Problem-based Learning: An Approach to produce "System Thinking-New Kind of Engineer"

Priyanka Mahendru, Prof. D.V.Mahindru

Abstract— This paper describes an investigation of the impact of problem-based learning (PBL) on undergraduate Electronics & Communication engineering students' conceptual understanding and their perceptions of learning using PBL as compared to lecture. Fifty students enrolled in an Electronics & Communication course at a SRMGPC, Lucknow, participated in this research. The study utilized a within-subjects A-B-A-B research design with traditional lecture as the baseline phase and problem-based learning as the experimental phase of the study. Participants completed pre- and post-tests surrounding the four topics covered in the study and also completed a Student Assessment of Learning Gains (SALG) survey. Results suggested participants' learning gains from PBL were twice their gains from traditional lecture. Even though students learned more from PBL, students thought they learned more from traditional lecture. We discuss these findings and offer implications for faculty interested in implementing PBL. Given the limited research on the beneficial effects of PBL on student learning, this study provides empirical support for PBL. We discuss findings from this study and provide specific implications for faculty and researchers interested in problem-based learning in engineering.

The engineering profession requires engineers to deal with uncertainty and solve complex problems of the field, sometimes with incomplete data (Mills & Treagust, 2003; NAE, 2004). In addition, engineers need to be able to function as effective members of teams and have strong communication and problem-solving skills (NAE, 2004). However, today's engineering graduates lack these skills and have difficulty applying their fundamental knowledge to problems of practice (Mills & Treagust, 2003; NAE, 2005; Nguyen, 1998; Vergara, et al., 2009).

In addition, while science and engineering jobs experienced annual average growth rate of 6.7% (compared to 1.6% for total employment) between1950-2000, the attrition rate for students has steadily increased and the annual graduation rate decreased by 20%, (Felder, Felder, & Dietz, 1998; NSB, 2008). One of the complaints from engineering students is that the current teaching pedagogies (such as, traditional lecture format) emphasize explicit instruction, working individually, and norm-reference grading, which can make learning extrinsically motivating rather than intrinsically motivating(Felder, et al., 1998). The main problem within engineering education is the gap between the active field and the passive classroom experience (Palmquist, 2007).

In general, the traditional lecture method within engineering education is deductive, "beginning with theories and progressing towards application of those theories" and the instructor presents information without a discussion of why the mathematical models are being developed and what practical problems they will solve (Prince & Felder, 2006). and not specific to the situation in which the task needs to take place. This pedagogical approach falls short because the knowledge is not grounded. Dewey suggested that educators needed to encourage inquiry and that education should be grounded on experience and linked to real-life activities in order to motivate and develop students into upstanding citizens. This paper describes one such approach; problem-based learning (PBL) has the potential to help students to cope with the demands of complexities of the field and problems they will face in their future careers.

Index Terms - Innovation, Ill- structured, Learning, Mentor, Problem, Process, System Thinking, and Understanding

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1. INTRODUCTION

Problem-based learning is **"Problem"......"based" ......"learning"**. Let us look at each of these words. A **problem** is something that is problematic to the student; something that cannot be resolved with the current level of knowledge and/or way of thinking about the issues. The nature of effective problems in problem-based learning is that they are ill-structured as opposed to well structured. The characteristics of PBL ill-structured problems are that they are real-life and authentic not teacher's exercises, messy not tidy, incomplete in the sense of lacking information needed for their resolution and iterative in the way that they produce further ideas,/hypotheses and learning issues (Barrows 1989; Stephen and Pyke 1977; Margeston 2001). It is vital that the problems are engaging, that they "smell real", are interesting and challenging to students. This engagement stimulates further learning and requires research, elaboration, further analysis and synthesis together with decisions and action plans.

The word "problem" in problem based learning needs to be interrogated. Problems are not always about something that is in difficulty that needs to be sorted out. An ill-structured design brief for an artist or an architect can be a problem. A dilemma for a doctor or a challenge for an engineer can be a problem. Problems are not always how to do something immediately practical in professional practice. Problems can also be about how to understand something.

Problems can be presented to students in a variety of formats including: scenarios, puzzles, diagrams, dialogues, quotations, cartoons, e-mails, posters, poems, physical objects, and video-clips

One of the most important points about problems in problem-based learning is that it is not a question that first the students receive inputs of knowledge e.g. lectures, practical's, handouts etc. and then "apply" this knowledge to a problem they are presented with later in the learning process. This type of a situation is nor problem-based learning it is problem solving (Savin-Baden 2000). It is like making a cake when you have already been given the recipe and all the ingredients.

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One of the defining characteristics of the use of problems in problem-based learning is is that students are deliberately presented with the problem at the start of the learning process. **This is like getting the challenge of preparing a celebratory meal for a special occasion where no recipes or ingredients are given.**

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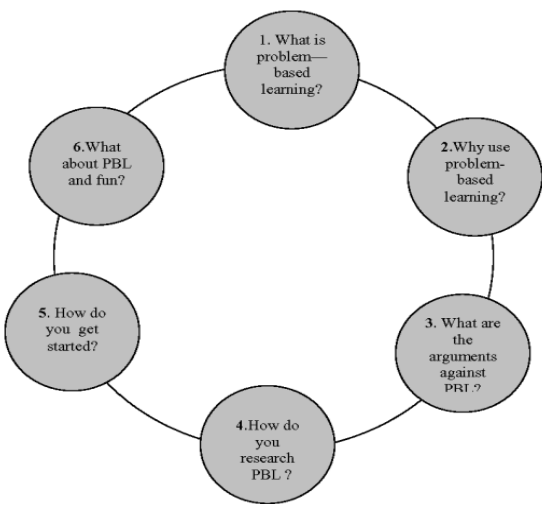
2.Description:

PBL, or **Problem Based Learning**, is an instructional method of group-based learning centered on utilizing each member of the group's own information, resources, and personal experiences. The group must then compile their knowledge in an effort to solve the open-ended problems. What makes this method of teaching interesting is that there is no one, real "right" answer.

The following diagram gives you a visual overview of the structure of the PBL



The learning that results from the **process of working towards the understanding** of a resolution of a problem. The problem is encountered first in the learning process (Barrows and Tamblyn 1980:1 my emphasis) .

An operational definition of problem-based learning is as follows:

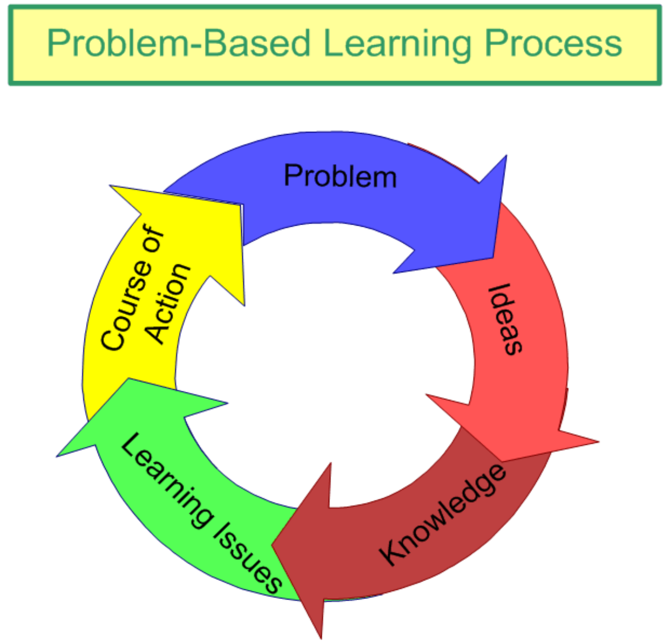
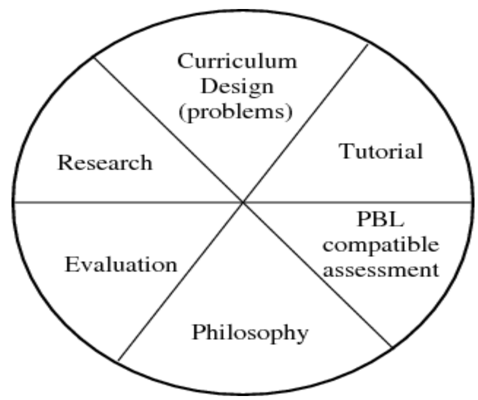


Figure 1: Problem Based Learning Process



i) First students are presented with a problem .
ii) Students discuss the problem in a small group PBL tutorial. They clarify the facts of the case. They define what the problem is. They **brainstorm ideas** based on the prior knowledge. They identify what they need to learn to work on the problem, what they do not know (learning issues). They reason through the problem. They specify an action plan for working on the problem.
iii) Students engage in independent study on their learning issues outside the tutorial. The information sources they draw on include: library, databases, the web and resource people
iv) They come back to the PBL tutorial (s) sharing information, peer teaching and working together on the problem
v) They present and discuss their solution to the problem
vi) They review what they have learnt from working on the problem. All who participated in the process engage in self, peer and tutor review of the PBL process and each person's contribution to that process.

2. REVIEW OF PREVIOUS WORK

The engineering profession requires engineers to deal with uncertainty and solve complex problems of the field, sometimes with incomplete data (Mills & Treagust, 2003;NAE, 2004). In addition, engineers need to be able to function as effective members of teams and have strong communication and problem-solving skills (NAE, 2004). However, today's engineering graduates lack these skills and have difficulty applying their fundamental knowledge to problems of practice (Mills & Treagust, 2003; NAE, 2005; Nguyen, 1998; Vergara, et al., 2009). In addition, while science and engineering jobs experienced annual average growth rate of 6.7% (compared to 1.6% for total employment) between1950-2000, the attrition rate for students has steadily increased and the annual graduation rate decreased by 20%, (Felder, Felder, & Dietz, 1998; NSB, 2008). One of the complaints from engineering students is that the current teaching pedagogies (such as, traditional lecture format) emphasize explicit instruction,working individually, and norm-reference grading, which can make learning extrinsically motivating rather than intrinsically motivating(Felder, et al., 1998).

The main problem within engineering education is the gap between the active field and the passive classroom experience (Palmquist, 2007).

In general, the traditional lecture method within engineering education is deductive, "**beginning with theories and progressing towards application of those theories"** And the instructor presents information without a discussion of why the mathematical models are being developed and what practical problems they will solve (Prince & Felder, 2006). and **not specific to the situation in which the task needs to take place.** Dewey (1938) argued. This pedagogical approach falls short because the **knowledge is not grounded** in context that such a traditional learning environment is too abstract and dull, leaving students with a sense of boredom and lack of motivation because they are presented with random information with no unifying factor. Instead, Dewey suggested that educators needed to encourage inquiry and that education should be grounded on experience and linked to real-life activities in order to motivate and develop students into upstanding citizens. Dewey also equated learning with doing and viewed learning as an activity, a process of discovery, where students need to be actively engaged in all aspects of the learning process (Savin-Baden, 2000).

Brown, Collins, and Duguid (1989) further emphasized that unless knowledge is developed in the context in which it is to be used, students will gain an
understanding of abstract concepts, algorithms, and procedures; thus, the knowledge remains inert and students are unable to use it. Brown and colleagues stated, "the activity in which knowledge is developed and deployed, is not separable from or ancillary to learning and cognition. Rather it is an integral part of what is learned" (p. 32). This is even more so the case for a complex enterprise such as engineering, which involves making decisions with real-world implications that carry risks and uncertain outcomes.

Recently, there has been a shift from using lecture-based teaching methods in the undergraduate courses in the STEM disciplines to using a more learner-centered teaching, such as problem-based learning (Lattuca, Terenzini, Volkwein, & Peterson, 2006). This shift is fueled by the need for future engineers to demonstrate the use of higher order thinking, problem solving, and more interpersonal aspects of a career, such as communication, social, and team-work skills (NAE, 2005). Specifically, the engineering field is seeing shifts in the types of engineers needed to emerge from college who are ready to participate as active and effective members of a global society. The National Academy of Engineers(NAE, 2004) developed a set of attributes future engineers will have to possess to be a competitive force within the field. Hence, it is important for engineering education to reexamine the use of typical lecture-based teaching methodology and consider incorporating learner-centered teaching.

One such approach, problem-based learning (PBL) has the potential to help students to cope with the demands of complexities of the field and problems they will face in their future careers.

3. CHALLENGES–AHEAD:

i) ENGINEERING LANDSCAPE IN INDIA (IIT BOMBAY STUDY)

To get a better handle on the problem, IIT Bombay undertook a study on the engineering landscape in India.
The study aimed to answer questions such as:
- Has the engineering education system been able to provide, quantitatively and qualitatively, the engineers required for the growth of the Indian economy?
- Has it provided the research and development leadership required for our industry?
- In the context of globalization, is there a need to modify the higher engineering education system in India?

The study shows that against the sanctioned seats of 6.57 lakh for Under Graduate Engineering education in India, only 2.37 Lac engineering degrees were awarded in 2007-08. This very clearly highlights the shortfall. In2006, India awarded about 2.37 lakh engineering degrees, 20,000 engineering Masters degrees and 1000 engineering PhDs, which means a total of 2.58 lakh engineering degrees of all types. This is clearly not enough! The awarding of degrees is also not evenly distributed across India. Five states – Tamil Nadu, Andhra Pradesh, Maharashtra, Karnataka and Kerala are said to account for almost 69% of the country's engineers. It is estimated that about 30% of the fresh engineering graduates are unemployed even one year after graduation; **and this is even as many sectors complain of lack of talent.** This clearly points that there is definite scope to improve quality of engineering education. Let us also look at the gender factor. At IIT Bombay, the percentage of women graduates to the total is about 8% at the B.Tech. level, 9% at the M.Tech level and about 17% at the Doctoral level including Science, Humanities and among the faculty – only about 10% of the IIT Bombay faculty comprises women.

Gender disparity in the engineering stream exists around the world, not just in India, and special efforts are being made by institutions, Governments and professional organizations to rectify these. Some Indian states have provided incentives like free tuition for women studying engineering. Overall, the study rightly points out that India has the potential to be a leading research and design hub in the world. **For this, we need to have a mechanism to identify important areas and develop policies and institutions accordingly.** Situations and problems we confront today demand composite responses and solutions.

4. THE TYPE OF ENGINEERS WE NEED:

i). NEW KIND OF ENGINEER

Globalization has resulted in highly dynamic and complex market leading to the requirement of a new kind of Engineer.

ii) SYSTEMS THINKING

This complexity demands a new way of thinking – it requires a Systems Thinking approach to macro level challenges and requires Engineers to keep one eye on the big picture even as they tackle specific tasks. Systems thinking provides a conceptual framework that helps make full patterns clearer and helps one to see how to modify these patterns more effectively.

This type of thinking is tricky to most of us because As Peter Senge says, it is a "discipline for seeing the whole". We are taught to break problems apart, to fragment the world! This appears initially to make
complex tasks more manageable; but we pay a hidden
Price: we can no longer see the consequences of our actions, and we lose our intrinsic sense of connection to a larger whole. **When we want to see the big picture, we try to reassemble the fragments and organize all the pieces. The task is futile– similar to trying to reassemble the fragments of a broken mirror!**

iii) MULTI-DISCIPLINARY APPROACH

Today's Engineers must also be able to view management activities through different lenses and work with people from different disciplines and diverse fields such as business, banking services and medicine.

We also have great minds, great thinkers. We just have to look for ways to bring them together. It is this fraternity of Engineers that will determine
"INDIA OF TOMORROW".

We have travelled a very long journey and our "Intellect" is second to none. What we need is to mould young professionals to the needs of our Industry. The eyes of the world are on us. We have the opportunity to become a superpower. We all owe it to ourselves to shoulder the responsibility.

" **Yesterday's collaborators are today's Competitors".**

We will decide our role on the global stage . To meet this challenge We need engineers with **"MULTI-DISCIPLINARY APPROACH"**

5. THE LOSE END: (HOLE TO BE PLUGGED)

i) INOVATION-LED GROWTH

India's future growth will be **driven not by cost but by innovation** in terms of product offerings, process efficiency, value engineering and cost reduction.

ii) DEVELOPMENTAL CHALLENGES

Even as we reach for the moon, there are millions here on earth for whom basic needs are elusive. No country can afford a skewed growth. If India has to achieve a 7% to 8% sustained growth, it needs not just **"Corporate India"** but the rural sector, the agricultural sector to grow as well. It is these areas that badly need the above cited engineering talent. The government, we and all of us together have to find ways to produce the above **brand of Engineers motivated enough to make it an attractive option for them to take up these challenges. However, today's engineering graduates lack these skills and have difficulty applying their fundamental knowledge to problems of practice (Mills & Treagust, 2003; NAE, 2005; Nguyen, 1998; Vergara, et al., 2009).**

In addition, while science and engineering jobs experienced annual average growth rate of 6.7% (compared to 1.6% for total employment) between1950-2000, the attrition rate for students has steadily increased and the annual graduation rate decreased by 20%, (Felder, Felder, & Dietz, 1998; NSB, 2008). One of the complaints from engineering students is that the current teaching pedagogies (such as, traditional lecture format) emphasize explicit instruction, working individually, and norm-reference grading, which can make learning extrinsically motivating rather than intrinsically motivating(Felder, et al., 1998). **The main problem within engineering education is the gap between the active field and the passive classroom experience (Palmquist, 2007).**

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6. PBL-A Break through

Problem based learning helps the student to:

- Develop Skill of discovering different facts and develop habit of collecting latest information and updates in all fields
- Freedom to express the problem and solution in one's own way

- It helps in developing team spirit
- Help in improving communication skill
- Makes the student flexible in processing information and handling different problems
- The teacher acts as facilitator and mentor rather than a source of solutions.

6.1Problem-based Learning: **PBL is any learning environment** in which the problem drives the learning. That is, before students **learn** some knowledge they are given a problem. The problem is posed so that the students discover that they need to learn some new knowledge before they can solve the problem. Some example problem-based learning environments include:

- research projects
- engineering design projects that are more than a synthesis of previously learned knowledge
- The traditional and well-known "Case approach", popular with business schools, **may or may not be problem-based learning.** Often the case is used to integrate previously-learned knowledge and hence would not be, according to this definition, problem-based learning.
- What's the big deal about PBL? Posing the problem **before** learning tends to motivate students. They know why they are learning the new knowledge. Learning in the context of the need-to-solve-a-problem also tends to store the knowledge in memory patterns that facilitate later recall for solving problems.
- What skills should a student have before entering a PBL program? They should be skilled at problem solving because that skill in needed as the students try to solve the problem.
- Does using PBL develop problem solving skills? **Not without explicit interventions on the part of the teacher.** PBL offers an opportunity to develop the skills
- Is PBL an example of cooperative learning? It depends. If the PBL is an individual project, then it does not require cooperation with others.
- Why does there seem to be so much confusion about what is and what is not PBL? Problem-based learning, learning because you need to solve a problem, has been around for centuries. Indeed, in the stone age, people learned skills and approaches to solve problems to survive. They just didn't say to each other "Hey, you are using PBL." In the 1960s McMaster Medical School introduced a learning environment that was a combination of small group, cooperative, self-directed, interdependent, self-assessed PBL. Since then this approach has been called "PBL". But PBL, can be in any form where a problem is posed to drive the learning. To overcome the confusion, It is suggested that we use the awkward terminology of small group, self-directed, self-assessed PBL when referring to learning environments similar to the McMaster Medical school approach.

6.2 Small group, self-directed, self-assessed PBL is a use of problem-based learning which embodies most of the principles known to improve learning. This learning environment is active, cooperative, self-assessed, provides prompt feedback, allows a better opportunity to account for personal learning preferences and is highly effective.

- If small group, self-directed, self-assessed PBL is so great for learning, why isn't everyone doing it? Probably**, because of fear of the unknown and resources**. Using this approach requires that teachers change. Change is not easy. This change, in particular, **expects teachers to change their role from being the center of attention and the source of all knowledge to being the coach and facilitator of the acquisition of that knowledge.** The learning becomes student-centered, not teacher-centered. For resources, the McMaster medical school model includes a tutor/teacher with each group. The groups are tutored. Hence, there is one teacher for every group of five or six students.
- This is resource intensive if you do this for only one course. This approach is not so resource intensive if the whole program is changed to this format. But what if you want to try small group, self-directed, self-assessed PBL as part of your course? or for only one course in your departmental program? Now, one is faced with classes of 30 to 200 with only one instructor.
- How can we use this medical school model with only one instructor with large classes of 30 to 300? One answer is to use tutor less groups. Here we provide the students with the training we give to tutors; we empower the student groups to be autonomous and accountable, with the tutor's role being to monitor and hold the individuals and groups accountable for their learning.

6.3 PBL and Problem Solving (Thinking Skill)

- **Problem solving** is the process used to solve a problem. Since problem-based learning starts with a problem so be solved, students working in a PBL environment should be skilled in problem solving or critical thinking or "thinking on your feet" (as opposed to rote recall). How is this handled? In research programs, we usually have qualifying examinations in which we test the **problem solving (thinking skills)** of the candidates before they are admitted. In the McMaster Medical school, one of five criteria for admission is a test of the candidates problem solving skills. Regrettably, some teachers embark on PBL without either pre-screening or developing their students skill in problem solving.

- Doesn't putting students in a PBL environment develop their problem solving skills? Regrettably no. Giving students an opportunity to solve problems rarely develops their skill in problem solving.

- Can you have problem solving skill development without using PBL? Sure. We have lots of examples. Conventionally, students learn the material in Chapter 5 of a text, and then use problem solving to solve the homework problems. Here students are using problem solving skills in a "subject-based" learning environment compared with a problem-based learning environment.

6.4 PBL and cooperative learning (Learning Environment)

- **Cooperative learning** is a learning environment where students work together to learn, as opposed to competing with each other for marks.

- Can you have cooperative learning without PBL? Sure. Cooperative learning can be used for subject-based learning. Here, you ask students to work together to solve problems, discuss ideas, compare ideas about a concept, or do any task. You do use cooperative learning when you use small group, interdependent, self-directed PBL. Can you have PBL without cooperative learning? Sure. Individual research or tasks in the .PBL mode do not require cooperative learning.

6.5 Use of small group, self-directed PBL

- Our experience has been with small group, self-directed, self-assessed PBL in tutor less groups. In the **chemical engineering program**, we use PBL as part of two courses: one topic or problem in a junior level course; and five topics in a senior level course (Woods, 1991). The students concurrently are taking five to seven required courses presented in the conventional format. Both PBL courses have about 30 to 50 students with one instructor. Hence, we use five to ten tutor less groups with five students per group. Before the students they have received about 50 hours of workshop style training in the processing skills. The outcomes for the PBL activity are the Chemical Engineering subject knowledge (process safety and engineering economics), lifetime learning skills and chairperson skills. Each problem is studied for about one week. Before the first PBL activity, the students have workshops introducing them to this PBL approach to learning and workshops on managing change. The students are required to submit journal reports frequently that make explicit their progress and activities within the PBL tutor less groups. The elaboration is done by having three meetings: a goals meeting, a teach meeting and an elaboration/feedback meeting. Student-generated learning issues are validated by the instructor during the goals meeting. The students' assessment of the partial PBL learning environment, as measured by the Course Perceptions Questionnaire (Knapper, 1994 and Ramsden, 1983), is d= +1 more positive than the responses from a control group of engineering students in a conventional program (N=47).

- At McMaster University, the **theme** school program was created. This is a program for interdisciplinary learning that students from all disciplines may elect to take on overload. Based on the research expertise at McMaster, one of the theme schools is on **new materials and their impact on society**. This school has five 3-credit courses, three 2-credit seminar courses and two 6-credit research internships. Enrolment is limited and by application. About 35 students were admitted in both the first and second year since it was started. Students are from English, biology, physical education, nursing chemistry, mathematics and engineering. The 3-credit courses use the small group self-directed problem-based format. For each course has two instructors and 1 teaching assistant. The first course is sophomore level. In each 13-week course the tutor less student groups handle 2 to 3 cases or problems.

- Concurrently they are taking 5 to 7 required courses in their major area. Except for the nursing program, all the other courses the students take are presented in the conventional lecture format. The students have received no formal training in the processing skills before they enrolled in the theme school. The approach has been to develop these skills concurrently. They have five explicit, 1½ h workshops that are given during the second semester of their sophomore year.

- The topics are understanding PBL and its expectations, managing change, problem solving, group skills and self-directed-interdependent small group learning. The student evaluations of the program have identified the importance of these explicit workshops and have recommended that these be given **before** the students encounter their first case problem. Currently, this program does not explicitly include the development of processing skills as valued outcomes nor are these skills formally assessed.

- The program got strengthened. The students are not required to do extensive journal writing. However, their written reports must demonstrate that they have synthesized information and material learned from other members of their group. Student's assessment of the PBL learning environment in the Theme school, as measured by the Course Perceptions Questionnaire is d = +2 more positive than their assessment of their "home" departments. Their responses for their home department were consistent with the responses from a control group of students in a conventional program that has enrolment limited and is by application.

- In Civil Engineering, Fred Hall uses small group, self-directed, self-assessed PBL in a junior level course; in Geography, Caroline Eyles and Fred Hall use this approach for a senior level project course.

7. THE METHODOLOGY:

a. Understand the problem:

The teacher introduces an "ill-structured" problem to a groupofstudents. The group discusses the problem statement and lists its significant parts.
The problem may appear as very tough for the group to solve but that is the real inspiration source to work hard on it. The group has to gather information and learn new concepts, principles, or skills that can help the process of finding the solution.

b. List the information already known to the group which can help the solution.

This includes both what each member of the group actually knows and what strengths and capabilities each team member has.
Each information and idea of every group member is important, no matter how strange it may appear: it can prove useful.

c. **Develop, and write out, the problem statement in your own words.**

Every person can understand the thing better in his own way expressions. Thus, a problem statement should come from the group's analysis of what the group knows, and what the group will need to know to solve it.

d. List all possible solutions.

The problem is discussed in group. Various possible solutions may appear together, now to search which solution is best, the group can list them all, then order them from strongest to weakest
Now, they can choose the one which appear them the best, or most likely to succeed.

e. Prepare list of actions to be taken with a "time bound" Solution.

Now, when the possible solution is decided, the group should prepare a list of necessary actions to be taken to reach to the solution. All these actions must have a time limit to avoid any kind of delay and all team members should work together or the work can be divided also depending on the kind of actions needed.

f. List information necessary to know.

Research the knowledge and data that will support your solution. Any information can be useful to fill in the missing gaps. Discuss possible sources like experts, books, web sites, etc.

g. Write your solution with its supporting documentation, and submit it.

Usually the group has to present their findings and/or recommendations to their classmates.
This should include the problem statement, questions, data gathered, analysis of data, and support for solutions or recommendations based on the data analysis: In short, the" process" and the "outcome".

h. Presenting and defending your conclusions.

The group has found a good solution but to present it confidently and convincingly is more important than any other thing. Otherwise all labor will go waste. The goal is to present not only your conclusions, but the foundation upon which they rest. The group should be preparing to state both the problem and the conclusion clearly as well as summarize the process and difficulties encountered.

8.CONCLUSIONS

In short, these are examples of the use of small group self-directed PBL where tutor less groups of five to six students function effectively. The class sizes are in the range 30 to 50 with one or two instructors. The students concurrently take conventional courses. The study has come to the conclusion that PBL will be able to address the problems listed below effectively, if the same is implemented in letter and spirit:

- The engineering education system will be able to provide, quantitatively and qualitatively, the engineers required for the growth of the Indian economy?
- It will provide the research and development leadership required for our industry?
- In the context of globalization, there is a need to modify the higher engineering education system in India?
- The PBL in engineering education should be able to produce the **"New Kind of , System Thinking, Innovation Led and multidisciplinary"** type of Engineer.
- This is the possible solution to the problem faced by Engineering Education. The Policy makers must give a serious thought while framing the future policies of technical education.

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