Research on the Learning Effect of Statics Course by the Problem-Based Learning Method Integrated With Design Thinking

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Abstract

Statics is a mandatory course in the departments of mechanical engineering, aerospace, and shipbuilding, and it can be challenging due to its combination of mathematical and physical concepts that students have previously studied. Typically, traditional teaching methods for statics focus on formula calculations and abstract concepts, which involve a significant number of mathematical equations. This study utilizes the problem-based learning method integrated with design thinking (DTPBL) to explore the teaching of the "Statics" course. The results of this study show that incorporating DTPBL into the statics course enhanced students' motivation to learn, enabled them to actively seek practical situational issues related to statics, improved their problem-solving and innovation abilities, and fostered better interaction between teachers and students.

Keywords: Statics, DTPBL, Learning Motivation, Engineering Education

Introduction

Learning motivation is an important key factor affecting students' learning outcomes. Students with low learning motivation are less likely to concentrate during class and are less willing to participate in classroom discussions. After analyzing the reasons for low learning motivation among students, it was found that the traditional one-way teaching method is a key factor. Therefore, in order to improve the effectiveness of teaching, teachers should understand how to motivate students' learning motivation and adopt effective teaching methods to positively influence students' learning motivation, enabling students to be more engaged in learning activities (Hofer, 2006). Therefore, it is very important to change the traditional teaching methods and develop new teaching models to enhance students' learning motivation.

Previous literature has proposed various solutions to address this issue, such as the impact of teaching variations on students' achievement motivation (Huang and Duan, 2002) and cooperative learning (Wang, 2012). Problem-solving ability is an important indicator of engineering students' learning outcomes. When students cannot link the course content with practical problems, their interest in learning naturally decreases, and their learning motivation cannot be enhanced. The traditional teaching method has long emphasized the teaching of theoretical knowledge while neglecting the cultivation of understanding and problem-solving ability in practical issues, let alone inspiring students' creative thinking. Therefore, this study employs a problem-based learning approach with design thinking incorporated into the teaching curriculum to cultivate and enhance students' learning motivation and problem-solving ability with creative thinking.

Problem-Based Learning (PBL) is mainly a student-centered learning model that focuses on practical problems and situations for discussion. In addition to triggering students' learning motivation, it can also connect classroom knowledge with life experiences, enhance students' learning interest, and promote self-learning (Norman, Schmidt, 1992). Design Thinking starts with human needs and seeks innovative solutions to various problems. Relevant research results show that Design Thinking courses can promote adults' career development and improve their ability to make self-changes (Burnett, Evans, 2016; Reilly, 2013; Lindsay, 2012).

Statics is a difficult course that includes mathematical and physical concepts that students have learned before. The traditional teaching method is theoretical lecture using chalkboards, without practical problem analysis and exploration of physical models. Problem-based learning has been studied since 2005 by introducing practical engineering problems into engineering courses. The related research results show that compared with traditional teaching methods, students are more motivated to learn (Al-Sarawi, 2005). In addition, a study on the effect of design thinking on college students' learning motivation and learning effectiveness showed that after incorporating design thinking into an electrical engineering project course, students' motivation was significantly increased, and their interest in the course made it more practical-oriented, achieving an effective integration effect (Chang Chia-Ming, Tamkang University, 2020). Therefore, problem-based learning with design thinking can be used as a new innovative teaching model to enhance students' learning motivation and creativity thinking in the field of engineering science.

Research Methodology

The teaching method of this project's curriculum is mainly classroom lectures, supplemented by problem-based learning group discussions. During the course, two practical problems will be selected based on the course content: 1. "PBL Problem 1" for the design of a labor-saving device system, and 2. "PBL Problem 2" for the design of a frictional force system. Through problem-based learning discussions, students will be trained in the ability to apply principles of statics to solve and integrate engineering practical problems. This study will collect information and data on students' learning motivation and attitudes towards the course through a "Learning Motivation Scale." The learning motivation scale used in the project includes three main motivation components: value, expectation, and emotional value.

The scope of data collection required for this teaching practice research is one semester (2021-1 semester), with a teaching time of 18 weeks, including student background information and their level of prerequisite knowledge. The related learning outcome data includes test scores, participation in discussions, practical work scores, DTPBL report scores, as well as student feedback data. Statics is a basic theoretical course, and the course is conducted by the teacher organizing PPT based on the content of the textbook for classroom teaching. In addition to explaining the background of the course, the teacher must also explain the derivation of formulas. After students have a certain level of statics foundation, the DTPBL learning is conducted in the following course content, which is divided into two stages in the plan.

The first stage is conducted after teaching the principles of equilibrium of particle forces, and the topic is "design of labor-saving device systems". This problem is an open practical engineering problem in the field of particle force equilibrium, which is quite challenging for sophomore students. During the DTPBL process, the teacher guides the students to explore the problem-solving direction and clarify the concept content and formula application in practical engineering problems within the scope of this learning. Through this, students' abilities to apply their knowledge of dynamic fundamentals to practical engineering problem-solving and integration are cultivated. In addition, suggestions are provided on the group division method, and students conduct three weeks of group DTPBL discussions. In the learning sheet, students are required to collect data, discuss, propose solutions, and share their thoughts and feelings in groups according to the problem discussion framework. Each group of students can discuss and analyze the problem they choose, propose initial solutions, and leave many reflections and impressions after completion. The second stage of PBL learning takes place after teaching the principle of friction. The topic is "Design of Friction Systems". After three weeks of group discussions, students fill out DTPBL reports. At the end of the semester, each group is arranged to present their results, including design steps, how to choose the best design, how the selected design operates, design content, and conclusions. Students are also asked to conduct peer evaluations in their reports to understand the design strengths and weaknesses of each group.

Results and Discussion

1. DTPBL Feedback Form

In the first stage of problem-based learning exercises, only preliminary discussions and solutions were conducted. Students' views on problem-based learning were generally positive, with 22.06% considering it ordinary and 77.94% considering it helpful or very helpful. This was reflected in the qualitative data from the reflections and feedback in the DTPBL learning materials. After the midterm exam, when the course entered the topics of friction and rigid body mechanics, the second stage of DTPBL practical engineering problems was practiced. In addition to group discussions, each group was required to write a complete report and present it with a PPT at the end of the term, sharing their design results and accepting challenges and evaluations from their classmates. According to the questionnaire statistics, in the second stage of problem-based learning exercises, 7.34% of students considered it ordinary, while 92.66% considered it helpful or very helpful. The results showed that at this stage, due to a deeper understanding of problem-based learning, students' recognition and appreciation of its usefulness in their learning had significantly increased.

2. Learning motivation scale (pre-test, post-test)

To evaluate the effectiveness of the DTPBL project, a survey was conducted using the Learning Motivation Scale tool on the students. 64 pre-tests and 62 post-tests were collected. The following bar chart is a comprehensive result of a survey on the Learning Motivation Scale. The average scores for each question are shown in Figure 1. The average scores for the pre-test ranged from 2.90 to 4.15. The analysis is shown in Table 1. Figure 2 shows the average scores for the post-test, which ranged from 2.65 to 4.24. The analysis is shown in Table 2.

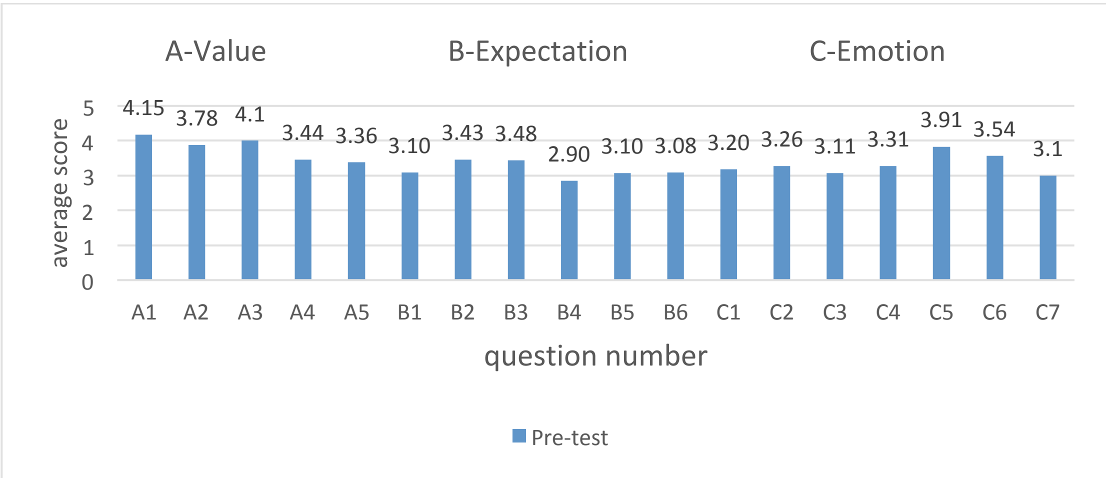

Figure 1. Average scores for each question in the pre-test questionnaire

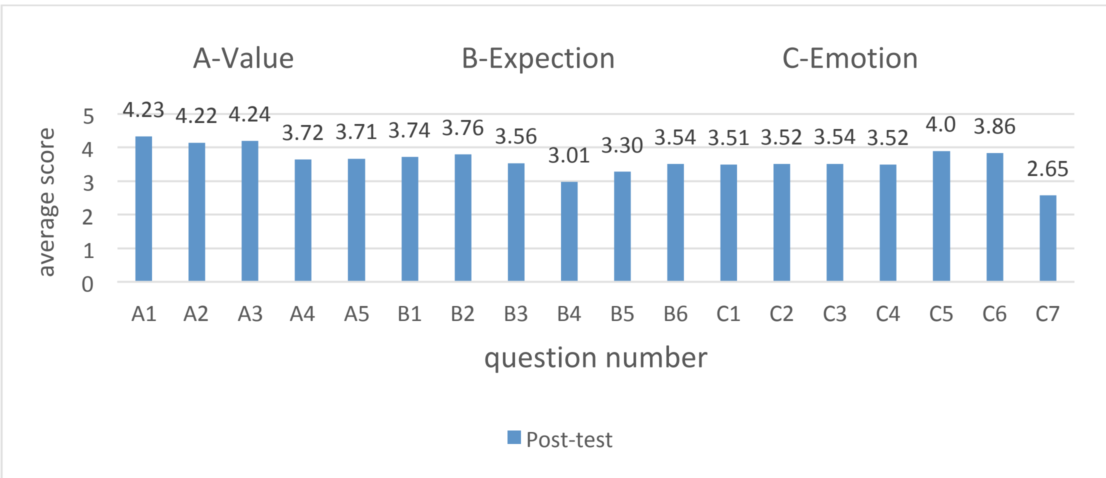

Figure 2. Average scores for each question in the post-test questionnaire

Table 1. Analysis of average scores for the pre-test questionnaire

<table>
<tr><td>Dimension</td><td>Average</td></tr>
<tr><td>Value(question A1~A5)</td><td>3.77</td></tr>
<tr><td>Expect(question B1~B6)</td><td>3.18</td></tr>
<tr><td>Emotion (question C1~C6)</td><td>3.39</td></tr>
<tr><td>Reverse questionC7</td><td>3.10</td></tr>
<tr><td colspan="2">analysis of high and low scoring questions</td></tr>
<tr><td colspan="2">high scoring questions：
Question A1: "I think that learning 'statics' is quite important for the subsequent study of mechanical engineering courses." Score: 4.15
Question B3: "I was able to solve the exercises on "Statics" textbook for problem on my own" Score: 3.48
Question C5: "In the 'statics' course, I care about whether or not I understand the content taught by the teacher." Score: 3.91</td></tr>
<tr><td colspan="2">low scoring questions：
Question A5: "I am very interested in the equilibrium of objects, and actively learn related knowledge in 'statics'." Score: 3.36
Question B4: "I am confident that I can understand the most difficult part of the 'statics' course." Score: 2.90
Question C3: "I am confident that I can achieve good grades in the 'statics' exam." Score: 3.11</td></tr>
<tr><td colspan="2">reverse-scored：</td></tr>
<tr><td colspan="2">Question C7: "I always feel anxious when I am taking the 'statics' course." Score: 3.10</td></tr>
</table>

Table 2. Analysis of average scores for the post-test questionnaire

<table>
<tr><td>Dimension</td><td>Average</td></tr>
<tr><td>Value(question A1~A5)</td><td>4.02</td></tr>
<tr><td>Expect(question B1~B6)</td><td>3.49</td></tr>
<tr><td>Emotion (question C1~C6)</td><td>3.66</td></tr>
<tr><td>Reverse questionC7</td><td>2.65</td></tr>
<tr><td colspan="2">analysis of high and low scoring questions</td></tr>
<tr><td colspan="2">high scoring questions：
Question A3: " I believe that the "Statics" course is important and quite useful for my future work. " Score:：4.24
Question B2: "I am confident that I can learn the basic theory taught in 'statics'." Score:3.76
Question C5: "In the 'statics' course, I care about whether or not I understand the content taught by the teacher." Score: 4.00</td></tr>
<tr><td colspan="2">low scoring questions：
Question A5: " I am interested in the phenomenon of object equilibrium and actively learning related knowledge on "statics". " Score:3.71
Question B4: "I am confident that I can understand the most difficult part of the 'statics'" Score:3.01
Question C1: "I always feel happy when I am taking the 'statics' course." Score: 3.51</td></tr>
<tr><td colspan="2">reverse-scored：</td></tr>
<tr><td colspan="2">Question C7: "I always feel anxious when I am taking the 'statics' course." Score:2.65</td></tr>
</table>

Then compare the changes in satisfaction with the pre-test and post-test, as shown in the radar chart in Figure 3. Overall, the post-test score has improved compared to the pre-test.

Evaluation of value: the average of questions A1~A5 is 3.77 to 4.02, slightly improved; evaluation of expectations: the average of questions B1~B6 is 3.18 to 3.49, slightly improved; evaluation of emotion: question The average of C1~C6 is 3.39 to 3.66, a slight increase; on the reverse question: question C7 dropped from 3.10 to 2.65. Finally, according to the pre-test and post-test learning motivation scale survey, after the introduction of DTPBL, the impact on students' learning can be obtained as follows:

1. Students agree that statics is an interesting course significantly improved.
2. Significant improvement in students' acceptance of statics as a useful and practical course.
3. Students' confidence in studying the statics course has improved significantly.
4. Students are more confident in learning the difficult content of statics.
5. Students can experience the fun of learning more in the course of statics.
6. Students are more focused on their studies in statics courses.
7. Students feel less anxious in the statics course.

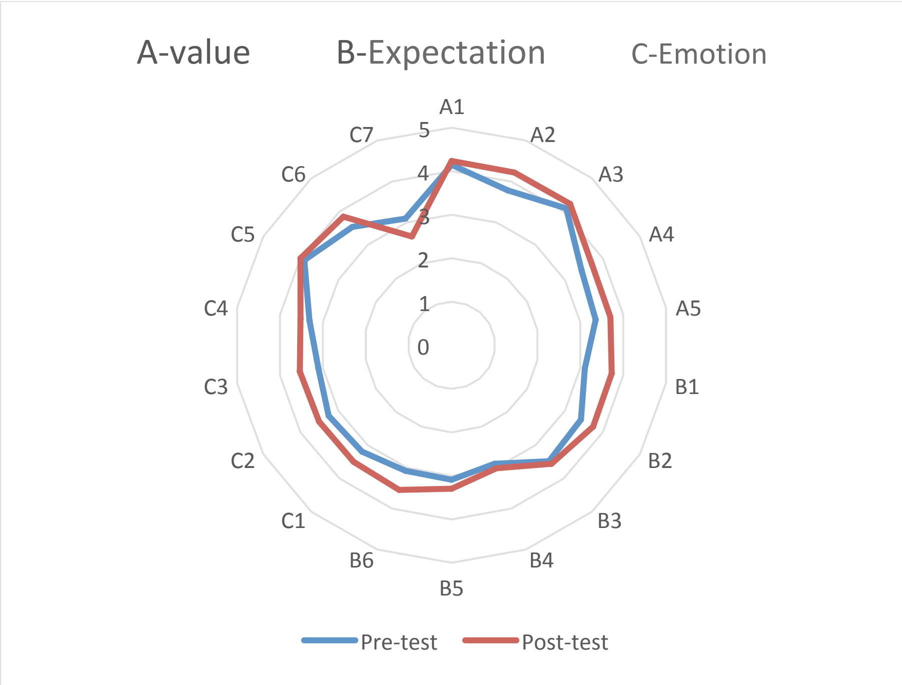

Figure 3. Radar chart comparing pre-test and post-test

In terms of learning outcomes, the average grade for the 2021-2 semester (the semester in which the project was implemented) was 73.95. The highest score was 93, the lowest was 50, and there were 2 failures. The average grade for the 2022-2 semester was 73.39. The highest score was 95, the lowest was 50, and there were 5 failures. The average grade during the semester of project implementation increased by 0.76% (Figure 4), and the number of failures decreased to 3. The grade distribution for the two semesters is shown in Figure 5. There are many factors that affect the average grades of a semester, and due to the implementation of innovative teaching methods, the calculation of grades is different, making it difficult to compare directly. However, from the qualitative feedback, it is clear that there has been a change in students' learning attitudes. This can also be seen from the survey on the motivation scale for learning, where significant results are evident in terms of values, expectations, and emotions.

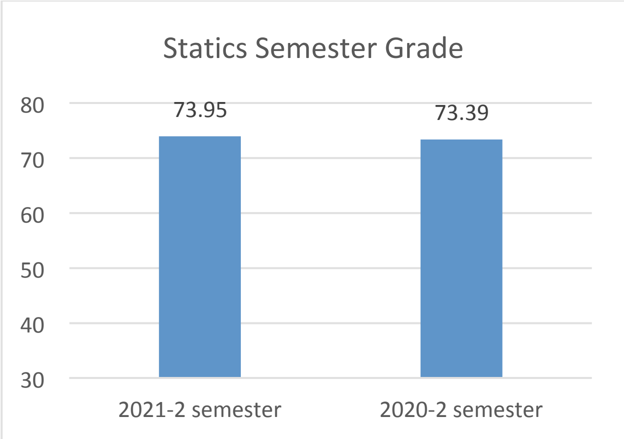

Figure 4. Statics Semester Grade

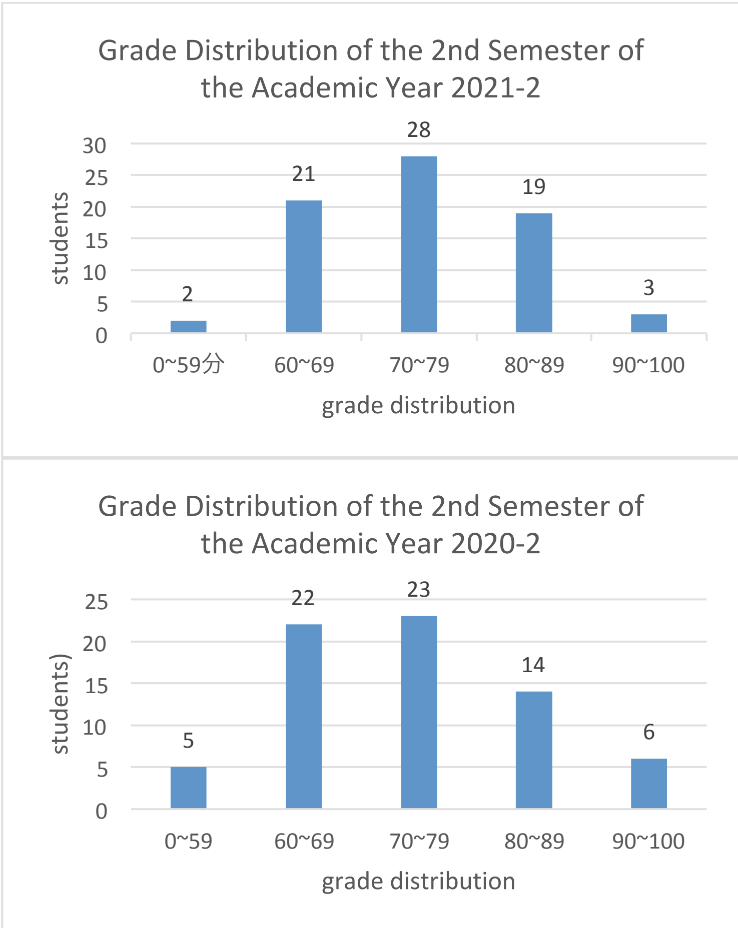

Figure 5. Histogram of Statics Semester Grade Distribution (The Academic Year 2020, 2021)

Conclusions

The results of this study indicate that the introduction of DTPBL in the statics course has led to enhanced student motivation for active learning. Students were able to actively seek out practical issues related to statics and improve their problem-solving skills, while also increasing interaction between students and teachers. The use of DTPBL also had a positive impact on student motivation in terms of value, expectation, and emotion. However, some students still found it difficult to participate in group discussions, possibly due to their long-standing habit of passive learning. Overall, students' efforts to adapt to the new teaching method under the guidance of the teacher were apparent from their qualitative feedback. Due to time, budget, and equipment constraints, PBL project design could only be presented in written form and simulation. It may be possible to improve this in the future through the use of materials such as paper clay models or 3D printing. The results of this study demonstrate that the appropriate introduction of DTPBL in traditional courses can be an effective way to improve teaching and should be promoted and applied to related engineering courses.

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