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Implementation of Project Based Learning in a Senior-Level Class in the Engineering Technology Program to Enhance Employment Opportunities

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Abstract

Engineering technology has become one of the lucrative career choices made by students in the recent years. The extensive career opportunities in a wide variety of industries have been demanding hands-on experience from the graduates of engineering technology program. Recent studies on the engineering work force demonstrated the need for communication skills in addition to technical knowledge. One way of achieving these employer-desired skills is by incorporating project-based learning in the upper-level classes of the engineering technology program. This paper will present a detailed study of implementing project-based learning technique in a senior-level class of the engineering technology program. This investigation showed that the hands-on experience earned by students who has a free hand in selecting the team, design, implementation, analysis, and presentation, improved the learning experience. The role of the instructor was more mentorship than instruction. Holding weekly meetings and reports had shown the continuous student engagement. Importance of peer evaluation was stressed throughout the semester. A self-assessment survey was conducted among the students to identify the progress made through project-based learning. This survey results showed that the implementation of project-based learning exhibited a significant improvement in the amount of progress made in each learning objective. This research has shown that the project-based learning mechanism has not only improved technical and communication skills, but also team management skills.

Introduction

The primary goal of manufacturing industry is to provide high quality and sustainable product. The life time of any product/service depends on design process, manufacturing processes, and operating conditions. All these parameters play a crucial role in determining the quality and reliability of a product. Utmost care needs to be taken in every step of the design process to ensure a safe and good quality product. Regardless of the sound design process followed in developing a product sometimes it tends to fail. Causes of failure include human error, poor maintenance, improper use, etc. To avoid such situations, products must be tested extensively to evaluate the failure criteria. Product design must also include both reliability and maintainability as design criteria. Incorporating these skills into engineering education to ensure better industry preparedness in the graduates is very important.

Maintenance, Replacement, and Reliability Engineering course emphasized the importance of including these criteria through project-based learning. Authors had a chance to redesign this course using project-based learning activities for the first time. project-based learning is a method of instruction in which learning outcomes are obtained through students addressing open ended inquiries. J. E. Mills, et al. [1] demonstrated that project-based learning is more effective compared to the traditional teaching techniques in the engineering education. H. A. Hadim, et al. [2] discussed the effectiveness of project-based learning in freshmen-level and junior-level engineering design courses. It is distinct project-based learning necessitates the creation of artifacts. The types of artifacts can include any tangible result, from design documentation to a working solution [3]. D. Kotasaki, et al. [4] evaluated the effectiveness of project-based learning to establish correlation with improved affectively and empirically measured student outcomes and skills, though causation has not been evaluated as randomized trials are challenging to conduct in a college setting. Project-based learning seemed to be effective in several areas and skills. Of particular interest to the present work is the "authentic" nature of project-based learning in comparison to more typical didactic methods [5]. It seems that authentic learning may correlate with improved career preparedness [6]. In general, the state of the research shows the need for further case studies, exploration, and experimentation to characterize the benefits, limitations, and conditions for success associated with project-based learning. Further, impact on career readiness is thus far largely unexplored.

The objective of this study is to investigate student response to changes implemented to improve analytical and communication skills through project-based learning. Analytical skills such as critical thinking, problem solving, data collection, and data analysis were investigated. Ability to work as a team member, creativeness, interpretation, writing/presentation skills were also assessed. This senior level course was offered once in any given academic year. Two cohorts over two academic years consisting a total of 58 students were examined. As survey was conducted at the end of each semester to record the growth in student's perspective. 72% responded to the survey and the results are presented subsequently in this paper. This study is predominantly based on the self-assessment of the students on the learning objectives.

Methodology

The improvements to the existing course emphasized on the new data analysis techniques, the practical approaches to problem-solving, and the usage of computer programs to study and improve current manufacturing process. These implemented changes offer an advantage to learn and implement computerized data analysis techniques compared to the traditional teaching methods. The importance of reliability in manufacturing industry was highlighted throughout the semester. A new topic focused on designing the experiments and analyzing the data is included to promote the analytical knowledge required for testing and manufacturing process improvement.

Students were asked to solve practical problems using hand calculations as well as computer programs. Computer program results were benchmarked by hand calculations to instill confidence in computational analysis. Students registered in this redesigned course were formed into groups and work on a two-part project in a semester. This senior level project involved 3D-Printing and Metal Casting. Students reviewed the advanced manufacturing journals in the field of 3D-Printing and metal casting areas to identify a suitable project to work on. This allowed students to familiarize with current research activities and to formulate a problem/question which eventually became a project. Upon defining problem statement, students performed a brain storming session to develop a feasible action plan to address the problem. Students designed, manufactured, and tested the parts obtained from 3D-Printing and metal casting processes. Figure 1 illustrates an example of various stages involved in the project.

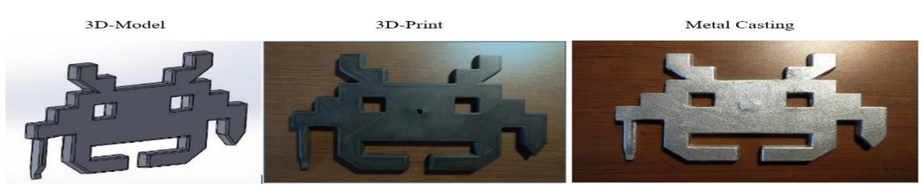

Figure 1. Sample project.

The data from both parts were analyzed using the data analysis techniques learned from the course lectures. Students used computer programs such as Excel spreadsheet programing, SolidWorks, and/or AutoCAD. SolidWorks and AutoCAD were used in designing the project models. Whereas, Excel programing was used to perform computerized data analysis. A detailed technical report and a presentation were submitted by the students. A panel consisting of three professors were involved in every step of this process to offer guidance for a successful completion of the project. The same panel served as an evaluating committee of these projects. The projects were evaluated based on (i) creativity, (ii) technological approach, (iii) testing accuracy, (iv) team work, and (v) presentation skills. At the end of the semester students were asked to participate in a survey to evaluate the learning objectives (LOs) presented in Table 1. These learning objectives were formulated to evaluate project-based learning activities implemented in this course. End results were filed with the department to support ABET re-accreditation of the Engineering Technology program. Best practices of the course in teamwork, communication, and diversity were commended by the panel members. Cheung, A. et al. [7] outlined the criteria, importance, and benefits of ABET accreditation. Fidan, I. et al. [8] presented the data collected from their study on ABET criteria and stressed on the importance of continuous improvement in STEM education.

Table 1. List of learning objectives for student assessment.

Learning Objectives	
LO - 1	Learning to apply course material to improve thinking, problem solving, and decisions
LO - 2	Acquiring skills inworking with others as a member of a team
LO - 3	Developing creative capacities (inventing; designing; writing, etc.)
LO - 4	Learning how to find, evaluate, and use resources to explore a topic in depth
LO - 5	Learning to analyze and critically evaluate ideas, arguments, and point of view
LO - 6	Learning appropriate methods for collecting, analyzing, and interpreting numerical information

Results

Self-evaluation of the students on the progress made in each learning objective was rated as (i) No Apparent Progress, (ii) Slight Progress, (iii) Moderate Progress, (iv) Substantial Progress, and (v) Exceptional Progress. Survey results obtained from both the semesters (Spring – 21 & Spring – 22) were presented in figures 2 through 7. These figures illustrate the amount of progress made by the percentage of students that observed in each learning objective embedded in this course instruction.

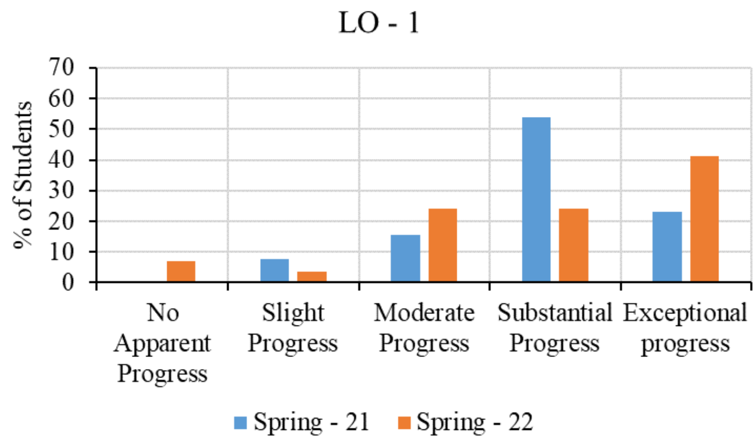

Figure 2. Student feedback on LO – 1.

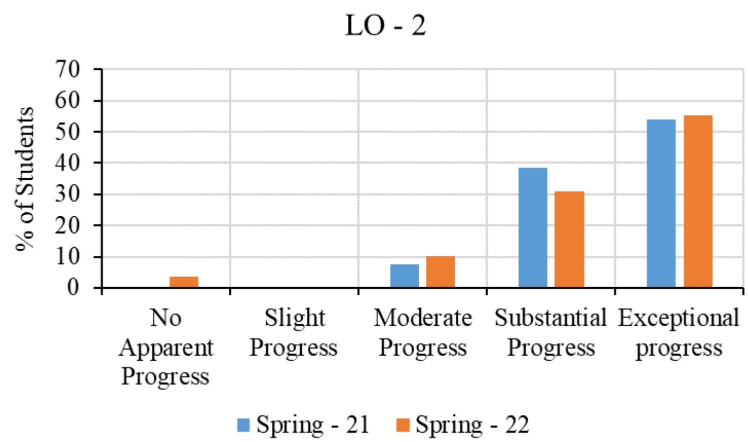

Figure 3. Student feedback on LO – 2.

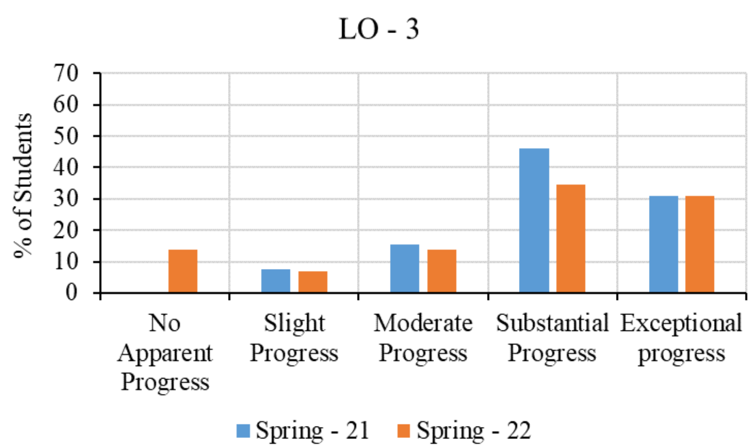

Figure 4. Student feedback on LO – 3.

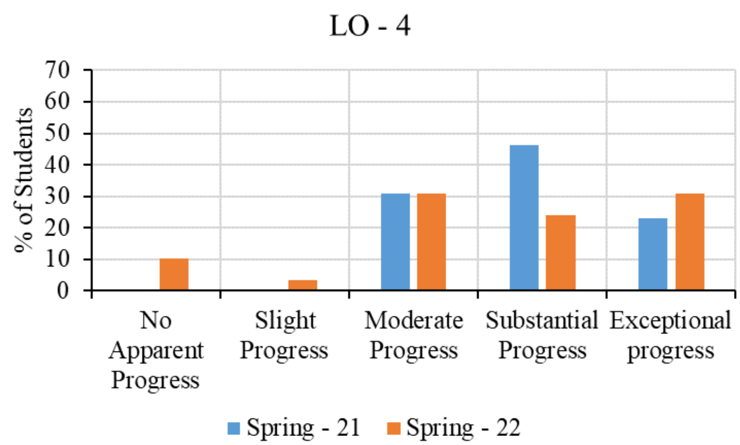

Figure 5. Student feedback on LO – 4.

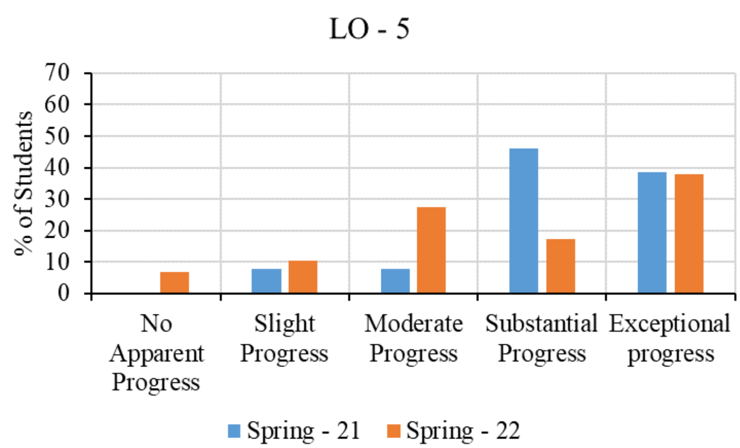

Figure 6. Student feedback on LO – 5.

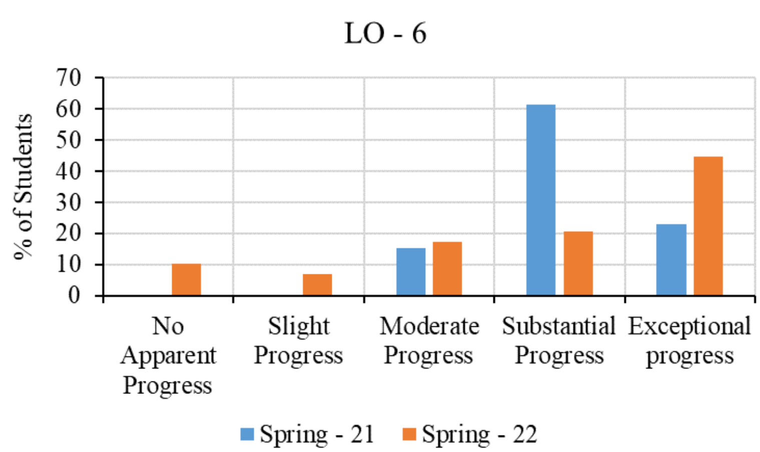

Figure 7. Student feedback on LO – 6.

Discussion

One of the important aspects of introducing project-based learning in engineering technology is not only to enhance the student learning experience but also to instill the ability to apply theoretical knowledge in projects. Figure 2 reinforces the student's ability to utilize course material in making informed engineering decisions. Figures 3 and 4 illustrates that students experienced significant progress in the ability to work in a team as well as the creative capacities by using project-based learning technique. The ability to attain, study, and utilize the required resources to complete the project in the project-based learning exercise was improved as presented in figure 5. Critical thinking enhances the ability to evaluate the viable solutions for an engineering problem. Figures 6 and 7 demonstrates the incorporation of the project-based learning resulted in the improvement of students' ability to collect, analyze, and present data.

The authors first experience with the project-based learning has demonstrated the positive effects on the student learning experience. One major observation of this study is that the lack of control group scenario with pre/post intervention is a limitation. However, the indirect assessment results presented in this paper shows the tremendous positive feedback from the students. The project-based learning activities incorporated in this course resulted in the preparation of workforce ready engineering technologists. The importance of the continuous improvement through the direct/indirect assessments has been noticed by the authors. This initial experimentation with the project-based learning in this course was found to be encouraging and the presented methodology will be reviewed/revised per future requirements.

Conclusion

This paper presents a best practice in the project-based learning of a senior level maintenance, replacement, and reliability engineering course. The course is offered for the engineering technology management concentration students. The integrated practices of the course from design to 3D printing and casting exercises was very well received by the students. A panel of the judging professors assessing the quality of the student works appreciated the high-quality performance presented in teamwork, communication and diversity. Curricular practices and student outcomes were shared with the departmental ABET assessment committee. The survey results to assess the student feedback on learning objectives 1 through 6 incorporated via project-based learning illustrated the following findings:

- The instructional methods implemented in this course were very well received by the students.
- The student feedback over two semesters indicated that the majority students have made either substantial or exceptional progress.
- Students felt exceptional progress in their ability to function effectively as a team member.
- Substantial progress was noticed in critical thinking, data collection/analysis, problem solving skills, per student's self-evaluation.
- Survey results reveal that project-based learning was found to be beneficial by the students.

Future improvements to this study will incorporate peer mentorship and day-based grading system.

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