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Implementation of project based learning technique to enhance engineering education

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IMPLEMENTATION OF PROJECT BASED LEARNING TECHNIQUE TO ENHANCE ENGINEERING EDUCATION

by

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ABSTRACT

This study investigated the impact of introducing a semester project into three engineering courses where practical application of theoretical knowledge is applicable. Three courses were examined in this work: an undergraduate course in quality, a graduate course in Lean, and a graduate course in Six Sigma. For this research, student teams were given hands-on-projects that included collaboration with local companies. Surveys were conducted to assess the impact of project based learning on students' knowledge. Student responses were recorded and analyzed to determine how students felt the use of the semester project affected the course and to identify the response patterns of students between the Quality and Six Sigma courses and the Lean and Six Sigma courses. Percentage responses were considered to determine whether the use of the semester project was useful or not. For determining the students' response patterns an analysis using the Chi-Square test of independence was performed. Results suggest that students felt that the use of the semester project helped them in learning, understanding, analyzing, and applying course concepts and principles. The responses also indicated that students felt they were actively involved in the process and were able to apply the concepts for solving real-world problems. Analysis of the results shows that students were split on the results, as responded in a similar pattern in some of the aspects, while there was a greater difference between response patterns in other statements. This shows that in some aspects more work is needed in order to make the semester project more useful and make students feel more challenged and help them succeed in their career after graduation in industry.

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1. INTRODUCTION

Project based learning (PBL) is a new approach used in courses where practical application of theoretical knowledge is used. Introducing a semester project in engineering courses where intense application of concepts and principles are involved gives students confidence in the workplace after graduating by solving real-world problems in an educational environment. Introducing a semester project in Quality, an undergraduate, and Lean and Six Sigma, graduate level courses which are the first courses to be taken for attaining a certification in Lean Six Sigma provided by Missouri University of Science and Technology, helps students gain in-depth knowledge and practical application experience in applying course principles. Quality management is a methodology providing tools and techniques for successful application of quality principles into various environments increasing the quality of a product or an organization. Lean is continuous process improvement through the reduction of waste of resources, time, and money. Six Sigma is a quantitative strategy, and its principles are mainly adopted to increase sales, customer satisfaction, and core competitiveness while improving management processes.

Projects that are developed and implemented within an organization follow sequential steps known as the principles of Six Sigma and are identified as Define, Measure, Analyze, Improve, and Control (DMAIC). Lean principles that incorporate both efficiency and effectiveness include value, value-stream mapping, flow, pull, and perfection (Womack and Jones, 2005). Lean utilizes significantly fewer resources to produce a larger variety of products at higher levels of product quality and service. Six Sigma and Quality management use DMAIC principles for increasing product output quality thus improving customer satisfaction. Providing engineering students with knowledge of these principles and the ability to solve practical engineering problems using these principles gives employers a workforce with the necessary skill set to implement Six Sigma and makes the graduating students more marketable.

To determine if PBL is being effectively implemented in the courses student responses to a survey about the use of the project can be considered (Amante, 2010). For PBL to be effective, students must be actively engaged and involved in discussions and solving real-world problems. The best approach to promote active learning is considered to be the use of instructional activities that involve students in doing things practically, to solve a problem by thinking about what they are trying to do using their theoretical knowledge, attain an ability to know how, when, and which tools to apply (Arthur and Zelda, 1987; Prince, 2004; Plaza, 2007; Vardi and Ciccarelli, 2008; Springer, 1999; Vivas and Allada, 2006).

This thesis analyzed student responses from Quality (EMgt 266), Lean (EMgt 472), and Six Sigma (EMgt 309) courses in two different phases. The first phase is comprised of percentage response comparisons for individual questions for every course to determine the impact of the use of the semester project. In the second phase an analysis between the responses to individual questions between two courses was performed to determine whether students received knowledge from both courses in the same manner.

Paper 1 presents a percentage response comparison for individual questions for the Six Sigma course to determine the impact of project based learning on students learning, critical thinking, and engagement knowledge.

Paper 2 presents the percentage response comparison for individual questions for the Six Sigma course to determine the impact of project based learning on students learning, critical thinking, and engagement knowledge and an analysis of the responses for individual questions between the Lean and the Six Sigma courses to determine whether students received knowledge from the use of the semester project in the same manner.

Paper 3 presents the percentage response comparison for individual questions in the Quality course to determine the impact of project based learning on students learning, critical thinking, and engagement knowledge and an analysis of the responses for individual questions between the Quality and the Six Sigma courses to determine whether students received knowledge from the use of the semester project in the same manner.

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PAPER

1. Employing Project Based Learning in Six Sigma Education

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Abstract

This paper presents an assessment of the impact of project based learning on students' knowledge in a graduate level Six Sigma course. There has been an increasing need of practical application of course concepts in early training stages. For this research, student teams were given hands-on-projects requiring the application of the Six Sigma methodology. A survey was conducted at the end of the course to measure the impact the semester project had on the students' knowledge. Student responses to this survey were recorded and an analysis was performed. The survey results suggest that the inclusion of semester project in the Six Sigma course had a positive impact on the student's knowledge. Further, the semester project was helpful in learning the Six Sigma concepts, increasing the student's thinking capability, and increasing engagement in the practical application of the theoretical knowledge. The results also indicate there are some aspects of the project where more work is needed for future improvements.

Keywords: Six Sigma; Project based learning; DMAIC

Introduction

Six Sigma is a quantitative business management strategy that aims to improve process output quality and increase customer satisfaction.[1] Six Sigma principles are mainly adopted to increase sales, customer satisfaction, and core competitiveness while improving management processes. The goal is to achieve a relatively defect free process where the defect is identified as customer dissatisfaction.[2] The Six Sigma approach has succeeded where other approaches such as Total Quality Management and Business Process Reengineering failed.[3]

Projects that are developed and implemented within an organization follow sequential steps known as the principles of Six Sigma and are identified as Define, Measure, Analyze, Improve, and Control (DMAIC). Providing engineering students with knowledge of these DMAIC principles and the ability to solve practical engineering problems using these principles gives employers a workforce with the necessary skill set to implement Six Sigma and makes the graduating students more marketable. Teaching Six Sigma in a classroom environment typically consists of prepared lectures and the presentation of examples and case studies. Another option is the introduction of project based learning (PBL), where students gain practical experience in Six Sigma methods through actively applying DMAIC principles to a semester project.

Project based learning has shown a positive impact on student learning through the application of theoretical knowledge, and gives students confidence and a greater understanding of the course material by solving real-world problems. PBL not only allows students to gain practical knowledge, but gives the instructor an opportunity to customize the learning experience and assess the student opinions of the project by collecting responses from a survey for future improvement.[4] For PBL to be effective, students must not limit themselves to rote learning, but must also being actively involved in discussions and problem solving. The engagement level of students should promote critical thinking, synthesis of concepts, and evaluation of observed results. It is proposed that approaches that best promote active learning are instructional activities involving students in doing things and thinking about what they are doing.[5]

Many students believe that the development of a new product involves only technical design. However, this leads to a decrease in success rate due to the failure to consider other important factors such as the quality of the product and customer satisfaction.[6] Research exists that examines the perceived effectiveness and the challenges/reasons for failure associated with these techniques in industry;[6] however, little research has been conducted addressing this in a classroom setting. A new approach, introducing a real time project as a semester project to help students understand the Six Sigma tools, principles, and overall process has been presented.[3, 8, 9] The main goal of this semester project was to give students the practical experience of applying DMAIC principles to a process, providing an opportunity for solving real-world problems using Six Sigma tools.

Applying the principles of Six Sigma in engineering institutions at the college and university level, helps to retain more well-qualified students from dropping out at an early stage.[10, 11, 12] Six Sigma principles can also be applied to colleges and universities to increase the quality of education, considering the student as a product, and the college and university as the industry.[11] Modules of education are identified, analyzed, and improvements are suggested in successful training for engineers.

There is a need to gather and measure the students' feedback on the use of the semester project in learning the course concepts and principles. This provides the mechanism to analyze the educational process and make suggestions for improving classroom instruction. A survey was conducted to measure the impact on a student's knowledge using the semester project. The following section presents the research methodology of how the surveys were evaluated and the results are presented in the results section. Finally, the conclusions and recommendations are provided.

Methodology

For this research, a graduate level course on Six Sigma was analyzed to determine the impact of project based learning on student knowledge and understanding of the course content. The semester project was designed for the students to gain practical knowledge on the application of Six Sigma principles and understanding of course concepts. Student teams were given hands-on collaborative projects to work on through the semester in order to allow for more discussion within the class and to promote a team approach towards solving the problem. This course was selected because it is typically one of the first courses taken in the Lean Six Sigma graduate certificate program and would yield a fresh perception from the students. The semester projects are conducted with local companies in teams of three to four students. Example semester projects include:

- Reducing variation in a chemical used for microchip processing.
- Improving yield in patterning monolithically integrated photovoltaic (PV) modules.
- Variation reduction in an oxygen regulator system used in hospital environments to supply medical grade oxygen to patients.

- Variation reduction in bending angles of sheet metal components for commercial and industrial heater doors.
- Defect reduction in line changeover for a beauty care manufacturer.

Upon completion of the semester project, a student survey was conducted to determine the benefits to the students of using the semester project. A survey questionnaire framed by Yadav et al. (2010) was adopted for the current survey, involving a set of 23 Likert-style questions.

The questions were categorized in accordance with the knowledge areas being observed by the instructor as they applied to the semester project. These categories included learning, critical thinking, and engagement. The learning category was comprised of questions representing how well the students are learning the application of the tools and techniques practically, and whether they knew how, when, and where to apply the tools. Questions in the critical thinking category evaluated how well the students thought about a problem in different perspectives, solved problems by utilizing material from other engineering courses, and applied these concepts to the current project for problem solving. Engagement questions focused on the level of involvement and ownership the students had for the semester project, including how well the format allows the students to present their ideas and discuss the problem in different ways, leading to a number of possibilities of solving a problem. In addition, the engagement questions evaluated how well the semester project allowed students to discuss more in class and listen and observe other students perspectives.

The questions were framed as multiple choice using Likert scale ratings which included Strongly Agree (5), Agree (4), Neutral/ Neither Agree nor Disagree (3), Disagree (2), and Strongly Disagree (1). The data collected on the survey contains responses of 54 students (Table 1) with the responses converted into percentages. While the sample size is small, the response rate was 79.4% of the students enrolled (68 enrolled).

A comparison was performed for each question to determine the students' reaction to the semester project. By analyzing the number of responses for each question on the Likert scale, it can be observed whether students agreed or disagreed to that particular statement. The initial analysis considered responses Agree as an aggregate of Strongly Agree and Agree; Disagree as an aggregate of Strongly Disagree and Disagree.

Results

The survey results were analyzed to determine the effectiveness of including the project in the course on students learning. Table 1 shows the results of the survey with the percentage of responses from the Likert scale survey and mean calculated using the previously mentioned enumeration of the scale. Based on the responses from the surveys and mean values, it can be observed that there is an overall positive impact on the student's knowledge through the use of the semester project. The standard deviation values given in the far right hand column are based on the Likert scale ratings of one through five.

The first section of the questionnaire addresses the learning category, where the questions were used to determine if the students were able to learn through the use of the semester project. This included learning course concepts, learning simultaneously through the applied project, as well as analyzing and synthesizing ideas and information. By looking at the responses and their mean values the following observations can be made: it can be said that students agreed that use of the semester project was relevant in learning the course concepts (96.30% agree), and also were able to analyze the basic elements (94.45% agree). The semester project allowed students to retain concepts from the class (68.52% agree), although some neutral responses were observed (24.07% neutral). Most of the students agreed that the semester project enabled them to synthesize ideas presented in the course (79.63% agree) with 50% of the students feeling that they covered more content in the class when given the semester project (33.33% responded neutral). 75.47% of the students agreed that the semester project helped them learn although some neutral responses were observed (20.75% neutral).

The second section of the questionnaire addressed the student's critical thinking capabilities. These questions were intended to determine if the semester project helped in understanding a problem and finding a solution. It can be observed from the responses that students felt they had gained a deep understanding of the course concepts and an ability to think about problems in multiple perspectives to find a solution. A majority of the students (77.36%) agreed that the semester project was thought provoking while 9.43% of the students disagreed and the others remained neutral. Most of the students felt they were able to view an issue from multiple perspectives (83.02% agree), while others showed a fair response (13.21% neutral). Most of the students agreed that the semester project allowed a deeper understanding of the course concepts (85.19% agree), and a majority of the students were able to utilize material from other engineering courses for problem solving (69.81% agree), with the remaining students reacting neutrally and disagreeing with the statements. The majority of the students felt that they were able to apply the course concepts and theories to new situations (71.70% agree), with 18.87% of students responding neutral and the remaining students disagreeing with the statement.

The purpose of the third section of the questionnaire was to understand if the students felt engaged while applying the course concepts in solving the semester project. The responses to the questions show that the students felt the semester project added a lot of realism (84.91% agree), largely due to involvement in the activity (64.15% agree), were more engaged (59.62% agree), and took a more active part in the discussions (55.77% agree). Even though there are some neutral responses to these questions, it shows that students were strongly engaged in the semester project. The semester project was not viewed as more entertaining that educational (50.94% disagree, 35.85% neutral), and a slight majority felt that use of the semester project format was neutral (50.94% agree, 32.08% disagree). 43.14% of the students liked the semester project, although slightly more were neutral (45.10%). This may be because some students felt the project took more time than it was worth (21.15% agree, 25.00% neutral) or it may be some of the students needed more guidance from the instructor (33.96% agree, 15.09% neutral). Some of the students were frustrated by the ambiguity (19.23% agree, 23.08% neutral) and also felt that use of semester project was inefficient (16.98% agree, 11.32% neutral). Overall, the students felt they were able to discuss more course ideas (81.13% agree), which improved their critical thinking capability and knowledge through discussions.

Using the coded responses from the Likert style survey, we can see that introducing a semester project allowed students to learn through the process, increase their critical thinking capability, and be more engaged while applying the processes in solving the problem. There is little or no negative impact observed on the student's knowledge by the use of the semester project; it allowed the students to learn more and gain practical knowledge through the application of course concepts and principles.

The standard deviation was calculated to show variation in student's response. In addition, this metric was utilized to determine statistical significance since a similar comparison to this course without the use of PBL using this survey could not be performed. Based on the standard deviation, the Learning and Critical Thinking categories were positively impacted using PBL. Two questions in the Engagement category were positively impacted using PBL. There were no negatively impacted questions in the survey.

In addition, the course was compared to previous semesters in which the project based learning was not implemented. Student comments from teaching evaluations prior to implementing PBL are provided in Table 2. These comments indicated that the students wanted a more hands on learning experience that was similar to the types of problems they would face in their professional career. This was one of the main drivers for using PBL, and the results of this survey indicate that the students favor this more engaging form of class design.

Based on the student comments, it is clear that students valued the need for case studies, real-world problems, and hands-on projects prior to implementing the semester project in the course. After implementing PBL, the student comments highlight the increased understanding and involvement through a real world project.

Conclusions

The survey results suggest that introducing a semester project was beneficial to students with only positive impacts observed on the student's education. Students felt that inclusion of the semester project helped them better understand the course concepts and made them better able to utilize material from other engineering courses in problem solving. In addition, students were able to analyze basic elements and synthesize the ideas by learning in the process of working on the semester project.

The critical thinking capability of students helps them to solve a problem by applying the course concepts practically, which also seemed to be achieved based on the responses. Students viewed the semester project as thought provoking, adding realism to class, and allowing for a deeper understanding of the course concepts. Students were able to view a problem in multiple perspectives and apply the concepts into other situations. The semester project allowed for more interactive discussions by allowing students to retain more from the class and feel engaged in the activity involving discussion which increased their knowledge and thinking and made it useful in applying theoretical knowledge.

There are some sections where changes need to be made to allow students to cover more content, make them feel less frustrated, and allow them to work without more guidance from the instructor. The projects should be designed more interactively, allow students to work willingly, and feel engaged working on the semester project, not only for attaining grades but to gain practical knowledge supportive for their future. The projects should be felt to be efficient in the total time of involvement. In addition, the neutral leaning response to whether other students said they liked the project and the mixed response whether the students felt the semester project was challenging suggests that improvements to the project could lead to a more enjoyable and engaging course experience. This could be accomplished by matching the student interests to the projects being approached. While this would be beneficial, it would require a significant lead time to gather information about the students, which may not be achievable in an introductory course.

The use of the semester project showed a positive impact on student's knowledge, learning more through the process, feeling confident in problem solving by thinking in different perspectives, and getting engaged in the process.

Recommendations

From the results, it is clear that use of the semester project in the Six Sigma course helped students better understand the course concepts and principles. The projects need to be framed such that students can concentrate more on application, be able to cover more content, and allow working without more guidance from the instructor. Framing the projects such that students can feel it is more challenging and allows them to take part more actively and learn more. Similar approaches in other engineering courses where practical application of theoretical knowledge is applicable can also be considered to benchmark and improve the project.

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Tables

Table 1: Student assessment of Six Sigma project

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Mean	Std. Dev.
LEARNING	%	%	%	%	%		
I felt the use of the semester project was relevant in learning about the course concepts.	50.00	46.30	1.85	1.85	0.00	4.44	0.63
The semester project helped me analyze the basic elements of the course concepts.	46.30	48.15	3.70	1.85	0.00	4.39	0.66
I felt that what we were learning in using the semester project was applicable to my field of study.	28.30	47.17	20.75	1.89	1.89	3.98	0.76
The semester project was helpful in helping me synthesize ideas and information presented in the course.	38.89	40.74	18.52	1.85	0.00	4.17	0.80
The semester project allowed me to retain more from the class.	37.04	31.48	24.07	7.41	0.00	3.98	0.96
I felt that we covered more content by using the semester project in the class.	22.22	27.78	33.33	12.96	3.70	3.52	0.98
CRITICAL THINKING	%	%	%	%	%		
I thought the use of the semester project in the class was thought provoking.	39.62	37.74	13.21	5.66	3.77	4.04	0.87

Table 1: Student assessment of Six Sigma project (Cont.)

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Mean	Std. Dev.
The semester project allowed me to view an issue from multiple perspectives.	30.19	52.83	13.21	3.77	0.00	4.09	0.77
The semester project allowed for a deeper understanding of course concepts.	40.74	44.44	7.41	4.55	0.00	4.19	0.87
The semester project brought together material I had learned in several other engineering courses.	13.21	56.60	22.64	5.66	5.66	4.15	0.74
I was able to apply the course concepts and theories to new situations as a result of using the semester project.	22.64	49.06	18.87	7.55	1.89	3.83	0.85
ENGAGEMENT	%	%	%	%	%		
The semester project added a lot of realism to the class.	47.17	37.74	3.77	5.66	5.66	4.15	0.82
I was more engaged in class when discussing the semester project.	25.00	34.62	28.85	5.77	5.77	3.67	0.89
The semester project was more entertaining than it was educational.	1.89	11.32	35.85	37.74	13.21	2.51	0.75
I felt immersed in the activity that involved the use of the semester project.	16.98	47.17	20.75	11.32	3.77	3.62	0.88

Table 1: Student assessment of Six Sigma project (Cont.)

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Mean	Std. Dev.
I took a more active part in the learning process when we discussed the semester projects in the class.	25.00	30.77	36.54	7.69	0.00	3.73	0.93
I was frustrated by ambiguity that followed when discussing the semester projects.	5.77	13.46	23.08	50.00	7.69	2.60	0.91
I felt that the use of the semester project in the course was inefficient.	3.77	13.21	11.32	45.28	26.42	2.23	0.90
I found the use of the semester project format challenging in the class.	7.55	43.40	16.98	30.19	1.89	3.25	0.99
Most of the students I know liked the semester project.	3.92	39.22	45.10	7.84	3.92	3.13	0.70
I needed more guidance from the instructor about the use of the semester project for the class.	9.43	24.53	15.09	47.17	3.77	2.89	1.06
The semester project took more time than it was worth.	9.62	11.54	25.00	42.31	11.54	2.65	0.98
The use of the semester project allowed for more discussions of course ideas in the class.	28.30	52.83	13.21	5.66	0.00	4.04	0.81

Table 2: Student evaluation comments prior to PBL implementation

Without PBL	With PBL
Introduce real-world problems that we have to analyze. Maybe finding a local company to observe their processes.	The semester project is a great way to implement all of the topics in this class. It made it much easier to understand when we had to immediately use it.
More hands-on projects.	The strength comes from a real life project. It made me understand the material better.
Have more case studies to let students learn about real situations.	The strengths of the course are the material learned and the project of learning how to use said material.
More case studies and examples with clear explanations.	Great involvement in the projects

2. Enhancing Engineering Education Using Project Based Learning for Lean and Six Sigma

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Abstract

Purpose – The goal of this research is to determine the importance and impact of project based learning on students' knowledge in Lean and Six Sigma courses where practical application of theoretical knowledge is necessary.

Design/methodology/approach - Students teams were given hands-on collaborative projects conducted with local companies. After completion of the project, a student evaluation survey was conducted and the responses were analysed in two different phases. The first phase consisted of collecting responses from the Lean and Six Sigma courses; observing the impact of the semester project on students' knowledge based on the response percentages. The second phase consisted of analysing the responses from both the Lean and Six Sigma courses, by performing a Chi-Square test of Independence to examine how similar the students received knowledge from the use of the semester project.

Findings - Results showed that the inclusion of the semester project in the courses had a positive impact on the students' knowledge in learning course concepts and the students were able to apply theoretical knowledge in solving real-world problems. It was also observed that there was difference observed in the response patterns for most of the questions between both courses.

Research limitations/implications - This research evaluates student learning with statistical tests. Further, this research states that application oriented courses should be

accompanied by projects as this will help in better understanding the course deliverables for the students.

Keywords: Lean, Six Sigma, Project Based Learning, DMAIC, Chi-Square Test of Independence

1. Introduction

Lean and Six Sigma are two approaches used for balancing the flow of production, decreasing defects, eliminating waste (non-value added activities), reducing economic losses, and increasing customer satisfaction. This is achieved by creating a planned product flow in the pursuit of perfection, increasing value to the customer, and improving the overall product quality. Lean is continuous process improvement through the reduction of waste of resources, time, and money. Six Sigma is a quantitative strategy that aims towards process improvement and production quality which increases customer satisfaction (Siong, 2006). Toyota, in implementing Lean manufacturing and six sigma principles, identified seven wastes: overproduction, waiting, transportation, processing, excess inventory, unnecessary movement, and defects. An eighth waste was later added: unused employee creativity. Kovach et al. (2011) examined the perceived effectiveness and the challenges/reasons for failure associated with these techniques in industry. Cudney and Elrod (2011) investigated the reasons for success and failure of implementing lean throughout the supply chain.

Efficiency is a major factor in product manufacturing. To increase efficiency a set of six S's have been identified: Sort, Set in order, Shine, Standardize, Sustain, and Safety (Keyte and Locher, 2004). Lean principles that incorporate both efficiency and effectiveness include value, value-stream mapping, flow, pull, and perfection (Womack and Jones, 2005). Lean utilizes significantly fewer resources to produce a larger variety of products at higher levels of product quality and service. Six Sigma uses a five-phase approach for continuous improvement with the phases identified as: Define, Measure, Analyze, Improve, and Control (DMAIC), for increasing productivity and customer satisfaction.

Providing engineering students with knowledge of Lean and Six Sigma principles and the ability to solve practical engineering problems gives employers a workforce with the necessary skill sets while making the graduating students more marketable. Teaching Lean and Six Sigma in a classroom environment typically consists of lectures and the presentation of examples and case studies. The introduction of project based learning (PBL) allows students to gain practical experience in Lean and Six Sigma methods through a semester project where they actively apply value, value stream mapping, flow, pull, perfection, and DMAIC principles improve their understanding of the concepts.

Project based learning is a process of learning through the practical application of theoretical knowledge. This approach allows students to gain practical knowledge and gives the instructor an opportunity to modify the course structure to include more active learning. To determine the benefits of using this method, student responses to a survey about the use of the project can be considered (Amante, 2010). For PBL to be effective, students must not limit themselves to routine learning, but must also be actively involved in discussions and problem solving. The engagement level of students should endorse critical thinking, synthesis of concepts, and evaluation of observed results. The best approach to promote active learning is considered to be the use of instructional activities that involve students in doing things practically, to solve a problem by thinking about what they are trying to do using their theoretical knowledge (Arthur and Zelda, 1987).

Vivas and Allada (2006) used thematic case-based learning to illustrate that presenting the tools and techniques helps students to understand how, when, and which tools and techniques should be applied. Zhan and Porter (2010) gave a brief description of how to educate students in Six Sigma and the importance of providing that education. They stated that students had a misconception that new product development involves only technical design and paid little attention to other factors such as quality and customer satisfaction, which play a major role and can be understood through the practical application of theoretical knowledge.

Van til et al. (2009), Ozelkan et al. (2007), Fang et al. (2007), Montgomery et al. (2005), Anderson-Cook et al. (2005), and Furterer et al. (2007) presented their views on the introduction of a semester project in Lean and Six Sigma courses and an evaluation of how a course project affected the students' knowledge. This evaluation was performed by conducting surveys and collecting responses from students for course improvement. The PBL approach along with a lab simulation engages students and improves learning through the practical application of tools and principles of Lean (Stier, 2003).

Applying Lean and Six Sigma principles to improve the education system and student instruction is another approach which allows students to gain more knowledge through experience during the learning process (Cooper, 2009; Patil et al., 2006). Hargrove et al. (2002) and Li (2011) discussed how Six Sigma principles are not only being used in industry, but also in educational institutions to decrease dropout rates of well qualified students at an early stage.

Collecting student feedback provides an indicator of how engaged the students are through the use of the semester project in learning the course concepts and principles for course improvements to enhance learning. This provides a mechanism to analyze the educational process and make suggestions for improving classroom instruction. With these issues in mind, a survey was conducted to observe the impact the semester project has on a student's knowledge. Additionally, a comparative study was carried out to analyze how the students received knowledge from the use of the semester project in both the Lean and Six Sigma courses. The following section presents the research methodology of how the surveys were evaluated and then the results are presented. A discussion and recommendations based on these results are provided in the conclusion.

2. Methodology

For this research, data was collecting using a survey in two graduate level courses on Lean and Six Sigma. The data were analyzed to determine the impact of project based learning on student knowledge and understanding of the course content. Student teams in both courses were given hands-on collaborative projects to apply the course concepts to a real-world process improvement project. These courses were selected since they are among the first courses taken in the Lean Six Sigma graduate certificate program. The semester projects are conducted with local companies by teams of three to four students. Some examples of the semester projects are:

i. Reducing variation in a chemical used for microchip processing.

ii. Improving yield in patterning monolithically integrated photovoltaic modules.

iii. Variation reduction in an oxygen regulator system used in hospital environments to supply medical grade oxygen to patients.

iv. Variation reduction in bending angles of sheet metal components for commercial and industrial heater doors.

v. Defect reduction in line changeover for a beauty care manufacturer.

A student survey was distributed upon completion of the semester project to observe the student's interest and knowledge working through the process of practical application of the theoretical knowledge presented in class. A questionnaire comprising of twenty-three questions with categories such as learning, critical thinking, and engagement framed by Yadav et al., (2010) was adopted.

The questions were categorized in accordance with the knowledge areas observed by the instructor and included learning, critical thinking, and engagement. The learning category was comprised of questions relating to how well the students are learning the application of the tools and techniques, and whether they knew how, when, and where to apply the tools. Questions in the critical thinking category assessed how well the students thought about a problem from different perspectives, solved problems by utilizing material from other engineering courses, and applied these concepts to the current project for problem solving. The engagement questions focused on the level of involvement the students had in the semester project, including how well the format allowed the students to present their ideas and discuss the problem in different ways, leading to a number of possible ways of solving a problem. The engagement questions evaluated how well the semester project allowed students to discuss the project in class and to listen to and observe other student's perspectives.

The questionnaire was based on the Likert scale rating which consisted of the categories: strongly agree (5), agree (4), neutral (3), disagree (2), and strongly disagree

(1). The collected survey data contains responses from 26 students from the Lean course and 54 students from the Six Sigma course. There were 28 students enrolled in the Lean course and 68 enrolled in the Six Sigma course; yielding a response rate of 92.9% and 79.4%, respectively.

The analysis consisted of two phases. The first phase was comprised of a comparison of each question to determine the students' reaction to the semester project for the Lean course. By analyzing the number of responses for each question on the Likert scale, the analysis determined whether the students agreed or disagreed to that particular statement. The initial analysis considered agree as an aggregate of strongly agree and agree; and disagree as an aggregate of strongly disagree and disagree.

The second phase involved analyzing the responses from the two courses to find out whether students received knowledge from the use of the semester project in the same manner in both courses. For this analysis, responses for each question from the two courses were analyzed using a Chi-Square test of independence with Statistical Analysis System (SAS). Twenty-three Chi-Square tests were run. Individual question comparisons provided information related to how a student felt about the project for a particular aspect in both courses. Performing the Chi-Square test of independence gives an idea of whether the students received knowledge from the use of the semester project in a similar manner in both courses.

Performing a Chi-Square test of independence using SAS also provided a wide range of statistical analysis results, including Pearson Chi-Square, Likelihood ratio Chi-Square, Fisher's exact test values, etc. Sample results from SAS, including all the tests performed, were tabulated and presented in Table 1. In addition, the Fisher's exact test results from various statistical analysis results used in the current evaluation are shown in Table 2.

3. Results

Survey results were analyzed to determine the impact on the student's knowledge through the inclusion of the semester project in the Lean and Six Sigma courses and to determine how the students gained knowledge from both the Lean and Six Sigma courses. The survey results include responses and the Fisher's exact value for 54 students from the Six Sigma course and 26 students from the Lean course. Percentages of the student's responses from the Lean course are presented in Table 1. A sample of results obtained from the SAS tool is presented in Table 3. The results for the twenty three questions including responses from both the courses and the Fisher's exact test values are tabulated and presented in Table 2.

First Phase

The first section of the questionnaire focused on learning. The questions were used to determine whether the students were able to learn through the use of the semester project. This included learning course concepts, simultaneous learning through the applied project, and the ability to analyze and synthesize ideas and information. The results suggest that the students were able to learn more through the use of the semester project.

For the Lean course, the responses indicated that the semester project was relevant in learning the course concepts (100% agree), analyzing the basic elements (100% agree), and synthesizing the ideas and information (96.15% agree). Students felt that they were learning through the use of the semester project (81.77% agree), with some neutral response (19.23% responded neutral). The semester project allowed students to retain information from the class (76.92% agree). Furthermore, 61.54% of the students also felt that they covered more content through the use of the semester project (19.23% responded neutral).

For the Six Sigma class, the students agreed that use of the semester project was relevant in learning the course concepts (96.30% agree), and also were able to analyze the basic elements (94.45% agree). The semester project allowed students to retain concepts from the class (68.52% agree), although some neutral responses were observed (24.07% neutral). Most of the students agreed that the semester project enabled them to synthesize ideas presented in the course (79.63% agree) with 50% of the students feeling that they covered more content in the class when given the semester project (33.33% responded neutral). 75.47% of the students agreed that the semester project helped them learn, although some neutral responses were observed (20.75% neutral).

The focus of the second section was on critical thinking. These questions were intended to determine if the semester project helped in understanding a problem and finding a solution. It was observed from the responses that the students felt they had gained a deep understanding of the course concepts and an ability to think about problems from multiple perspectives to find a solution.

For the Lean course, the results indicated that there is a positive impact on the students thinking capability by the use of the semester project. The responses showed that the semester project was thought provoking (92.31% agree), students were able to understand the course concepts deeply (84.61% agree), and at the same time they were able to apply the concepts to a new situation (96.16% agree). Students were able to view an issue from multiple perspectives for solving the problem (88.46% agree). Moreover, 61.53% of the students were able to bring together material from other courses, although some disagreement was observed (23.08% responded neutral).

For the Six Sigma course, a majority of the students (77.36%) agreed that the semester project was thought provoking while 9.43% of the students disagreed and the others remained neutral. Most of the students felt they were able to view an issue from multiple perspectives (83.02% agree), while others showed a fair response (13.21% neutral). Most of the students agreed that the semester project allowed a deeper understanding of the course concepts (85.19% agree), and a majority of the students were able to utilize material from other engineering courses for problem solving (69.81% agree), with the remaining students reacting neutrally and disagreeing with the statements. The majority of the students felt that they were able to apply the course concepts and theories to new situations (71.70% agree), with 18.87% of students responding neutral and the remaining students disagreeing with the statement.

The purpose of the third section of the questionnaire was to understand if the students felt engaged while applying the course concepts in solving the semester project. Learning and thinking is achieved when the student is strongly engaged in the practical application of the course concepts, which were achieved in both courses.

For the Lean course, the results indicated that the semester project added a lot of realism to the class (96.15% agree) and students felt immersed in the application of Lean concepts while they were involved in the semester project (76.92% agree). A majority of the students were engaged in the class while discussing (61.54% agree) with some neutral responses (34.62% responded neutral). In addition, 61.54% of the students took an active part in the learning process, while 34.62% responded neutrally. The semester project was not viewed as more entertaining than educational (53.85% disagree, 30.77% neutral). Also, 27.92% of the students were frustrated by the ambiguity involved while discussing the projects with a few neutral responses (15.38% responded neutral), which may be because some of the students needed more guidance from the instructor (19.23% agree and 34.62% responded neutral). When asked if the use of the semester project in the course was inefficient, 73.08% of the students disagreed, while a few responded positively (19.23% agree), which may be because the project format was challenging with a more uniform distribution of responses (46.15% agree and 34.62% disagree). Many students thought the semester project took more time than it was worth (84.61% agree), which could be due to the amount of labor involved in the application of the principles. Most of the students liked the semester project (60% agree and 40% responded neutral), because it allowed students to get engaged in the activity. The semester project allowed for more discussions in the class (52.31% disagree) with 38.46% students responding neutral.

For the Six Sigma course, the responses to the questions show that the students felt the semester project added a lot of realism (84.91% agree), largely due to involvement in the activity (64.15% agree). In addition, the students were more engaged (59.62% agree), and took a more active part in the discussions (55.77% agree). Even though there are some neutral responses to these questions, it shows that students were strongly engaged in the semester project. The semester project was not viewed as more entertaining that educational (50.94% disagree, 35.85% neutral), and a slight majority felt that use of the semester project format was beneficial (50.94% agree, 32.08% disagree).

43.14% of the students liked the semester project, although slightly more were neutral (45.10%). This may be because some students felt the project took more time than it was worth (21.15% agree, 25.00% neutral) or it may be some of the students needed more guidance from the instructor (33.96% agree, 15.09% neutral). Some of the students were frustrated by the ambiguity (19.23% agree, 23.08% neutral) and also felt that use of semester project was inefficient (16.98% agree, 11.32% neutral). Overall, the students felt they were able to discuss more course ideas (81.13% agree), which improved their critical thinking capability and knowledge through discussions.

Second Phase

In this phase a comparison of responses from the Lean and Six Sigma courses was performed to determine whether students had the same level of learning, critical thinking, and engagement. For this analysis, a Chi-Square test for each individual question was performed. For each test, the Fisher's exact values were calculated and are presented in last column of Table 2. The results indicate that students from both courses felt that the use of the semester project was relevant but a slight difference between the response patterns was observed (0.63). Students enhanced their learning through the use of the semester project in both courses (0.98) and also were able to analyze the basic elements (0.91). The semester project helped students to synthesize ideas in both courses, but analysis indicated a large difference between response patterns (0.26). Students from both courses retained more from the class (0.89). Students felt that more content was covered in Lean than Six Sigma leading to a difference in the response patterns between both courses (0.55).

Students from the Lean course felt the use of the semester project was more thought provoking (0.57), were able to view an issue from multiple perspectives (0.41), and allowed for a deeper understanding of course concepts (0.40), leading to a difference between the response patterns for both courses. The data also indicated that more students were able to bring together material from other courses in the Six Sigma course than the Lean course indicating a difference in the response pattern between both courses (0.61). A higher difference in the response patterns for both courses was observed for the statement regarding whether students were able to apply course concepts to new situations, because students from the Lean course completely agreed and some students from the Six Sigma course showed unbiased and disagreement towards the statement (0.11).

Students from the Lean course strongly agreed that the semester project added a lot of realism to the class, which leads to some difference between the response patterns for both courses (0.75). There was a smaller difference in the response patterns observed on the statement students were more engaged when discussing the projects; the majority of the students showed little disagreement (0.84). Students showed disagreement towards the statement, the semester project was more entertaining than educational with more difference observed in the response patterns between both courses (0.64). Analysis indicated a larger difference in the response patterns between both courses where students felt immersed in the activity involved with the use of the semester project (0.39), took more active part in the learning process (0.32), and also showed disagreement towards the statement, “I was frustrated by the ambiguity when discussing the semester projects”

(0.54). Students showed disagreement towards the statement regarding the use of the semester project in the course was inefficient (0.89).

The use of the semester project format was more challenging (0.98). Since most of the students from the Lean course liked the semester project, there was a greater difference in the response pattern that was observed between both the courses (0.35). Students from the Lean course did not need more guidance from the instructor; therefore, a greater difference was observed in the response patterns (0.16). There was a large difference observed in the response pattern to the statement that the semester project took more time, where the Lean students agreed completely and the Six Sigma students showed distributed responses (0.00). The semester project did not allow for more discussions for a majority of the students in the Lean course, but it did allow for more discussions in the Six Sigma course. Therefore, a higher difference was observed between the response patterns for both courses (0.00).

From the SAS analysis results between the responses from both the Lean and Six Sigma courses, it is observed that in some aspects where students felt that with the use of the semester project they were learning through the process, helping to analyze basic elements, and allowing them to retain more from the class. Students also felt that the project added a lot of realism to the class and allowed them to be more engaged in class when discussing the project. Students also felt the project format challenging allowing them to feel the project was efficient. A greater difference was observed in the response patterns between both courses in other aspects allowing students to gain knowledge in irregular patterns by the use of the semester project.

4. Conclusions

The survey results suggest that introducing a semester project in the Lean course was beneficial to students with no negative impacts observed on the student's education. Students felt that the inclusion of the semester project helped them better understand the course concepts in problem solving. In addition, students were able to analyze basic elements and synthesize the ideas by learning as they worked on the semester project.

The critical thinking capability of students helps them solve a problem by applying the course concepts practically, which also seemed to be achieved. Students viewed the semester project as thought provoking, adding realism to class, and allowing for a deeper understanding of the course concepts. The semester project allowed students to retain more from the class and helped the students to view a problem in multiple perspectives and apply the course concepts to other situations. The semester project was more interactive, and encouraged students to work hard by getting them involved in the activity, making them take an active part.

There are some changes that need to be made to allow students to cover more content, make students able to utilize material from other engineering courses in problem solving, make them feel less frustrated, and adjust the amount of guidance from the instructor. The projects should be designed to allow students to feel more engaged while working on the semester project, not only to attain good grades but to gain practical knowledge. The projects should be designed such that the students feel it is efficient with respect to the total time of involvement required. In addition, the neutral mixed response to whether the students felt the semester project was challenging suggests that improvements to the project could lead to a more enjoyable and engaging course experience. This could be accomplished by matching the student interests to the projects. While this would be beneficial, it would require a significant lead time to gather information about the students, which may not be achievable in an introductory course or within the time limitations of one semester.

The use of the semester project showed a positive impact on student’s knowledge, learning through the process, feeling confident in problem solving by thinking from different perspectives, and getting engaged in the process.

Looking at the SAS analysis results we cannot come to a conclusion that students from both courses felt the same about the use of the semester project. Students from both courses felt that with the use of the semester project they were able to learn through the process of applying the concepts and were able to analyze basic elements. The semester project allowed students from both courses to retain more from the class and feel engaged while discussing the projects in class, adding a lot of realism to the class. The semester project format was challenging and also was efficient for students from both courses. There are sections were students felt the use of the semester project had a positive impact but did not feel the same from both courses. This varies because Lean and Six Sigma are two different courses which involve controlled production to maintain the process flow and output quality of the product thus increasing customer satisfaction.

5. Recommendations

From the results, it is clear that use of the semester project in the Lean and Six Sigma courses helped students better understand the course concepts and principles. The projects need to be framed such that students can concentrate more on application, be able to cover more content, and allow the students to work with less guidance from the instructor. The projects should also be framed such that students can feel it is challenging, allowing for more discussions in solving a problem. Similar approaches in other engineering courses where practical application of theoretical knowledge is applicable can also be considered to improve the projects.

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Tables

Table 1: Students percentage responses for survey on Six Sigma and Lean course

Questions	Percentage Responses									
	Strongly Agree		Agree		Neutral		Disagree		Strongly Disagree	
	Six Sigma	Lean	Six Sigma	Lean	Six Sigma	Lean	Six Sigma	Lean	Six Sigm a	Lean
LEARNING	%	%	%	%	%	%	%	%	%	%
I felt the use of the semester project was relevant in learning about the course concepts.	50.00	57.69	46.30	42.31	1.85	0.00	1.85	0.00	0.00	0.00
The semester project helped me analyze the basic elements of the course concepts.	46.30	38.46	48.15	61.54	3.70	0.00	1.85	0.00	0.00	0.00
I felt that what we were learning in using the semester project was applicable to my field of study.	28.30	26.92	47.17	53.85	20.75	19.23	1.89	0.00	1.89	0.00
The semester project was helpful in helping me synthesize ideas and information presented in the course.	38.89	46.15	40.74	50.00	18.52	3.85	1.85	0.00	0.00	0.00
The semester project allowed me to retain more from the class.	37.04	38.46	31.48	38.46	24.07	19.23	7.41	3.85	0.00	0.00
I felt that we covered more content by using the semester project in the class.	22.22	23.08	27.78	38.46	33.33	19.23	12.96	19.23	3.70	0.00
CRITICAL THINKING	%	%	%	%	%	%	%	%	%	%
I thought the use of the semester project in the class was thought provoking.	39.62	38.46	37.74	53.85	13.21	7.69	5.66	0.00	3.77	0.00
The semester project allowed me to view an issue from multiple perspectives.	30.19	42.31	52.83	46.15	13.21	3.85	3.77	7.69	0.00	0.00
The semester project allowed for a deeper understanding of course concepts.	40.74	46.15	44.44	38.46	7.41	15.38	7.41	0.00	0.00	0.00
The semester project brought together material I had learned in several other engineering courses.	13.21	15.38	56.60	46.15	22.64	23.08	5.66	15.38	1.89	0.00

Table 1: Students percentage responses for survey on Six Sigma and Lean course (Cont.)

	Six Sigma	Lean	Six Sigma	Lean	Six Sigma	Lean	Six Sigma	Lean	Six Sigma	Lean
I was able to apply the course concepts and theories to new situations as a result of using the semester project.	22.64	23.08	49.06	73.08	18.87	3.85	7.55	0.00	1.89	0.00
ENGAGEMENT	%	%	%	%	%	%	%	%	%	%
The semester project added a lot of realism to the class.	47.17	53.85	37.74	42.31	3.77	3.85	5.66	0.00	5.66	0.00
I was more engaged in class when discussing the semester project.	25.00	30.77	34.62	30.77	28.85	34.62	5.77	3.85	5.77	0.00
The semester project was more entertaining than it was educational.	1.89	3.85	11.32	11.54	35.85	30.77	37.74	50.00	13.21	3.85
I felt immersed in the activity that involved the use of the semester project.	16.98	15.38	47.17	61.54	20.75	23.08	11.32	0.00	3.77	0.00
I took a more active part in the learning process when we discussed the semester projects in the class.	25.00	11.54	30.77	50.00	36.54	34.62	7.69	3.85	0.00	0.00
I was frustrated by ambiguity that followed when discussing the semester projects.	5.77	11.54	13.46	15.38	23.08	15.38	50.00	57.69	7.69	0.00
I felt that the use of the semester project in the course was inefficient.	3.77	0.00	13.21	19.23	11.32	7.69	45.28	50.00	26.42	23.08
I found the use of the semester project format challenging in the class.	7.55	7.69	43.40	38.46	16.98	19.23	30.19	30.77	1.89	3.85
Most of the students I know liked the semester project.	3.92	12.00	39.22	48.00	45.10	40.00	7.84	0.00	3.92	0.00
I needed more guidance from the instructor about the use of the semester project for the class.	9.43	3.85	24.53	15.38	15.09	34.62	47.17	34.62	3.77	11.54
The case study took more time than it was worth.	9.62	19.23	11.54	65.38	25.00	15.38	42.31	0.00	11.54	0.00
The use of the semester project allowed for more discussions of course ideas in the class.	28.30	11.54	52.83	7.69	13.21	38.46	5.66	30.77	0.00	11.54

Table 2: Student responses for survey on Six Sigma and Lean course with Fishers Exact test value

Questions	**Responses**										**Fisher's Exact p-value**
	Strongly Agree		**Agree**		**Neutral**		**Disagree**		**Strongly Disagree**		
LEARNING	**Six Sigma**	**Lean**	**Six Sigma**	**Lean**	**Six Sigma**	**Lean**	**Six Sigma**	**Lean**	**Six Sigma**	**Lean**	
I felt the use of the semester project was relevant in learning about the course concepts.	27	15	25	11	1	0	1	0	0	0	0.63
The semester project helped me analyze the basic elements of the course concepts.	25	10	26	16	2	0	1	0	0	0	0.91
I felt that what we were learning in using the semester project was applicable to my field of study.	15	7	25	14	11	5	1	0	1	0	0.98
The semester project was helpful in helping me synthesize ideas and information presented in the course.	21	12	22	13	10	1	1	0	0	0	0.26
The semester project allowed me to retain more from the class.	20	10	17	10	13	5	4	1	0	0	0.89
I felt that we covered more content by using the semester project in the class.	12	6	15	10	18	5	7	5	2	0	0.55

Table 2: Student responses for survey on Six Sigma and Lean course with Fishers Exact test value (Cont.)

CRITICAL THINKING	**Six Sigma**	**Lean**	**Six Sigma**	**Lean**	**Six Sigma**	**Lean**	**Six Sigma**	**Lean**	**Six Sigma**	**Lean**	**Fisher's Exact p-value**
I thought the use of the semester project in the class was thought provoking.	21	10	20	14	7	2	3	0	2	0	0.57
The semester project allowed me to view an issue from multiple perspectives.	16	11	28	12	7	1	2	2	0	0	0.41
The semester project allowed for a deeper understanding of course concepts.	22	12	24	10	4	4	4	0	0	0	0.40
The semester project brought together material I had learned in several other engineering courses.	7	4	30	12	12	6	3	4	1	0	0.61
I was able to apply the course concepts and theories to new situations as a result of using the semester project.	12	6	26	19	10	1	4	0	1	0	0.13
ENGAGEMENT											
The semester project added a lot of realism to the class.	25	14	20	11	2	1	3	0	3	0	0.75
I was more engaged in class when discussing the semester project.	13	8	18	8	15	9	3	1	3	0	0.84
The semester project was more entertaining than it was educational.	1	1	6	3	19	8	20	13	7	1	0.64

Table 2: Student responses for survey on Six Sigma and Lean course with Fishers Exact test value (Cont.)

	Six Sigma	**Lean**	**Six Sigma**	**Lean**	**Six Sigma**	**Lean**	**Six Sigma**	**Lean**	**Six Sigma**	**Lean**	**Fisher's Exact p-value**
I felt immersed in the activity that involved the use of the semester project.	9	4	25	16	11	6	6	0	2	0	0.39
I took a more active part in the learning process when we discussed the semester projects in the class.	13	3	16	13	19	9	4	1	0	0	0.32
I was frustrated by ambiguity that followed when discussing the semester projects.	3	3	7	4	12	4	26	15	4	0	0.54
I felt that the use of the semester project in the course was inefficient.	2	0	7	5	6	2	24	13	14	6	0.89
I found the use of the semester project format challenging in the class.	4	2	23	10	9	5	16	8	1	1	0.98
Most of the students I know liked the semester project.	2	3	20	12	23	10	4	0	2	0	0.35
I needed more guidance from the instructor about the use of the semester project for the class.	5	1	13	4	8	9	25	9	2	3	0.16
The case study took more time than it was worth.	5	5	6	17	13	4	22	0	6	0	0.00
The use of the semester project allowed for more discussions of course ideas in the class.	15	3	28	2	7	10	3	8	0	3	0.00

Table 3: Sample report from SAS analysis

Statistic	DF	Value	Prob
Chi-Square	3	2.2901	0.5144
Likelihood Ratio Chi-Square	3	3.1937	0.3627
Mantel-Haenszel Chi-Square	1	0.0009	0.9764
Phi Coefficient		0.1692	
Contingency Coefficient		0.1668	
Cramer's V		0.1692	

WARNING: 50% of the cells have expected counts less than 5. (Asymptotic) Chi-Square may not be a valid test.

Pearson Chi-Square Test	
Chi-Square	2.2901
DF	3
Asymptotic Pr > ChiSq	0.5144
Exact Pr >= ChiSq	0.6071

Fisher's Exact Test	
Table Probability (P)	0.0398
Pr <= P	0.6377

3. Project Based Learning for Enhancing Quality and Six Sigma Education

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Abstract

Background – Practical application of theoretical knowledge has become essential for engineering students to succeed in their career. To attain practical knowledge students must know when, where, and how to apply the concepts. To satisfy this requirement, project based learning was introduced in engineering courses on Quality, an undergraduate level, and Six Sigma, a graduate level course, where the practical application of theoretical concepts is necessary to enhance learning.

Purpose – The goal of this research is to determine the importance and impact of project based learning on students' knowledge in Quality and Six Sigma courses where practical application of theoretical knowledge is necessary.

Design/methodology/approach - Students teams were given hands-on collaborative projects conducted with local companies. After the completion of the project, a student evaluation survey was implemented and the responses were analysed in two different phases. The first phase consisted of collecting responses from the Quality and Six Sigma courses and observing the impact of the semester project on students' knowledge based on the response percentages. The second phase consisted of analysing the responses from both the Quality and Six Sigma courses and performing a Chi-Square test to examine how similar the students received knowledge from the use of the semester project.

Conclusions - Results showed that the inclusion of the semester project in the courses had a positive impact on the students' knowledge in learning course concepts and the students were able to apply theoretical knowledge in solving real-world problems. It was also observed that there was difference observed in the response patterns for almost all of the questions between both courses.

Keywords: Quality, Six Sigma, Project Based Learning, Chi-Square Test

Introduction

Six Sigma and Quality are approaches used to improve customer satisfaction by increasing the quality of a product. Six Sigma is a quantitative strategy, which is focused on process improvement and production quality to increase customer satisfaction (Siong, 2006). Six Sigma principles are mainly adopted to increase sales, customer satisfaction, and core competitiveness while improving management processes. Quality management is a methodology that provides tools and techniques for the successful application of quality principles in various environments. The goal is to achieve a relatively defect free process where the defect is identified as customer dissatisfaction (Black and Revere, 2006). Customer satisfaction can be achieved by applying Six Sigma principles to improve production quality by applying quality improvement tools. The Six Sigma approach has succeeded where other approaches such as Total Quality Management and Business Process Reengineering failed (Montgomery et al., 2005). Kovach et al. (2011) examined the perceived effectiveness and the challenges/reasons for failure associated with these techniques in industry. Six Sigma uses a five-phase approach for continuous improvement with the phases identified as: Define, Measure, Analyze, Improve, and Control (DMAIC), for increasing productivity and customer satisfaction. Quality

Management uses tools and methodologies for improving product quality, thus increasing customer satisfaction.

Providing engineering students with knowledge of Quality and Six Sigma principles and giving them the ability to solve practical engineering problems gives employers a workforce with the necessary skill sets while making the graduating students more marketable.

Quality, an undergraduate level course, requires more guidance from the instructor. Since basic tools and methodologies about quality engineering are being taught it is important that students get in-depth knowledge and are more involved in the activities that focus on the application of the tools. Six Sigma, a graduate level course, requires less guidance to understand a problem and find a solution. Graduate students tend to have a better understanding of the course concepts and principles since they typically have some knowledge from their undergraduate studies and from internships, coops, or work experience. Six Sigma uses some of the same principles taught in the Quality course, which also aids in helping students understand the more in-depth concepts and achieve the goal of the semester project. It is essential to have basic knowledge about quality methodologies and tools before applying Six Sigma principles.

Undergraduate students are taught basic engineering concepts which allow them to gain knowledge to choose a particular research area of interest in which they plan to pursue their graduate education and future career. Students in undergraduate programs typically need more guidance than graduate students in order for them to become better researchers.

Teaching Quality and Six Sigma in a classroom environment typically consists of lectures and the presentation of examples and case studies. The introduction of project based learning (PBL), allows students to gain practical experience in Quality and Six Sigma methods through a semester project where they actively apply quality and DMAIC principles to improve their understanding of the concepts. Project based learning is a process of learning through the practical application of theoretical knowledge. This approach allows students to gain practical knowledge and gives the instructor an opportunity to adjust the teaching practice to better engage the students. To determine the effectiveness of this method, student responses to a survey about the use of the project can be considered (Amante, 2010).

For PBL to be effective, students must not limit themselves to routine learning, but must also be actively involved in discussion and problem solving. The engagement level of students should promote critical thinking, synthesis of concepts, and evaluation of observed results. The best approach to promote active learning is considered to be the use of instructional activities that involve students in the practical application of the topics to solve a problem using their theoretical knowledge (Arthur and Zelda, 1987; Prince, 2004; Plaza, 2007; Vardi and Ciccarelli, 2008; Springer, 1999).

Research by Fang (2011), Wirth (2007), Wang and Li (2010) and Wu et al. states that implementing quality principles and also teaching students the principles of quality will lead to flexible learning for increasing effectiveness of undergraduate education and improve the students future. Zhan and Porter (2010) gave a brief description of how to educate students in Six Sigma and the importance of providing that education. They stated that students had a misconception that new product development involves only technical design and paid little attention to other factors such as quality and customer satisfaction, which play a major role and can be understood through the practical application of theoretical knowledge.

Akili (2011), Yang et al. (2012), McIntyre (2003), Smith et al. (2005), Fang et al. (2007), Montgomery et al. (2005), Anderson-Cook et al. (2005), and Furterer et al. (2007) presented their views on the introduction of a semester project in Quality and Six Sigma courses and an evaluation of how a course project affected the students' knowledge. This evaluation was performed by conducting surveys and collecting responses from students for course improvement. The PBL approach along with a lab simulation engages students and improves learning through the practical application of tools and principles of Quality (Stier, 2003).

Applying Quality and Six Sigma principles to improve the education system and student instruction is another approach which allows students to gain more knowledge through experience during the learning process (Patil et al., 2006). Hargrove et al. (2002), Karl (2005), and Li (2011) discussed how Quality and Six Sigma principles are not only being used in industry, but also in educational institutions to decrease dropout rates of well qualified students at an early stage.

Collecting student feedback provides the instructor with information that conveys how engaged the students are in the semester project and in learning the course concepts and principles. This also provides a means to evaluate the educational process and make suggestions for improving classroom instruction. With these issues in mind, a survey was conducted to observe the impact the semester project has on a student's knowledge.

Additionally, a comparative study was carried out to analyze how the students received knowledge from the use of the semester project in both the Quality and Six Sigma courses. The following section presents the research methodology of how the surveys were evaluated and then the results are presented. A discussion and recommendations based on these results are provided in the conclusion.

Methodology

For this research, data was collected through a survey from Quality, an undergraduate level, and Six Sigma, a graduate level course. The survey data were analyzed to determine the impact of project based learning on student knowledge and understanding of the course content. Student teams in both courses were given hands-on collaborative projects to apply the course concepts to a real-world process improvement project. These courses were selected since they represent similar topics in quality and process improvement; however, the Quality course is at the undergraduate level and the Six Sigma course is at the graduate level. The semester projects are conducted with collaboration from local companies by teams of three to four students. Some models of the semester projects are:

i. Improving process flow in a community resale shop.
ii. Reducing variation in a chemical used for microchip processing.
iii. Improving yield in patterning monolithically integrated photovoltaic (PV) modules.
iv. Variation reduction in an oxygen regulator system used in hospital environments to supply medical grade oxygen to patients.

v. Variation reduction in bending angles of sheet metal components for commercial and industrial heater doors.

A student survey was distributed upon completion of the semester project to observe the student's interest and knowledge working through the process of practical application of the theoretical knowledge presented in class. A questionnaire framed by Yadav et al., (2010) comprising of twenty-three questions with categories such as learning, critical thinking, and engagement was adopted.

The questions were categorized in accordance with the knowledge areas observed by the instructor and included learning, critical thinking, and engagement. The learning category comprised of questions related to how well the students are learning the application of the tools and techniques, and whether they knew how, when, and where to apply the tools. Questions in the critical thinking category assessed how well the students thought about a problem from different perspectives, solved problems by utilizing material from other engineering courses, and applied these concepts to the current project for problem solving. The engagement questions focused on the level of involvement the students had in the semester project, including how well the format allowed the students to present their ideas and discuss the problem in different ways, leading to a number of possible ways of solving a problem. The engagement questions evaluated how well the semester project allowed students to discuss the project in class and to listen to and observe other student's perspectives.

The questionnaire was based on the Likert scale rating which consisted of the categories: strongly agree (5), agree (4), neutral (3), disagree (2), and strongly disagree

(1). The collected survey data contains responses from 34 students from the Quality course and 54 students from the Six Sigma course.

The analysis consisted of two phases. The first phase was comprised of a comparison of each question to determine the students' reaction to the semester project for the Quality course. By analyzing the number of responses for each question on the Likert scale, the analysis determined whether the students agreed or disagreed to that particular statement. The initial analysis considered agree as an aggregate of strongly agree and agree; and disagree as an aggregate of strongly disagree and disagree.

The second phase involved analyzing the responses from the two courses to determine whether students received knowledge from the use of the semester project in the same manner in both courses. For this analysis, responses for each question from the two courses were analyzed using a Chi-Square test with Statistical Analysis System (SAS). Twenty-three Chi-Square tests were run. Individual question comparisons allowed an understanding how a student felt about the project for a particular aspect in both courses. Performing the Chi-Square test of Independence provides insight of whether the students received knowledge from the use of the semester project in a similar manner in both courses.

Performing a Chi-Square test using SAS also provided a wide range of statistical analysis results, including Pearson Chi-Square, Likelihood ratio Chi-Square, Fisher's exact test values, etc. Sample results from SAS, including all the tests performed, were tabulated and presented in Table 1. For the current evaluation, Fisher's exact test results from various statistical analysis results were considered as shown in Table 2.

Results

Survey results were analyzed to determine the impact on the student's knowledge on the inclusion of the semester project in the Quality and Six Sigma course and to determine how the students gained knowledge from both the Quality and Six Sigma courses. The survey results include responses and the Fisher's exact value for 54 students from the Six Sigma course and 34 students from the Quality course. Percentages of the student's responses from the Six Sigma and Quality courses are presented in Table 1. A sample of results obtained from the SAS tool is presented in Table 3. The results for the twenty three questions including responses from both the courses and the Fisher's exact test values are tabulated and presented in Table 2.

<u>First Phase</u>

The first section of the questionnaire focused on learning. The questions were used to determine if the students felt that they were better able to learn through the use of the semester project. This included learning course concepts, simultaneous learning through the applied project, and the ability to analyze and synthesize ideas and information. The results suggest that the students were able to learn more through the use of the semester project.

For the Quality course, the responses indicated that the semester project was relevant in learning the course concepts (85.29% agree), analyzing the basic elements (94.12% agree), and synthesizing the ideas and information (79.41% agree) with some neutral responses (17.65% responded neutral). Students felt that they were learning through the use of the semester project (76.47% agree), with some neutral response

(20.59% responded neutral). The semester project allowed students to retain more concepts from the class (70.59% agree). Furthermore, 52.94% of the students also felt that they covered more content through the use of the semester project (35.35% responded neutral).

For the Six Sigma class, the students agreed that use of the semester project was relevant in learning the course concepts (96.30% agree), and also were able to analyze the basic elements (94.45% agree). The semester project allowed students to retain concepts from the class (68.52% agree), although some neutral responses were observed (24.07% neutral). Most of the students agreed that the semester project enabled them to synthesize ideas presented in the course (79.63% agree) with 50% of the students feeling that they covered more content in the class when given the semester project (33.33% responded neutral). 75.47% of the students agreed that the semester project helped them learn, although some neutral responses were observed (20.75% neutral).

The focus of the second section was on critical thinking. These questions were intended to determine if the semester project helped in understanding a problem and finding a solution. It was observed from the responses that the students felt they had gained a deep understanding of the course concepts and an ability to think about problems from multiple perspectives to find a solution.

For the Quality course, the results indicated that there is a positive impact on the students thinking capability through the use of the semester project. The responses showed that the semester project was thought provoking (64.71% agree) with some neutral responses (23.53% responded neutral), students were able to understand the course concepts deeply (82.35% agree), and at the same time a majority of the students were able to apply the concepts to a new situation (76.47% agree) with some neutral responses (20.59% responded neutral). Students were able to view an issue from multiple perspectives for solving the problem (82.35% agree). Moreover, 73.53% of the students were able to bring together material from other courses, although some neutral responses were observed (20.59% responded neutral).

For the Six Sigma course, a majority of the students (77.36%) agreed that the semester project was thought provoking while 9.43% of the students disagreed and the others remained neutral. Most of the students felt they were able to view an issue from multiple perspectives (83.02% agree), while others showed a fair response (13.21% neutral). Most of the students agreed that the semester project allowed a deeper understanding of the course concepts (85.19% agree), and a majority of the students were able to utilize material from other engineering courses for problem solving (69.81% agree), with the remaining students reacting neutrally or disagreed with the statements. The majority of the students felt that they were able to apply the course concepts and theories to new situations (71.70% agree), with 18.87% of students responding neutral and the remaining students disagreeing with the statement.

The purpose of the third section of the questionnaire was to understand if the students felt engaged while applying the course concepts in solving the semester project. Learning and thinking is achieved when the student is strongly engaged in the practical application of the course concepts, which were achieved in both courses.

For the Quality course, the results indicated that the semester project added a lot of realism to the class (70.59% agree) with some neutral responses (26.47% responded neutral). A majority of the students felt immersed in the application of concepts while they were involved in the semester project (41.18% agree) with some neutral and disagreement observed (38.24% responded neutral and 20.59% disagreed). A majority of the students were engaged in the class while discussing (50.00% agree) with some disagreement observed (26.47% responded disagree). In addition, 55.88% of the students took an active part in the learning process, while 29.41% responded neutrally. The semester project was not viewed as more entertaining than educational (41.18% disagree, 38.24% neutral). Also, 26.47% of the students were frustrated by the ambiguity involved while discussing the projects with some neutral responses (38.24% responded neutral), which may be because some of the students needed more guidance from the instructor (26.47% agree and 29.41% responded neutral). When asked if the use of the semester project in the course was inefficient, 81.25% of the students disagreed, while a few responded positively (11.76% agree). Students did not feel that the project format was challenging with more distributed responses (20.59% agree and 38.24% disagree). Many students disagreed that the semester project took more time than it was worth (58.82% disagree); although some neutral and agreement was observed (23.53% responded neutral and 17.65% agreed). Most of the students liked the semester project (55.88% agree and 32.35% responded neutral), because it allowed students to get engaged in the activity. The semester project allowed for more discussions in the class (67.65% disagree) with 17.65% students responding neutral.

For the Six Sigma course, the responses to the questions show that the students felt the semester project added a lot of realism (84.91% agree), largely due to involvement in the activity (64.15% agree). In addition, the students were more engaged (59.62% agree), and took a more active part in the discussions (55.77% agree). Even though there are some neutral responses to these questions, it shows that students were strongly engaged in the semester project. Most students did not view the semester project as more entertaining that educational (50.94% disagree, 35.85% neutral), and a slight majority felt that use of the semester project format was beneficial (50.94% agree, 32.08% disagree). 43.14% of the students liked the semester project, although slightly more were neutral (45.10%). This may be because some students felt the project took more time than it was worth (21.15% agree, 25.00% neutral) or it may be some of the students needed more guidance from the instructor (33.96% agree, 15.09% neutral). Some of the students were frustrated by the ambiguity (19.23% agree, 23.08% neutral) and also felt that use of semester project was inefficient (16.98% agree, 11.32% neutral). Overall, the students felt they were able to discuss more course ideas (81.13% agree), which improved their critical thinking capability and knowledge through discussions.

Second Phase

In this phase a comparison of responses from the Quality and Six Sigma courses was performed to determine whether students had the same level of learning, critical thinking, and engagement. For this analysis, a Chi-Square test for each individual question was performed. For each test, the Fisher's exact values were calculated and are presented in the last column of Table 2. The results indicate that students from both courses felt that the use of the semester project was relevant in learning concepts but no similarity between the response patterns was observed (0.00). Students enhanced their learning through the use of the semester project in both courses but some difference in response patterns was observed (1.0). Students felt that the use of the semester project was helpful but a similarity between responses does not exist for several statements including students were able to analyze the basic elements (0.04), the semester project helped students to synthesize ideas in both courses (0.02), students felt that more content was covered (0.06), and retained more information from the class (0.03).

Students form both courses were able to bring together material from other courses indicating a little difference between response patterns (0.91), were able to view an issue from multiple perspectives (1.0), and were able to apply course concepts to new situations (0.83). Students from both courses felt that the use of the semester project was more thought provoking but a larger difference between response patterns was observed (0.28). The semester project allowed for a deeper understanding of course concepts for both courses but no similarity between the response patterns was observed (0.01).

The analysis indicated a difference in response patterns between both courses because of the distributed responses where students felt immersed in the activity involved with the use of the semester project (0.58). No similarity between response patterns was observed for the statements the semester project added a lot of realism to the class (0.01), took more active part in the learning process (0.05), the semester project format was more challenging (0.02), and the use of the semester project in the course was inefficient (0.07). A greater difference in response patterns was observed for the statements the semester project was more entertaining than educational (0.18), students were frustrated by the ambiguity when discussing the semester projects (0.22), and students were more engaged when discussing the semester project (0.21).

Students from both courses felt that the use of the semester project was helpful but a little difference between the response patterns was observed for the statements, students liked the semester project (0.79) and the semester project took more time than it was worth (0.88). Students from the Quality course showed disagreement leading to greater difference observed in the response patterns towards the statement, I needed more guidance from the instructor (0.50). The semester project allowed for more discussions for students from both courses but a larger difference was observed between response patterns for both courses (0.19).

From the SAS analysis results between the responses from both the Quality and Six Sigma courses, it is observed that in some aspects students from both courses responded in the same pattern when they reported they were learning through the use of the semester project, able to bring together material from other courses, able to view an issue from multiple perspectives, applied course concepts to new situations, took more time than it was worth, and said they liked the semester project. A greater difference was observed in response patterns between both courses in other aspects allowing students to gain knowledge in irregular patterns by the use of the semester project. This may be because Quality is an undergraduate level and Six Sigma being a graduate level course. In the Quality course the principles, philosophies, and methodologies for quality management practice are discussed, whereas in Six Sigma the adaption and applications of these principles are utilized for improving the output quality.

Conclusions

The survey results suggest that introducing a semester project in the Quality and Six Sigma course was beneficial to students with no negative impacts observed on the student's education. Students felt that the inclusion of the semester project was relevant in learning course concepts and that they were learning through the process. The semester project allowed students to better understand the course concepts involving problem solving. The semester project allowed students to retain more information and also allowed more content to be covered in the class. In addition, students were able to analyze basic elements and synthesize the ideas by learning as they worked on the semester project.

The critical thinking capability of students helps them solve a problem by applying the course concepts practically, which also seemed to be achieved. Students viewed the semester project as thought provoking, said it added realism to class, and allowed for a deeper understanding of the course concepts. The semester project allowed students to view a problem from multiple perspectives and apply the course concepts to other situations. The semester project was more interactive, enabling them to bring together material from other courses and encouraged students to work hard by getting them involved in the activity which enabled them take an active part. Students felt the use of the semester project was efficient by not taking more time than it was worth and allowing for more discussions of course ideas. Also, students liked the semester project.

There are some changes that need to be made to allow students to feel less frustrated and adjust the amount of guidance from the instructor. The projects should be designed to allow students to feel more engaged while working on the semester project, not only to attain good grades but to gain practical knowledge. In addition, the neutral mixed response to whether the students felt the semester project was challenging suggests that improvements to the project could lead to a more enjoyable and engaging course experience. This could be accomplished by matching the student interests to the projects. While this would be beneficial, it would require a significant lead time to gather information about the students, which may not be achievable in an introductory course or within the time limitations of one semester. The use of the semester project showed a positive impact on student's knowledge, learning through the process, feeling confident in problem solving by thinking from different perspectives, and getting engaged in the process.

The SAS analysis results do not provide a definite conclusion that students from both courses felt the same about the use of the semester project. Students from both courses felt that they were able to bring together material from other courses, were learning when using the semester project, were able to view an issue from multiple perspectives, and could apply course concepts to new situations. Students from both courses also felt that the semester project did not take more time than it was worth, and students liked the semester project. There are sections were students felt the use of the semester project had a positive impact but did not feel the same from both courses. This varies because Quality and Six Sigma are two different courses which involve applying quality methodologies to maintain and improve the output quality of the product.

Recommendations

From the results, it is clear that use of the semester project in the Quality and Six Sigma courses helped students better understand the course concepts and principles. The projects need to be framed in such a way that students can concentrate more on the application, feel less frustrated, and allow the students to work with less guidance from the instructor. The projects should also be framed such that students can feel it is challenging, allow for interactive participation and get students actively involved in making the project more educational. Similar approaches in other engineering courses where practical application of theoretical knowledge is applicable can also be considered to improve the projects.

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Tables

Table 1: Students percentage responses for survey on Six Sigma and Quality course

Questions	Percentage Responses									
	Strongly Agree		Agree		Neutral		Disagree		Strongly Disagree	
	Six Sigma	Quality	Six Sigma	Quality	Six Sigma	Quality	Six Sigma	Quality	Six Sigma	Quality
LEARNING	%	%	%	%	%	%	%	%	%	%
I felt the use of the semester project was relevant in learning about the course concepts.	50.00	11.76	46.30	73.53	1.85	14.71	1.85	0.00	0.00	0.00
The semester project helped me analyze the basic elements of the course concepts.	46.30	20.59	48.15	73.53	3.70	5.88	1.85	0.00	0.00	0.00
I felt that what we were learning in using the semester project was applicable to my field of study.	28.30	26.47	47.17	50.00	20.75	20.59	1.89	2.94	1.89	0.00
The semester project was helpful in helping me synthesize ideas and information presented in the course.	38.89	11.76	40.74	67.65	18.52	17.65	1.85	2.94	0.00	0.00
The semester project allowed me to retain more from the class.	37.04	11.76	31.48	58.82	24.07	23.53	7.41	5.88	0.00	0.00
I felt that we covered more content by using the semester project in the class.	22.22	2.94	27.78	50.00	33.33	32.35	12.96	11.76	3.70	2.94
CRITICAL THINKING	%	%	%	%	%	%	%	%	%	%
I thought the use of the semester project in the class was thought provoking.	39.62	23.53	37.74	41.18	13.21	23.53	5.66	11.76	3.77	- 0.00
The semester project allowed me to view an issue from multiple perspectives.	30.19	29.41	52.83	52.94	13.21	11.76	3.77	5.88	0.00	0.00
The semester project allowed for a deeper understanding of course concepts.	40.74	11.76	44.44	70.59	7.41	8.82	7.41	8.82	0.00	0.00

Table 1: Students percentage responses for survey on Six Sigma and Quality course (Cont.)

	Six Sigma	Quality	Six Sigma	Quality	Six Sigma	Quality	Six Sigma	Quality	Six Sigma	Quality
The semester project brought together material I had learned in several other engineering courses.	13.21	20.59	56.60	52.94	22.64	20.59	5.66	5.88	1.89	0.00
I was able to apply the course concepts and theories to new situations as a result of using the semester project.	22.64	17.65	49.06	58.82	18.87	20.59	7.55	2.94	1.89	0.00
ENGAGEMENT	%	%	%	%	%	%	%	%	%	%
The semester project added a lot of realism to the class.	47.17	29.41	37.74	41.18	3.77	26.47	5.66	2.94	5.66	0.00
I was more engaged in class when discussing the semester project.	25.00	17.65	34.62	32.35	28.85	23.53	5.77	23.53	5.77	2.94
The semester project was more entertaining than it was educational.	1.89	5.88	11.32	14.71	35.85	38.24	37.74	41.18	13.21	0.00
I felt immersed in the activity that involved the use of the semester project.	16.98	14.71	47.17	26.47	20.75	38.24	11.32	20.59	3.77	0.00
I took a more active part in the learning process when we discussed the semester projects in the class.	25.00	5.88	30.77	50.00	36.54	29.41	7.69	11.76	0.00	2.94
I was frustrated by ambiguity that followed when discussing the semester projects.	5.77	5.88	13.46	20.59	23.08	38.24	50.00	35.29	7.69	0.00
I felt that the use of the semester project in the course was inefficient.	3.77	0.00	13.21	11.76	11.32	14.71	45.28	67.65	26.42	5.88
I found the use of the semester project format challenging in the class.	7.55	0.00	43.40	20.59	16.98	41.18	30.19	32.35	1.89	5.88
Most of the students I know liked the semester project.	3.92	5.88	39.22	50.00	45.10	32.35	7.84	8.82	3.92	2.94

Table 1: Students percentage responses for survey on Six Sigma and Quality course (Cont.)

	Six Sigma	Quality	Six Sigma	Quality	Six Sigma	Quality	Six Sigma	Quality	Six Sigma	Quality
I needed more guidance from the instructor about the use of the semester project for the class.	9.43	11.76	24.53	14.71	15.09	29.41	47.17	41.18	3.77	2.94
The case study took more time than it was worth.	9.62	8.82	11.54	8.82	25.00	23.53	42.31	52.94	11.54	5.88
The use of the semester project allowed for more discussions of course ideas in the class.	28.30	11.76	52.83	55.88	13.21	17.65	5.66	14.71	0.00	0.00

Table 2: Student responses for survey on Six Sigma and Quality course with Fishers Exact test value

Questions	**Responses**										**Fisher's Exact p-value**
	Strongly Agree		**Agree**		**Neutral**		**Disagree**		**Strongly Disagree**		
LEARNING	**Six Sigma**	**Quality**	**Six Sigma**	**Quality**	**Six Sigma**	**Quality**	**Six Sigma**	**Quality**	**Six Sigma**	**Quality**	
I felt the use of the semester project was relevant in learning about the course concepts.	27	4	25	25	1	5	1	0	0	0	0.00
The semester project helped me analyze the basic elements of the course concepts.	25	7	26	25	2	2	1	0	0	0	0.04
I felt that what we were learning in using the semester project was applicable to my field of study.	15	9	25	17	11	7	1	1	1	0	1.00

Table 2: Student responses for survey on Six Sigma and Quality course with Fishers Exact test value (Cont.)

	Six Sigma	Quality	Six Sigma	Quality	Six Sigma	Quality	Six Sigma	Quality	Six Sigma	Quality	**Fisher's Exact p-value**
The semester project was helpful in helping me synthesize ideas and information presented in the course.	21	4	22	23	10	6	1	1	0	0	0.02
The semester project allowed me to retain more from the class.	20	4	17	20	13	8	4	2	0	0	0.03
I felt that we covered more content by using the semester project in the class.	12	1	15	17	18	11	7	4	2	1	0.06
CRITICAL THINKING											
I thought the use of the semester project in the class was thought provoking.	21	8	20	14	7	8	3	4	2	0	0.28
The semester project allowed me to view an issue from multiple perspectives.	16	10	28	18	7	4	2	2	0	0	1.00
The semester project allowed for a deeper understanding of course concepts.	22	4	24	24	4	3	4	3	0	0	0.02
The semester project brought together material I had learned in several other engineering courses.	7	7	30	18	12	7	3	2	1	0	0.91

Table 2: Student responses for survey on Six Sigma and Quality course with Fishers Exact test value (Cont.)

	Six Sigma	Quality	Six Sigma	Quality	Six Sigma	Quality	Six Sigma	Quality	Six Sigma	Quality	**Fisher's Exact p-value**
I was able to apply the course concepts and theories to new situations as a result of using the semester project.	12	6	26	20	10	7	4	1	1	0	0.83
ENGAGEMENT											
The semester project added a lot of realism to the class.	25	10	20	14	2	9	3	1	3	0	0.01
I was more engaged in class when discussing the semester project.	13	6	18	11	15	8	3	8	3	1	0.21
The semester project was more entertaining than it was educational.	1	2	6	5	19	13	20	14	7	0	0.18
I felt immersed in the activity that involved the use of the semester project.	9	5	25	9	11	13	6	7	2	0	0.58
I took a more active part in the learning process when we discussed the semester projects in the class.	13	2	16	17	19	10	4	4	0	1	0.05
I was frustrated by ambiguity that followed when discussing the semester projects.	3	2	7	7	12	13	26	12	4	0	0.22
I felt that the use of the semester project in the course was inefficient.	2	0	7	4	6	5	24	23	14	2	0.07

Table 2: Student responses for survey on Six Sigma and Quality course with Fishers Exact test value (Cont.)

	Six Sigma	Quality	Six Sigma	Quality	Six Sigma	Quality	Six Sigma	Quality	Six Sigma	Quality	**Fisher's Exact p-value**
I found the use of the semester project format challenging in the class.	4	0	23	7	9	14	16	11	1	2	0.02
Most of the students I know liked the semester project.	2	2	20	17	23	11	4	3	2	1	0.79
I needed more guidance from the instructor about the use of the semester project for the class.	5	4	13	5	8	10	25	14	2	1	0.50
The case study took more time than it was worth.	5	3	6	3	13	8	22	18	6	2	0.88
The use of the semester project allowed for more discussions of course ideas in the class.	15	4	28	19	7	6	3	5	0	0	0.19

Table 3: Sample report from SAS analysis

Statistic	DF	Value	Prob
Chi-Square	4	0.8015	0.9382
Likelihood Ratio Chi-Square	4	1.1488	0.8865
Mantel-Haenszel Chi-Square	1	0.0108	0.9174
Phi Coefficient		0.0960	
Contingency Coefficient		0.0955	
Cramer's V		0.0960	

WARNING: 40% of the cells have expected counts less than 5. (Asymptotic) Chi-Square may not be a valid test.

Pearson Chi-Square Test

Chi-Square	0.8015
DF	4
Asymptotic Pr > ChiSq	0.9382
Exact Pr >= ChiSq	1.0000

Fisher's Exact Test	
Table Probability (P)	0.0127
Pr <= P	1.0000

SECTION

2. CONCLUSIONS

The survey results suggest that introducing a semester project in the Quality, Lean, and Six Sigma courses was beneficial to students with no negative impacts observed on the student's education. Students felt that the semester project helped them in learning the course concepts making them better able to understand how to apply them for problem solving. Students were able to analyze basic elements, synthesize the ideas by learning, and apply the principles to new situations. Students viewed the semester project as thought provoking, adding realism to class. The semester project allowed for deeper understanding of course concepts, allowing students to retain more from the classes and allowing them to view an issue from multiple perspectives. Students felt the semester project was more interactive, and encouraged them to work hard by making them take an active part and getting them involved in the activity.

The results indicate that some changes need to be made in certain aspects, such as allowing students to utilize material from other engineering courses, making them feel less frustrated, and allowing them to work with less guidance. The projects should be designed to allow students to cover more content and feel more engaged while discussing. The projects should be designed such that the students feel the project format is challenging, making it efficient with respect to the total time of involvement required. This could be accomplished by matching the student interests to the projects. While this would be beneficial, it would require a significant lead time to gather information about the students, which may not be achievable in an introductory course or within the time limitations of a single semester. The use of the semester project showed a positive impact on student's knowledge, learning through the process, level of confidence in problem solving by thinking from different perspectives, and getting engaged in the process.

When the SAS analysis results are considered, we cannot come to a conclusion that students from the Lean and the Six Sigma courses felt the same about the use of the semester project. Students from both courses felt that through the use of the semester project they were able to learn the methods shared in the course and were able to analyze basic elements. The semester project allowed students from both courses to retain more information from the class and engaged the students more through discussing the projects in class, adding more realism. The semester project format was challenging and also was efficient for students from both courses.

Student's response patterns from the Quality and the Six Sigma courses show that they were able to bring together material from other courses, learn when using the semester project, and able to view an issue from multiple perspectives. Students were able to apply course concepts to new situations and did not feel that the semester project took more time than it was worth, leading to the students being in favor of the semester project.

There are sections were students felt the use of the semester project had a positive impact but they did not respond in the same pattern between both the Lean and the Six Sigma courses, and the Quality and the Six Sigma courses. This variation could be because Quality and Six Sigma are two different courses which involve applying quality methodologies to maintain and improve the output quality of the product and Lean uses controlled production to maintain the process flow.

VITA

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