International Journal of Business, Human and Social Sciences
ISSN: 2517-9411
Vol:2, No:4, 2008

Creative Thinking Skill Approach Through Problem-Based Learning: Pedagogy and Practice in the Engineering Classroom

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***Abstract*—**Problem-based learning (PBL) is one of the student centered approaches and has been considered by a number of higher educational institutions in many parts of the world as a method of delivery. This paper presents a creative thinking approach for implementing Problem-based Learning in Mechanics of Structure within a Malaysian Polytechnics environment. In the learning process, students learn how to analyze the problem given among the students and sharing classroom knowledge into practice. Further, through this course's emphasis on problem-based learning, students acquire creative thinking skills and professional skills as they tackle complex, interdisciplinary and real-situation problems. Once the creative ideas are generated, there are useful additional techniques for tender ideas that will grow into a productive concept or solution. The combination of creative skills and technical abilities will enable the students to be ready to "hit-the-ground-running" and produce in industry when they graduate.

***Keywords*—**Creative Thinking Skills, Problem-based Learning, Problem Solving.

I. Introduction

SOCIETY nowadays becomes complicated and dynamic. In order to suit society's needs, it is undesirable for universities and colleges to produce graduates who can only work within the restricted framework of solving textbook problems. People are expected to accommodate variations in the demands of everyday tasks [1]. Thus, universities or colleges should also modify their education system to match the requirements of industry and commerce. Curriculum should be reformed to create classroom in which students are challenged to think creatively about subjects by discovering, understanding, analyzing and applying knowledge in new situations [2].

In Malaysia, efforts are being made to foster creative thinking and problem solving through curricular and co-curricular activities [3]-[4]. Teachers are encouraged to use methodologies to promote creative thinking and students are encouraged to be innovative and come up with creative products. Students can be encouraged to participate in this process by enabling them to become aware of the ways in which they think, learn and problem-solve. The way of thinking will also attempts to involve students in the teaching-learning process through evaluations of what is taking place during learning and can provide a window into the student's thinking processes.

This study was supported by the Ministry of Higher Education, Malaysia, Polytechnic of Malaysia, Universiti Sains Malaysia and Universiti Tun Hussein Onn Malaysia.

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II. Problem-Based Learning

Problem-based learning (PBL) is one of the student centered approaches and has been considered by a number of higher educational institutions in many parts of the world as a method of delivery. PBL is a total pedagogical approach to education that focuses on helping students develop self-directed learning skills. It derives from the theory that learning is a process in which the learner actively constructs new knowledge on the basis of current knowledge. PBL provides students with the opportunity to gain theory and content knowledge and comprehension. PBL helps students develop advanced cognitive abilities such as creative thinking, problem solving and communication skills [2]-[4].

Through Problem-based learning (PBL), students use "triggers" from the problem case or scenario to define their own learning objectives. Subsequently they do independent, self directed learning before returning to the group to discuss and refine their acquired knowledge. Thus, PBL is not only about problem solving, but rather it uses appropriate problems to increase knowledge and understanding.

Group learning facilitates not only the acquisition of knowledge but also several other desirable attributes such as communication skills, teamwork, problem solving, independent responsibility for learning, sharing information and respect for others. PBL can therefore be thought of as a small group teaching method that combines the acquisition of knowledge with the development of generic skills and attitudes. Presentation of technical material as the stimulus for learning enables students to understand the relevance of underlying scientific knowledge and principles in technical practice.

However, when PBL is introduced into a curriculum,

several other issues for curriculum design and implementation need to be tackled. PBL is generally introduced in the context of a define core curriculum and integration of basic and sciences. It has implications for staffing and learning resources and demands a different approach to timetabling, workload and assessment. Recently, modified PBL techniques have been introduced into technical education with real problem being used as the stimulus for learning.

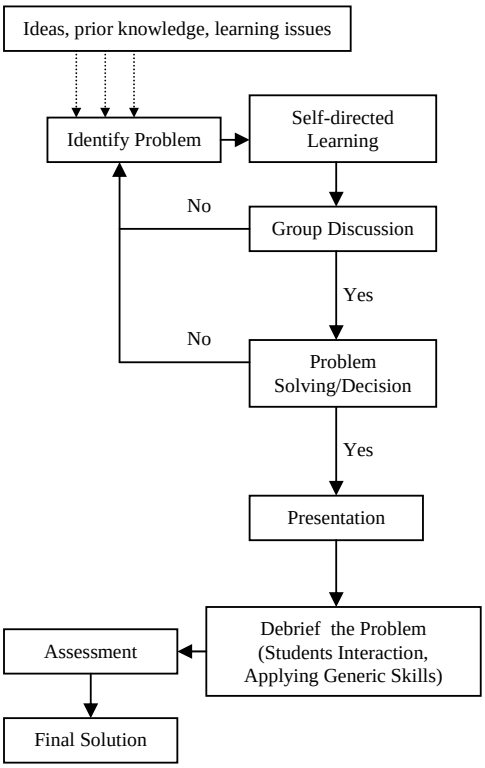


Fig. 1 Flowchart of Problem Solving Process in PBL

Fig. 1 shows the flowchart of problem solving process in Problem-based Learning approach. PBL exercises typically proceed through four phases – problem presentation, problem investigation, problem solution and process evaluation. The problem would be a real-world situation, complex and open-ended that will challenge higher-order thinking, creativity and synthesis of knowledge [5]. Problem-Based Learning helps students develop creative thinking skills such as cooperative and interdisciplinary problem solving. Students learn to work both independently and collaboratively. Even though students engage in self-directed learning through PBL, they regularly convene to share, evaluate and critique each other's work during the group meeting. They deal with multiple and often conflicting goals and values, work with constraints and determine the most appropriate action to take.

III. Problem Solving

Teaching students to provide, as fast as possible, the one correct answer to a problem, does not contribute towards fostering students problem-solving abilities. If the emphasis is on the correct solution, the student's originality and creativity can be stifled [6]. In the learning process, students learn how to analyze the problem given among the students and sharing classroom knowledge into practice. Further, through this course's emphasis on problem-based learning, students acquire creative thinking skills and professional skills as they tackle complex, interdisciplinary and real-situation problems.

There's nothing as theoretically interesting as good practice. This is particularly true of efforts to relate constructivism and creative thinking as a theory of learning to the practice of instruction and for helping students become more effective problem solvers. Problem solving is often seen as an experimental study requiring first-hand student participation and gathering evidence that permits a question posed to be answered. There is the need for students to think creatively forwarding hypotheses, point out ways of solving the problem and carry out a careful analysis of the results.

IV. Creative Thinking Skills

At the simplest level "creative" means bringing into being something that was not there before and has been brought into being. The word "creativity" covers a wide range of different skills. Creative skills needed to change concepts and perceptions.

In most descriptions of problem solving, there is usually a step called "search for alternatives". This implies that creativity is needed in this step. Creativity is poorly understood and difficult to teach but there are positive techniques that everyone can learn. Edward de Bono notes creative techniques such as focus, challenge, alternatives, concepts etc [7]. Creative thinking should take its place alongside our other methods of handling information. A person sitting down with the deliberate intention of generating an idea in a certain area and then proceeding to use a creative thinking technique systematically should represent a normal state of affairs.

Creative thinking will make students move "sideways" to try different perceptions, different concepts, different points of entry. Students can use various methods including provocations to solve the problems. Creative thinking has very much to do with perception to put forward different views. The different views are not derived each from the other but are independently produced. In this sense, creative thinking has to do with exploration just as perception has to do with exploration.

What causes creativity in the individual? Can the creative process be identified? A widely used of creativity tests is Torrance Tests of Creative Thinking (TTCT)[9]-[10]. Three creative abilities measured by these tests are originality, fluency and flexibility. These abilities are defined as; originality: the ability to produce uncommon or unique

responses; fluency: ability to produce a large number of ideas; flexibility: the ability to produce a variety of ideational themes or categories.

Originality in the technical context is the ability to find new ways to adapt existing ideas to new conditions. The habit of always asking questions about a situation will make student creative in thinking. They are always asking questions such as: "Why do we do this?" How can we improve this design?" Is this really safe for the building?" Originality is nurtured when students are willing to challenge the obvious.

Idea fluency is the ability to generate a large number of ideas from which to choose. Research has indicated that the more ideas one has the greater is the likelihood of finding a usable solution. Delaying evaluation of the ideas during the process of generating ideas can facilitate idea fluency. Students can make notes, records their observations and opinions of problems in a way to assist in the process of idea fluency. A different way for developing idea fluency is to use special times or locations in which students tend to make a discussion in creative way.

Flexibility is the ability to consider a wide variety of rather dissimilar approaches to a solution. To be flexible, students need to be aware of mental blocks that can lock them into a fixed way of doing a particular thing in a specific manner.

In their work habits, the creative students were more flexible and more willing to shift approaches when faced with a complex problem [4]. They tend to spend more time in the initial steps of problem identification and desired greater variety of potential solutions in the solution finding stage.

Edward De Bono identified that there are two broad and distinguishable uses of creativity. One of these is "everyday" creativity in which creativity becomes part of normal thinking and can therefore be applied to any situations that require thinking [7]. This should happen without any formal or deliberate effort. Then there is specific creativity where a definite need has been defined. In this case there is a formal and deliberate effort to use the systematic techniques of creative thinking to generate new ideas. There are three aspects to for creativity:

1. Defining the focus or creative task
2. Structure for the deliberate application of the systematic creative thinking tools
3. Evaluation and implementation of the output of the creative thinking

Defining the Focus

There may be problems that arise and identify themselves. Individuals make definite creative focuses. There may be an obvious creative need. All these are ways in which creative focuses can emerge.

Structure for Creative Thinking

Once the creative focus has been defined, it can be subjected to deliberate creative thinking. This can be done by groups or individuals or a combination of both in a discussion session among group members. It often happens that the group that has the concern or problem will organize its own deliberate creative thinking session to tackle the problem.

Evaluation and Implementation

The group that has the creative focus may also be involved in evaluating the ideas that come out of the deliberate creative thinking. In such cases the process is continuous. If the "thinking" group is different from the "implementation" group, attention has to be paid to the transfer of ideas so that those expected to act on the idea are brought in at an early enough stage to feel some ownership in the new ideas.

Learning with creative thinking is important to be creative at each stage of discussion. The definition of thinking task needs to be creative. The structure for applying thinking process needs to be creative. The output of thinking effort needs to be creative. Finally, the evaluation and implementation needs to be creative.

Creative thinking needs a framework of application; otherwise, students are not going to find themselves in a position where they are expected to generate new ideas. No matter how good the techniques may be, if they are not used, they will not achieve much.

V. Method and Implementation

A quasi-experimental pretest-posttest was used in the study. The population for this study consisted 60 students of Diploma in Civil Engineering in Malaysian Polytechnics. From the targeted population, samples were randomly divided into two groups of learning method as shown in Fig. 2.

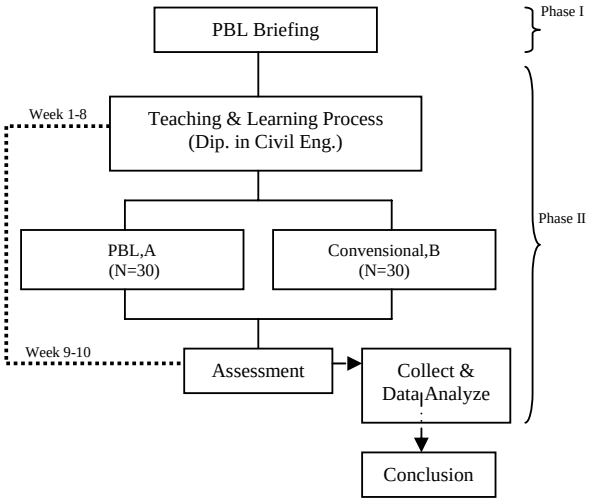
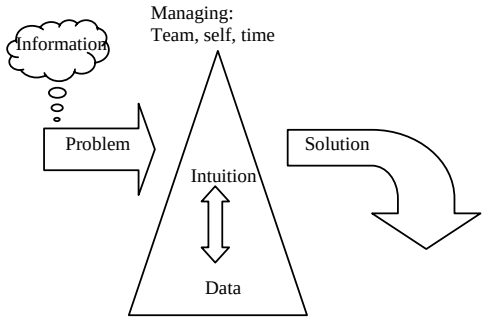


Fig. 2 Flowchart of Quasi-experimental Design

They are group A as an experimental group and group B as a control group for the session. The measured dependent variables in this study were the students skills in creative thinking and the independent variables were the mode of teaching. The instrument used to determine the dependent variables were the pre-test and post-test of *Torrance Test of Creative Thinking* (TTCT)[8].

This paper proposes a Problem-Based Learning model of Howard Barrows that uses the McKinsey strategic problem-solving model and the SSCS model for teaching structural problems in Mechanics of Structure in Polytechnic of Malaysia [9]-[10]. The McKinsey model was adapted for engineering need. This need comes from an engineering problem. Once a problem has been identified, the next step is analyzing the problem. McKinsey calls this step "framing the problem" and breaking it down into its component elements in order to come up with an initial hypothesis as to the solution [11]. Designing the analysis is the next step in this model. Student must determine the analysis that must be done to prove the hypothesis. This step also includes developing work plans for group study efforts. Next, is gathering the data by emphasizing the use of fact finding and interviewing as a source of information gathering.



Analyzing information::
- Framing-hypothesis-issue trees
- Designing outline-work plan
- Gathering data-facts-interview
- Interpreting-analyzing-evaluating

Fig. 3 McKinsey Model

TABLE I
PROBLEM-BASED LEARNING MODEL

LEARNING PROCESS AND PROBLEM SOLVING						
A : Form Student Group	**B : Student Preparation (Giving the problem)**	**C : Tutorial 1 (Building by group process)**	**D : Self-directed Learning**	**E : Tutorial 2 (Bridging the processing skills)**	**F : Presentation**	**G : Debrief the problem**
Assign work : Assign group leader Plans, manages and controls the session Assistant Take notes during discussion Group members Participate actively in the meeting	Problem discussion Stating hypothesis, assign tasks among the group	Tutor guidance using creative thinking skills Discussion among group members Define problem Describe problem scenario according to prior knowledge Discussion and assign tasks	Explore the information Notes, references, internet	Tutor guidance using cognitive and creative thinking approach Concept map, students discussion, decision making on problem solution.	Tutor guidance using cognitive skills Students enhance their ability on generic skills	Tutor evaluation Evaluation/ Conclusion from students for the presentation

CREATIVE THINKING SKILLS (adapted from Infor Resources System)		
Explore the Challenge	**Generate Ideas**	**Prepare for Action**
Goal: Fully understand the problem by examining the situation and restating the problem in as many ways as possible. **Start here when:**You want to pinpoint the right problem to solve. **Diverge:** Restate the issue from as many perspectives as possible. Use the statement starters:*How to...How might...In what ways might....* **Converge:** Select the statement that best identifies the issue you want to work on. **Finish with:**A well defined statement of the problem.	**Goal:**Generate many ideas to help you solve your well-defined problem. **Start here when:**You need novel approach, useful ideas to solve your problem. **Diverge:** Come up with many ideas that might solve your problem. Keep going!Even as you see good ideas emerge, keep pushing for novelty. **Converge:** Select the most promising and intriguing ideas to pursue. **Finish with:**An idea or selected list of ideas to help solve the problem.	**Goal:**Turn promising ideas into workable solutions. **Start here when:**You have some good ideas that need strengthening. **Diverge:** Phrase your best ideas as solutions, using the statement starter:"What I see myself doing is...."Consider what you like, Potentials (what it might lead to if implemented) and Concerns(ask "How to..." "How might..." or "In what ways might...".Generate ideas to overcome the concerns. **Converge:** Select the best ideas to overcome your concerns. Rephrase those ideas into a new and improved statement of the solution using the statement starter: "What I **now** see myself doing is....." **Finish with:**A well developed, detailed and improved solution.

As shown in Fig. 3, time management is very important in McKinsey model. There is never enough time to get all possible data. It is up to the student to find the most pertinent data in the least amount of time. Interpreting the results is the final step, analyzing and evaluating to test the hypothesis.

SSCS model specifically for science instruction on the premise that for a problem to be meaningful to a student, it needs to be identified and defined by the student and that students meaningfully learn problem-solving skills and science concepts. As shown in Fig. 4, this model consists of four phases; Search, Solve, Create and Share as shown in Fig. 3[6].

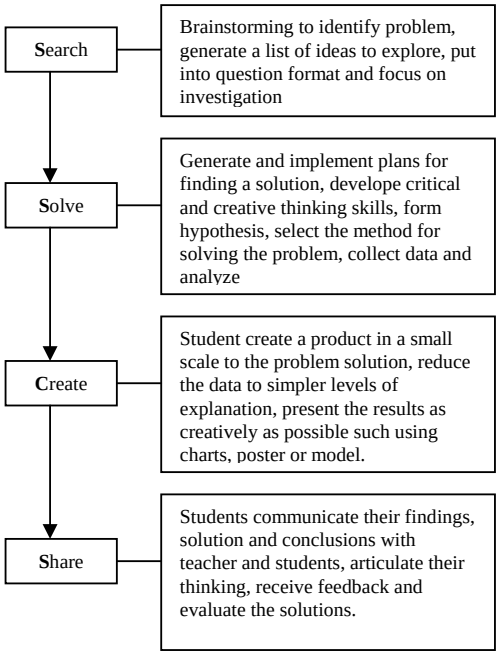


Fig. 4 Model SSCS

Problem-based Learning that used in this paper begin with the group assign as shown in Table I. The member of each group 4-5 students consist of group leader, assistant and members. This PBL model started with a unstructured problem that given to the group of students. These problems were similar in nature to the real problem but on a smaller scale. Students need to explore creatively in thinking the issues of the problem by using the statement starters; *How to...How might....* to identify the problem [12]. Once the problem has been identified, the next step is framing the problem and breaking it down in its component elements in order to come up with an initial hypothesis, identifying relevant facts in the case and identifying learning issues.

Tutor guidance was provided in the first tutorial sessions. Each student has an opportunity to verbally reflect on their current beliefs about the diagnosis and assume responsibility for particular learning that was identified. The students generate the learning issues based on their analysis of the problem. During this process, students focused on what they did not know and hence found out materials in order to solve the problem outside class time. The role of the tutor was to facilitate the students as to identify the location of the necessary resources. After the session, the all student engage in self-directed learning. There are no assigned texts. Rather the students are totally responsible for gathering the information from the available library and computer database resources. After self-directed learning, the students meet again to emphasize the use of fact finding and interviewing as a source of information gathering. At these stages (stage C, D & E), Student was expected to come up with many ideas that might solve the problem. The last parts of the model are creating the final presentation and debrief the problem and the students have to share their knowledge during the presentation.

VI. Findings and Discussion

Table II shows the results of Creative Thinking Skills referred to originality, fluency and flexibility components for students with different learning approaches in both experimental and control classes.

TABLE II
MEAN SCORES FOR CREATIVE THINKING

Method	Originality		Fluency		Flexibility	
	Pre	Post	Pre	Post	Pre	Post
PBL	38.27	46.77	48.45	58.91	35.18	39.19
Conventional	34.58	40.22	41.56	49.88	29.51	30.51

The findings indicate that the overall creativity of students is characterized mainly by two component abilities names originality and fluency. Students who achieve a high score on originality have the ability to produce ideas which are unexpected. The highest score on fluency shows that students are capable of producing a large number of ideas in response to problem-solving situations. The flexibility scores defined that most of students not flexible in their approach to learning and acquisition of concepts.

The results of the study indicate that Problem-based Learning approach could raise-up the creative thinking skills of students compared to Conventional Learning approach.

VII. Conclusion

Our goal in this paper was to present PBL as an instructional model that could encourage the creative thinking skills during the learning process. Once the creative ideas are generated, there are useful additional techniques for tender ideas that will grow into a productive concept or solution. Even though students perceived that learning through PBL was difficult, they said that they did more thinking than memorizing, understood the lessons better through discussion and could accept this method of instruction.

Creative skills must be practiced until the thought patterns in our minds become comfortable with these creative lateral thinking techniques. We can create these creative grooves in

our mind so these techniques will be utilized. This also can help students produce better, more satisfying and more creative. The combination of creative skills and technical abilities will enable the students to be ready for industry needs when they graduate.

ACKNOWLEDGMENT

The authors acknowledge the Ministry of Higher Education, Malayia, Polytechnic of Malaysia, Universiti Sains Malaysia and Universiti Teknologi Tun Hussein Onn Malaysia for their cooperation.

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