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Evaluating Individual Learning Effectiveness on Project-Based Learning Methodology by Comparing Team-Based and Individually Assigned Projects

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EVALUATING INDIVIDUAL LEARNING EFFECTIVENESS ON PROJECT-BASED LEARNING METHODOLOGY BY COMPARING TEAM-BASED AND INDIVIDUALLY ASSIGNED PROJECTS

ABSTRACT

Engineering education has attained significant attention in recent years due to the increasing need to better prepare future engineers for the challenges in modern industrial settings. Among these, finding solutions to complex analytical problems through collaboration, using abilities such as self-learning can be considered the most critical challenges. Project-based learning has surged as a solution in educational institutions to better prepare students in both analytical and interpersonal skills, which are in high demand for engineering professionals. In the Project-based learning methodology, team projects bring several advantages to traditional learning methods such as promoting collaboration, cultivating inter-personal skillset, learning outside of the classroom and critical thinking. However, it can also have uneven distribution of the workload where only certain members of the team learn the intended topics. This results in low student-learning effectiveness when focusing on the classroom average outcome. This project focuses on evaluating the effectiveness of project-based learning by utilizing a component design problem, based on constraints and expectations, and comparing the final component design, the project report and evaluation results from the project performed in groups and individually in two different classes. This learning assessment was conducted in the Mechanical Design class, a junior level course in the Mechanical Engineering curriculum. The potential impact that working in a team or individually has on a student will be assessed by evaluating the performance of each student with a written report and an in-class quiz regarding the topics of the project.

INTRODUCTION

The focus of Engineering Education is to provide engineering students with better tools, combining technical and soft skills, to face the evolving challenges in modern industrial settings. However, the core of engineering education relies heavily on a traditional lecture-based approach. In this setting, the information is transmitted by the instructor to the students and can result in the latter selectively learning part of the material while dismissing the rest[1]. This can have a negative impact on the overall learning outcome for any engineering college level course due to the passive role of the student. To address this problem, the engineering education community has proposed and implemented solutions such as flipped classroom, and problem-oriented project-based learning. The former can be generally defined as the use of asynchronous video content for lectures and take-home problems while dedicating most of the lecture time to interactive activities, such as problem solving in groups[2]. Flipped classroom methodologies have seen an overall positive response from participating students[2]. However, it is still in the early stages of development and assessment and has not been widely implemented in college education. On the other hand, project-based learning has been broadly executed with the objective of enhancing the learning outcome of the students in engineering classes. In project based learning, the fundamental principles are acquired by solving a problem, which adds a context and makes the information more relevant, which results in enhanced knowledge retention in the students[3]. Adderley et al. defined the project method utilizing the following points[4]: (1) A solution to a problem must be involved in the project; (2) Initiative is needed by the student/group of students, as well as a variety of educational activities; (3) an end product such as a thesis, report or model is common; (4) projects are performed for a considerable length of time; (5) professors and teaching assistants perform advisory roles. This definition clearly embraces the fundamentals of project-based learning and depict a clear image of the roles of both the student body and the teaching staff in this teaching method, as well as the beginning point and the expected end result in this type of model.

The adoption of project-based learning in engineering education has been on the rise in recent decades due to a combination of several factors. One of the most important ones is the shifting expectations for future practicing engineering professionals as the problems grow in complexity, rely more on an interdisciplinary approach for solutions and the industry becomes globalized. The expectations for engineering graduates have expanded to include not only problem solving abilities, mastery of technical skills and the ability to produce innovative technologies, but also to have interdisciplinary skills such as, but not limited to, project management, communication, collaboration and life-long learning[5]. However, traditional lecture-based learning aids almost exclusively in the development of the technical skills. As a consequence, trends in engineering education have surfaced recently that aim at incorporating design and other engineering practice skills such as teamwork and project management under the supervision of the ABET engineering criteria 2000[6]. Based on these trends, project-based learning has been widely adopted as a complement to traditional lecture-based courses and enhance students' soft skills. Particularly, project-based learning aims at promoting self-learning abilities in students, which promote life-long learning, a valued skill in engineering graduates.

Project-based learning approaches has been implemented in many undergraduate engineering curricula due to its capability to enhance teamwork, communication, problem solving and life-long learning skills in students as well as its flexibility to be incorporated to traditionally taught courses easily. However, concerns still exist on the potential drawbacks it could bring; among the most important ones are uneven distribution of work when working in teams, disengagement from individual students to other student members or the project itself and development of the project through dishonest means. All of these could hinder the objectives of project-based learning and ultimately have a negative effect on the student learning effectiveness. This research paper compares student performance in a PBL for a junior level, mechanical engineering course. The comparison is performed between the Spring 2015 and Fall 2015 classes of Mechanical Design, where a design project consisting of shaft design and optimization was incorporated to the curriculum; the project was approached as a group and individually for each course, respectively.

IMPLEMENTATION OF PROJECT BASED LEARNING VARIANTS ON MECHANICAL DESIGN COURSE

Mechanical Design is a 3-hour, junior level course in the mechanical engineering curriculum at The University xxxxxxxxxxxxa. Its goal is to implement the theoretical foundation learned in previous classes such as Statics and Mechanics of Materials to mechanical engineering components such as gears, shafts and bolts. Additionally, the course is concerned with the design, analysis and optimization of these and other mechanical components employed extensively in industry. The class combines elements from traditional-lecture based teaching, such as lectures, quizzes and tests with project-based learning approaches. For the Spring and Fall classes in 2015, two projects were implemented as part of the curriculum for the class. The first one consisted of designing a seatbelt buckle utilizing Computer Aided Design (CAD) software and employing Finite Element Analysis (FEA) to analyze the distribution of stresses on the component and locate potential points of failure; this project was carried out individually in both classes. For the second project, the objective was to design a mechanical shaft with a design factor equal or greater than three as well as maintaining the greatest ratio of maximum and minimum Von Mises stresses possible. Beside the requirements, the only constraint of the project was the limitation of the shaft's length to one meter. Therefore, several parameters such as the material, radial dimensions and overall design of the shaft were left to the students' criteria. An example of the different development stages of project 2 performed by a student group is shown in Figure 1.

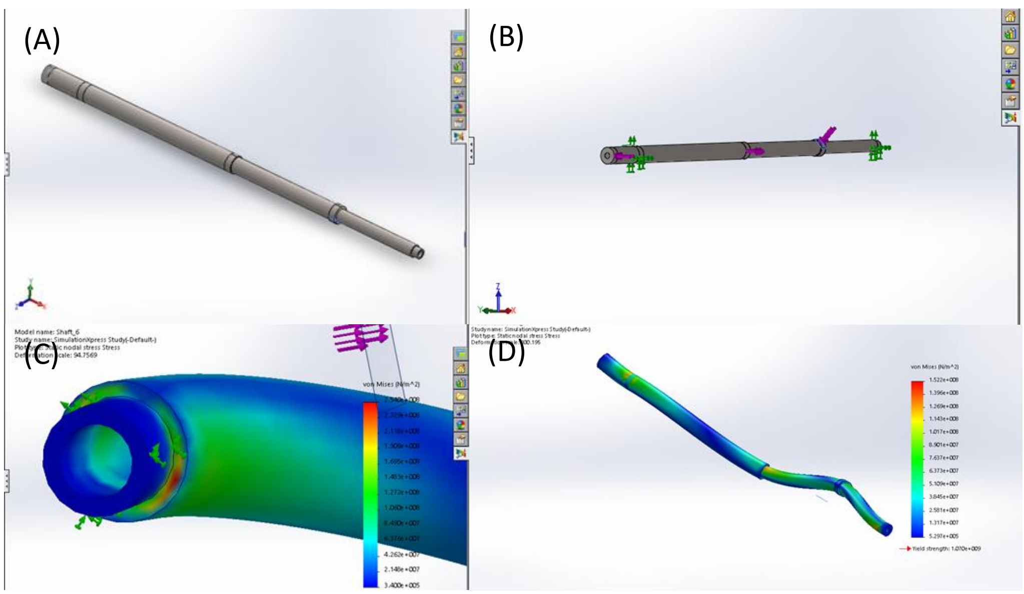


Figure 1. Example of different design stages in the mechanical shaft design project: (A) Initial design stage, (B) addition of forces and constraints for FEA, (C) stress distribution in component, (D) Shaft deformation under applied load.

In order to assess the effectiveness of the project setup, the students were instructed to work in groups for the Spring 2015 class, while working individually in the Fall 2015 course. These projects had the following objectives:

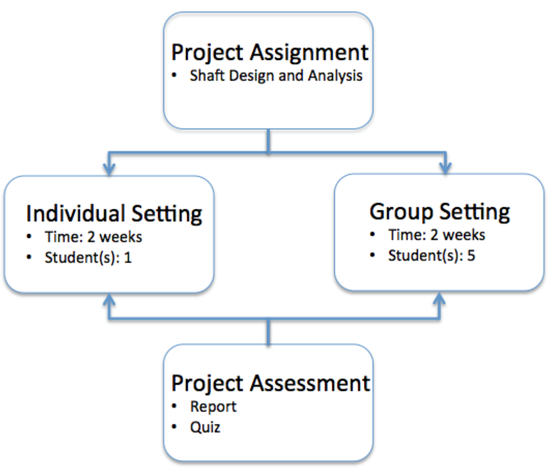
[1] Apply and extend the theoretical concepts learned in class regarding the design of mechanical components to a real world design problem in an interesting and challenging way

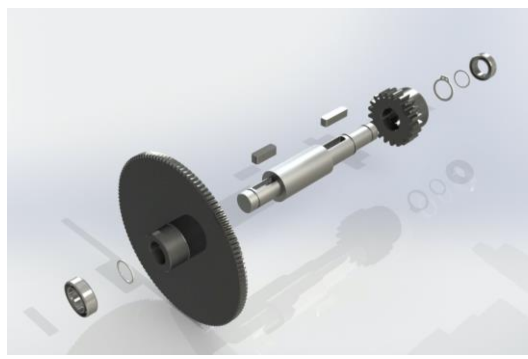
[2] Integrate tools such as SolidWorks, NX and Hypermesh software packages, which are widely used in industry, to the design process and evaluation of the mechanical components
[3] Encourage students to develop self-learning skills by tailoring the project requirements and employing the potential depth of these mechanical devices as motivators
[4] In the group-based projects, promote teamwork, communication and collaboration skills in every member of the group

In order to ensure that these projects were met, the role of the professor was maintained as an advisor rather than becoming an active agent in the problem solving stages of the projects. Evaluation for these projects consisted in turning in a written report and an oral presentation. The evaluation included these two elements as means of grading the performance of the students in the project as well as contributing to the development of their soft skills. Additionally, a quiz covering the contents of the project was employed to evaluate the understanding of the material. Finally, the students' opinion regarding PBL methodologies was recorded using an anonymous survey. The analysis of the performance is discussed in the following section.

ASSESMENT OF GROUP-BASED AND INDIVIDUAL PBL EFFECTIVENESS

The project assigned to classes is exactly the same for Spring 2015 and Fall 2015: Shaft design and analysis. The only difference is the settings either being group (5 students) or individual (1 student). Both classes were given 2 weeks to work on the project. During the two weeks of time, project review and Q&A session are given in the exact same way. At the end the two weeks, project reports were expected from each group or each student. A quiz was given to assess the student learning outcomes of the knowledge related to the project. The whole experimentation setting is shown in Figure 2 (a) below. Figure 2 (b) shows the design requirement of the shaft in a typical setup.





(a) (b)

Figure 2: (a) Settings for group and individual project, (b) typical view of shaft design.

Therefore, by assessing the report and quiz, the learning outcome could be concluded. The report was graded in mainly engineering perspectives according to design requirements such as the total weight, maximum stress and minimal stress. The quiz mainly focuses on the relevant knowledge not only within but also outside the project. The detailed assessment result is shown in Table 1 below.

Table 1: Assessment results of Spring 2015 and Fall 2015 projects

Assessment Tools	Group setting Spring 2015	Individual setting Fall 2015
Report (Group vs. individual)		
Total Weight	91%	85%
Max. Stress	85%	89%
Min. Stress	90%	90%
Blue Print	86%	95%
Average	88%	90%
Quiz (both individual)		
Knowledge directly related to project	82%	92%
Knowledge indirectly related to project	96%	83%
Average	89%	87%

From the results, it can be observed both individual and group projects generate similar learning results. Note that the report is returned back in one report per group (5 students), while one report per student for these two settings. In addition, all scores are based on total of 100 points. We took 5 representative reports and 5 representative quizzes then took the average the score and reported in the table. Regarding the report, it is clear that they are comparable in almost all subsets of the requirement: total weight, maximum stress, minimum stress, and blue print of the shaft design. However, interesting things arise for the quiz assessment. It is shown that individual setting scores better in knowledge directly related to projects. This is mainly due to the fact that for individual setting, every student is required to do all the required subtasks in the project; therefore their knowledge on all aspects of the project is to a good extent. However, for group setting, there are 5 students in each group, each student is only taking care of 1 specific task. In-group setting, they are not required to take care of all subtasks so their knowledge of the whole project is limited. On the other side, individual setting scores lower in knowledge indirectly related to project compared with group setting. This is mainly for the group setting; students are required to participate in group discussion thus this inspired learning from each other with knowledge indirectly related to the project.

CONCLUSION

Project based learning has draw significant attention in the recent years due to its popularity in stimulus student learning. However, it can also have uneven distribution of the workload where only certain members of the team learn the intended topics. This results in low student-learning effectiveness when focusing on the classroom average outcome. This project focuses on evaluating the effectiveness of project-based learning by utilizing a component design problem, based on constraints and expectations, and comparing the final component design, the project report and evaluation results from the project performed in groups and individually in two different classes. It is found that students learning outcomes are comparable in all engineering aspects. However, individual setting is better in knowledge directly related to the project since they are required to learn all aspects of the project. Group based setting is better in knowledge indirectly related to project since the group discussion inspired learning from each other group members.

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