group D Students' experiences about teamwork

Question no	Question	F	Fα	Does Significant difference exist
DQ_1	I feel group work is a challenging task	0.33	2.77	No
DQ_2	Teamwork was critical for completion of this project	0.85	2.77	No
DQ_3	My teammates helped me to understand the concepts	3.14	2.77	Yes
DQ_4	I learned to take different perspectives and opinions	0.059	2.77	No
DQ_5	I learned how to lead the project through teamwork	0.204	2.77	No
DQ_6	I feel we could have done better in teamwork	0.421	2.77	No
DQ_7	I am satisfied with my group's performance in this semester	3.36	2.77	Yes
DQ_8	I am looking forward to work on more complex projects	1.96	2.77	No

Appendix A_{10} Summary of overall data

Model	Cohort	Groups	Essays	Interviews	Reports	Open ended questions	Survey	Project grades	Course grades
CLPBL-1	97	19	82	16	18	86	86	97	94
CLPBL-2	126	33	105	28	32	106	106	126	119
CLPBL-3	152	30	-	2	30	133+117 = 250	133	152	149
	375	82	187	46	80	442	325	375	362

Appendix A_{11} List of courses attended

Name of the Course	Place/ Organizer	ECTS
Project Courses		
PBL and supervisory skills	AAU/Prof. Lars Peter Jensen	2
PBL & Engineering education research- from research questions to research methodologies & publications	AAU/ Prof. Anette Kolmos Prof. Erik de Graff	4
Introduction to qualitative research in technology, science and education	AAU/Prof. Tim Richardson, AAU/Prof. Paola Valero	3
Study Circle Meetings	AAU/ Prof. Anette Kolmos	2
	Sub-total	**11**
Professional communication	AAU/Prof. Anette Kolmos	2.5
Modeling the Dynamics of wind generating systems	AAU/Prof. Ewen Ritchie & Krisztina Leban	4
Writing & Reviewing Scientific Papers	AAU/Prof. Jakob Stoustrup	3.75
Preparation of research plan for PhDs	AAU/Prof. Frede Blaabjerg	1
Bayesian Statistics, Simulation and Software With A View To Application Examples	AAU/Prof. Søren L. Buhl	3
Theories of science	AAU/Prof. Ole Ravn Christensen	2.5
	Sub-total	**16.75**
Conference Papers		
PBL in engineering education in India: Prospects & Challenges	Chennai, India	2
Students' experience of Aalborg PBL model	SEFI, Lisbon	2
Relevance of PBL to Indian engineering education	Coventry University, UK.	2
PhD Conference	AAU/ Prof. Jette Hoggard	1
	Sub-total	**7**
	Total ECTS	**34.75**

Appendix A_{12} List of lectures and workshops conducted

Sr. No.	Topic	Date	Speakers	Organization	No of attendees
1.	Project based learning	18th June 2010	Mr.Vikas Shinde	Walchand Institute of Technology, Solapur	36
2.	Workshop on PBL	7-9th March 2011	Prof. Anette Kolmos Prof. Erik De Graff Prof.Clauss Monrald Splid Ms.Chungfang Zou Mr.Vikas Shinde	STES Campus, Lonavala	168
3.	Cultural issues in implementing PBL	14th Oct 2011	Mr.Vikas Shinde	Aalborg University, Denmark	13
4.	PBL in Indian engineering education	27th July 2012	Mr.Vikas Shinde	SKNSCOE, Pandharpur	63
5.	Role of PBL to address issues of Indian engineering education	07th and 8th August 2012	Mr.Vikas Shinde	Sinhgad Institute of Technology, Lonavala	26
6.	Implementing PBL in Indian engineering education	Dec 2012	Mr.Vikas Shinde	Amrutwahini College of Engineering, Sangamner	41
7.	One day workshop on PBL in Management Education	January 2012	Mr.Vikas Shinde	Bharati Vidyapeeth Institute of Management Studies, Mumbai	14
8.	One day international workshop on Project and Problem based learning	16th March 2013	Prof. Anette Kolmos Prof. Thomas Ryberg Mr.Vikas Shinde	Sandip Foundation, Nashik	105

Appendix A_{13} List of Publications

Vikas V. Shinde, Anette Kolmos, Problem Based Learning in Indian Engineering Education: Drivers and Challenge, Proceedings of Wireless VITAE 2011, Chennai, India, 2nd International Conference on Wireless Communication, Vehicular Technology, Information & Theory and Aerospace & Electronic System Technology, 28-02-11 - 03-03-11.http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5940816

Vikas V. Shinde, Anette Kolmos, Students' experience of Aalborg PBL Model: A case study, European society for engineering education, SEFI annual international conference, Lisbon, Portugal *WEE2011*, September 27-30, 2011. http://www.sefi.be/wp-content/papers2011/T7/43.pdf

Vikas V. Shinde, Relevance of the problem and project based learning (PBL) to The Indian engineering education 3rd International Research Symposium on PBL 2011, 28-29 November 2011.http://vbn.aau.dk/files/57931848/PBL_across_the_disciplines_research_into_the_best_practice.pdf

Vikas V. Shinde, Designing theory of machines and mechanism course on project based learning (PBL) approach, 4th International Research Symposium on PBL 2013, Malaysia, 2-4 July 2013.

Other Published papers

Shinde V., Inamdar S., (2013) Problem Based Learning (PBL) for Engineering Education in India: Need and Recommendations, Wireless Personal Communications: Volume 69, Issue 3 (2013), Page 1097-1105

Prarthana Coffin, **Vikas Shinde** and Mohamad Termizi Borhan, How the preparation phase of DBR influences the design process of PBL curriculum, International Consortium for Educational Development, ICED2012, Bangkok, Thailand, 22 – 25 July 2012.

Prarthana Coffin, **Vikas Shinde** and Mohamad Termizi Borhan, Shared experience on DBR and influences the design process of PBL curriculum, submitted **for publication in European** Journal of engineering education.

Problem Based Learning in Indian Engineering Education: Drivers and Challenges.

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Abstract— ***PBL as an education model in engineering education is successfully implemented worldwide. Also, since past few years the concept of PBL is progressing well in India. Main focus of this paper is to assess drivers for progress and challenges of PBL implementation for Indian engineering education based on past and ongoing research. Although, PBL has been accepted and successfully implemented at many places in a country, more research and sustainable efforts are required to make it acceptable and deep rooted in engineering education. It is concluded that PBL has a major role to play to raise the quality of engineering education in India considering positive results of PBL and recent developments in the educational sector.***

Keywords- PBL, Drivers, Challenges, Implementation, Education.

I. INTRODUCTION

Engineers play a major role in the economy of any country. They are expected to work in diverse areas and complex situations in industries, defense, civil, education and many other fields. Engineering Profession demands a range of skills from professional to personal, ethical to societal. Although, profession became much demanding today, it did not hinder the demand of qualified and employable engineers in India. To cater this demand, more engineering educational systems set up in India that resulted in an increase in the engineering graduates passing out every year but quality of engineers became questionable. The engineering education is a very complex system and the challenge before it is to educate and train students in such a way that they will become skilled, competent and employable engineer.

In India, education is teacher centric and instruction based to deliver content. Students in India are exposed to various curriculum gaps such as lack of interactions with stakeholder; syllabi not at par with industry needs, less focus on skill development etc. Also, quality of education, teaching and teacher related issues are raised by students from time to time. These shortcomings in the education system have resulted in unemployable technical human resource in India. Hence, there is an urgent need to focus on learner centric method which helps the learner to acquire knowledge and improve skills to make them employable. Considering the success of the problem and project based learning (PBL) as an educational model in the field of higher education worldwide it is felt that PBL will fulfill the need of Indian engineering system.

II. LITERATURE SURVEY

A. *International status in engineering education*

Today, PBL has been accepted and implemented as an educational model for almost all the streams and levels of education. Worldwide there exists many PBL models practiced in different ways. These models vary depending on local culture, history of education and several other aspects pertaining to local conditions The first universities to develop and implement the PBL curriculum was McMasters University, Canada in 1968 for medicine courses and later in Denmark, a problem based and project organized model was implemented at Aalborg University in 1974 [1]. Studies indicated many diverse issues such as curriculum content, skills and competencies, role of academic and supporting staff etc. It is also felt that there is a need to conduct cross institutional studies at national and international level [2]. Research results from the past seemed to be inconclusive on the effectiveness of PBL. For perfect conclusions on the effectiveness, more research in engineering is required. Also, for successful integration more research is necessary with regards to barriers, drivers and challenges in the organizational change of PBL [3].

Victoria University (VU), Australia introduced PBL into engineering curricula for different courses in 2006. It suggests that PBL approach cannot be based on definitive educational theories. There are many multivariate models that satisfy to what is defined to be PBL pedagogy. Implementation of PBL to engineering curriculum needs to be placed in a local context and must be developed with careful considerations of social, economic, ethnic diversity of the students and the university academic culture [4]. In the year 2004-2005 University Technology, Malaysia (UTM) has introduced the PBL for a Process Control course. Based on the survey of students, PBL was found to be effective in developing and enhancing generic skills in students [5]. 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 [6]. 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 [7]. The methodologies used for the study of PBL range from conceptual study to empirical study, quantitative and qualitative studies, small scale and large scale level etc. As small scale studies provide details, large scale studies aims at the representativeness. It is difficult to draw the conclusions, as these studies are the outcome of diverse practices and methodologies. Results of studies confirm that there is a significant increase in the skills in PBL curricula and it is expected that more skilled engineer will have better employability. Apart from above listed there are many models implemented worldwide; we have listed only few of them.

B. PBL Status in India

PBL workshop series for Middle School Teachers of humanities science is regularly conducted by Homi Bhabha Centre for Science Education, Mumbai. Responses through these seminars suggested that major hurdles for implementing PBL in Indian schools include large class size, lack of teaching-learning resources and resistance to adopt new approaches. An important hurdle is a lack of guidance to teachers in conducting PBL research. [8]. Effectiveness of PBL Instructions on knowledge and skills of students of the undergraduate program in Electronics & Communication Engineering at Chitkara Institute of Engineering and Technology, Punjab was assessed in three subjects, over a period of four semesters. Mantry et al compared Traditional pedagogy with PBL. She designed open ended Technical Problems (TPs) to achieve Learning Objectives. Scope of TPs was designed such that the students could achieve all the Technical Nodes while attempting to solve them. Students were informed about PBL and evaluation strategies before implementation. Students achieved better scores in Knowledge and Skill tests, showed better attitudes towards learning and utilizing the class time more effectively when taught in PBL environment [9]. At the end of semester feedback of students was taken for a particular course and she found that students supported PBL. Also, presentation and teamwork skills were also largely improved in the PBL class [10].

In another case of PBL studies, the effect of the project on the engineering education is emphasized under the concept of Robotic Competition. The Manvendra et al experiences over a period of six years with engineering students of the Indian Institute of Technology (IIT) Delhi have realized the significance, impact and consequence of such competition. Authors realized that the use of project helps to understand aspects of engineering product development along with techniques essential for proper coordination of the large team of students and project management [11]. Intel India, offers a course Intel Teach and Learn Program for teachers and learners for their professional development and acquiring essential skills such as problem solving, critical thinking, and collaboration. Intel Teach courses promote student-centered approaches and help teachers transform instruction to engage students for learning, creativity, and communication, with appropriate use of technology. Intel India also works closely with 35 institutes for research and curriculum development [12].

In year 2007 American Society for Engineering Education (ASEE), along with academic and business leaders from leading US and Indian universities have launched an initiative Indo-US Collaboration for Engineering Education (IUCEE). The goal of the IUCEE is to improve the quality engineering graduates in the US and in India to make them globally competitive. IUCEE also, focus on increasing the number of engineering faculty to collaborate on research and teaching. Research, Curriculum, Delivery and Quality are the areas in education where IUCEE has emphasis. [13]. Chattisgarh Swami Vivekanand Technical University, Bhilai has also established PBL learning centre and is studying PBL implementation issues in the curriculum in a broader sense. The university has started PBL in Bachelor degree courses of engineering and technology since 2008. Poornima group of Education, Rajastan also has an autonomous PBL centre which organizes seminars and workshops related to PBL. They have their educational model which works on a well designed knowledge wheel. Apart from above listed resources related to the engineering, many studies of PBL and its implementation in Medical and language curricula can be found in literature [14]. So far the study of PBL has been limited to case studies. This literature survey reveals that although many initiatives are taken but not concentrated efforts are being carried out to evolve a structured and scalable change in the pedagogy or to implement it in engineering education.

III. DRIVERS

PBL status in India becomes a major driver because educators started to recognize importance of it. Also, there is a huge scope for experimentation and implementation. Based on the author’s experience and documentary analysis important factors which support the need of PBL implementation in India are discussed.

1) *Awareness of global best practices:* Due to staff and student mobility and exchange programs, knowledge sharing platforms, private-public partnerships Indian population became aware of global best practices in education. many educational institutes adopted PBL due to awareness. More they become aware more are the chances that PBL will progress. Planned workshops and conferences will provide necessary platforms to increase the awareness.

2) *Quality of education and student-teacher related issues:*Survey indicates that 28 % students in India are not satisfied with the quality of education and 37 % says they are not satisfied with faculty and pedagogy related issues [15]. The current education system and pedagogical methods followed in India do not match to the expectations of the stakeholder. It is teacher centric, strongly relies on traditional pedagogy. There is a need to innovate and experiment to make learning more meaningful otherwise students will focus only on scoring marks rather than learning. Due to this, there is a demand-supply mismatch between supply of employable engineer and demand for it. Also, the gap between learning through the educational system and employer’s expectation from employees is widened. The education system needs to respond and adapt to the changing demands as per the new technology and industry expectations. Engineering educators need to be more conversant with new and existing practices

and should also incorporate innovation and improvements. Hence there is an urgent need to understand the current trends in education. Also, there is a need to shift to the learner centric pedagogy to motivate the students towards learning and to make them employable. It is expected that knowledge about PBL will motivate them to adopt innovative approaches and help them to change the educational environment.

3) *Student Population:*Although India currently boasts on one of the world's largest most qualified pools of scientific and engineering manpower, it has been forecasted that current capacity is not sufficient to cater its domestic needs. Prospective student's population in 2011-12 will be 1.5 million and expected to increase up to 10 million in 2020 [16]. Indian engineering student community though very large has never experienced PBL in a structured manner. If, India has to fulfill its forecasted demands for skilled manpower of 550 million [17], it has to focus on learner centric methods. This will ensure they will acquire knowledge and skills to become globally competent.

*4) Government initiatives and support:*Role of education in nation building is felt by the government, industries and many private bodies. Country is experiencing sweet change and reforms in the field of education. Government of India expects a wide and effective use of the ICT as a tool in education through the National Mission on Education through ICT. Under this Mission**,** research in critical areas relating to imparting of education and connectivity for integrating knowledge with the advancements in other countries is to be attempted. The mission focuses on capacity building efforts of educational institutions without compromising the quality of education, knowledge empowerment of the people and promoting new, upcoming multi-disciplinary fields of knowledge [18]. To make the education more meaningful and relevant to life experiences PBL method was implemented by Gujarat Council of Educational Research and Training (GCERT), Gandhinagar. This initiative is based on the Project work which develops their skills of observation, sensitivity and curiosity. Learning is achieved by active participation in projects. Project work was made compulsory for to teachers who are trained for 20 days on special training module [19].

Ministry of Human Resource and Development (MHRD), India has approved nine national projects related to skill development and employability. The Union Finance Minister also emphasized the need to streamline content/curriculum development, setting up of competency standards. He advised to develop the benchmarks and thresholds, in line with the international best practices. The key outcome of these efforts is related to the employability of the trained individuals. The Central Government is also implementing the Technical Education Quality Improvement Program (TEQIP) assisted by the World Bank and Indian National Digital Library for Science & Technology (INDEST) program to improve the quality of technical education and research [20].

Number of technological Intellectual Property Rights (IPRs) and inclination towards research indicates quality of engineering education. The master output in India has shown cumulative annual growth rate (CAGR) of 11.6 %.and since 2001 CAGR of 7.5%. This suggests that the students are not inclined to per sue higher education. The annual number of engineering Ph.D. percentage present value is less than 1% of the engineering graduates which is alarmingly low hints a lack of inclination towards research [21]. Several students do not take up research due to the lack of financial support. Also, Research is often not a viable option for several engineers. The gap between attractive pay packages and scholarship is one of the main reasons. To promote research in basic sciences, the Ministry of Human Resource Development (MHRD) has increased the scholarship amount of aided technical institutions [22]. It will help to attract good students to research and to reward them. Many steps towards educational reforms and innovation in education are taken and encouraged by governments. It is hoped that concept of PBL will have a definite role to achieve and to get the desired outcome of these initiatives.

*5) Growth in Unemployability rate and demand of skilled manpower:*The employment rate is defined as the number of people currently employed divided by the population of working age who seeks employment. The rate of unemployment in India is rising alarmingly. The unemployment rate in India is increased to 8 percent in 2007 from 7.3 per cent in 1999-2000. Current unemployment rate in india is 10.7 [23]. This was because the working age population grew faster than the total population. Many shortcomings in the education system have resulted in unemployable technical human resource in India. According to the survey, jointly carried out by the Federation of Indian Chambers of Commerce and Industry (FICCI) and the World Bank, 64 percent of surveyed employers are not satisfied with the quality of engineering graduates skills means only 36% are employable. A major skill gap exists among Indian engineering graduates. There is a urgent need to focus on employability and quality, says a survey [24].

It has been forecasted that current capacity of skilled human resource is not sufficient to cater its domestic needs. Also, the growing global demand for appropriately skilled, industry oriented professionals and a gradually widening demand-supply gap are expected to test the limits of India's manpower development capabilities. Also, India's domestic and industrial need of creating a skilled worked force by 2022 is 550mn. As per the joint study conducted by Information and Credit Rating Agency of India Limited (ICRA) and NSDC (National Skill Development Corporation), the incremental skilled workforce requirement in 20 high growth sectors including education and the unorganized sector is 240-250mn till 2022 [20]. To develop such a huge skilled manpower, educational and training system cannot simply rely on traditional instruction based teaching; they need to adopt the new methods one of them could be PBL.

IV. CHALLENGES

1) *Intercultural issues and religious diversity:*India is the largest democratic nation and is the second most populous nation of the world. The current Indian population is estimated to be around 1.2 billion and by 2026, this number will be approximately 1.4 billion. India has 28 states, 18 official languages and 160 dialects [26]. Every state has its own culture and the education system including various boards, state run universities and autonomous bodies. Also, it has a diverse range of religious groups. Implementation of a PBL in such diverse country is very demanding and daunting task. Hence, PBL model should have versatility and acceptability to all groups and for all levels of the students, to design such a model is a challenging task. Students in a class can be from different origin, background and may speak a different language which makes the matter more challenging.

*2) Diversity in technical education and class size:*Technical Education plays a vital role in human resource development of the country by creating skilled manpower, enhancing industrial productivity and improving the quality of life. All India Council of Technical Education (AICTE) is an apex body who conduct a survey in a technical education field. Technical Education covers diverse courses and programs in engineering, technology, management, architecture, town planning, pharmacy and applied arts & crafts, hotel management and catering technology. The technical education system in the country can be broadly classified into three categories – Central Government, State Government & Self-financed institutions. Currently India has 65 centrally funded institutions, 236 universities, 101 deemed universities, 140 research institutions and staggering 20,769 higher education institutes. Out of these 20,769, science and engineering has a share of 30%. These are supported by Industrial Training Institutes (ITI) and diploma level (Polytechnic) institutes [20]. Except centrally funded and autonomous institutes, all other institutes have affiliation to any of the University. These Universities decides the curriculum and the evaluation strategy in these institutes. Institutes do not have any right to change the curriculum content. Considering this case, PBL model must be designed carefully to integrate in a fixed curriculum. To do it, in such a diverse educational system is a challenging task. Typically in India one engineering institutes have at least four programs of engineering having sanctioned annual intake of 60 students per program for four year course. This makes total students strength in a college as 1000 and single class strength sometimes exceeds 70. Administration of such a class in PBL environment will require additional resources, which are sometimes difficult to get.

3) *Shortage of Faculty and trained personnel:*There is a shortage of competitive and qualified faculty to teach in technical institutes. Even those, who are available, have seldom experienced or made their students experience cooperative learning. Even those, who have rarely done so, have rarely experimented with PBL. This means that for PBL implementation most important issue is a faculty and trained personnel. Also, vision and mindset of management plays a major role to decide the acceptability of PBL. To motivate all of them to adopt PBL will remain a long distant dream unless and otherwise government makes it compulsory through legislation and jurisdiction.

4) *Lack of teaching –learning and other resources:*As discussed earlier one of the main hurdle for PBL implementation is a shortage of trained faculty. Due to want of literature and other learning resources faculty lacks in knowledge and have improper information. This has an impact on the further progress of PBL. Also, PBL model implementation demands more resources and reallocation of them. Listed resources include trained faculty, class rooms, group rooms, well equipped library and laboratories, internet access etc. These resources are not the common features in Indian Education system especially in private run engineering colleges. Most of these colleges have limited resources and mostly have conservative approach.

5) *Motivation to change:*A major challenge in PBL implementation is to motivate educators, administrators and policy makers to adopt PBL as an educational model. To make the matter worst faculty will try to resist it, as they are happy with the traditional instruction based pedagogy. Change from traditional teaching to PBL is a paradigm shift. This shift must be administered carefully for successful integration and implementation of PBL. Also, student community must accept it and must be trained before implementation. Gradual and well planned implementation will serve the purpose.

6) *Lack of legislation and jurisdiction:*All the PBL experiments carried out so far have no jurisdiction, in any of the Indian Universities. Thus, Indian engineering student community has never experienced PBL in a structured manner. It is possible to implement the PBL if proper legislation and jurisdiction framework are designed. Designing such a framework are a challenging task.

Summary of drivers and challenges for PBL implementation in engineering education is listed in Table 1.

TABLE 1 SUMMARY OF DRIVERS AND CHALLENGES.

Drivers	**Challenges**
Awareness of global best practices	Intercultural issues and religious diversity
Quality of education and student-teacher related issues	Diversity in technical education and Class size
Student population	Shortage of Faculty and trained personnel
Government initiatives and support	Lack of teaching-learning and other resources
Growth in unemployment rate and demand of skilled manpower	Motivation to change
	Lack of legislation and jurisdiction

V. CONCLUSIONS

Based on the available literature and author’s judgment – experiences following conclusions can be written.

a. PBL is widely accepted as an education model worldwide including India. Studies concluded that PBL helps to improve the skills and make engineers more employable.
b. Indian engineering student community though very large has never even experienced PBL in a structured manner. Well thought and concentrated efforts must be carried out to evolve a structured and scalable change in the pedagogy.
c. Quality of education, teaching learning issues, student population, government initiatives and support, growth of unemployability rate and demand of skilled manpower are found to be major drivers for PBL
d. Intercultural issues and religious diversity, Diversity in technical education, Shortage of Faculty and trained personnel, want of teaching-learning and other resources, Lack of legislation and jurisdiction are the major identified issues in PBL implementation of India.
e. Considering its positive results and recent developments in the educational sector, it is concluded that PBL has a definite role to play in raising the quality of engineering education in India. For sustainable growth of PBL there is a urgent need to build model institute based on PBL model.

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Students' experience of Aalborg PBL Model: A case study

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ABSTRACT

In September 2010, newly structured Problem Based Learning (PBL) model was implemented at the Master Level at the Aalborg University. In this article, the students' experience of this PBL model is documented. The experience gained from this case study is particularly useful for studies in India. This study encompasses three groups of 15 students. All were mechanical engineering students in their seventh semester during the autumn semester 2010.The primary objective of the case study is to understand the PBL modeland the entire PBL process by focusing on how, what and where students learn.

This case study used a mixed research method and sequential design approach. Two questionnaires were designed to collect quantitative data. In the first questionnaire, the educational background of each student was recorded. At the end of the semester, the second questionnaire recorded student responsesto their learning and experience while working in a team. During the semester, qualitative methods such as periodic observation and informal discussion were used. At the end of the semester, semi-structured interviews were conducted to complete the triangulation. Finally, conclusions were drawn by evaluating the data collected using each method. To obtain a perspective for the Indian case, the results of this case study are compared with the Indian context. It is concluded that a PBL model setting is conducive for learning and improved process competencies.

Keywords

PBL, Case study, Mixed Methods, Team Work, Learning

INTRODUCTION

Recently, an Indian nationwide survey indicated that 64% of graduateengineers were unemployable. They lack higher order thinking skills and an ability to work in teams. Also, there is a lack of employability skills and process skills. The industry demands these skills, but the current education system and pedagogy cannot fulfill the needs of the industry [1]. Also, students in India are exposed to various curriculum gaps such as curriculum design, syllabi that are not on parwith industry needs And unaligned courses. Also, lack of innovation in teaching-learning methods affected quality of education in India. These shortcomings in the education system have resulted in unemployable technical human resource in India. Hence, there is an urgent need to improve skills thatwould make engineers employable.

Today, Problem and Project Based Learning (PBL) has been accepted and implemented as an educational model in several education systems throughout the world. Many PBL models exist and are practiced in different ways. Thus, the PBL word is used for diverse educational practices. There is a considerable lack of clarity regarding the concept of problem-based learning [5]. These models vary depending on the culture, history of education and other local conditions. The first university to develop and implement the PBL curriculum was McMasters University, Canada in 1968 in medicine courses. Later in Denmark, a problem based and project organized model was implemented at Aalborg University in 1974 [2].

Problem and Project Based Learning (PBL) can be defined as an instructional strategy in which students have to work with ill-structured problems and must make an effort to find meaningful solution. These ill-structured problems are contextualized. PBL encourages students to learn and work together. It also encourages students to learn about collaboration, different approaches to the problem, cooperation and responsibility [7]. Studies also concluded that PBL helps to improve process competencies such as team work, problem solving and analysis, and written and verbal communication,among other things. Also, empirical studies concluded that PBL helped student to manage projects and get real-life work experience [7, 9,14]. Considering the success of the PBL model worldwide, it is a hope that PBL will help Indian students improve these skills as well. Hence, it is the intention to apply a PBL method to engineering education in India.

However, Indian engineering students and teacher communities, though extremely large, have never experienced PBL in a structured manner [9]. Key drivers for PBL implementation in India are quality of education, student population, employability, accreditation needs and the demand for skilled labor. However, intercultural diversity, diversity in technical education, shortage of faculty, lack of resources, lack of legislation and jurisdiction are the main barriers for PBL implementation in India [13]. Hence, it was essential to gain greater insight into the PBL model in practice. Aalborg University was used to conduct a case study in order to better understand the PBL model. This is a pilot case study for the author's PhD research "PBL model design and implementation in India". The experience and perspectives obtained through this case study are valuable for research in India. Since September, 2010 a newly structured PBL model was implemented in themechanical engineering master's degree programme at Aalborg University (as shown in table 1) [4].

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Thestudy was conducted to learn about this PBL model and to develop methodologies for comparing Danish and Indian students' experiences in PBL. In this paper, students' experience of this new AAU PBL model have been shared as viewed by novice learner. Although the sample size is small in this case study, the student population will be much higher in India. The understanding derived from this case study will be useful input for PBL model design in the Indian context.

Table 1 PBL model for master's level students [4, 11].

Module	ECTS	Grading	Assessment
Project	15	7-point scale	External
Course-1	5	Pass/fail	Internal
Course-2	5	Pass/fail	Internal
Course -3	5	Pass/fail	Internal

ECTS-European credit transfer system.

METHODS

A case study approach was found suitable for this research. It can be described as an in-depth study of a distinct, single instance of a class of phenomena such as an event, an individual, a group, an activity or a community [8]. In this case study, three groups of students were examined for a complete semester. The case study as a methodology can be used to validate findings emerging from other studies [8]. In this case, the motivation was to assess student learning in Denmark and develop research methodologies which can be used to assess learning from PBL in India.

Sample size

There were 15, 7th semester mechanical engineering students at the master's level. Detailed socio-demographic analysis of the sample is given in table 3.

Ethical issues

For this case study, permission was sought from the head of the board of studies for the programme. Permission to observe the groups was also sought from the supervisors of the three groups. All the students were informed about the purpose of the study andconsent was obtained from allthe group members. The study was promised to be anonymous, meaning student names would not be revealed.

Study design

A mixed method sequential approach was used in this research [3]. Table 2 below shows the summary of the different methods used in this study.

Table 2Summary of methods used in the case study [3]

Phase	Tool	Method
Beginning of Semester	Questionnaire -01	Quantitative
During the semester	Observation	Qualitative
	Informal discussion and Observation	Qualitative
End of Semester	Questionnaire -02	Quantitative
	Semi-structured interview	Qualitative

The sample size in this case study is small, but, considering the case study as a pilot for Indian case, two questionnaires weredesigned. These questionnaires will be useful in conducting similar research in India. Also, responses from this study can be compared to Indian case. In this study, two questionnaires were used in two different phases. As shown in the table 2,the first questionnaire was used at the start of the semester and the second questionnaire was used at the end of semester. The questionnaire was pretested and piloted before being administered. Focus group discussions were observed periodically during the whole semester.

The purpose of the first questionnaire was to collect primary information about the sample size. It had few open-ended questions seeking opinions from the participants about PBL. The purpose of the second questionnaire was used to collect responses (quantitative data) for the clusters as shown in figure 1. This questionnaire had closed-ended responses to which each participant was expected to respond on a five point-scale. These questionnaires were distributed to the three focus groups. The focus groups were observed periodically during the project meetings. A total of four group meetings and one supervisory meeting was observed for each group. Different opinions and points from informal discussions during these meetings were noted in a notebook for reference. These observations and informal discussions provided useful qualitative data. At the end of semester, a semi-structured interview was conducted for the purpose of data triangulation. The data collected were both quantitative and qualitative. Quantitative data were analyzed using Microsoft Office Word and Excel. Qualitative data were referred from the notebook and interviews. This data were compared to ensure validity. Data were then clustered into categories of similar meaning as shown in figure 1. The responses in the clusters are combined to interpret the meaning of the data, which addresses the purpose of the study.

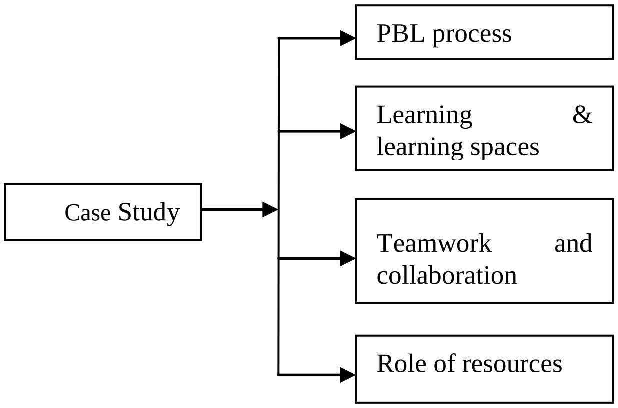

Figure 1 Different clusters of the case study.

RESULTS

Socio –demographic analysis

There were 15 (n=15) participants of which only one (n=1) is female. In terms of age, thirteen (n=13) participants werebetween 23 and 26 and two (n=2) are 30. In terms of language, all spoke Danish, except one student. Out of the fifteen participants, thirteen (n=13) students had continued their education from Aalborg University, and two (n=2) students from another university. All of them have mechanical engineering or production engineering backgrounds. Two students (n=2) out of the fifteen had prior work experience. Table 3 shows a detailed socio-demographic analysis of the sample

Table 3 Socio-demographic analysis of the groups

Sr. No	Name	Age	Male / female	Local(L)/ International(I) student	Year Of Graduation	Qualification Branch	University	Work experience
Group-A								
1.	Shuren	23	M	L	2010	Mechanical	AAU	-
2.	Rajmu	23	M	L	2010	Mechanical	AAU	-
3.	Jerre	22	M	L	2010	Mechanical	AAU	-
4.	Rooney	24	M	L	2010	M/C and Production	AAU	Yes
5.	Sorrays	23	M	L	2010	Mechanical	AAU	-
6.	Madhis	23	M	L	2010	M/C and Production	AAU	-
Group-B								
7.	Patrik	25	M	L	2009	M/C and Production	AAU	-
8.	Chang	23	M	I	2010	Manufacturing and automation	Guang Dong,China	-
9.	Border	24	M	L	2010	Mechanical	AAU	-
10.	Keeper	24	M	L	2010	Mechanical	AAU	
Group-C								
11.	Morray	24	M	L	2010	Mechanical	AAU	-
12.	Thoase	24	M	L	2010	Mechanical	AAU	-
13.	Jorten	26	M	L	2010	Manufacturing processes	AAU	-
14.	Chinare	30	M	L	2004	Mechanical	SDU,Odense	Yes
15.	Ritka	30	F	L	2010	Mechanical	AAU	-

Note: Student names are changedin the above table.

Qualitative results

In this section, we document some of the qualitative data from the first questionnaire.

The question was posed: Why did you choose to study at Aalborg University?

The responses were that they heard good things about the university like the PBL model, group work, formal-study atmosphere, good reputation in industry and healthy campus placements. Regional recruitment was the most significant factor as most of the students were born and raised near Aalborg. At the beginning of the semester, a study guide was made available and most of the students knew their project area. All the students were working on the same project: *"Stress and Deformation Analysis of Load Carrying Structural Elements"*. Even though they were working on the same project, they chose suitable and different component to work. When asked why they had chosen this project, they responded,

> *"We had no choice, it was compulsory".*

The students enjoyed the teamwork and spent over half the semester in group rooms working on the project. When we asked them about the group composition, most of them were satisfied. Then we asked them why they were satisfied?

They responded that they worked well together and maintaineda proper meeting atmosphere. They also reported group members being interested, eager to learn and goal oriented. Also they said their group had an excellent mixture and variety in terms of skills in order to complete the project work. Finally, such attributes as friendship, chemistry and awareness of each other's strengths and weaknesses was reported as key to group satisfaction. When we asked them for a more detailed explanation, they talked about each other's technical skills, personal and generic characteristics. While commenting on teamwork, they felt that for a successful project, each person in the team had to work in collaboration with other members.Project meeting attendance was the main concern, and the agreement stated that if for any reason someone could not attend a group meeting, he or she must inform the team members. Also, the agreement urged seriousness while working and keeping deadlines. This example shows how students maintain their own work ethics. Students found PBL to be an interesting way to learn and work. One student commented, *"Project work motivates us and makes us responsible for our own learning"*.A few also felt that PBL is not suitable for developing countries. Three students did not comment on PBL at all. Most students feltlike the real work environment in the group room.

PBL Process

Understanding the PBL process was one of the most important objectives of this case study. The study guide, the curriculum formed the basis to understand the PBL process and were supplemented by empirical study. Figure 2 depicts the PBL process.

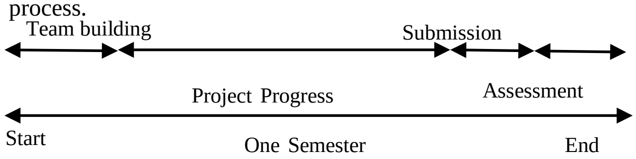

Figure 2 PBL process model for one semester in Aalborg

At the start of the semester, a study guide was provided to the students and preliminary counseling about the semester work is done. On project day, the project catalog is provided to the students. This project catalog has a list of projects and students have to choose their project. Then they are allowed to choose their group. Once they finalized their team, it has been observed that for next few days, their focus is to understand each other and the problem statement. This is the team building phase. In this phase, the focus is to derive common understanding about the project. During this phase they will understand each other's strength and weaknesses. Hence, at the end of this phase, a coherent group is formed. Once the team is formed, they divide the work to be completed within the group based on individual choices and negotiations. They collaborate and cooperate with each other to complete their assigned task. Once their task is over, work will be shared in the group meeting with everyone. In this way, students learned in a cooperative environment. The supervisor comments on the work. Normally, students invite the supervisor to the meeting by email. Here students learn professional communication. The agenda for the meeting is prepared by the students and sent to the supervisor. The meeting agenda may be comprisedof specific technical or individual difficulties. The meeting is then conducted according to the agenda. Sometimes, we observed the supervisor explaining the critical points on the black board available in the group room. In one month, the supervisor may have at least two to three meetings with the group. This is the way students manage and control their project work, thus teaching studentstimemanagement and project-management skills. In a complete semester, this mini cycle will be repeated numerous times until the end of the project. It is called project progress phase since during this phase project work is progressing.As the submission deadline approaches, it has been observed that students spend much more time than the regular meeting time in the group rooms. They were observed to be extremely busy andworking under tremendous deadline pressure. This is also recorded in quantitative data. Sometimes, they refused having me present in the group room at this time by saying we were busy and could not talk with me. This shows their urge to keep and respectdeadlines. At the time of submission, all the information is written in the form of a thesis. This thesis writing experience helps them to learn to present the project findings. Also, they learn to interpret the results from their experiments. At the end of the semester, the group is examined. The project examination is conducted for the group. First, the group presents their work to the audience which may be comprised of students and staff members. This experience helps the students to learn to address an audience and to learn presentation skill. An individual interview with the students is also conducted by the examiner along with the supervisor. Grades then depend on student performance in the interview. Most of the students felt that the grade they received reflected their work.

Quantitative results

In this section, information obtained from the two questionnaires is reported. Table 4 and 5 provide information about the students' prior knowledge and their responses to the questions. These preliminary responses are necessary for us to know the students perceptions and knowledge about PBL. Also, this information was crucial to understand students' perception and knowledge about the group work. Results showed that almost all students have prior experienceworking in teams. In table 4 and 5 the students' responses are recorded. The frequency of the supervisory meetings varied among groups with the maximum being four per month. Almost all the students attended at least one course on PBL. The knowledge about PBL increased as they progressed to complete their bachelor degree. Also, most of them did not want to take a course on PBL because they felt it has been the way they have learned for years. Finally, the responses to the second questionnaire are tabulated and discussed in the following section.

Table 4 Student responses and information about the group

Question no	Question	Response by the students	Remarks by author
1.	Do you have any experience with working in a group?	Yes-14, No-1	One student is an international student; hence, he did not have any experience with working in teams.
2.	Have you signed a group agreement? (This is a group response)	Yes -2 , No-1	Two groups had very simple considerations for making an agreement.
3.	Did you know anyone from your group before group formation?	Yes -14	Most of them completed their bachelor's from AAU in 2010.
4.	Frequency of group meetings?	4 days/week.	As per the time table they have to meet almost every day to complete the assignment and project work.
5.	Frequency of group meetings with supervisor?	1 / month to 4 / month.	Normally, supervisor meetings are scheduled as needed by students.

Table5Student responses about PBL

Question no	Question	Response by the students	Remarks by author
1.	Are you familiar with the Aalborg PBL model?	Yes -14, No-01	Most of them are locals and completed their bachelors from AAU.
2.	Have you attended any courses on PBL?	Yes-14,No-01	All have attended basic course on PBL as most of them are from AAU.
3.	What is your knowledge about PBL?	Avg-10,Good-1,Low-2,No-1,No Response -1	Some of them enhanced their knowledge of PBL by attending more than one course on it.
4.	Would you like to attend a course on PBL in future?	No-14, Yes-01	They say it's the way they have learned in the past few years.

Learning and learning spaces

This section addresses how the project affects student learning and behavioral aspects such as motivation, satisfaction is discussed and tabulated in table 6. Responses to questions 1 to 3 shows that that 93 % of students were motivated to learn and accepted the responsibility of their own learning. Only 43% of students said they became independent or self-directed learners. This is because they spent most of the time in the group rooms, and they learned by sharing with each other. This is also validatedby the qualitative data in which we discussed that students learn in a cooperative environment. Student responses to questions 4 and 5 showed that they worked better when they were in a group room working on a project than in the classroom. But the response to questions 6 and 7 indicates that classroom instruction was significant, constructive and useful for the project work. This is because the courses are aligned with the project work, and hence the role of classroom learning was essential to facilitate the project process. Classroom instructions and project work complement each other to a greater extent. It was also observed that project work and deadlines put students under pressure and made them work beyond their natural capacity and working hours. This can be seen in response to questions 8 and 9. Still, students are satisfied with their experience of working on the project andtheir own learning. Almost 80 % of students feltthey received grades as per the work they did in the semester. The students taught and learned from each other throughout the project process and in classrooms. This learning is also supported by reading from the books and Internet resources. Input from the supervisor and discussion with other groups also played a role in the learning process.

Table 6 Student responses to learning and learning spaces

Question No	Question(s)	Student's Response, n(%)				
		Strongly Disagree	**Disagree**	**Neutral/No Opinion**	**Agree**	**Strongly Agree**
1	This project helped me to take responsibility for my own learning			1(7%)	9(60%)	5(33%)
2	The project motivated me to learn			1(7%)	9(60%)	5(33%)
3	I learned to become a more independent and self-directed learner		1(7%)	7(50%)	5(36%)	1(7%)
4	My learning through projects was better than classroom learning			3(21%)	10(72%)	1(7%)
5	I feel I could have learned more by attending classes than working on projects	1(8%)	5(42%)	4(33%)		2(17%)
6	I found classroom learning relevant to the projects			2(13%)	13(87%)	
7	I found instruction given in class useful and constructive				10(71%)	4(29%)
8	I feel project work put me under tremendous pressure	1(7%)	2(14%)	3(21%)	8(58%)	
9	I feel project work made me to work beyond my natural capacity		4(29%)	4(29%)	6(42%)	
10	Working on a projects was a good experience				9(64%)	5(35%)
11	The project engaged my learning and thinking skills throughout the semester			1(7%)	7(50%)	6(42%)
12	Overall, I am satisfied of my learning				10(71%)	4(29%)
13	I feel learning I did through the project will be reflect in my grades			3(21%)	8(58%)	3(21%)
14	Overall, I feel satisfied with my experience this semester			1(7%)	11(78%)	2(15%)

Team work and collaboration

Table 7 is used to write this section. It has been found that most of the time, students work in group rooms. Responses about group work and collaboration suggest that they worked better as a team and without leader in the group. In response to how they divided the different tasks, they replied that they discussed them among themselves and divided the work up. Responses to questions3 to 7 suggest that the students enjoyed working in a group and believe there is a scope to improve in an ability to work as a team member. Although they knew each other, working in a group created conflicts. Hence, 85% of students replied that they had conflicts but resolved them for the purpose of the project. In interviews, students admitted to having different opinions and, therefore, conflicts. But, these conflicts did not affect the project work since we continued to work as a team. During the discussion, they informed us that teammates are changed every semester possibly for this reason. The responses to questions 4 and 5 suggest that the students feel confident working in a team and can work with the other teammates of diverse ages and cultures. Figure 3 shows student responses to teamwork and collaboration.

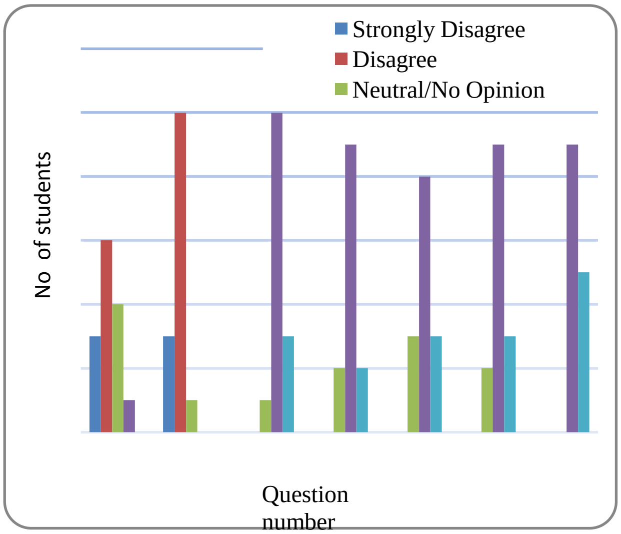

Figure 3 Student responses about their teamwork and collaboration

Role of resources

Table 8 below is referred to in writing in this section. PBL resources include human resource such as teachers, supervisor laboratory staff and other departmental staff. These people have a definite role in the PBL model. Assessing the role of these people is beyond the scope of this research.But, from response to questions 1 and 2, it can be understood that the supervisor has a vital role in facilitating the project process. Also, the supervisor's comments are found to be extremely valued by the students and found to be constructive for the project work. Most of the students are satisfied with their supervisors. One of the vital resources is a group room, which is particularly beneficial for students to work together in a real-work environment. Another resource includes laboratory and Internet access. All the students responded that the laboratory and Internet facility is essential for timely completion of the project. Since, in this case all students were working on the same project, they had to share the lab based on priority. The laboratory was identified as a crucial resource for the completion of this particular project. For one project group project work was delayed since the lab was occupied by another group.

Table 7 Student responses on teamwork and collaboration

Question No	Question(s)	Student Responses, n (%)				
		Strongly Disagree	Disagree	Neutral/No Opinion	Agree	Strongly Agree
1	Our collaboration in a team was not up to the level of my expectations	3(22%)	6(43%)	4(28%)	1(7%)	
2	The team was headed by one leader	3(21%)	10(72%)	1(7%)		
3	The team member's roles was crucial for project outcome			1(7%)	10(72%)	3(21%)
4	I can work with other team(s) that have more diverse skills, cultures and age groups.			2(15%)	9(65%)	2(15%)
5	I feel I can improve my ability to work in a team			3(21%)	8(58%)	3(21%)
6	We solved our conflicts			2(15%)	9(64%)	3(21%)
7	Working in a team was a nice experience				9(64%)	5(36%)

Table 8 Student responses on role of resources

Question no	Question	Student Responses, n(%)				
		Strongly Disagree	Disagree	Neutral/No Opinion	Agree	Strongly Agree
1.	I found the supervisor's instructions and suggestions useful and constructive at various stages of project				9(65%)	5(35%)
2.	Supervision was at the level of my expectations			4(29%)	8(57%)	2(14%)
3.	The laboratory was a crucial resource for the project work		1(7%)		10(72%)	3(21%)
4.	Sharing resources was done on a priority basis		1(7%)	6(45%)	4(31%)	2(15%)
5.	Availability of the laboratory was 100%		5(36%)	6(43%)	3(21%)	
6.	Project work could not go as planned due to unavailability of resources		7(50%)	3(21%)	4(29%)	
7.	Internet access has an effect on the project outcome				6(43%)	8(57%)

DISCUSSION

Responses to the initial questionnaire and analysis through informal discussions suggest that students enjoy working in teams and learning to manage conflicts. They share information with each other and collaborate to achieve the desired learning outcome.To control and monitor the project work, project management tools are often used by the students. It was observed that student engagement in the project process gradually increased during the semester. A similar result found by Thomas et al. indicates that PBL engages students in authentic experience, fosters self-regulation in learning and increases the involvement of the student in the learning process [12].

The responses to a final questionnaire indicate that students learn to work in a team and feel confident working with the different people. They feel satisfied with their collaboration. 85% of students reported that they had had conflicts in their team but had solved them to complete the project. Also, 58% of students responded that the project work put them under tremendous pressure, and that they worked beyond their capacity. All of them felt that the roles of team memberswere essential in achieving the project outcome.

About the learning experience, 80% of students responded that they learned more while working on the project compared to instruction and lecture-based learning in a classroom. They feel that the project work and the learning associated with it are related to real-work environment. This shows the effect of project work on motivation and learning. The students also felt a certain relevance of the classroom instructions in their project work. 80% of students feel that their final grade reflected their work. They found the project work useful in acquiring professional and core employability skills. It was found that,the supervisor's suggestions were very valued by the students. 29% of the students reported that project work was delayed due to non-availability of the lab, and they used it based on priority. Overall, all the students felt satisfied with working on the project and in settings available to them.

PERSPECTIVES FOR THE INDIAN CASE

In this section, based on the author's experience in India and at AAU, Denmark, the perspectives for the Indian case are obtained. These perspectives are the outcome of a comparison of curriculum, survey reports and results from this case study.

Curriculum structure

The curriculum in Aalborg is defined by clear objectives, skills and competencies to be obtained at the end of the semester; whereas in India, this is not normal practice. At AAU, the project work carries 50% of the ECTS and becomes a key driver for students.

Comparatively, in India the curriculum is structured in 4 to 6 courses and project work carries approximately 20 to 25% of the marks. The project work is a powerful motivation for learning. At AAU, the courses offered in the semester support the project work. In India, the courses offered during the semester do not complement the project to a great extent.

In India, project work starts from the 6th semester onwards in four-year bachelor course, but at Aalborg University project work starts from the first semester. It is also observed that thetimetable is tailor made for students in the PBL curriculum. Most of the lectures are arranged for before lunch. After lunch, the students are free to work on assignments and projects. In India, provisions for project work are made differently, varying across institutes. Normally, institutes provide time slots for project a work during the week. Compared to the Indian context, the examination pattern is similar for project assessments. In India they have group presentation followed by individual interviews. The groups are assessed by an external examiner accompanied by the supervisor. Based on the performance on the project examination, the students are awarded marks rather than grades. At AAU, grades are declared immediately, but in India students have to wait for a declaration of results. Hence, it is concluded that in the PBL environment the courses, project work and timetables must be aligned with the learning objectives.

Team work and Cooperative Learning

In India, project work starts from the 6th semester onwards in four-year bachelor course, but at Aalborg University project work starts from the first semester.This makes the difference since students at AAU get three times more experience working in a team. Therefore it can be easily understood that the students are more competent and confident with teamwork. Also,students of Aalborg University will work on more than four projects they will be also competent in project management aspects. As a result, it can be observed that more learning takes place in a group room than in a classroom. The results of research carried out on PBL have shown the importance of teamwork for students' motivation as well as for the relevance of learning [06]. Indian students struggle with this aspect as most of them have not become acquainted with working in a team. Students in India never experienced cooperative learning in a structured manner. Cooperative learning is a crucial difference when comparing AAU to India. Also,students have been found to learn problem solving and analysis skills, use of modern tools, verbal and written communication and work ethics etc. A better learning environment for skill improvement has also been observed in students at Aalborg University. These skills are necessary for an engineer. However, it has been reported in a survey that Indian engineers lack employability skills, and that there is a significant skill gap [1]. To inculcate these skills, is a difficult challenge for the Indian education system. Hence, it is a hope that PBL can be a useful method for engineering education in India. Aalborg university students have a better chance of learning and acquiring critical fundamental process competencies since the students are actively involved in the learning process. The role of active learning in engineering in order to help students develop skills and competencies to prepare them for the engineering profession is confirmed in the literature [14]. It is concluded that the setting offered in a PBL model is conducive to improved process competencies when compared to India. Therefore, this case study is essential for the author to get concrete experience in a PBL environment before designing a model for the Indian context.

Group rooms

An essential feature of the Aalborg PBL model is teamwork meaning that students have to work in groups. To facilitate this, Aalborg University has 1200 group rooms. The group room makes a difference in team work as students have a place to come and work together. A group room is just like an office for students; it is like they are practicing engineers. It is confirmed that group rooms with Internet access are one of the important factorsin the success of the PBL model at Aalborg University. In India group rooms for students are not a regular feature at most of the universities. As a result, students in India work independently with occasional group meetings. Also, the team-building process takes a rather long time in India since students have no prior orientation or experience with team work. Thus, project work get seldom delayed.

The role of the teacher and the supervisor

As per my observation, the role of the teacher in both Denmark and India seems to be similar. However, the difference between what is taught in class and how it is relevant to the project work is notable. The supervisor at Aalborg is replaced by a guide in India. As the name suggests, teachers are the guide for project work. In India it is that the guide who has a leading role in deciding the direction and fate of the project work. When compared to a supervisor at Aalborg, the supervisor acts as a facilitator for students and does not have any role in deciding the direction and outcome of the work. In the worst scenario, a supervisor has to interfere in a group, but normally students make their own critical decisions and are held responsible to deadlines. Also, there is an exception in the pattern of the supervisory meetings. The time and agenda for the meeting is communicated by the students to the supervisor. Mostly, the venue for a supervisory meeting is a group room. In India, the project meetings are normally conducted in the supervisor's (guide's) office. Some institutes provide separate time slots and places for the project meetings. At Aalborg, students request a meeting with their supervisor by email while in India students come personally to meet guide. Sometimes meetings are arranged by phone. It has been found that the students are attracted to AAU due to the educational settings it offers. Most of the students are aware of the PBL approach and prefer it over the traditional teaching approach. This case study has provided deep insight into the PBL model. As this is a pilot case study for the Indian context, learning derived from this is an essential input into designing a PBL model.

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RELEVANCE OF THE PROBLEM AND PROJECT BASED LEARNING (PBL) TO THE INDIAN ENGINEERING EDUCATION

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ABSTRACT

The recent employers' survey (2009) indicated that Indian graduate engineers lack critical employability skills such as problem solving, teamwork and communication. Owed to this issue the Indian engineering educators are searching for the suitable alternative. Problem and Project Based Learning (PBL) could be one of the alternatives. Why PBL is a suitable alternative to Indian engineering education is discussed in this article. The skill set required by the Indian industry is mapped with the learning outcomes achieved by PBL. The skill set demanded by the industry is obtained from the Indian research and the PBL learning outcomes are discussed with the support of existing literature. Based on the mapping results, it is concluded that PBL could be a suitable alternative to acquire the skills demanded by the industries. However, PBL implementation in India needs to be considered carefully as Indian educational settings are different from PBL settings.

Keywords: Engineering Education, employability skills, PBL, literature review.

INTRODUCTION

Engineers play a significant role in the economy of any country. They are expected to work in different areas and difficult situations at workplaces. The engineering profession became demanding as Indian (world) industries demands different skills such as professional, soft and personal skills (Blom, 2009, Goel, 2006). Although, profession became demanding, it did not inhibit the requirement of professional and employable engineers in India (in the world). To cater the demand of skilled engineers, more engineering educational systems were set up in

India. It resulted in an increase in the volume, but the quality of the graduate engineers became questionable (Rao, 2006). Recent surveys conducted by National Association of Software and Services Companies (NASSCOM, 2005, Blom 2009) reported that Indian engineers lack critical employable skill. There is a gap between industry expectations and graduate engineering skills. It is also reported that, the academic settings offered in India do not push for development of skills. Also, various government reports indicated the deep concern about the quality of an engineering education and hinted for radical changes in the curriculum and teaching learning practices in India (Rao, 2006, Knowledge Commission, 2008, Yashpal, 2010).

In this paper, the outcome of one of the most remarkable Indian study is discussed. This survey was conducted in 2008 jointly by Federation of Indian Chambers of Commerce and Industry (FICCI) and World Bank. It was supported by Ministry of Human Resource and Development (MHRD), India. It outlines that 64% Indian graduate engineers are unemployable and lack in higher order thinking skills and process skills. This survey proposed an urgent need to focus on skill development.

Considering the previous results Problem and Project Based Learning (PBL) could be one of the alternatives to address an issue of competence development. Why PBL is a suitable alternative to Indian engineering education is discussed in this article. Relevance is judged by matching skills demanded by the Indian industries reported in a survey to the learning outcomes attained in PBL. The PBL principles and research data were used to emphasize PBL strategy could be connected to address most of the skills demanded by the industry. However, it is also recommended that PBL implementation in India needs to be considered carefully as Indian educational settings are different from PBL settings. The article concludes with a list of possible PBL implementation issues in India.

RESEARCH METHODOLOGY

To address the research topic, most of the initial data (skills demanded by the Indian industries) is referred from the FICCI, and the World Bank survey. The secondary data was collected from the existing international publications. The literature review was restricted to the cases in which PBL is applied at an engineering institute and published after year 2000. The cases reported here are from the articles published in the journal, conference proceeding and books. Only those articles are included in which authors reported effect of PBL on skills or learning outcomes of students. This qualitative data are compared and mapped with the survey data. An outcome of this comparison is reported and discussed based on PBL characteristics and principles. Finally, article concludes with possible barriers of PBL implementation in India.

INDIAN SURVEY-BACKGROUND AND RESULTS

In this section, significance of the FICCI survey is discussed in the back drop of various studies conducted by Ministry of Human Resource and Development (MHRD), India arranged in chronological order. In 2005, the NASSCOM and McKinsey came with the report that, only 25% of the engineering education graduates are employable by a multinational company. Most of the surveyed employers linked this situation to the shortcomings from the education system. In the same year, the Planning Commission, Government of India came with the broad agenda to focus on enhancing the quality of educational institutions and an emphasis for appropriate arrangement for the development of skills and transforming learning patterns (p-13) at these institutions. In view of recommendations by Planning Commission National Knowledge Commission (NKC, 2006) on higher education was constituted in June, 2005. The purpose is to prepare a draft for transformation of India's knowledge related infrastructure. The NKC submitted recommendations to the Government in 2008.

Following this report in February 2008 MHRD, higher education department constituted a committee under chairmanship of Prof. Yashpal. It reported a deep concern in respect of growing engineering colleges by saying they have largely become, mere business entities dispensing very poor quality education (p-05) and indicated that there exists a gap between learning from institution and expectations from industries. Committee also recommended that the universities must adopt a curricular approach which treats knowledge in a holistic manner to create opportunities to bridge the gap by relating to the world outside (p-12). It hinted that Indian higher education system needs a drastic overhaul (p-54) with proposal of curricular reforms at undergraduate programs to enable students to have opportunities to access all curricular areas and integration of skills with academic depth (p-64). In view of these reports there was an increasing demand from teachers, administrators, and policy makers to identify the kinds of skills demanded by the employers from an engineering graduate. So, to identify skills demanded by the employers an Employer Satisfaction Survey was carried out in 2009.

This survey was supported by Government of India, the World Bank and the (FICCI). İt was designed by considering 10 learning outcomes out of 11 (in abbreviated form) and previous employers' surveys. These learning outcomes are established by India's National Board of Accreditation, (NBA) which is the only official accreditation body for assessing quality of engineering education in India. In this survey 157 industries across the India responded. According to the survey, 64 percent of surveyed employers are not satisfied with the quality of engineering graduates skills. A major skill gap exists among Indian engineering graduates. The skill gap is considered as the difference between the importance rating (highly demanded skills) and the satisfaction rating. A high skill gap signals that the skill is important and that the graduates do not meet the expectation. As can be seen from figure 1, the graduate engineer lacks in process skills such as teamwork, lifelong learning and communication skills.

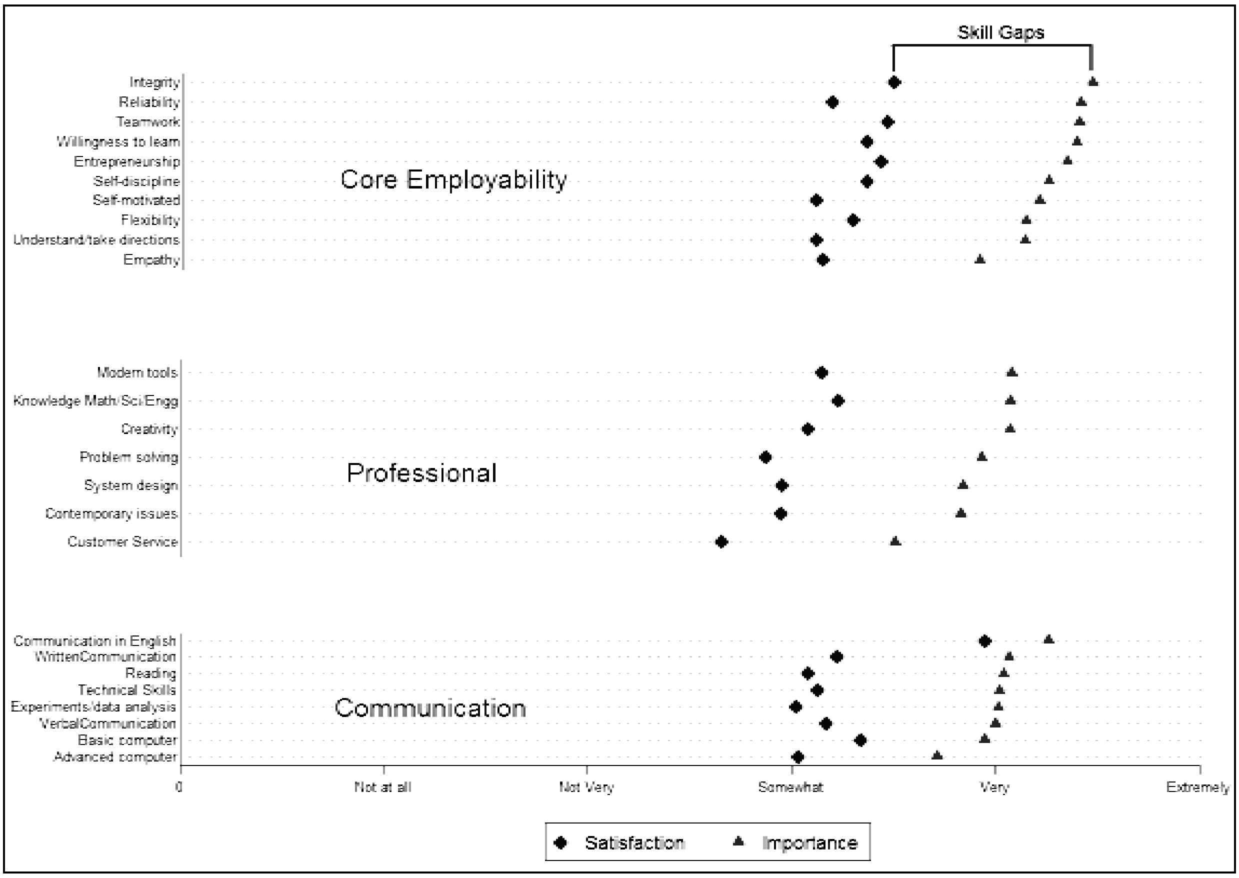

Figure 1 Skill Gaps (Source: Blom, 2009)

As can be seen from figure 1 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 assessment methods, and to build curriculum with emphasis on soft skills [Blom, 2009]. An essence of this report is that Indian engineering institutions needs to raise the quality of education imparted and must make provisions to ensure that the graduate engineers' skill are getting developed to meet industry demands.

REFLECTION ON THE SURVEY RESULTS

In this section, the survey outcomes are reflected to understand why engineering graduate lacks in skills? The engineering education institutions in India can be broadly classified into three categories – Central Government, State Government & Self-financed institutions. The Central Government and State Government institutions are financially supported by Indian government and are generally considered as institutes imparting quality education. The self-financed (privately owned) institutes are the institutions which get very little financial support from government and contribute 90% of current capacity of engineering education system (Goel et al 2004). These institutes (sometimes more than 100) generally have an affiliation to any of the state University who decides the curriculum. Typically, the undergraduate degree curriculum in India has a period of four years divided into the eight semesters.

In most of these institutions instruction based pedagogy is followed with a high emphasis on the grades. The evaluation of the learning is based on the written examination in which students' ability to remember and reproduce the knowledge is tested. As a result the focus of the pedagogy is to facilitate the students to obtain good "grades". The students tend to focus to obtain good grades (at least 60%) in these written examinations as industry (in general for campus placements and jobs in reputed organizations) demands for the students with grades 60% or more. Also, lack of motivation and innovative methods in teaching process had an impact on the student's psychology; they tend to seat in the classrooms for mere fulfillment of attendance criteria decided by university. So students are increasingly becoming passive learners with less engagement in learning process.

As discussed above, all the students' in the institutions have to follow a common written examination organized by a university. It means that semester after semester, as per the Bloom's Taxonomy students are tested for low level cognitive skills (remember, understand and apply) (Goel & Sharda, 2004). Furthermore, the students higher level cognitive skills (analysis, synthesis, and evaluation) were not tested enough. So the curriculum settings do not promote to develop higher order thinking skills and process skills of the engineering students. As a result students lack in these skill and are unemployable. These observations are confirmed by the different national level studies as discussed in preceding section. In the next section how PBL can be suitable alternative to address this issue is discussed.

THE PBL PRINCIPLES AND THE CHARACTERISTICS

The first university to develop and implement the Problem Based Learning curriculum was McMasters University, Canada in 1968 for medicine courses. Later in Denmark, a problem based and project organized model was implemented at Aalborg University in 1974 for engineering education [Kolmos, 2004]. The six core characteristics of PBL was described by Barrows (Barrows, 1996), in 1996 are

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

Since then the PBL strategy has progressed well and embraced by many leading universities in the world. Although at present many PBL models coexist, Graaff and Kolmos (Graaff, 2009) pointed out that these models share common principles of learning: cognitive learning, contents, and social.

The cognitive learning approach means that the learning is organized around the problems and will be carried out in the projects. A problem becomes central part of learning process and becomes motivation for learning. The students learn by his experiences while confronting to tasks involved in the problem solving process. A content approach especially concerns disciplinary and interdisciplinary learning. It is an exemplary practice carried out to address learning objective of the subject or curriculum. It also supports the relationship between theory and practice. The third principle emphasize on the concept of working in a team. The team or cooperative learning is a process in which learning is achieved through dialogue and communication between the team members. Students not only learn from each other, but also share the knowledge. Also, while working in a team they develop collaborative skill and critical project management skills. This is called as learner centric and participant directed approach in which students own their projects and make decisions to get desired outcome.

A PBL PROCESS

Based on the principles, PBL process can be explained as follows. In PBL settings students learn while solving the problems working in a team. Problem becomes a motivation for learning. To address the problem they will decide what is needed to learn and will search the relevant information from various source (Self Directed Learning). They will find most relevant information for problem solving and will share the same with the team members. By sharing the information, the team members learn from each other (peer and cooperative learning). In this way student will acquire information management, and collaboration skills. They will also understand the process, method and engineering tools which are used to solve these problems. They learn to make critical decisions and manage their work by applying project management principles (Du, 2004).

To receive a theoretical background of the subject they will attend the lectures in a classroom. This background will help them to understand and to decide the direction of their project work. During project work emphasis is also given on laboratory work so that they have hands on experience of working on experimental set ups and tools. This will help them to acquire working knowledge of machines, engineering tools and practices. Finally, students will submit the report of preliminary findings to the supervisor for suggestions. The report will be finalized in consultation with the supervisor. The students have to appear for the examination which generally comprises of group presentation and individual oral examinations. Students will be awarded the grades based on their performance in the presentations and responses to the questions in oral examination. In this way communication (written and verbal) and presentation skill will be improved.

As discussed above, PBL environment provides ample opportunities for learning. This learning is achieved in various modes (self-directed, peer, classroom, reading and sharing the literature). In addition to this, students will acquire the skills as PBL setting offer them several situations to practice and apply knowledge to solve the problem. Based on the above discussion it can be established that in PBL setting, higher order cognitive skills such as problem solving, critical thinking, creativity and application of theory to practice will be enhanced. Also, important process skills such as teamwork, communication (oral and written), project management and lifelong learning will be improved.

EFFECT OF PBL ON KNOWLEDGE AND SKILLS

One of the frequently cited literatures about the effect of PBL on knowledge and skills is done by Dochy (2003). He pointed out there is a strong positive effect of PBL on the skills of the students. He concluded that students in PBL gained slightly less knowledge, but remembers more of the acquired knowledge. Empirical studies conducted at Aalborg University concluded that PBL helped students to improve process competencies. Process skills are the skills which are used in the application of knowledge. These include problem solving, critical thinking, communication, teamwork, self-assessment, change management and lifelong learning skills. The PBL environment provides ample learning opportunities in which students learn by cooperation, and collaboration with peers [Du, 2004, Shinde, 2011b].

An increasing number of cases have adopted the PBL method in engineering education to boost students' problem solving skills (Uden and Dix, 2004). Research undertaken by four British Universities showed that well-structured project work can improve students' key transferable skills and information retention rate [Willmot, 2003]. The problem-based learning (PBL) method can be adopted in engineering courses to create learning environments that help students develop problem-solving, collaboration, communication, and self-directed learning (SDL) skills, as well as content expertise (Dunlap, 2005). PBL method was found to be effective in developing and enhancing generic skills in students at University Technology, Malaysia (UTM). The survey results indicated that the generic skills of the 70% students had improved due to introduction of PBL at UTM [Khairiyah, 2005].

Effectiveness of PBL instructions on knowledge and skills of the undergraduate engineering students at Chitkara institute of technology, Rajastan, India was assessed over a period of four semesters by Mantry et al. Their results indicated that the students achieved better scores in knowledge and skill tests, showed better attitudes towards learning in PBL environment. Also, process skills were largely improved in the PBL class [Mantry et al 2008]. Singh et al realized the impact of Robotic Competition on students of the Indian Institute of Technology (IIT) Delhi. They realized that the project helped students to understand aspects of product development, teamwork and project management [Singh et al 2008]. As discussed in this section, the previous studies indicated that when the PBL method is applied in the curriculum, there is significant increase in the skill levels and learning motivation of the students.

MAPPING OF PBL OUTCOMES WITH SKILL GAPS

In this section, skill gaps identified by Blom as seen in figure 1 are mapped with the learning outcomes achieved by the students in a PBL setting. The mapping exercise is done based on the discussion and result of empirical studies reported in preceding section. The ‘X’ mark in the following table denotes that the skill can be achieved in the PBL environment. In the original survey an author used many terms which may require explanation. These terms are explained in the table 2 below.

Table 2 Terms and their explaination.

Skill	**Explanation**
Flexibility	responds well to change
Creativity-	identifies new approaches to problems
Empathy	understands the situations, feelings, or motives of others
Reliability	can be depended on to complete work assignments
Integrity	understands/applies professional and ethical principles to decisions
Self-discipline	exhibits control of personal behavior
Basic computer	e.g., word-processing
Creativity	identifies new approaches to problems
Advanced computer-	e.g., spreadsheets, databases

Table 3 Alignment of skills demanded by employers and PBL learning outcomes

Core Employability Skill gaps	**Learning outcomes achievable by PBL**	**Professional Skill gaps**	**Learning outcomes achievable by PBL**	**Communication Skill gaps**	**Learning outcomes achievable by PBL**
Reliability		Problem solving	**X**	Experiments/data analysis	**X**
Self-motivated	**X**	Creativity	**X**	Reading	**X**
Willingness to learn	**X**	Use of modern tools	**X**	Technical Skills	**X**
Understand/take directions		System design to needs	**X**	Written Communication	**X**
Integrity		Contemporary issues		Verbal Communication	**X**
Teamwork	**X**	Apply Math/Sci/Engg know.	**X**	Advanced computer	**X**
Entrepreneurship		Customer Service		Basic computer	**X**
Self-discipline	**X**			Communication in English	**X**
Flexibility					
Empathy	**X**				

RESULTS AND DISCUSSION

In the table as can be seen 18 skills out of 25 skills are matched. It is to be noted that the matching is done to understand the normative view. Also, in some cases it is assumed that the skill is matched as it is not possible to show exactness of the matching as in case of empathy. The meaning of empathy is ability to understand others. It can be assumed that the collaboration between the team members is not possible unless and until understanding between the team members. Skills such as teamwork, problem solving, project management and communication are the part of the PBL process, hence can be assumed to be perfect matching. In PBL students ability to apply the knowledge is tested, hence ability to apply science and mathematics, experimental data analysis skills can be said to be matched. In PBL settings curriculum is designed in such a way that students are in general exposed to use of computer platforms (word, excel, internet) and modern tools such as modeling and analysis software during their work. So, it's natural that computer skills get enhanced during the process. It can be concluded that by using PBL settings most of the skills demanded by the Indian employers can be achieved. This may lead to bridge the gap between employers' expectations and learning achieved at the education institute.

PERSPECTIVES FOR INDIAN CASES

Based on the different PBL cases from the world, it is confirmed that PBL is an accepted educational strategy. Also, it can fittingly address issues such as low motivation and skill levels of the students. PBL can be a suitable alternative to traditional pedagogy in Indian engineering education. Indian institutes are built for traditional teaching, PBL implementation at these institutes seems to be difficult. There seems to be multiple barriers for PBL implementation, important ones are listed here. Historically, teachers and students in India are practicing traditional teaching in which most of the focus is on content coverage. It can be expected that teachers and students will resist the change. Furthermore, the students in India are habitual to traditional teaching and evaluation methods. In PBL settings they need to be active learners which may pose challenge.

A lack of literature and guidance in PBL curriculum design, shortage of trained faculty in PBL hindered the further progress of PBL in India. Most of the institutes or universities in India are built by considering traditional teaching. For example in PBL setting the group rooms are important to facilitate the group work. Also, the library equipped with reference books, on line database of the journals is important source of information to support the project work. Such facilities are not the regular feature of Indian institutes.

Generally, an educational system; especially privately owned have conservative approach to embrace innovative methodologies due to financial implications. Also, these institutes do not promote educational research as compared to research in traditional engineering disciplines. Furthermore, engineering education research (EER) is not a recognised field in India. PBL as an alternative is just started to get the recognition in few of the universities in India. Although, PBL seems to be a suitable alternative to Indian engineering education, concentrated and scalable efforts are required to make PBL as an acceptable method in India.

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

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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

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typically include previous research and contextual understanding, design formulation or intervention design, implementation and 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.

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.

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

2.1.1 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.

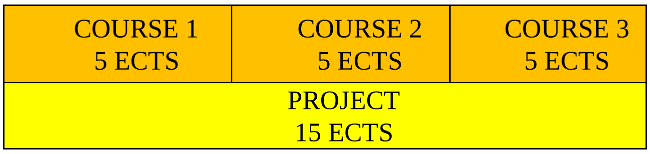
2.2.2 Review of PBL models and related literature

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.



COURSE 1 5 ECTS	COURSE 2 5 ECTS	COURSE 3 5 ECTS
PROJECT 15 ECTS		

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.

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