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Implementing Project-Based Learning in Physics and Statics Courses

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Abstract

The pre-engineering courses offered at West Kentucky Community and Technical College (WKCTC) prepare students for a smooth transfer to a four-year institution at the junior level. However, students in certain courses occasionally fail to meet the learning outcome targets. Students often struggle with the connection between the concepts learned in class and the real world. To improve the learning outcomes, new pedagogical strategies beyond the traditional lecture-based teaching need to be adopted. Project-based learning (PBL) is an instructional approach that engages students' interest and motivation, relates the theoretical concepts students studied inside the classroom and their applications explored during the activities outside of the classroom and provides more opportunities for direct interactions among students. This paper presents the implementations of PBL in Physics I and Statics courses at WKCTC. Sample team projects are described in details and the assessment on learning outcomes are discussed.

Introduction

Students at West Kentucky Community and Technical College (WKCTC) can pursue University of Kentucky (UK)'s Bachelor of Science degrees in either chemical or mechanical engineering without leaving home. All four years of classes can be taken on the WKCTC campus. Faculty members at our physics department work closely with the university professors to ensure that students have a solid background in physics and some engineering courses to facilitate a smooth transfer of students to a four-year university. Mechanical engineering students at UK are required to take a sequence of lab courses, Engineering Experimentation I and II, in their junior and senior year. These experimental courses require students to design and conduct experiments, as well as to analyze and interpret experimental data, so it would be beneficial to students if they start working on hands-on projects in their sophomore year at WKCTC.

Student learning outcomes of all courses offered at WKCTC are assessed at the end of each semester. One major purpose of assessment is to identify areas which need improvement. It has been noticed that students in certain courses occasionally failed to meet the learning outcome targets in spite of the diligent work of the faculty members. Students sometimes struggle with the connection between the concepts taught in class and the applications in the real world. Traditional lecture-based courses where students sit, watch the professor solve problems and then passively absorb information has not been an effective way to facilitate student learning. New pedagogical strategies beyond lecturing need to be adopted.

Projects have the potential to deepen student learning and foster classroom engagement by combining student interest with a variety of challenging, authentic problem-solving tasks.[1] Project-based learning (PBL) is a comprehensive approach to facilitate student learning where students are presented with challenging real-life, open-ended problems and work actively to investigate and seek solutions to problems.[2] Project-based learning is sometimes used interchangeably with the term problem-based learning, another student-centered active learning approach. One of the distinctions between the two strategies is that project-based learning is more directed to the application of knowledge while problem-based learning is more directed to the acquisition of knowledge.[3] It is widely recognized that project-based learning is an effective instructional approach that results in high levels of student engagement and achievement. [4-6]

This paper presents the implementations of PBL in Physics and Statics courses at WKCTC. These two courses have been taught with the traditional lecture method for over eight years. The primary goals of implementing the PBL approach into the courses are to engage students' interest and motivation, to relate the theoretical concepts students learned inside the classroom and their applications explored during the activities outside of the classroom and to provide more opportunities for direct interactions among students.

Project Description

In the fall of 2013, project-based learning was implemented in the sophomore-level four-credit hour Physics I course. The class meets three times per week for seventy minutes in a lecture setting. The outline of the general education learning outcomes of this course include:

(a) Knowledge of human cultures and the physical and natural worlds
Students will explain basic concepts and principles in physics and their integration into everyday life.
(b) Intellectual and practical skills
Students will demonstrate an understanding of the methods of science inquiry.
(c) Personal and social responsibility
Students will explain how scientific principles relate to issues of personal and/or public importance.
(d) Integrative and applied learning
Students will apply scientific principles to interpret and make predictions in physics.

As part of the required coursework, students worked on a group project, which contributed 15% of the final course grade. Each project group consisted of four or five students. Although PBL does not necessarily imply teamwork, working in groups help students develop collaborative and co-operative skills, provide students with the opportunity to learn from each other, and help enhance interactions among students with various backgrounds. To prevent groups from sharing the same idea, different projects were assigned to the groups. One group of students was asked to build a human leg model that can be used to verify the impulse-momentum theorem. In this project, students first conducted some research and built the leg model using parts of the PASCO bridge set, as shown in Figure 1. A load cell was attached to the foot, which allowed the measurement of the force exerted on a ball when the ball was kicked. Figure 2 shows the measured impulse using DataStudio. To calculate the change of momentum, students need to figure out the velocity change of the ball. To my surprise, the students did not use motion sensors or photogates to find the velocity. What they did was putting a ball on a stool to make the initial velocity of the ball be zero. After the ball was kicked and hit the ground, the final position of the ball was recorded. The horizontal distance traveled by the ball could be measured. Then the students measured the height of the stool to calculate the total time that the ball was in the air, thus the velocity of the ball right after it was kicked could be solved. Another group of students was asked to build a human arm model that could be used to measure the forces exerted by the biceps muscle when a person lifts a weight. Students were also required to validate their measurements using the material learned in the Equilibrium Chapter. Students reported their group results two weeks after the project was assigned.

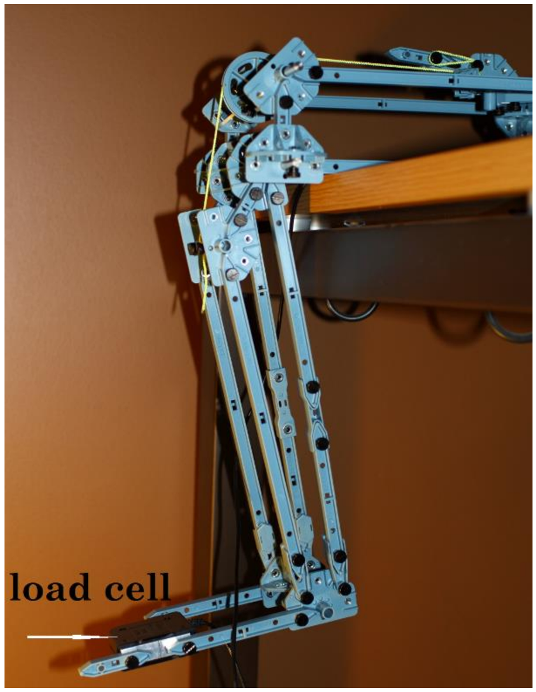

Figure 1: The human leg model

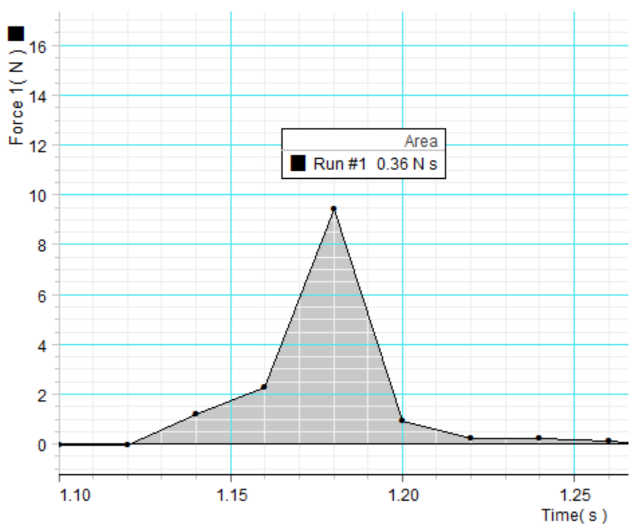

Figure 2: The measured impulse when a ball was kicked

To implement the PBL approach in the sophomore-level three-credit hour Statics course, emphasis is placed on designing models, data analysis, technical writing, and classroom presentations. Assigning different projects can prevent groups from sharing the same ideas, but it is hard to guarantee that different projects have the same level of effectiveness and interestingness. The same project is assigned to all groups in the spring of 2014. The project is designed to encompass almost all the fundamental topics covered in the course and to address a set of course competencies as listed in the course syllabus. The project is related to the design and analysis of a truss bridge. The tasks include: 1) Building a Pratt bridge model which spans a gap of 65 cm, 2) Conducting static tests to measure the internal force in each truss member when a 1-kg car passes over the model bridge, 3) Comparing the experimental results with hand calculations, and 4) Changing the design of the bridge to minimize the maximum compression, as well as keeping the cost of the project as low as possible.

A sample truss bridge built using parts of the PASCO bridge set is shown in Figure 3 and the measured internal force in each truss member of the bridge model is shown in Figure 4.

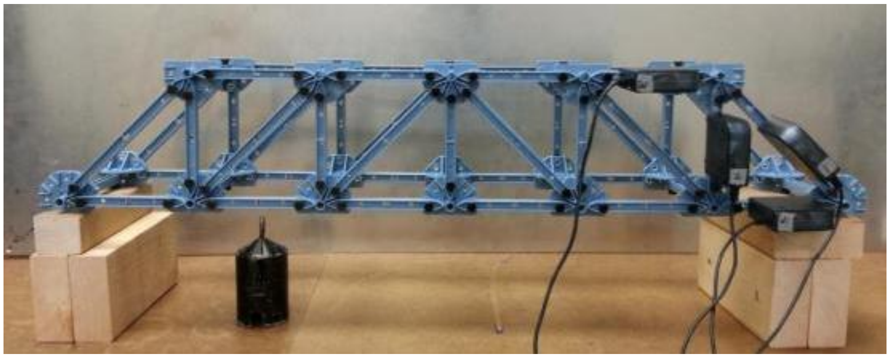

Figure 3: The truss bridge model

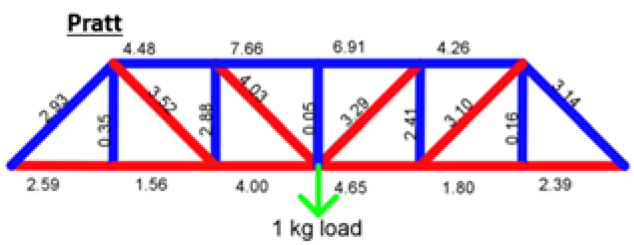

Figure 4: The measured internal force in each truss member

Considering the fact that most of our sophomore students may not have good time management skills, milestones and dates are created by the instructor. Students are given one week of time to think about the project, make initial plans and discuss project-related issues and questions with the instructor. Students are required to give group presentations on their final design plans at the end of week two. Students conduct the experiments and analyze the results in week three. At the end of week four, students present their results of the project. Team technical report is due one week after the presentation on the final results.

Assessment

The project grades were based on the group as a whole, but student participation in the project was observed by the instructor. All of the students received a project grade of “B” or above, indicating that the students have demonstrated an understanding of the methods of science inquiry, part (b) of the course learning outcomes. To assess the impact of the project used in the physics course, students were asked to complete an anonymous survey. The first part of questions were designed to compare students' knowledge in specific physics concepts before and after doing the project, so they were a little bit different for each of the groups. The rest questions were the general questions and they were the same for all the groups. Nine students took part in the survey. All of them were the traditional students. Out of the 9 students, 7 were males. The survey results are presented in Figures 5-8.

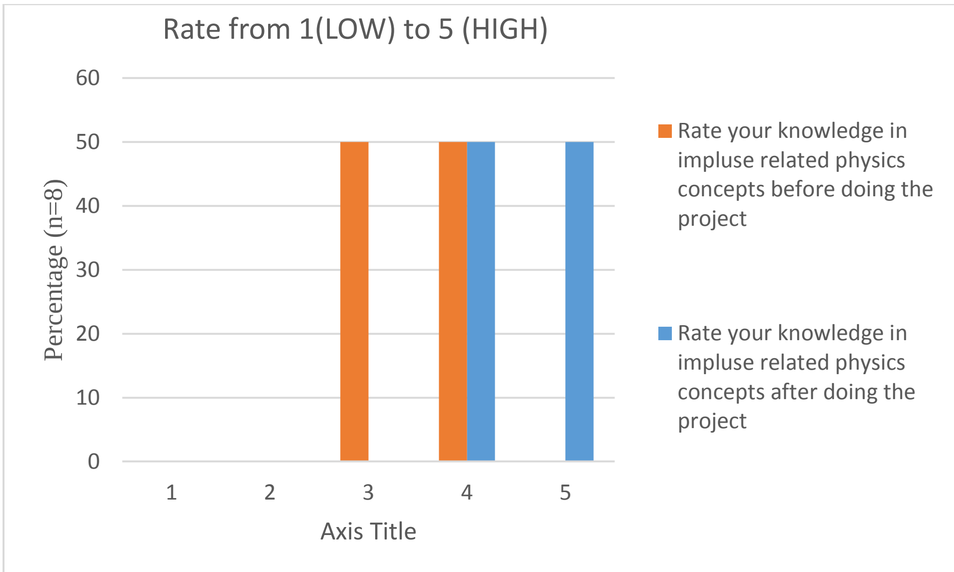

Figure 5: Student responses to survey questions regarding the knowledge in specific physics concepts before and after doing the project

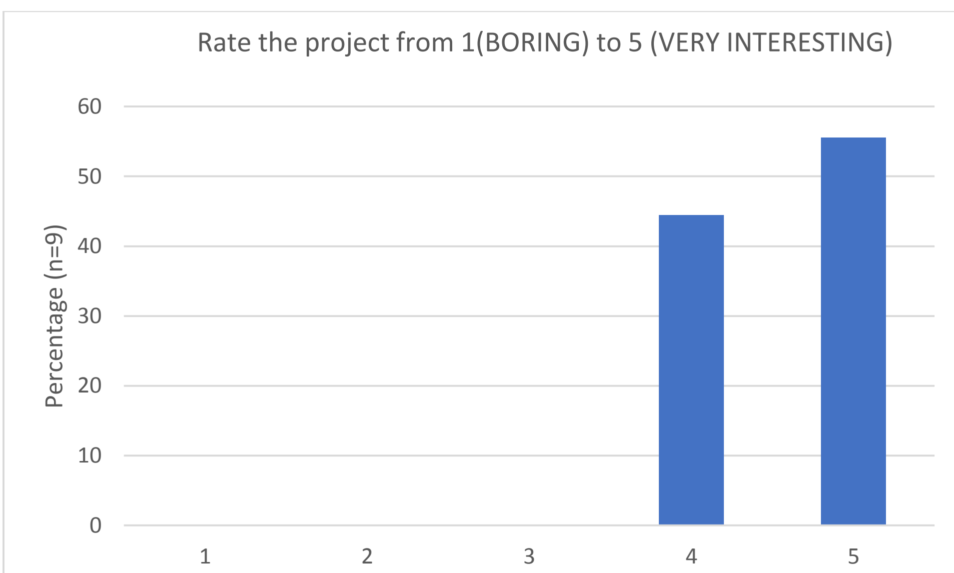

Figure 6: Student responses to the survey question regarding interestingness of the project

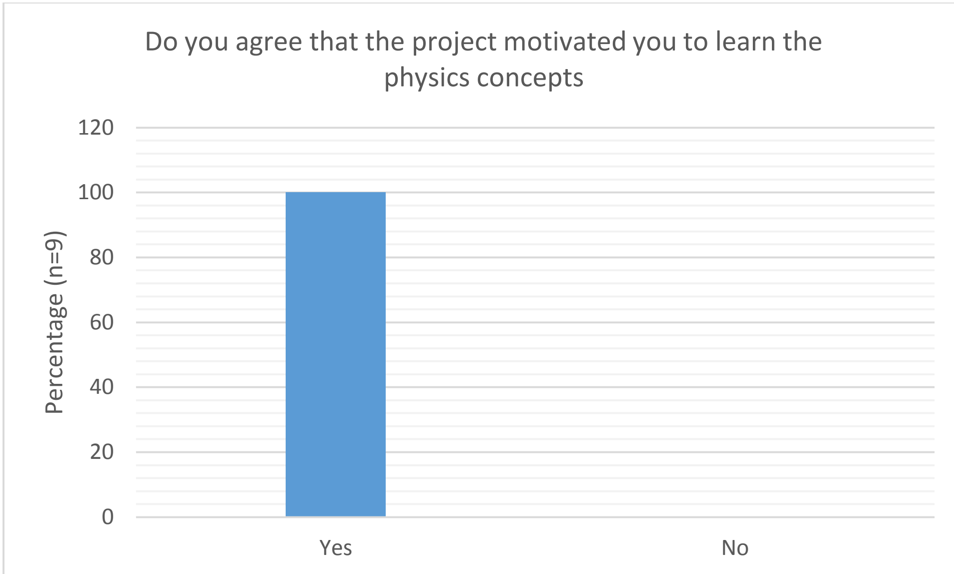

Figure 7: Student responses to the survey question regarding the effectiveness of the project

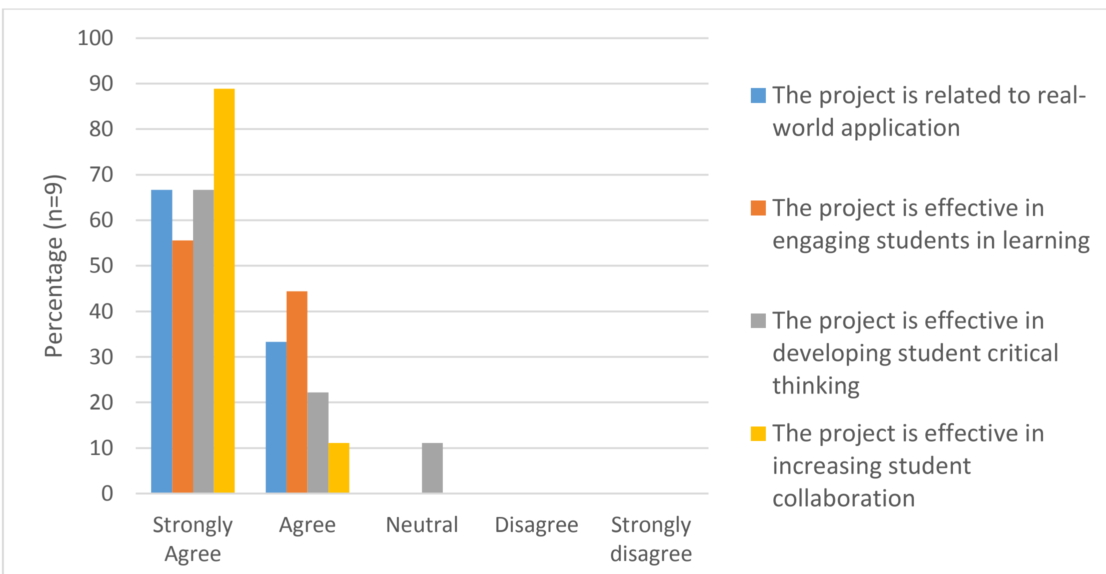

Figure 8: Student responses to the general survey questions

Figure 5 shows that the ratings of students' knowledge in the related physics concepts increased from 3 or 4 to 4 or 5 after doing the project. The results show that the students were more confident about the concepts related to the project. Figure 6 reveals that about 45% of the students thought the project was interesting and about 55% thought it was very interesting. Apparently, the students enjoyed doing the project. Figure 7 shows that 100% of the students agreed that the project motived them to learn physics. Figure 8 shows that all students agreed that the project was related to the real-world application, effective in engaging students in learning and effective in increasing student collaboration. 90% of the students agreed that the project was effective in developing student critical thinking.

New assessment procedures are added to fairly evaluate the individual contributions and the group achievements. The assessment of the statics project includes self-assessment and peer-assessment. Students provide a rating for themselves and other group members. Students are required to make comments on things that they have learned during their project experience. Also a survey similar to the one used in the physics class will be given to the statics class at the end of the spring of 2014. The assessment results are not available at this moment, but the author will present the results during the conference presentation.

Conclusion

The encouraging survey results have reflected a strong agreement with the main goals of incorporation of the PBL into traditional lecture-based courses. Projects have served as bridges to connect classroom learning and real-life applications. The implementation of hand-on projects have made the learning of science and engineering principles more enjoyable. Through project-based learning, students are not only more confident with their understandings of the materials presented in a course, but they are also better prepared for the upper-level engineering design and laboratory courses.

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