AC 2009-1177: PROBLEM-BASED TEACHING AND LEARNING IN AN INTRODUCTORY-LEVEL LEAN MANUFACTURING SYSTEMS COURSE

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Problem-Based Teaching and Learning in an Introductory Level Lean Manufacturing Systems Course

Abstract

Problem based learning (PBL) is a widely used technique in the development of technical curriculum delivery (Putnam, 2001)\(^{18}\). In the design and development of an introductory level lean manufacturing course taught at Purdue University, a PBL approach was utilized. The approach allowed the instructor to expose students to a manufacturing strategy that has been adopted by manufacturers world-wide. Immersing students in the context of lean manufacturing strategies required a combination of manufacturing facility tours and simulation type exercises in lab. This made the class more challenging, motivating, and enjoyable, while allowing students to acquire the basic knowledge and skills needed by industry. Class evaluations, collected over four semesters, reveal that PBL is a strong approach to teaching an introductory level lean manufacturing course.

Introduction

Manufacturers in the US are forced to increase the pace at which they adopt and integrate new technologies into their operations due to competitive pressures that force them to become more efficient. In such an environment, a skilled workforce is necessary for the continued prosperity and viability of these manufacturers. According to the council on competitiveness, the next generation of innovators needs to have skills that make them: 1) better at using scientific inquiry techniques, 2) better at the use and development of technical designs and 3) equipped for changes in the nature of their jobs (Council on Competitiveness, 2004)\(^5\). The problems that future engineers and technologists face render obsolete the sole use of traditional teaching methods. Traditional teaching methods can be defined as a formal way of presenting content by an instructor (Vella, 1992)\(^23\). Utilizing this method of teaching is oftentimes a one-way process in which learners are not stimulated to question or verify that they have learned the material covered (McIntosh, 1996)\(^{14}\). Simply being able to regurgitate knowledge does not create a practitioner that is competent in undertaking the concept in the real world (Barrows & Tamblyn, 1980)\(^3\). To promote conceptual understanding, teaching and learning should be an intellectually challenging experience in which learners and teachers interact simultaneously (Price & Mitchell, 1993)\(^{17}\).

Inactively listening to explanations of a complex subject does not develop a learner’s understanding of the topic. True understanding is achieved only when prior knowledge and thinking are actively expanded by the learner through dedicated learning (Ross, 2006)\(^{19}\). Furthermore, if learners are immersed in the environment in which they will use the concepts being taught, retaining this knowledge is more likely (Albanese & Mitchell, 1993)\(^1\). Problem based learning (PBL) is used by professional schools world-wide as a means to develop problem solving, critical thinking, and self directed learning skills (Putnam, 2001)\(^{18}\). In essence, PBL enables learners to solve problems by being able to identify, analyze, synthesize, and present
findings (Duch, Groh, & Allen, 2001). According to Barrows (1992), the purpose of PBL is to aid learners in becoming independent learners. This teaching approach fosters interdisciplinary learning. In addition, it enables multiple outcomes which enhance metacognitive skills, competence with multi-dimensional problems, and delivers real life perspectives.

With these potential benefits, PBL was considered as a great method for developing an introductory course in lean manufacturing. Lean manufacturing is a socio-technical improvement strategy that organizations use to improve their operational effectiveness by managing variability from customers, suppliers, and internal operations (Shah & Ward, 2007). The strategy utilizes several concepts that require mutual interdependence for maximum benefit and sustainability to the organization implementing it (Herren & Braiden, 2007). As competitive pressures force many businesses to become more agile and flexible, their workers are forced to adopt complex understanding and problem solving skills in technical areas. However, research pertaining to worker preparedness indicates that colleges and universities are not adequately preparing graduates for this new work environment (Wieman, 2008). Manufacturing has become a field where global view and technical savvy are desirable qualities for all persons involved. Since the 1980’s, manufacturing has undergone significant changes in operational costs and product quality. The lean managers of the 20th century are now retiring and there are not enough new lean experts to lead US manufacturing into the next 20 years (Linford, 2007).

**Background**

Research surrounding instructional design models has found that effective learning takes place in environments that are problem-based. Learners in these environments undergo four distinct phases of learning, namely: 1) activation of prior experience, 2) demonstration of skills, 3) application of skills, and 4) integration of these skills into real-world activities. Mostly, instruction is concentrated in the skill demonstration phase while other phases are ignored (Merrill, 2002). Activating the learner’s prior experience forces the instructor to begin instruction at the knowledge level of the learner and avoid the presentation of abstract concepts not obtained in previous learning experiences. At this phase of the learning process, demonstration of what students already know is initiated. The instructor gains insight to learners’ existing knowledge while expanding their repository. In the next phase, demonstration of skills involves the regurgitation of the newly acquired knowledge. If demonstration is inconsistent with the desired learning outcomes, the learning becomes ineffective; therefore, pertinent topics must be overtly presented to learners. In the application phase, there is a reduction in the amount of time and effort spent coaching learners as they attempt to develop their skills through practice. Learning is obtained when discussion and reflection of the new knowledge garnered commences. Integration is the final phase, where learners demonstrate skill improvement because they have integrated it into their lives.

The characteristics of Problem based learning (PBL) allow this teaching approach to incorporate the distinct phases of learning aforementioned. PBL is founded upon the following components – Context-specific Problems, Independent Study, and Evaluation. It is an approach to the art of teaching that entails utilization of a specific context in which learners use information to create their own meaning to presented content and problems (Putnam, 2001). Boud and Feletti (1991) describe PBL as a way to construct and teach courses using a problem to trigger learning.
amongst participants. PBL’s emphasis on context enhances its flexibility and enables different versions (e.g. Problem Simulated PBL and Student Centered PBL) used in various disciplines such as medicine, nursing, mathematics, physics, etc. (Williams, Iglesias, & Barak, 2007). Furthermore, the Constructivist theoretical framework identifies a philosophical view, which best explains the beliefs about learning and knowledge acquisition in the PBL approach (Boud & Feletti, 1998). At the core of the philosophy is the concept that learning takes place when interactions occur between the individual and their environment (Savery & Duffy, 2001). This highlights the benefits of independent study, where the instructor serves as a facilitator of learning and implements a more hands-off approach. When applied to education, Constructivism is perceived as an active process through which learners construct new ideas or concepts based on their current or past knowledge (Boud & Feletti, 1998; Kearsley, 1996). Lastly, PBL warrants adaptation of traditional evaluation. With this approach and problems (e.g. case studies), there is more than one right answer. In addition, the process of obtaining solutions and their justifications demonstrates the skills acquired, which could be difficult to assess.

**Integration of Theoretical Framework and Course Structure**

In order to facilitate effective learning, a model should support instructional goals, desired knowledge, and skill competencies. Successful structures assist instructors in developing and student in achieving the course goals and objectives. Creating such a model requires the identification of core features for the central concept taught that lend themselves to different teaching approaches and delivery of content. The integrative typological model proposed in this section links the theoretical core of PBL to the course objectives and goals established for an industrial technology (IT) introductory course on lean manufacturing, IT 214.

Introduction to Lean Manufacturing (IT 214) is one of the core courses taken by students majoring in Industrial Technology (IT) at Purdue University. The course has been taught for four semesters. Its weekly format consists of two fifty-minute lectures and a two-hour lab. Typically, industrial technology students pursuing a bachelor’s degree take classes in operations management and control and material processing. IT 214 strictly focuses on the management and control of operations using lean production techniques. The main objectives of the course are to introduce students to: 1) the importance of manufacturing, 2) the differences between traditional and lean manufacturing principles, 3) the background of lean manufacturing, 4) the purpose of implementing lean, 5) the lean tools and techniques used in implementation and 6) employ appropriate mathematical and basic statistical tools appropriate for lean manufacturing.

For novices, it is essential to explain the meaning of lean manufacturing, the underlying theories that give it credence, and the mechanisms that are used to implement it. There are main features representing the theoretical core of IT 214, and they drive the desired instructional features necessary for learner understanding. The features of instructional design that are typically used span four main categories, namely: content, immersion, interactivity, and communication. Instructional design delivery is based on the knowledge and skill complexity desired by the instructor or course objectives. Content delivery takes the form of text, images, or a combination of the two. If a thorough understanding is desired, a combination of the two delivery methods is used. Immersion ranges deals with the context through which problems are disseminated. The number of participants determines the level of interactivity, teams representing the highest level of interaction. Communication is simply the maintenance of 1-way or 2-way communication
Integrating the PBL approach to the structure of IT 214 yields a model that depicts 1) teacher influence, 2) learner influence, 3) phases of learning, 4) problem-based phases, and 5) evaluation. The Problem Selection Criteria component identifies the three essential components needed by any problem (e.g. case studies) used in the class to assist in the learning process. These criteria are very context-specific and based on lean manufacturing type problems and scenarios. Problem Presentation demonstrates the different delivery styles used in the course to present information pertaining to lean manufacturing principles. In IT 214, a variety of delivery styles are used such as lecture, lab, plant tours, and case studies. The variety helps to keep the interaction between the instructor and learners interesting. Problem Solving explains how the learners engage the phase of learning that requires an application of the skills learned. In this phase, teamwork is used to solve lab-based problems, which usually involve software for problem resolution. In addition, students partake in independent study, which provides students the experience of role assignment and research. Lastly, the Evaluation component contains exams and a final project. The students are evaluated using these two metrics, which demonstrate their integration of skills with real-world issues. This model serves as an adequate high-level depiction of the PBL model used to structure IT 214. The following sections elaborate on the different elements of the model.

**Diagram 1. PBL model for IT 214**

### Problem Selection Criteria/ Characteristics of PBL problems in IT 214

Problems in the field of manufacturing span three basic areas- communication, technology, and management (See Diagram 2). Communication problems arise in manufacturing when the different facets of an operation are unable to effectively share information with each other. The
most notorious communication problems exist in traditional manufacturing organizations that are unionized. Unionized manufacturing facilities tend to have very strict worker-management rules, pertaining to job function, that hinder the ability of the organization to respond to external threats. Threats to an organization can come from increased globalised competitive pressures, governmental regulations, or changes in customer preferences. Technology related problems refer to the misuse or underuse of the hardware or software infrastructural capabilities a manufacture currently possesses. Failure to utilize these capabilities could cause the manufacturing of defective products which ultimately affects profitability. Seamlessly controlling a manufacturing entity is determined by management’s use of its communication and technological infrastructure. Management problems arise based on the interaction between human resources and the technical infrastructure. It is the responsibility of management to plan and control operations in order to transform inputs (raw materials and labor) into outputs (goods and services). Problems covered in IT 214 span these areas which overlap each other during the semester. The concepts that are covered are complex and constantly changing the way manufacturing operations are viewed; therefore, current articles are chosen for case studies.

Diagram 2. Problem areas in the field of manufacturing

In order to create the PBL environment, “good” problems have to be chosen. A “good” problem first engages and then motivates students to probe for a better understanding of the concept being taught (Duch et al., 2001). At the beginning of the course, IT 214 students are presented with their first case study problem, entitled “W. Va. Mill town suffers slow death”. The problem covers the concept of traditional manufacturers and their slow decline, over the last 28 years, through the personal story of a mill worker in the midst of being laid off. National Steel Corporation faced a number of external challenges that their management could not handle. As
American manufacturers were being exposed to global competition, they restructured most of their businesses by reducing workforce and outsourcing underperforming operations. This topic allows the instructor to present learners with a historical perspective of the field of manufacturing and also to highlight one of its perennial problems, poor management decisions. This historical perspective illustrates the decline of US manufacturing hegemony and how it all will affect the layman if manufacturers are unable to successfully adopt new production strategies. Students are given the chance to identify issues that led to the demise of the town and its only livelihood. Once they have identified all the factors, leading to the town’s demise, they are given the option of suggesting ways that the town could have avoided the lost of the steel mill. This first case study provides students with a sense of ownership as they are encouraged to provide a potential solution to the problem using their newly garnered knowledge about traditional manufacturers. Meta-level discussions then ensue at the end of the case study in order to integrate isolated ideas into a holistic and in-depth understanding. Five case studies are presented throughout the duration of the course and they present problems based on the different concepts that are covered during the lecture (See Table 1).

<table>
<thead>
<tr>
<th>Week 2</th>
<th>An Overview of manufacturing</th>
<th>Case Study 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 3</td>
<td>Lean manufacturing</td>
<td>Case Study 2</td>
</tr>
<tr>
<td>Week 4</td>
<td>The roots of lean</td>
<td>Case Study 3</td>
</tr>
<tr>
<td>Week 6</td>
<td>Analyzing lean</td>
<td>Case Study 4</td>
</tr>
<tr>
<td>Week 10</td>
<td>The competition</td>
<td>Case Study 5</td>
</tr>
<tr>
<td>Week 12</td>
<td>Lean tools</td>
<td>Case Study 6</td>
</tr>
</tbody>
</table>

Management and communication related problems are easily presented in the form of case studies; however, technical problems are a bit more difficult to present. Technical problems presented in IT 214, are related to the hardware infrastructural needs of a manufacturing entity. These problems entail calculations that pertain to production capacity and inventory re-stocking frequencies. Calculations are presented by providing capacity specifications for a particular process in order to find operations which could be improved. Little’s law is the underlying concept that is presented in this section of the course. The law states that at every given work-in-progress (WIP) level, work-in-progress is equal to the product of throughput and cycle time. The law holds for all production lines and can be applied to single operations, a production line or an entire manufacturing facility (Hopp & Spearman, 2001). The “science of manufacturing” as expounded by Hopp and Spearman (2001) seeks to establish some fundamental tenets of manufacturing to provide some basic laws of manufacturing. Students therefore use the concept of Little’s law to calculate the length of queues, cycle times, inventory in stock, and the number of times inventory is being replenished over a given time period. By utilizing Little’s law, a context for understanding the functions of manufacturing operations is created. This allows problems that manufacturing engineers typically would face in their work environments to be solvable. The skill of synthesis is brought to focus as students are given the opportunity to bring together multiple ideas, while viewing the manufacturing operation as a system.

Problem Presentation
Concepts that are difficult are less likely to be understood by readings or tutorials; therefore, they are best presented via lectures (Boud & Feletti, 1998). Central to IT 214 is the lecture portion of the class which spans lean’s definition, metrics, and implementation. Lecture is worth 67% of the total grade in the class and is presented through the use of 1) formal lectures, 2) case study discussions of everyday manufacturing problems and 3) mathematical problems that cover the theoretical concept of capacity control in a manufacturing facility (See Diagram 1). Material introduced in lecture is later followed up by a lab section that entails 1) the mastery of FactoryCAD and FactoryFLOW, 2) plant tours, and 3) a final all encompassing project that encourages students to use the lean metrics, and tools they have learned to analyze a hypothetical facility. The curricula enables students to learn, how to learn, by giving them the ability to determine what is needed to solve particular problem. However, motivation is an important factor that affects student learning and therefore the case has to be made that engaging in learning will in the end be beneficial to the learner (Uden & Beaumont, 2006). Problems that are presented to students, in both the lecture and lab, are done to engage them from a theoretical or practical standpoint, with the sole objective of enhancing their comprehension.

Comprehension is achieved when plausible explanations, for how and why phenomena or relationships occur, are presented by students in their final projects. This usually entails the gathering of information from multiple sources for satisfactory demonstration of comprehension.

**Problem Solving and Evaluation**

Problem-based learning (PBL) allows some of Bloom’s taxonomy for categorizing the levels of abstraction, to be covered in IT 214. The first five levels of the domain- cognitive skills, knowledge, comprehension, application analysis and synthesis- are all cognitive behaviors and are engendered in IT 214. Knowledge is assessed by the recalling of previously learned material, and represents Bloom’s lowest level of learning outcome. By displaying the ability to grapple with the meaning of material, comprehension can be assessed as the student justifies methods and procedures for solving problems. Once the ability to learn and understand the meaning of material has been accomplished then the learners are sent to apply their knowledge through a final semester project. This final project allows them to 1) apply previously learned material, 2) analyze the results of their project, and 3) then synthesize its composite parts. Application takes place when students are first given a description of a manufacturing facility and are then asked to reproduce it based on specifications for the facility. With the semester-long training in AutoCAD and FactoryCAD, the students can reproduce of the facility. A two week timeline is normally given for eight teams to complete their drawings. Once the facilities are drawn, a material flow analysis then takes place. Based on prior knowledge students understand how an efficient manufacturing facility is laid out; therefore, all critical operations are positioned closer to each other. This makes it possible for simulations to be done using FactoryFLOW, a material analysis software, to determine the cost of transporting raw material to the various operations in the facility. Students identify the most expensive routes. Then, they are responsible for explaining why and how this particular route is more expensive than others.

Assessment is problematic within PBL as self-directedness, motivation, effort, attitude and problem solving are the anticipated measured variables of outcome skills such as application, analysis and synthesis. Traditional methods of assessing students are poor indicators of Bloom’s higher level cognitive behaviors, and ultimately they deter students from pursuing their own
When groups of students are placed in teams to work on problems, assessment becomes more difficult as success is determined by their ability to communicate clearly on an intellectual and emotional level. However, the creation of teams has the advantage of distributing skill sets amongst students evenly (Duch et al., 2001); Michaelson & Black, 1994). Teams, have also the added advantage of engaging minority students as the possibility of their ideas being suppressed is lower (Duch et al., 2001; Felder, Felder, Mauney, Hamrin, & Dietz, 1995). Measuring the benefits of teams in a PBL environment is challenging as the instructor is responsible for assessing each student’s performance during the team project. The instructor is also responsible for providing the criteria for which learners will be assessed prior to students being placed in teams. Assessment techniques, such as, peer to peer and self ratings in group settings are known to have little measurement information and poor validity. However, these rating methods can contribute to a learners performance in a team settings (Boud & Feletti, 1998).

Initially, assessment of work done in IT 214 is done from a purely individualistic standpoint; however, as the semester progresses students are placed in teams. Learning in the lecture section of the class is assessed based on six case studies, three tests, five home work assignments, and a final in class presentation on a particular topic given to a team to undertake. PBL promotes the learners ability to collaborate and participate in shared decision making (Duch et al., 2001). This is a critical skill set that will be necessary for future manufacturing engineers who will be responsible for working in collaborative teams that span product design through to product marketing (Hayes, Pisano, Upton, & Wheelwright, 2005). Therefore, teams are comprised of four to five students who are randomly chosen and this normally takes place in the middle of the semester. Teams created in lecture are similar to those created in lab. Thus, learners develop a tight nit bond with each other early on before the final group project is presented. Furthermore, team formation is done after the second test so that student would have already grasp the main concept of the course, lean manufacturing.

The six case studies that are covered in the lecture are based on the topic at that point in the semester. They require students to read and answer questions that follow the article. Once the student has done his or her reading, on the day the case studies are due, a discussion between professor and students takes place, as students are further challenge to reveal their opinions about the article and also to suggest novel approaches to solving the problem at hand. Students who typically do well in this section of the class are those that can tie the concepts discussed in lecture with those in problems in the case study. Because case studies are better at assessing reading, writing and comprehension skills they are not good at assessing the analytical skills that learners in a technology field should also possess. Tests are therefore centered on problems that require calculations and then justifications as to what the results represent. Home work provides students with the necessary practice they require for mastering the possible scenarios that could be presented on the tests. Use of Little’s law and inventory control strategies requires students be able understand and explain the situations that require their application. Once the ground work has been laid students are presented with their final project that will utilize all the concepts and skills they have learnt thus far.

Students are placed in teams for a lecture presentation and a lab final project. The final project allows students to play the role of a lean implementer team in a manufacturing facility that is in
need of improving its material handling strategies so as to increase production volume. Seven wastes are typically found in manufacturing facilities. For this particular problem, the waste of transportation is the only waste that students can actually reduce in a simulated environment. Their new design of the manufacturing facility is based on reducing or eliminating this waste in a new design when compared with the original facility. The improvements they make to the original facility can be verified as being good or bad based on a material flow analysis that is done on the original facility that the instructor has in his possession. An assessment of team and individual contribution can be done once team members explain their new designs and illustrate why it is less costly to transport raw materials and finish goods around the facility they designed in a presentation. Each member on the team is allowed the chance to explain a part of the presentation. Questions from the professor and other teams follow the presentation and a subjective assessment is made for the team’s collaborative effort by the professor.

Evaluation of the students’ performance was based on written exams (assessing skills with regards to mathematical based problems) and a final project (assessing skills with regards to contextual based problems). Comparison of these two metrics revealed interesting differences. Written exam assessment was based on the three exams that students took during the course of the semester. These exams were mainly based on lecture material and mathematical based problems. However, the final project was assessed based on the redesign of a manufacturing facility, a presentation entailing the reasons for their particular design, and a written report detailing the cost savings for making such a change. Comparing the two assessments, it is clear that students perform better on the final project than on written exams (See Table 2). On average three times as many students were able to display mastery of the lean manufacturing concept on a final project versus that of three written exams.

### Table 2. Evaluation of mastery regarding lean manufacturing

<table>
<thead>
<tr>
<th></th>
<th>Number of displaying mastery of concept of written exam</th>
<th>Percentage of students displaying mastery of concepts on written exam</th>
<th>Number of Students that displayed mastery of concept in final project</th>
<th>Percentage of Students displaying a mastery of concept on final project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall 2006</td>
<td>3</td>
<td>7.89</td>
<td>15</td>
<td>39.47</td>
</tr>
<tr>
<td>Spring 2007</td>
<td>8</td>
<td>20.00</td>
<td>19</td>
<td>47.50</td>
</tr>
<tr>
<td>Fall 2007</td>
<td>2</td>
<td>5.56</td>
<td>12</td>
<td>33.33</td>
</tr>
<tr>
<td>Spring 2008</td>
<td>4</td>
<td>10.00</td>
<td>13</td>
<td>32.50</td>
</tr>
</tbody>
</table>

**Student’s Attitude Toward PBL in IT 214**

Using PBL as a means of facilitating learning means that the instances of passive knowledge assimilation are minimized. Essential to the use of PBL environments are the diverse learning formats that are used by the instructor. The effectiveness of such formats has to be evaluated by the end users who provide the instructor with feedback about the quality of instruction (Bangert, 2004). Potential concerns about learning experiences are actively sought from learners, so that adjustments can be made to course content and delivery. Evaluations of IT 214 have been conducted for the past four semesters - fall 2006 thru spring 2008. This feedback has been used to maintain class consistency. Students were asked to give feedback about the course based on four items, namely; 1) consistency of objectives and course content, 2) teaching methods used, 3) guidance provided when there was a problem, and 4) use of appropriate delivery methods. Demographic information, such as the academic level of the student, gender, major expected grade and the importance of the course to the student, are also collected every semester in
combination with feedback on the course itself. Data collected is based on a five point Likert scale that ranges from strongly agree to strongly disagree. On average, there are 38 students enrolled each semester. The majority are industrial technology students; this is a required course. The course is also heavily dominated by male students who are in their sophomore or junior level.

In the fall of 2006, there were 38 students in the class of which 36 took the survey. The class was divided into two sections with 13 people taking the survey in the first section and 23 in the second. In both sections, students rated the four items with an average response of agree, 4.0 or higher. In both sections students were in agreement that: 1) the course content and objectives were consistent with each other, 2) the teaching methods enabled them to learn, 3) the instructor was helpful when they had problems and 4) the delivery of course content was appropriate (See table below). The spread of responses was less than one standard deviation which indicated uniformity in the answers of students in the class. In the spring of 2008, IT 214 had 40 students enrolled of which 30 took the course evaluation survey. Once again, students were in agreement that the four items being measured about IT 214 were what they expected. The spread of responses was also below one standard deviation further cementing the uniformity of student responses (See Table 3).

<table>
<thead>
<tr>
<th>Item 1</th>
<th>Item 2</th>
<th>Item 3</th>
<th>Item 4</th>
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</thead>
<tbody>
<tr>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Fall 06</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Section 1</td>
<td>4.4</td>
<td>0.51</td>
<td>4.1</td>
</tr>
<tr>
<td>Section 2</td>
<td>4.1</td>
<td>0.87</td>
<td>4.1</td>
</tr>
<tr>
<td>Spring 07</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Section 1</td>
<td>4.4</td>
<td>0.51</td>
<td>4.2</td>
</tr>
<tr>
<td>Section 2</td>
<td>4.3</td>
<td>0.80</td>
<td>4.1</td>
</tr>
<tr>
<td>Fall 07</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lecture</td>
<td>3.9</td>
<td>0.63</td>
<td>3.6</td>
</tr>
<tr>
<td>Lab</td>
<td>4.0</td>
<td>0.48</td>
<td>3.5</td>
</tr>
<tr>
<td>Spring 08</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Section 1</td>
<td>3.9</td>
<td>0.48</td>
<td>3.9</td>
</tr>
<tr>
<td>Section 2</td>
<td>4.4</td>
<td>0.33</td>
<td>3.9</td>
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In the fall of 2007 the items used for the class evaluation were overhauled, by separating lecture and lab sections. A total of 29 students took the lab evaluation while 19 students took the lecture evaluation (out of 36 students enrolled in IT 214). The overhaul lasted for that semester only and it revealed a different perspective from students on the use of problem-based learning (PBL) in the lab and lecture sections of IT 214. When questioned about the course content in the lab and lecture sections agreed that they was consistency with the stated objectives. Similarly, when questioned about the appropriateness of teaching methods, for both lab and lecture, student agreed that it enabled them to learn. However, they did so with much less confidence when compared to previous semesters. The students responding to lab section of the evaluation were not able to agree that help from the professor was sufficient. Furthermore, when questioned
about the appropriateness of content delivery methods students were unable to agree. However, this was not the case for the lecture, students were able to agree that help from the instructor and course delivery methods were appropriate (See Table 3).

In the spring of 2008 the course evaluation reverted to a similar style similar to the first two semesters of evaluation in which the class was divided into two sections. Forty students were enrolled in the class of which 31 students completed the evaluation. This survey revealed that students were in agreement with the consistency of course content and objectives, teaching methods, instructor aid during problem solving sessions and the delivery of content (See Table 3).

Discussion

The results collected over the duration of four semesters shows that PBL approach in a technical area is feasible. However, its use should be monitored in both lecture and lab as it could have a different expected outcome. For example, in the fall 2007, IT 214, was evaluated from the standpoint of lecture participants and lab participants. The results showed that students were not in agreement about the aid provided to them during the lab and also about the delivery method used. These discrepancies may have been due to the fact that a few extra items were added to the survey. These items were similar in nature to those used in previous semesters. In some cases, similar items were rated slightly higher than those that were used in prior semester. For example, one of the items used read, “My instructor is actively helpful when students have problems and the other my instructor provides adequate opportunity for individual assistance.” For both of these questions the same number of respondents answered. In the first question the respondents answered agree, undecided and strongly disagree. For the second question the respondents answered strongly agree, agree and undecided. What triggered different response from the students on similar questions? It is quite possible that the students were confused by the similarity in the items used in the survey.

Another issue that may have had an impact on PBL use in a technical field is class size. When there was a large amount of students in a section, 17 or more, it was noted that some of the average ratings on the items declined compared to previous semesters when they were fewer students enrolled. Teacher availability seems to play a big role in how students perceive their problems are being addressed. Another explanation for a decline in respondent approval could be what they perceive as being the usefulness of the lesson after they have finished taking the class. In the lab sections of the class, students constantly encounter problems they feel they have not been prepared for and so they resorted, most times, to the instructor for help. Upon showing students the location of the answers to their questions, students generally regained confidence and started working more on their own. However, the experience in their opinion might not have been worth it. In discussion with some of the students who have taken IT 214, concerns were expressed regarding their opinion that they will not reuse the software used in lab again until the end of their undergraduate studies. They became aware of this by speaking to students doing their capstone projects and also counselors who are familiar with the course material.

Assessing the students based on final projects and written exams, it is clear that students learn more with the addition of the projects rather than just traditional exams. Problems presented to
them in a fashion that enables them to research, analyze and then evaluate their findings. This allows students to use a combination of skills, verbal and written, to display mastery of the concept. In order for students to continually use and develop these apparent skills they possess, upper level classes need to assess them based on their ability to display a combination of verbal and written skills.

Conclusion

This paper shows that the use of PBL is a viable option for teaching students in the field of industrial technology new concepts. IT 214 exposes students to several problems that they will have to constantly address in order to be successful in industry. Case studies, math based problems, and a final project all present students with potential problems that are both local and global in nature. PBL use may also have added advantages in lecture based settings versus lab/hands-on-based settings. For introductory courses in manufacturing rote-based learning may be preferable initially, however, they may not be particularly beneficial to learners who have better written and verbal skills. Once students demonstrate that they can maneuver the tasks of the hands-on approach, they should be exposed to their first problem in which they will have to come up with their own solutions. PBL is definitely an approach that can be used to teach technical expertise to novices.

Bibliography