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Impact of interventions on students' conceptual understanding of dynamics principles and self-efficacy

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Impact of reflective learning practices on students' learning of engineering dynamics

Introduction

Engineering is known as a challenging major that many students withdraw because of low academic achievement [1]. Component Display Theory defines learning in two dimensions: content and performance [2-4]. Content includes accepting facts, concepts, procedures, and principles; while performance refers to three phases of learning including remember, application, and generalities. Higher levels in both dimensions suggest a higher understanding degree an individual gains. However, students' feedback and assessment results suggest that application of the principles is a bottleneck to many students' learning experience in fundamental engineering courses.

While engineering design has been widely used to improve students' skills in applications, students have limited opportunities to learn from projects in fundamental engineering courses due to broad spectrum of content, strict schedule, relatively large enrollment, limited budget, and students' design skills. This study selected engineering dynamics course as an example to improve students' capability in applying the principles in dynamics into problem solving through reflective learning practices.

Engineering dynamics is a high-enrollment engineering core course; while one of the most difficult courses to teach and learn in engineering [5]. Dynamics is a challenging course because it not only requires a certain level of mathematics skills, but also covers a broad spectrum of concepts and principles [6-7]. For example, students need to learn through kinematics and kinetics principles of Force and Acceleration, Work and Energy and Impulse and Momentum for particles and rigid bodies within 15 weeks of time frame. Many students indicated that they "remembered" and "understood" the principles learned in Dynamics; however, they had difficulties in applying the learned principles into problem solving.

Reflective learning is defined as the "cycle of inquiry for the purpose of making meaning or finding solutions for a troubling situation or question" [8]. It enhances a person's understanding by identifying the cognitive schema, strengthening reasoning, and promoting knowledge transfer [9-11]. In the present study, reflective learning refers to students' cognitive activities through the practice in and after the dynamics class. For example, reflective learning practices can help a student to contextualize principles in engineering dynamics and make meaningful connections among the principles and problems. It also promotes the knowledge transfer from surface to deeper construct.

The objective of the present study is to investigate the impact of reflective learning practice on students' learning of dynamics. The present study addresses the following research question:

> To what extent can reflective learning improve students' learning of engineering dynamics?

Research Method

Two groups of students in engineering dynamics courses participated in the present study. The students enrolled in an engineering dynamics course at a 4-year university in the State of Georgia were the control group and the students in State of South Dakota were in the experimental group. The following paragraphs describe the research method step by step.

Step1: Collected baseline data from the two groups through a 30-minute pre-test. The pre-test includes 11 multiple-choice questions and 4 open-ended questions that align to ABET's requirements on mathematical application, problem identification, interpretation, and formulation.

Step 2: Calculated the grades of students in the experimental group in each category listed in Step 1 in the pre-test.

Step 3: Besides homework, ten practice questions covering key knowledge in the present chapter and previous chapters were selected at the end of each chapter. Students in the experimental group worked on the practice questions after/in class with emphases on problem analysis and identification. In the present study, reflective learning is achieved through the following steps during the practices after/in class. Students in the experimental group

1) summarized the theories/principles they had learned in the dynamics course (noticing),
2) describe the patterns and/or features of the theories/principles (making sense),
3) identified the situations that confirmed or contradicted with the pre-assumptions (making sense),
4) applied proper theories/principles to solve problems (working-with-meaning),
5) analyzed advantages and disadvantages of a potential solution with peers (working-with-meaning), and
6) explored and analyzed other options to solve specific types of problems with peers (transformative learning) [12].

Students in the control group received regular lectures and homework assignments but no team practices.

Step 4: Collected post treatment data from both experimental and control groups. The post-test consists of the same questions as the pre-test. The pre- and post-tests were valid because of following reasons:

1) The questions were designed closely with the guidance of ABET requirements and the textbook of Engineering Mechanics Dynamics [7].
2) No test questions were released to the students after the pre-test.
3) No feedback on the pre-test questions/solutions was provided before the post-test.
4) The time interval between the pre- and post-test was 4 months.

Data Collection

Data on students' pre- and post-tests were collected from a total of 57 undergraduate students in dynamics courses at two universities in Georgia (GA) and South Dakota (SD) respectively. Table

1 shows student demographics. As seen from Table 1, the majority of the 57 students were males (87.7%), and the female students accounted for 12.3%.

Table 1. Student demographics

	Gender		Major*		Grade**		
	Male	Female	ME	CEE	SO	JR	SR
Experimental Group	23	1	23	1	10	11	3
Control Group	27	6	22	11	10	19	4
Total	50	7	45	12	20	30	7

*ME: Mechanical engineering; CEE: Civil and environmental engineering
**SO: Sophomore; JR: Junior; SR: Senior

In response to the ABET criteria, the practice activity was designed with 3 problem identification questions, 4 problem interpretation questions, 5 problem formulation questions, and 3 mathematical application questions. Table 2 shows the distribution of questions in the pre- and post-tests in the four categories as described above. Students' responses to the pre- and post-tests were graded with the same weight for the 15 questions. For example, a student can gain 1 point for answering one question completely correctly or 0 point for incorrect answer.

Table 2. Distribution of the questions in the four categories

Category	Question Number
Problem identification	6, 8, & 9
Problem interpretation	1, 3, 5, & 11
Problem formulation	2, 4, 7, 10, & 12
Mathematical application	13, 14, & 15

Results

Figure 1 a-b show the results of comparing students' achievement in the pre-test in the control and experimental groups. To compare the performance of the students in the two groups, the following criterion is defined in this study:

Percentage of correct response (PCR) = (The number of students who selected the correct answer to a question/ Total number of students in the group) × 100%

For example, if 15 out of 30 students answered question A correctly in the pre-test while 20 in the post-test, the PCR of question A in the pre-test is 50%, PCR in the post-test is 67%. The PCR increases by 17%.

Data indicate that, on average, students in the experimental group were at similar or lower cognition levels than those in the control group at the beginning of dynamics course in terms of problem identification, problem interpretation, problem formulation, and mathematical application. The PCRs are lower than 50% for 7 (out of 15) questions in the control group, while for 9 in the experimental group.

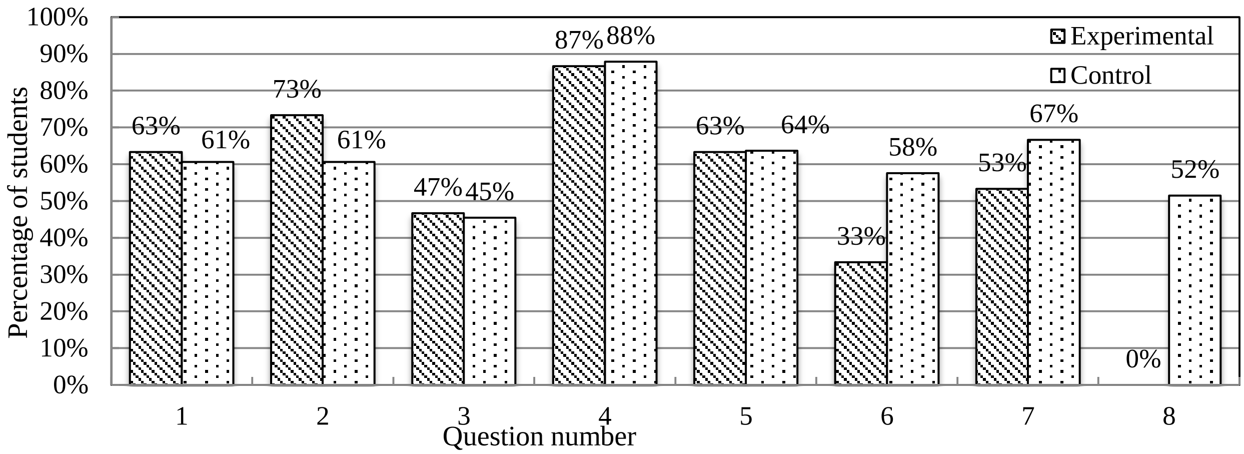

Figure 1 a. PCRs of questions 1-8 in pre-test

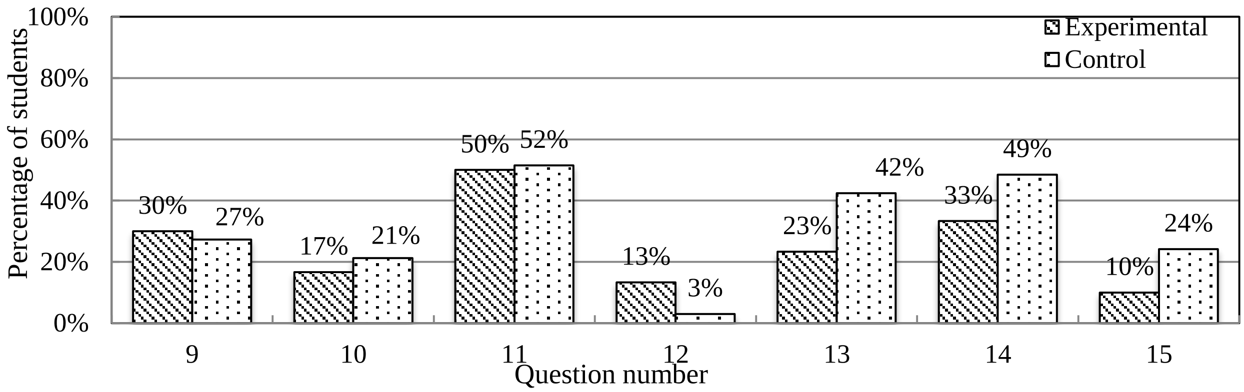

Figure 1 b. PCRs of questions 9-15 in pre-test

Figure 2 a-b show students' performance in the post-test. Table 3 demonstrates average PCRs of the two groups in the pre-and post-tests.

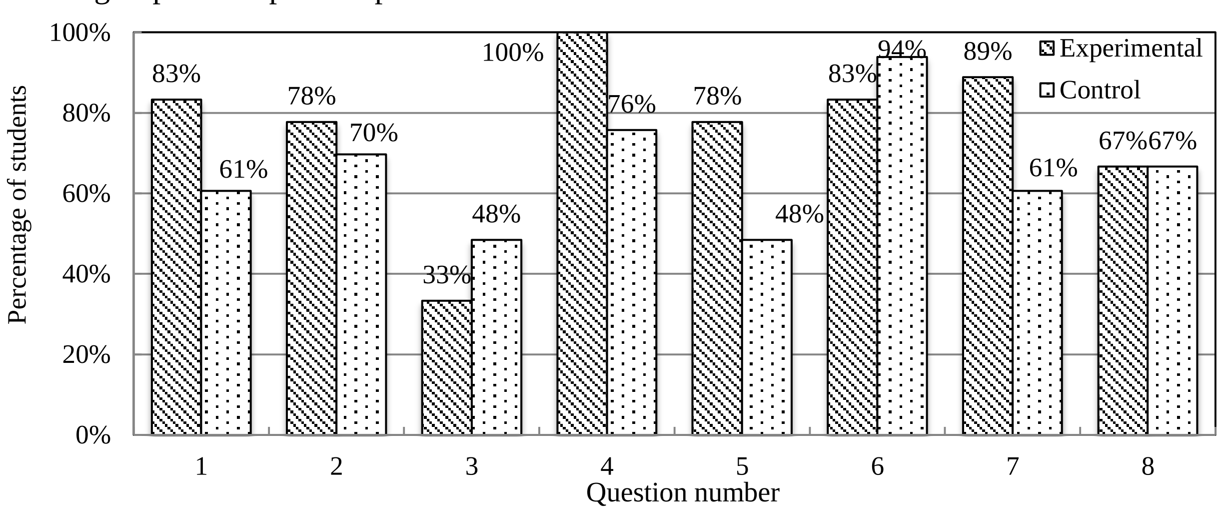

Figure 2 a. Percentage of correct responses to questions 1-8 in post-test

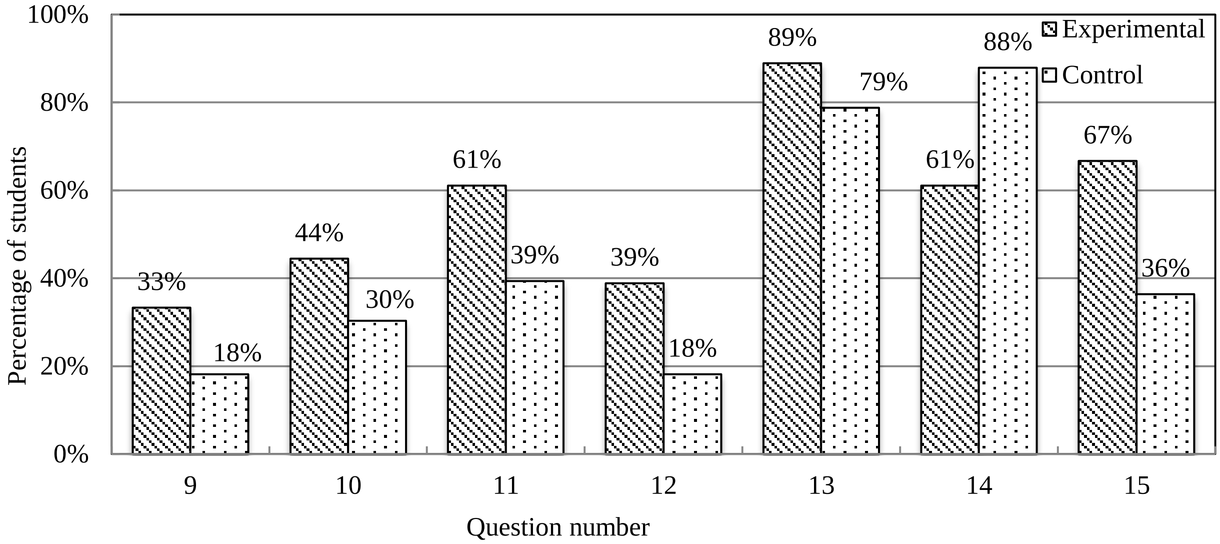

Figure 2 b. Percentage of correct responses to questions 9-15 in post-test

Table 3. Average PCRs of the four question categories

Category	Experimental Group		Control Group	
	Pre	Post	Pre	Post
Problem identification	21.0%	61.0%	45.7%	59.7%
Problem interpretation	48.3%	63.8%	55.5%	49.0%
Problem formulation	48.6%	70.0%	48.0%	51.0%
Mathematical application	22.0%	72.3%	38.3%	67.7%

Control group: The PCRs of 9 (out of 15) questions increase at the end of the semester. The nine questions include 3 questions focused on mathematical application, 2 on problem identification, 1 on interpretation, and 3 on problem formulation. The increases of PCRs range from 3% to 39% with the highest increase in mathematical application and the lowest one in problem interpretation. The PCRs decrease for 5 questions in the post-test, including 1 question on problem identification, 2 on problem interpretation, and 2 on problem formulation. Furthermore, students in the control group had lower average PCRs in Problem interpretation (Table 3).

Experimental group: Similar or higher PCRs are found in most questions questions in the post-test, except for question 3 (Problem interpretation), 6 (Problem identification), and 14 (Mathematical application). The increases of PCRs range from 3% to 67%. Compared with the control group, the experimental group has gained larger increases in PCRs for 12 (out of 15) questions. Students gained significant increases in all of the four question categories in terms of average PCRs (Table 3).

Discussions and future study

This pilot study investigated impact of reflective learning on students' learning of engineering dynamics. On average, the experimental group performed better than the control group after the reflective learning practices in terms of problem identification, problem interpretation, problem formulation, and mathematical application. Particularly, the results indicate promising effectiveness of the proposed reflective learning practices on improving students' skills in problem identification and problem interpretation.

Semi-structured interviews will be designed for the experimental group students to collect qualitative data to investigate how interactive learning practices help improve their understandings of dynamics. The relationships among engineering self-efficacy, student reflection's degree, and their academic performance in dynamics will also be assessed. A longitudinal study assessing these students' knowledge retention in engineering dynamics should be conducted. This pilot study assumed environmental and instructor factors were all controlled.

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