SYNOPSIS

Unlike a broad-based education in arts or sciences, the engineering education system is designed to train engineers for the engineering profession. Hence, it has to meet the challenges and needs for engineers to support the global economy. As the nature of technology and industry changes, the education system needs to be responsive and adapt to the changing demands. There is a need for engineering educators to be conversant with existing practices in industry while also acting as agents to bring in innovation and improvements. Initially the focus of the engineering education system in India was to produce engineering graduates to implement operate and manage the growing industry that mainly relied on imported technology. Subsequently as the economy grew, there emerged a need for technology development and then for research and development. The engineering institutions that were primarily set up for undergraduate teaching started emphasizing research and evolved Masters and Doctoral Programs.

The growth of sanctioned intake in bachelor's degree of engineering for the period 1990 to 2001, in India, stands at 9.1, with the CAGR for the period 1996 to 2001 standing at 17.4% Out of this astounding growth rate, the growth rate in computer engineering and information technology stands at 37.7% CAGR, followed by electronics and electrical engineering. About 32% of the sanctioned strength in 2001 was in computer engineering and information technology. For 2006, Computer Science and Information Technology accounted for 34% of the total, 39% for Electronics and Electrical Engineering, 12 % for Mechanical and 4% for Civil Engineering [1]. Compare above figures with the growth rates in the US, where the CAGR for total B. Tech. degrees stands at 27% for the period 1996 to 2006. Out of this, the highest growth rates are for Biomedical Engineering (16.3%), Aerospace Engineering (12.8%) and Computer Sciences and Engineering (7.7*%)* [2].

India clearly has one of the highest growth rates in terms of sanctioned intake for engineering education. Are these high growth rates impacting quality and resulting in unemployment/ under employment of fresh engineering graduates? It is estimated that about 30% of the fresh engineering graduates are unemployed even one year after graduation (based on ATMRs of a few states) [3]. Several industry leaders complain about the shortage of quality engineering graduates. Though there is no conclusive statistics, it seems that the present growth is impacting quality.

It is also possible that the quality has not been able to match the quantity. There has been long lasting and never ending debate on the parameters used for the measurement of quality of engineers and engineering education. Despite this, out of many reasons assigned for the decline for quality in engineering education, pedagogy of engineering education is considered to be at the forefront.

This study used a teaching pedagogy of Problem Based Learning (PBL) to compare any significant changes in knowledge, skills, and attitude to the traditional teaching of engineering graphics. Although, PBL is generally believed to better prepare students for learning and group work, it has yet to be fully embraced – methodically - throughout our educational system – specifically, in India. Yet, traditional engineering education, with its roots firmly embedded in the Industrial Revolution, still leans on the transmission of knowledge to the solution of an ill-structured problem, the content of which is centered about a set of structured objectives. In turn, these objectives are coupled to standard techniques and solutions and are taught as theoretical, practical, and other topics, which are often followed by preformatted homework exercises or tutorials [4]. This instructor-centered *ceteris paribus* approach to finding solutions for engineering problems is important for uniformity and stability in traditional instruction, especially while engineering as a profession is undergoing change, a change where the essential skill for an engineer is the ability to communicate clear design ideas for solving a problem, adopting a structured approach, finding out the solutions in stipulated time and implementing it.

The literature implied an overall need that graduates of engineering are and want to be creative, and the engineering industry wants thinkers and problem-solvers, so likewise we should use Problem Based Learning (PBL) education techniques that foster creativity in students [5]. PBL allows students to solve problems creatively through an active-learning approach. Regarded as an active-learning inquiry method, PBL is based on the principle of using problems as a starting point for the acquisition and integration of new knowledge. Techniques such as Problem Based Learning can instill skills, attitudes, and experiences to enrich engineering to include greater understanding of the problem itself, working in teams and adopting a well thought of approach to solving, modeling, simulating, implementing, testing and finally troubleshooting. It is a process by which a group of students actively engages in learning and contributes, as opposed to sitting passively in a lecture hall, listening to, and memorizing facts [6]. An article by Clough and Kauffman [7] supported using the Problem Based Learning approach as a means of improving engineering education. They suggested that "we have to provide our workforce and students with skills, attitudes and experiences that will enable them to seek both lifelong facts and knowledge, along with the ability to use those skills as and where they are needed". Another change suggested by Johnson [8] for improving engineering education is that "industry needs workers to be both thinkers and problem solvers". To do this, we must use innovative and creative ways to teach the process and not teach in a vacuum but provide an eloquent variance from traditional education and re-anchor the accountability and responsibility. Students should be held more accountable for their own learning in engineering disciplines through student centered learning by using techniques such as PBL [9].

In order for engineers to retain a competitive edge, they need to be provided with up-to-date knowledge and skills, the ability to solve problems, visualize, and the attitude to adapt to change. Consequently, engineering education is undergoing change, and the literature suggests those engineering skills, attitudes, and experiences enrich the engineering experience to include greater understanding of visualization, problem solving and other engineering skills. The professional organizations and literature [8] [10] suggest we produce workers who are creative problem solvers and we use innovative methods, such as PBL, to allow engineering students to develop problem-solving and teaming skills for open-ended design and solving real life problems. Within the literature of Albanese and Mitchell [11], we see widespread support about the benefits of PBL, its motivational effects on students working open-ended problems and its beneficial long-term effects on lifelong learning. Success in an engineering curriculum has long relied on the ability to creatively solve problems [12]. However, there is little information on the use and application of PBL methods to engineering studies. There is even less information on the scholarly application of this method to real-life problems in engineering disciplines and its use as a stimulation tool. Aside from the industrial and educational need for change, the literature indicates many critical engineering reports and engineering professionals who seek active change in engineering education. One of the latest to emerge is Engineering Criteria 2000 (EC2000) [13], which focuses on outcomes assessment for demonstrating program success, and is endorsed by the Accreditation Board for Engineering and Technology (ABET). The EC2000 document attempts to encourage accountability and continuous improvement in engineering education, to which many 2 and 4 year schools already seek active change in engineering studies, especially since the mid 1950s when Dr. Grinter of VPI chaired the 44-member American Society for Engineering Education (ASEE) Committee that produced the Grinter Report (ASEE, 1955/1994) [14], to become the essential blueprint for engineering science revolution in USA. Similar to EC2000, a reprint of the Grinter Report (ASEE, 1955/1994) [14] revisited many recommendations for engineering design and other elements in a curriculum to include "development of student creativity, use of open-ended problems, development and use of modern design theory and methodology, formulation of design problem statements and specifications, consideration of alternative solutions, feasibility considerations, production processes, concurrent engineering design, and detailed system descriptions" [14]. To place a slant on real-life factors and constraints, it also considered "realistic constraints, as economic factors, safety, reliability, aesthetics, ethics, and social 5 impacts". The report was intended to address immediate concerns and have a short term impact on the engineering profession, and the report did initially suggest sweeping changes in the engineering curriculum to include problem-solving, active-learning, and visualization techniques. It also promoted engineering education to establish the foundation of successful practice, effective teaching, and relevant research in engineering design. Later, the National Research Council [19], in its Improving Engineering Design report also mirrored this change. Furthermore, to improve engineering education, the National Science Foundation (NSF), the Carl Perkins Act, and the Accreditation Board for Engineering and Technology (ABET) have also approved the revision of engineering programs by funding educational grants for creative problem solving, engineering design, or applied design education or curricula. Some results of this type of work are outlined by Barr and Juric [15], Kenley [16], and Miller and Bertoline [17]. Consequently, EC 2000 is just one of the latest recommendations to emerge in a long list of ongoing engineering education improvements seeking active change in engineering education. The reform of engineering education is not restricted to 2 and 4 year schools. Through the Perkins Act and other educational curriculum grants, reform has trickled down to high school to allow problem-centered learning methods. For instance, over 5 years, from 1996 to 2001, the NC Department of Public Instruction, NC State University, and Wake Forest University Medical School hosted statewide workshops in Problem Based Learning [18]. The two universities used a Perkins and a 5-year NSF grant to further induce and elevate science, technology, architecture, and mechanical engineering 6 teachers and North Carolina high-school teachers and college instructors and with problem based learning classroom skills. In the PBL workshops, teachers were taught facilitation skills, case study creation, and PBL assessment and rubrics. As new facilitators, they were taught to relinquish control while maintaining the quality and integrity of the learning environment. To model characteristics of lifelong learners, they were taught that helping students find solutions are the keys not the right answers. The process of learning this facilitation skill enabled teachers to empower students with ownership of learning, so there would be no more “guess what I’m thinking in class.” Teachers were taught to encourage different pathways for different students and to allow them to seek answers. Teachers were encouraged to use prompt-style questions and suggestions in order to facilitate but not direct the class, which included: What would be helpful to do now? Is that a learning issue? How do you know that? What does that have to do with the problem? Does everyone agree with that statement? To sum up, the professional organizations and literature suggest we must produce innovative workers who are creative problem solvers and use innovative methods, such as problem-based learning, to allow engineering students to fully develop their problem-solving and teaming skills and be more creative with open-ended design and graphic solutions. Most engineering problem solving is accomplished via team and group work, so why not use a problem-based education approach?

Need of Study:

Issue 1: Till now there have been many studies on pedagogical practices in higher education and published results are available on effects of pedagogy viz. collaborative learning, Project based learning and Problem based learning on knowledge gain, skill gain and attitudes of students of both medical and engineering streams. These studies can be categorized based on University, Students, Pedagogy, Courses taught and the selection of measured parameters and the variety of independent parameters. So far, the studies have been carried out on different courses in engineering. Sometimes favorable results and sometimes equivalent results have been found in all these studies.

Issue 2: Cognitive style and Gender are taken as independent parameters, as various studies suggested that the process of learning and problem solving have some relation, whatsoever, with these two parameters. However, the correlation of these two parameters with pedagogy has never been studied.

Issue 3: So far the study of PBL has been limited to a particular teacher designing a strategy to deliver the course curriculum using PBL and then measuring the effects. In this particular study, three courses are designed once and are then delivered twice, by two different facilitators, to two different batches of students. This way, the theory of extrapolation can be applied with greater confidence.

Issue 4: The step by step description of what is happening in the PBL class and then relating the results drawn to the statement analysis is a unique feature, which gives a real insight into the class and how the relevant discussion amongst various participants – students and facilitator is.

Issue 5: So far the practicing PBL places are autonomous Universities and Institutes, worldwide. A lot of freedom rests with the teacher and the University to decide the curriculum and the evaluation strategy. The Institute, where this study was conducted is one of the many self aided institutes, where the affiliating University decides the curriculum and even the pedagogy to a large extent. By this study, a unique and maiden effort to integrate PBL to traditional evaluation strategy has been initiated and implemented.

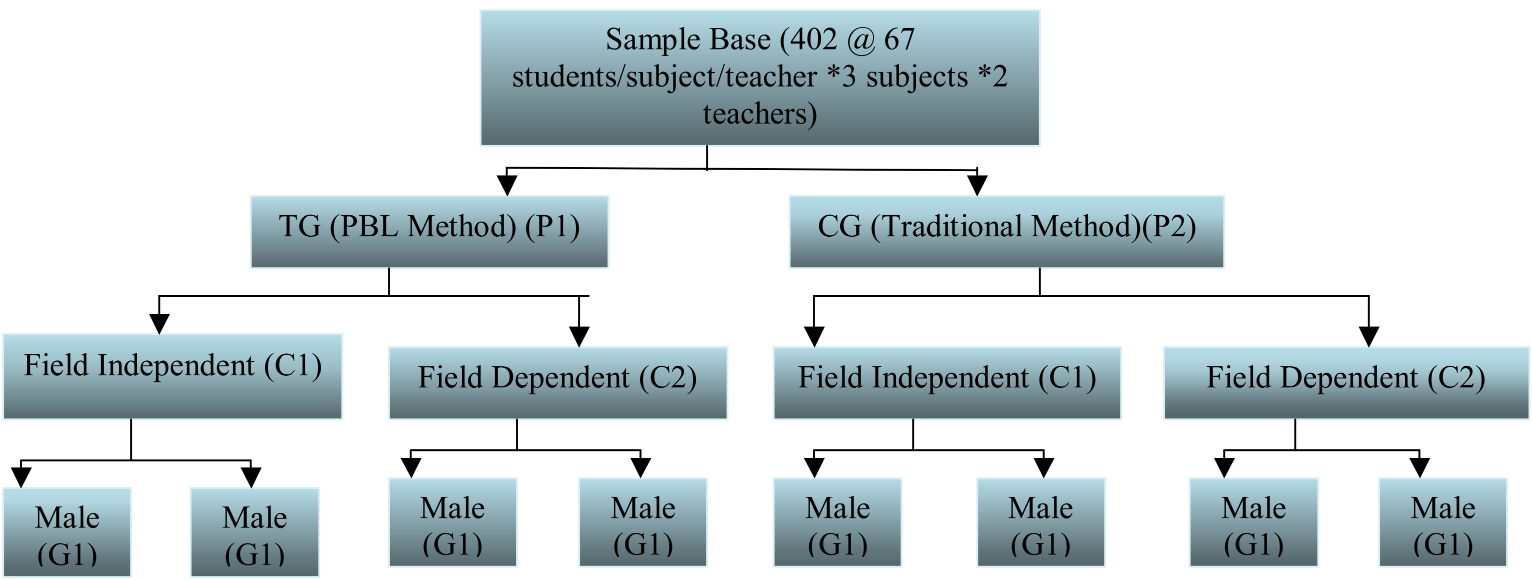
Issue 6: All the PBL experiments carried out so far have no jurisdiction, in any of the Indian Universities or Institutes (affiliated or autonomous). Thus, Indian engineering students Community though very large (approximately 20 lac students), has never even experienced PBL in a structured manner.

Issue 7: Technical Education in India is already reeling under acute shortage of competitive faculty. Even those, who are available, have seldom experienced or made their students experience cooperative learning during undergraduate studies. Even those, who have rarely done so, have rarely experimented with PBL, inspite of its positive results, worldwide. This study thus, can trigger a series of such experiments in ECE and other branches of engineering (with particular reference to India) so that widespread results are available and can be extrapolated in students.

Design of Study:

The study was aimed at studying the effectiveness of Problem Based Learning Instructions on knowledge and skills of students of Undergraduate program in Electronics and Communication Engineering at Chitkara Institute of Engineering and technology in three subjects – Analog Electronics (AE), Digital Electronics (DE) and Pulse Switching Circuits (PDSC). The Institute is affiliated to Punjab Technical University, Punjab. The experiment was carried out in above three subjects over a period of four semesters, as described in the layout of sample base.

The factorial design of 2x2x2 was used because it permits to evaluate the combined effect of two or more independent variables simultaneously. The layout of the factorial design is given in figure



Pedagogy:

(a) The teaching pedagogy for the Traditional thread continued to be "traditional" using Lecture, Tutorial and Practical classes, with the teacher as "Sage on Stage". The teacher made the Lecture plan and Lab Plan – an hour wise, lecture wise, lab wise schedule, for delivery of whole syllabus, right from knowledge level to the application level. She also delivered the course in accordance to the same. The quasi-open-ended-problems, as given in the section VI, were changed into more closed-ended-ones and given to the traditional group for practice, in the tutorial classes. These problems were given in addition to many other analytical questions, which the students practiced in tutorial classes. The lecture and tutorial sessions were interlaced throughout the semester. The content delivery in the Lecture classes was one way - from teacher to students. However the students were allowed to work in groups, practice analytical problems and discuss the issues in Tutorial classes. The practice session for a particular topic was always after the concept was delivered and understood by the students in the Lecture classes. The practical sessions in the Lab classes had objectives, again, determined by the prescribed study scheme and syllabus of the affiliating University and the teacher. All in all, there was a clear demarcation in the Lecture, Tutorial and Lab classes in terms of the delivery of content, what the students performed and the Learning Objectives.

(b) For the PBL thread, there was no structured plan in terms of delivery of content. However, the teacher – here, termed as Facilitator - prepared a complete set of Technical Nodes and Learning Objectives. Chapter 1 deals with the aspects of engineering education in India vis-à-vis engineering education worldwide. The theory of Problem Solving and concept of cognition are introduced. The historical aspect of PBL is elaborated and principal research questions are framed.

The facilitator designed open – ended Technical Problems (TPs) and got them authenticated by a group of senior teachers. While designing TPs, care was taken that the scope was broad enough so that the students could achieve all the Technical Nodes and Learning Objectives in the conceptual, while attempting to solve them.

Students grappled with these fuzzy Technical Problems (TPs) – one at a time, and tried to understand the scope, issues and concepts stemming from or inherent in the TP before attempting to identify the learning points that would guide them towards the formulation of an eventual response (in the form of a theory, hypothesis, solution or argument).

There was no demarcation of Lecture, Tutorial or Practical classes and the total time available for the course was divided into several two hour PBL-sessions. The students developed an understanding and also found the solution to the TP while traversing the conceptual space, covering the technical nodes and also learned to work in teams. The role of the teacher was changed from the "content-delivery-man" to a facilitator. The students worked on their Technical Problems, trying to find out one of the many possible solutions, determining and achieving their own theoretical and practical Learning Objectives. The teacher remained and worked as "guide-by-side", truly taking up the role of a facilitator. She carefully monitored each and every step of the groups and remained aware of the progress made by the groups. At times, when the facilitator felt that all the students encountered the same kind of bottleneck at some point, the facilitator even delivered a structured lecture or called upon all the students to perform the same experiment, so that they all can proceed further.

Moodle™ software was used for online submission of assignments and presentations for both the threads and also to extend the discussion among students even beyond the class room.

Analysis of Data:

The data was analyzed using descriptive statistics such as Mean, Median and Mode, SD, skewness and kurtosis. To draw statistical inferences, and to test hypotheses, three-way ANOVA was employed. The p-value analysis showed that pedagogy significantly contributes to knowledge and skill gains of the students. It also showed that the females responded better to pedagogy for their knowledge gain. There was no effect of cognitive styles on the dependent parameters. The Reaction scale form was used to measure the attitude of the students to pedagogy. PBL students showed very positive attitude towards learning. The statistical results achieved are tabulated in Chapter 5.

Conclusions:

1. The students taught through PBL achieved better scores in Knowledge and Skill tests in the three subjects of Analog Electronics, Digital Electronics and PDSC.
2. The students in the PBL class also showed better attitudes towards learning and utilizing the class time more effectively.
3. There was no significant interaction in cognitive style and Pedagogy

4. There was a significant interaction in the gender and pedagogy. The females responded better to PBL than the males.
5. There was no significant interaction between pedagogy, gender and cognitive styles

Implications of present study

1. The urgently needed paradigm shift in teaching pedagogy from Teacher centered to Student centered approach, from Teaching to Learning has been justified with this study. Although lacs of students are undergoing Technical Education in India, not concentrated efforts are being carried out to evolve a structured and scalable change in the pedagogy.
2. The present Study showed that PBL approach is a better pedagogy than Traditional – L/T/P approach.
3. The students in PBL thread scored better marks and their performance in knowledge test was significantly better than those in Traditional Thread.
4. The students in PBL thread acquired better skills as compared to students in Traditional Thread. This was markedly visible by their performances in Skill Test.
5. The females responded better to PBL than males in Knowledge construction, but not in acquiring better skills.
6. The cognitive styles of the students did not influence the knowledge gain and skills of the students under study.
7. All the above results indicate that after training the teachers for PBL, the pedagogy of PBL can be and should be used on a wider basis for imparting technical education.
8. Care must be taken to carefully draft the open Ended Technical Problems so that all the Technical Nodes and Learning Objectives are touched upon in the scope of the Problems, then only the syllabus of that particular subject is covered.

Scope of Future Study

1. The effects of pedagogy, gender and cognitive styles on the knowledge, skill and attitudes have been studied in this research work.
2. Learning in Humans is dependent on and related to many factors – Cognitive style being one of them. Other factors can be studied for their influence on learning of the students.

3. Further study to measure the problem solving abilities – specifically- of engineers can be taken up, with the same parameters.
4. The effect of enhanced learning capabilities and their effect on performance of these PBL students when they work in Industry on real life problems, can be studied.
5. The pedagogy – PBL is to be made scalable and the teacher training issue to be addressed at larger platform to handle such class. The ways and means to do so can be taken up.
6. Similar studies can be taken up in other branches of engineering too.
7. This study carried out has typically 21 -25 students in PBL thread in each subject. The effect and figures will change if larger class is required to be handled. Means and ways to incorporate PBL in larger classes are to be found out and the outcomes be measured.

Organization of Chapters:

1. Chapter 1 is the introduction to the research work
2. Chapter 2 describes the overview of related literature
3. Chapter 3 enlists the detailed methodology and the design of sample for conducting this study.
4. Chapter 4 is the most important one to describe the Traditional and PBL practices as applied to the three subjects – AE, DE and PDSC. The chapter describes in detail the various tools used to assess the students and the design of open ended technical problems
5. Chapter 5: After the conduct of experiment in six different batches and with two different facilitators, the data for knowledge and skill tests were gathered and three-way ANOVA was applied to test the data and draw concluding inferences. The test was also applied to test the hypotheses and answer the principal research questions.
6. Chapter 6: The results are summarized in chapter 6. Major conclusions are listed and scope of future study is also given here.
7. Chapter 7: References are given in the end and the appendices also supplement the body of the thesis

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