AC 2012-4441: TEACHING CREATIVE THINKING USING PROBLEM-BASED LEARNING

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Teaching Creative Thinking Using Problem-Based Learning

Abstract

As global competition and technological innovation continue to challenge business organizations, the ability to solve diverse and complex problems has become essential for students in every academic discipline. While pursuing their careers, technology and engineering students will soon realize that the development of creative problem solving skills is fundamental for success in today's workplace.

For several years the author has been teaching creativity using a problem-based learning approach. The author has discovered that learning can be more relevant and interesting to students if they are actively involved in the learning process. In the course the author provides students, individually and in teams, with a variety of unstructured and open-ended problem solving activities and assignments. These activities and assignments of actual or simulated real world challenges are used to develop creative problem solving skills that will help prepare students for the 21st century workplace.

In the paper, the author will describe the problem-based learning approach used to teach creativity. The author will identify the benefits students derive from problem-based learning. Also, examples of how the author uses problem-based learning activities and assignments to teach creative thinking skills will be provided. Additionally, the author will provide ideas for technology and engineering faculty on how they can utilize problem-based learning in their courses.

Introduction

The author's research in creative thinking and experience as a teacher and industry consultant/trainer has made him aware of the need for education on creative thinking. As globalization continues to impact every industry, in every part of the world, the need to develop creative thinking skills cannot be overstated[4, 5]. As a result, there is an increasing demand for students who possess the thinking skills that can facilitate innovation and creative problem solving[6, 7, 9]. It is paramount for engineering and technology programs to develop curricula and courses that emphasize the development and use of creative thinking skills for problem solving and decision making.

Since 2004, the author has been using a Problem-Based Learning (PBL) approach to teach "Creativity in Business and Industry," which is listed as OLS 350, in the Construction Science and Organizational Leadership (CSOL) Department.

Teaching Creativity Using Problem-Based Learning

Throughout the author's teaching career, he has experimented with different learning approaches to improve the content and delivery of his courses. For the last several years,

problem-based learning assignments and activities have been integrated into OLS 350 to help students develop effective problem solving skills.

The author has discovered that the use of problem-based learning is an effective way to facilitate the development of creative thinking skills. Problem-based learning has been described as "an instructional strategy in which students confront contextualized, ill-structured problems and strive to find meaningful solutions"[10]. PBL is "an approach that challenges students to learn through engagement in a real problem"[12]. The PBL approach used in the author's course emphasizes unstructured problem solving assignments and activities.

The open-ended nature of assignments and activities used in OLS 350 are actual or simulated problems that can help prepare students for future life challenges. Rather than relying exclusively on the traditional lecture method or recycled case studies, the PBL used in the author's course involves students solving both personal and job related problems. Problem-based learning allows students to develop their problem solving skills along with other relevant skills necessary for dealing with various life situations. In the course, the author uses a combination of lectures, student discussions, presentations, assignments and activities to promote learning.

Origin of the Author's Problem-Based Learning Approach

The author is aware that students have various degrees of experience with personal and/or work related problem solving, either through their direct experiences or indirectly by knowing of the problems of others[13]. As a result, problem-based learning appeared to be a natural and intuitive way to promote learning, while helping students to develop their creative problem solving skills.

OLS 350 is offered in the Fall and Spring semesters of the school year with the typical class size varying from 18-26 students. During each semester of teaching the course, the author noted that students were more participative when a given creativity technique or concept was used to solve their personal/work related problems or the problems of people they knew. This prompted the author to begin researching and experimenting with PBL. Overtime, the author began to gradually incorporate more problem solving assignments and activities into the course. Because the problem-based learning approach promoted student interest and relevance in the course, the author began to appreciate this approach as an effective learning method. As a result, the author has intentionally structured his creativity course to integrate additional PBL experiences into the curriculum.

Student Benefits Derived From Problem-Based Learning

Using a problem-based learning approach is an alternative and effective way to introduce, discuss, and learn about a given (creativity) topic or concept. The author has noted that the use of PBL has facilitated learning about a given creativity issue, raised the level and quality of student participation, and made the course more enjoyable for the students. PBL assignments and activities are adaptable to the experience and expertise of a given

instructor, and have been used successfully with traditional classroom courses, distance learning courses and training workshops for industry. The PBL approach used in OLS 350 provides students with the opportunity to analyze their attitudes and beliefs about problem solving and facilitates the use of different thinking skills, including critical thinking.

Problem-based learning involves active student learning as opposed to traditional passive learning methods. Based on the author's experience, students enjoy discussing their personal and/or work related problems, rather than just reading chapters in a textbook or listening to lectures on a given creativity topic. Table 1 summarizes the major student benefits derive from using problem-based learning[1, 10, 11, 12, 13].

Table 1: Major student benefits derive from PBL

- An alternative and enjoyable way to learn
- Students learn from other student problems
- Can be used to deal with personal and/or work related situations
- Expertise (by students) with a given problem/subject matter is not required
- Effective way to improve student participation
- Challenges the beliefs of students about problem solving & learning
- Complements other learning methods
- Students learn from their own experiences (self awareness)
- Adaptable to the experience and expertise of a given instructor
- Alleviates the monotony of class lectures
- Student centered
- Can engage in detailed or general problem solving discussions
- Students are encouraged to use different thinking skills
- Embraces outcome based learning
- Students receive immediate feedback
- A natural and interesting way to learn
- Expands the disciplinary breadth and depth of a subject
- Students assume more responsibility for their learning
- A subtle or indirect way to raise the awareness of different viewpoints
- Contributes to life long learning
- Emphasis on critical thinking
- An interactive learning method

Overview of Creativity Modules and Topics

As stated previously, in addition to PBL assignments and activities, the author uses other learning methods to help students develop their creative thinking skills. Table 2 provides an overview of the relevant creativity modules and topics used in the author's course[8].

Table 2: Overview of Creativity Modules and Topics

Module	Topic
1. Introduction to Creativity	Define Creativity
	Importance of Creativity
2. Visualization & Creativity	Benefits of Visualization
	Visualization Techniques
3. Mental Barriers	Major Barriers to Creativity
	Overcoming Mental Barriers
4. The Creative Process	Creative Problem Solving Process (CPSP)
	Guidelines for Problem Solving
5. Problem Definition	Misperceptions about Problems
	"Problem as Stated" & "Problem as Understood"
6. Idea Generation	Guidelines for Generating Ideas
	Idea Generation Techniques
7. Idea Evaluation	Going from Quantity to Quality
	Making Ideas Practical
8. Idea Judgment	Developing Judgment Criteria
	Using a Judgment Matrix
9. Solution Implementation	From "What If" to "What Is"
	Guidelines for Solution Implementation

Teaching Creativity: PBL Assignments and Activities

A common complaint of tradition classroom instruction has been that the course structure in many classes is rarely conducive towards real world situations[2, 6, 7, 12]. In many courses, students are taught to look at problems in isolation, and given a specific set of facts and details which culminated in a specific solution. In reality, most problems are complex and can have different approaches for solving them, thus highlighting the need for the development of effective problem solving skills[8].

The recognition of concerns associated with traditional course structure was considered by the author when developing OLS 350. In addition to traditional learning methods, the author uses a variety of problem-based learning assignments and activities to teach creative thinking. As a part of continuous improvement, each semester these assignments and activities are evaluated and if necessary modified, to improve their pedagogical value. Incidentally, the author has found that many of the assignments and activities used to teach creativity in the classroom have also been effective when providing training for industry and community organizations.

Table 3 summarizes the problem-based learning assignments and activities used to teach creativity. Each PBL assignment and activity involves a class discussion and student/team presentation.

Table 3: Overview of PBL Assignments and Activities

Assignment/Activity	Title
1. Assignment 1	Problem Brief
2. Assignment 2	Semester Problem Assignment
3. Assignment 3	Mandala Assignment
4. Activity 1	You Are Already Creative
5. Activity 2	Paradigm Shifts
6. Activity 3	Voice of Judgment (VOJ)
7. Activity 4	Problem as Stated & Problem as Understood
8. Activity 5	Visual Connections
9. Activity 6	SCAMPER Technique

Assignment 1: Problem Brief

Assignment Description: The Problem Brief is written outline of the Semester Problem Assignment where students are required to identify and solve a personal or work related problem. Major parts of the Brief include- problem title and definition (Problem as Stated & Problem as Understood), and a written description and sketch of the 3-dimensional representation of the problem and solution.

Student Learning Outcomes:

- Develop problem solving skills
- Able to define a problem and identify solutions
- Understand the components of the Creative Problem Solving Process (CPSP)
- Promotes imagination
- Develop writing and sketching skills

Assignment 2: Semester Problem Assignment

Assignment Description: Students are required to use their imaginations to create 3-dimensional representations of the personal or work related problems and solutions identified in their Problem Briefs.

Student Learning Outcomes:

- Develop problem solving skills
- Simulation of an actual problem situation
- Promotes imagination
- Able to define a problem and identify solutions
- Understand and utilize the five phases of the CPSP
- Learn from the experiences of other students
- Develop presentation skills

Assignment 3: Mandala Assignment

Assignment Description: Students are required to use their imaginations to create their Mandalas. A Mandala is a physical representation of a person's life (past, present and future).

Student Learning Outcomes:

- Identify the life challenges impacting students
- Able to engage in problem solving
- Analyze past life events (self awareness)
- Develop proactive strategies to deal with future life challenges
- Learn from the experiences of other students
- Promotes imagination
- Develop presentation skills

Activity 1: You Are Already Creative Activity

Activity Description: Students are required to respond to a variety of questions about their creativity experiences, including: when/where they currently use their creativity, who/what inspires their creativity, and when/where they would like to use more creativity.

Student Learning Outcomes:

- Analyze past experiences (self awareness)
- Develop proactive strategies to deal with future life challenges
- Learn from the experiences of other students
- Develop writing and presentation skills

Activity 2: Paradigm Shift Activity

Activity Description: Each student is to identify a past personal or work related situation where change was forced upon him/her. Students are required to answer several questions about their paradigm shifts, including: why (factors) the change occurred, what they learned from the change, and what advice they would offer others on how to deal with similar paradigm shifts.

Student Learning Outcomes:

- Analyze past experiences (self-awareness)
- Learn from the experiences of other students
- Understand the factors affecting change
- Identify (problem solving) strategies for dealing with change
- Develop writing and presentation skills

Activity 3: Voice of Judgment (VOJ) Activity

Activity Description: Students are required to evaluate a past life challenge and respond to questions, including: how the VOJ inhibited their behavior and opportunities, and advice to others on how to deal with the VOJ in the future.

Student Learning Outcomes:

- Analyze past experiences (self-awareness)
- Learn from the experiences of other students
- Understand the sources of the VOJ

- Learn how to deal with the VOJ
- Develop writing and presentation skills

Activity 4: "Problem As Stated" and "Problem As Understood" Activity
Activity Description: The class is divided into teams of 4-7 students and asked to identify personal/work-related problems of each team member. Each team is required to determine the "Problem as Stated" (PAS) and "Problem as Understood" (PAU) for each student problem identified.
Student Learning Outcomes:
- Understand the team process
- Ability to engage in team problem solving
- Exposure to a variety of problem situations
- Develop writing and presentation skills

Activity 5: Visual Connections Activity
Activity Description: The class is divided into teams of 4-7 students and asked to identify and solve student problems (personal/work-related). Each team is required to use the Visual Connections technique to identify ideas/solutions for solving the problems identified.
Student Learning Outcomes:
- Understand the team process
- Ability to engage in team problem solving
- Exposure to a variety of problem situations
- Able to utilize the Visual Connections idea generation technique
- Develop writing and presentation skills

Activity 6: SCAMPER Technique Activity
Assignment Description: The class is divided into teams of 4-7 students and asked to generate ideas for improving or changing certain products or services. Each team is required to use the SCAMPER idea generation technique.
Student Learning Outcomes:
- Understand the team process
- Ability to engage in team problem solving
- Exposure to a variety to problem situations
- Able to utilize the SCAMPER idea generation technique
- Develop writing and presentation skills

OLS 350 Assessment Methods and Results

The author regularly experiments with various assessment methods to evaluate his courses. Some of the assessment tools and results for OLS 350 (Spring 2011) are listed in Table 4 (results of selected questions from Student Evaluations), Table 5 (average scores for PBL assignments/activities), and Table 6 (average scores from Exams 1-3).

Table 4: Selected questions from the Spring 2011 Student Evaluations (OLS 350)

1. Strongly Disagree, 2. Disagree, 3. Neither Agree/Disagree, 4. Agree, 5. Strongly Agree

Evaluation Questions	**Average Score**
1. The format of the course is appropriate to the stated course objectives.	4.84
2. Evaluation methods in this course are appropriate to the course objectives.	4.47
3. This course contributes to my professional growth.	4.42
4. The instructional materials used in this course were appropriate.	3.89
5. As a result of this course I can list and explain 5 reasons why creative problem solving is important in today's global economy.	3.84
6. As a result of this course I can describe the 5 components of the Creative Problem Solving Process.	4.00
7. As a result of this course I can prepare a Problem Brief.	4.05
8. As a result of this course I can create a Mandala.	4.16
9. As a result of this course I can list 5 major barriers to creativity.	3.95
10. As a result of this course I can apply the components of the Creative Problem Solving Process.	3.95

Table 5: Average scores of PBL Assignments and Activities for OLS 350- Spring 2011

Assignment/Activity	**Average Score**
1. Problem Brief (40 pt.)	37.5
2. Semester Problem (100 pt.)	100
3. Mandala (50 pt.)	50
4. You Are Already Creative (10 pt.)	9.5
5. Paradigm Shifts (10 pt.)	9.2
6. Voice of Judgment (10 pt.)	8.4
7. Problem as Stated & Problem as Understood (10 pt.)	9.5

There were 3 exams given in the course. Some of the exam questions were derived from the course objectives, PBL assignments/activities and student input. Additionally, problem solving was required in each exam.

Table 6: Average scores from Exams 1-3 (OLS 350- Spring 2011)

Exam	Students	Points Per Exam	Average Score
Exam 1	25	100	66.4
Exam 2	23	100	75.8
Exam 3	22	100	76.0

Ideas For Integrating Courses With Problem-Based Learning

Faculty play a pivot role in preparing students for their future careers. Providing the most effective learning opportunities are paramount to helping students achieve academic success. Therefore, it's important for faculty to become familiar with the various methods of learning available, including problem-based learning. Fortunately, PBL can be incorporated into most engineering and technology courses without significantly altering the structure of those courses.

Problem-based learning can be used to introduce a given topic, summarize a given topic, and/or provide relevant and real world examples of a given engineering concept. These open-ended, unstructured, and real world problem situations can be used with individual students or student teams.

Many engineering faculty are currently using their creativity to improve their courses[3]. Faculty need to continue their creative efforts in order to identify opportunities where problem-based learning can be incorporated into their courses. The ideas offered by the author can be used with most engineering and technology courses and assignments.

- **Class Discussions:** Instructors can incorporate PBL into their courses during any discussion about the different career concerns students may encounter in the corporate world. When discussing the future roles engineering and technology students will undertake, instructors can use PBL to help students develop ideas for dealing with specific problems they will likely encounter in the workplace.

- **Case Studies:** Instructors can use PBL with individual students or student teams when discussing case studies on engineering/technology concerns.

- **Laboratory Work:** For courses involving laboratory work, instructors can use PBL when discussing appropriate laboratory behavior and relate that behavior to appropriate workplace behavior. The instructor can relate lab problems to similar problems encountered in the workplace.

- **Employed Students:** If there are students who are currently employed, PBL can be used to discuss the concerns about the products or services offered by their

employers. A review of the engineering and/or technology practices and policies of their current employers can be facilitated using PBL.

- **Guest Speakers:** Instructors can use PBL when guest speakers are invited to discuss career opportunities or concerns in engineering and technology.

- **Research Assignments:** Instructors can use PBL with individual students or student teams to research assignments on work related problems and/or career challenges students may encounter in the workplace.

- **Experiential Learning:** Experiential learning has become an important agenda in academia. Therefore, instructors can incorporate PBL as an experiential course assignment/experience. The instructor can use PBL to help students understand real life, work related problems/experiences.

- **Multidisciplinary Learning:** Instructors can incorporate multidisciplinary learning into their technical courses and use PBL to help students deal with non-technical career related concerns. For example, the instructor can develop a "current topic assignment" where students are required to research and solve a non-technical problem related to their careers.

Ideas For Integrating Specific Engineering Topics With PBL

The author provides some ideas on how instructors can incorporate problem-based learning with specific engineering and/or technology topics. For example, PBL can be used with class topics, assignments or discussions involving: (1) planning and scheduling, (2) just in time (JIT), (3) plant layout, (4) methods and motion studies, (5) statistical techniques, (6) measuring performance, and (7) continuous improvement.

(1) Topic: Planning and Scheduling
After providing students with a newspaper article on the poor performance of a given company, the class can be divided into problem solving teams to brainstorm ideas on how forecasting, capacity utilization and material requirements planning (MRP) can improve operations and workload.

(2) Topic: Just in Time (JIT)
After providing students with a newspaper article on global competition, the class can be divided into problem solving teams to brainstorm ideas on how implementing "Just in Time" (JIT) can reduce waste and meet the competitive challenge.

(3) Topic: Plant Layout
After providing students with a newspaper article on industry consolidation of manufacturing companies, the class can be divided into problem solving teams to brainstorm ideas on how efficient plant layouts can reduce costs.

(4) Topic: Methods and Motion Studies
After providing students with a newspaper article on U.S. companies investing overseas, the class can be divided into problem solving teams to discuss reasons why different production costs exist between the U.S. and other countries. The teams can develop ideas for promoting efficiency.

(5) Topic: Statistical Techniques
After providing students with a newspaper article on manufacturing unemployment, the class can be divided into problem solving teams to discuss the causes of the unemployment. While using statistical methods to review the unemployment statistics, the teams can develop ideas for reducing manufacturing unemployment.

(6) Topic: Measuring Performance
After providing students with a newspaper article on the declining U.S. productivity, the class can be divided into problem solving teams to brainstorm ideas on how to accurately measure employee performance and improve organizational productivity.

(7) Topic: Continuous Improvement
After providing students with a newspaper article on offshore outsourcing, the class can be divided into problem solving teams to brainstorm ideas on how organizations can reduce waste and improve the efficiency of the factors of production in order to limit outsourcing.

Suggestions for Assessing PBL

It's important for instructors to experiment with various assessment methods while using PBL. Fortunately, PBL assignments and activities can be assessed by modifying or supplementing traditional assessment techniques[1].

Describing in advance the criteria that will be used for assessment will help students to understand the expectations of a given PBL assignment/activity. Also, the real world relevance of assignments/activities, along with other benefits associated with PBL (see Table 1) can facilitate student understanding of the assignments/activities and assessment criteria.

As is true with most courses, devising assessment criteria for evaluating PBL assignments/activities normally occurs with the initial development and continuous improvement of the course. At the same time, assessment is a multidimensional process involving the use of different assessment methods, including student input[12]. Instructors need to determine the value or points allotted for each assignment/activity. The course syllabus can be used to summarize the assessment criteria and course requirements. At a minimum, PBL assignments and activities, along with the assessment methods, need to satisfy the stated course objectives. Some suggestions for PBL assessment methods can include:

(1) Exams/quizzes

- Include questions that require an understanding of the course objectives.
- Include questions that require problem solving of specific work related situations.
- Include questions related to the specific PBL assignments/activities discussed in class.
- Student input should be considered when developing exams/quizzes.

(2) One approach for assessing PBL assignments/activities is to use some or all of the steps in scientific method. Instructors can evaluate how a given PBL assignment/activity satisfies each step in scientific method: (1) define the problem, (2) gather data and information on the problem, (3) identify a tentative solution, (4) test the solution, and (5) implement the solution[8].

- Assessment criteria can include:
  (a) Whether the problem was accurately defined (the Problem as State & Problem as Understood)?
  (b) Did the solution(s) solve the problem?
  (c) Did the student engage in critical thinking?
  (d) How is the solution going to be implemented? (identify concerns).
  (e) During student presentations: evaluate the use visuals, and presentation preparation & skills.
  (f) During group/team presentations: evaluate the quality of collaboration and initiatives undertaken by individual team members.

(3) Student input should be part of the assessment process:

- Use class discussions to evaluate/critique PBL assignments/activities.
- Select (random) students to act as presentation evaluators.
- Include a "continuous improvement" discussion after each PBL assignment/activity.

(4) Student Evaluations:

- Include a "continuous improvement" survey with Student Evaluations:
  (a) Did the course satisfy the stated course objectives?
  (b) What can be done to improve the course in general?
  (c) How effective was a specific PBL assignment/activity in raising student awareness or understanding of the problem situation discussed in class?
  (d) How can specific PBL assignments/activities be improved?

Conclusion

In today's competitive and dynamic economy, creative thinking is an integral component for not only career success, but also organizational success. Students in every major and employers in all industries can derive benefits resulting from creative thinking. Therefore, it is important for universities to provide students with creative thinking skills. The author has been using a problem-based learning approach to help students develop their creative thinking skills. PBL can be an effective way to promote learning by helping to make a given course or topic more interesting and relevant. Fortunately, PBL can be

integrated into the curricula of most engineering and technology courses without significantly altering the structure of those courses.

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