Investigating the Impact on Students' Engagement, Perception, and Success of Several Active Learning Strategies for a Large Gateway Engineering Course: Static.

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Abstract

Teaching and learning engineering is a difficult task, especially for large gateway courses such as Engineering Analysis: Statics. Statics is the first engineering class where the students go one step beyond memorizing concepts and procedures. They have to apply them, make connections, and start closing the gap between purely theoretical knowledge and engineering application of those concepts. This transition has proven to be difficult for the students as reflected in the very high Fail/Pass ratio for this class in most universities and colleges. Engineering education researchers are increasingly emphasizing the need of incorporating high impact learning practices (HIP) to help students succeed. This paper describes several active learning strategies and HIPs used for improving the success and engagement in Statics: Socratic discussions, debates, guided inquiry, polls, small groups, collaborative assignments, project based homework, and a semester long experiential learning project among others. Analysis of the data regarding students' success and Student Perception of Instruction surveys are presented and discussed.

Keywords

Active Learning, Experiential Learning, Statics, Project Based Homework.

Introduction

Education research has shown that students' motivation to learn, retention, and graduation increase when they are involved in meaningful and relevant learning experiences[1,2]. Hands-on learning via physical models and manipulatives has been documented to help in closing students' gap between theory, previous knowledge, and real life situations as they develop team work as well as other spatial and motor skills [2-8]. Engineering education shows that purely traditional lecture-based learning environment does not adequately prepare students to succeed in the collaborative and challenging engineering careers. A meta-analysis of 225 studies comparing active learning with traditional lecture concluded that the positive impacts of active learning over lecture are well established [9].

The purpose of this research was to investigate the effect of introducing several active learning strategies in a large-size engineering class regarding students' success, engagement, and students' perception of instruction (SPI). Engineering Analysis: Statics was selected for this study for several reasons. In the University of Central Florida (UCF), Statics is a large size (150-250 students per section) gateway engineering course. Approximately 1,700 students take this class every year and between 40% and 60% of them fail (grade WDF) in their first attempt. (An active learning approach improves student performance and retention in STEM. Students exposed to active learning are more engaged, remember more, and apply knowledge better 10. As stated before, long traditional lectures, assigned textbook homework problems, and tests may not be the most effective way to convey information, develop knowledge, and assess the students. In addition, solutions for the textbook assigned homework problems are easy to find in solutions manuals and commercial homework sites on the internet. An active learning approach improves student performance and retention in STEM. Students exposed to active learning are more engaged, remember more, and apply knowledge better [10].

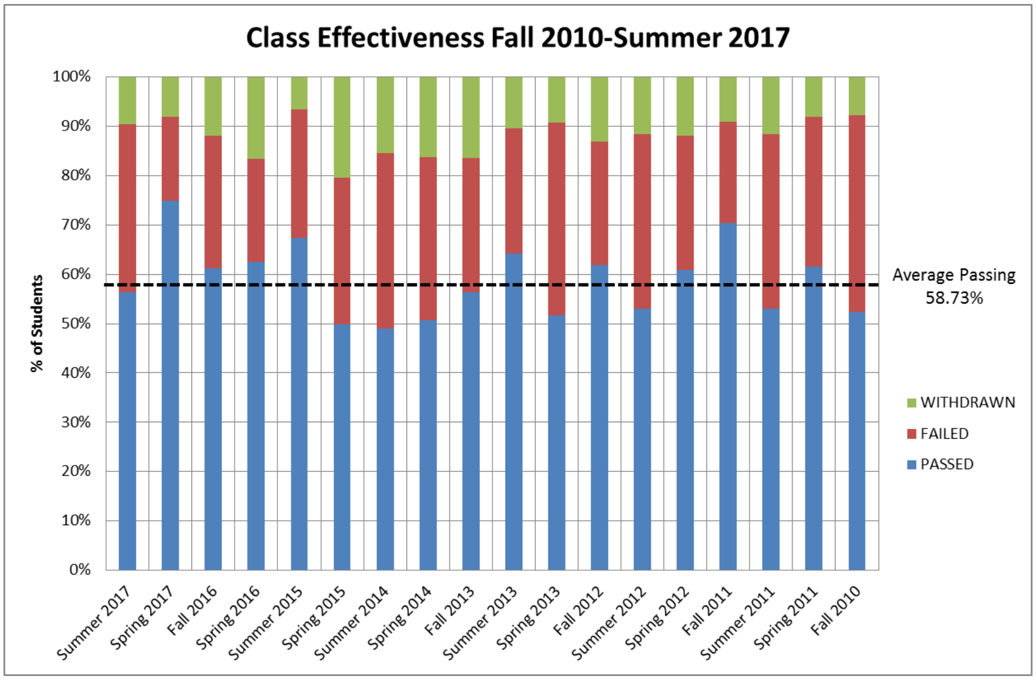

Figure 1. Class Effectiveness from Fall 2010 to Summer 2017 (Adapted from [2])

Methodology

Based on previous studies and personal classroom experiences, several active strategies were incorporated in the Statics course. In following subsections those activities and some results regarding students' success and are discussed.

Socratic Lecturing and Class Discussions

During every class meeting, questions are presented to the students (Figure 2a). After showing and reading the question(s), the professor asks students to vote by lifting their hands. After the first round of voting, students are asked to convene in groups of two or three students to discuss each option for 1-2 minutes and vote again. Usually, the amount of answers per option changes. Finally, students are asked to defend their final choice by stating why they think theirs is the correct one and why the others' are incorrect. The facilitator wraps up the discussion by clarifying any possible doubt. The main objective of this non-graded activity is to increase class engagement and participation as well as debating important class concepts. Figure 2 shows the students' survey results regarding class engagement/participation (Figure 2b) and understanding of the concepts (Figure 2c).

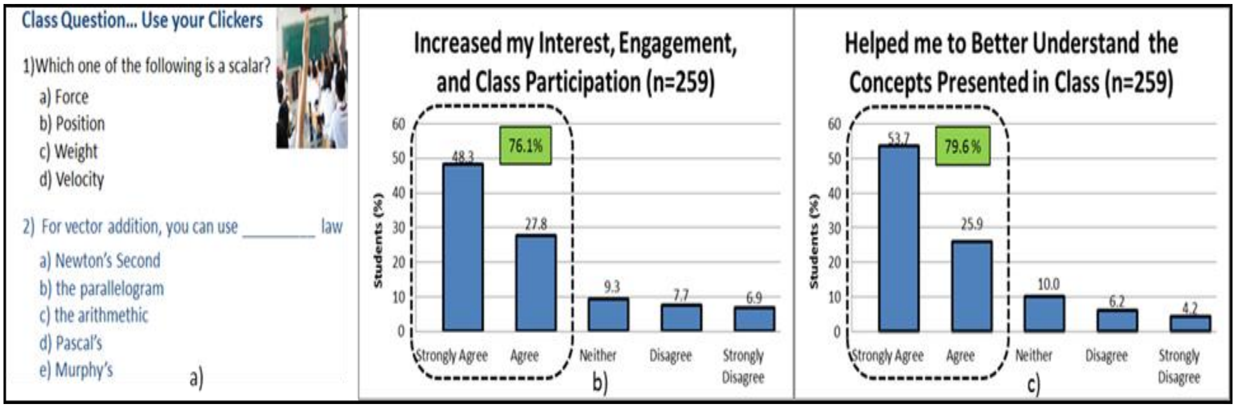

Figure 2. Socratic Lecturing and Class Discussions

Open ended questions and Brainstorming

This is another example of non-graded activity destined to increase engagement and spark curiosity/interest about future courses. Despite appearing similar to Class Discussions open ended questions involve high order critical thinking beyond the class' scope. Figure 3 a) refers to a typical example of vector addition: calculating the force in the bracket. However, the following part "Which component of the assembly is the most important?" elicits a very engaging class discussion allowing the students to learn about connectors, bolts, adherence between concrete and steel bracket (relating it to the previously learned "friction force" from physics), concrete and soil properties, and factors of safety. Figure 3 b) and 3 c) show students' opinions.

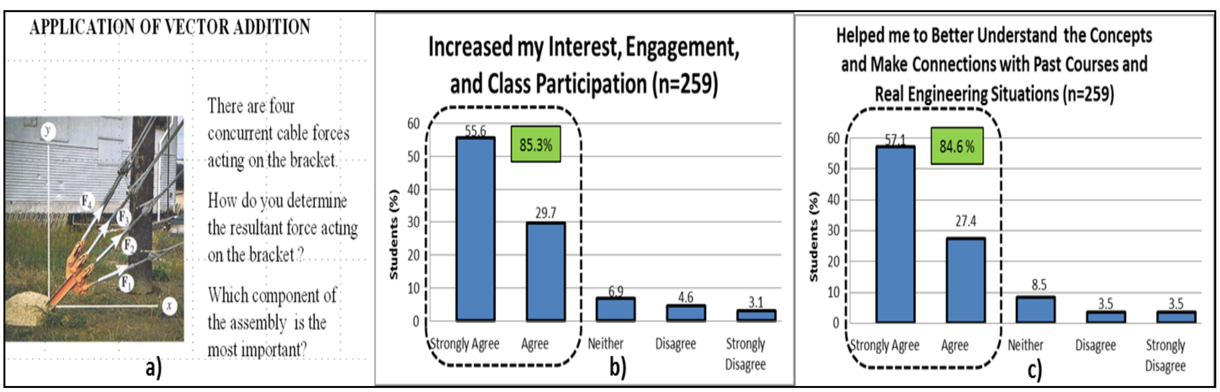

Figure 3. Open Ended Questions

Graded unannounced group class activities (group quizzes)

Could happen in any lecture, usually takes around 15 minutes, and is completed in pairs (Figure 4 a) and 4 b). This activity promotes a high class attendance as students need to be present for not losing the points. Students must come prepared to every class, be focused, and ask questions since they need to understand the concepts to be successful if the activity happens. Figure 5 shows students opinions regarding the effect of this activity in preparedness (Figure 5a), engagement/participation (Figure 5b), and understanding the concepts(Figure 5c). If the instructor deems it necessary, students are asked to create a physical model of the problem and compare with their analytical results (Figure 4c)

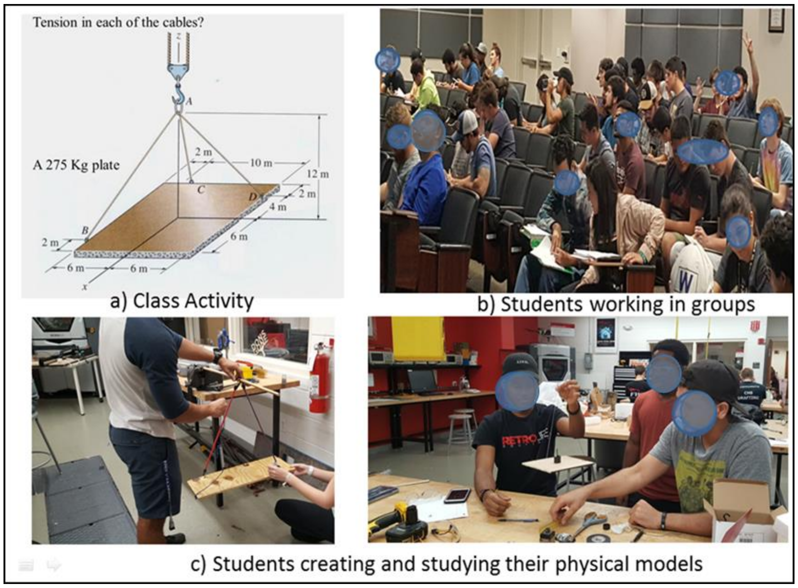

Figure 4. Unannounced group class activity

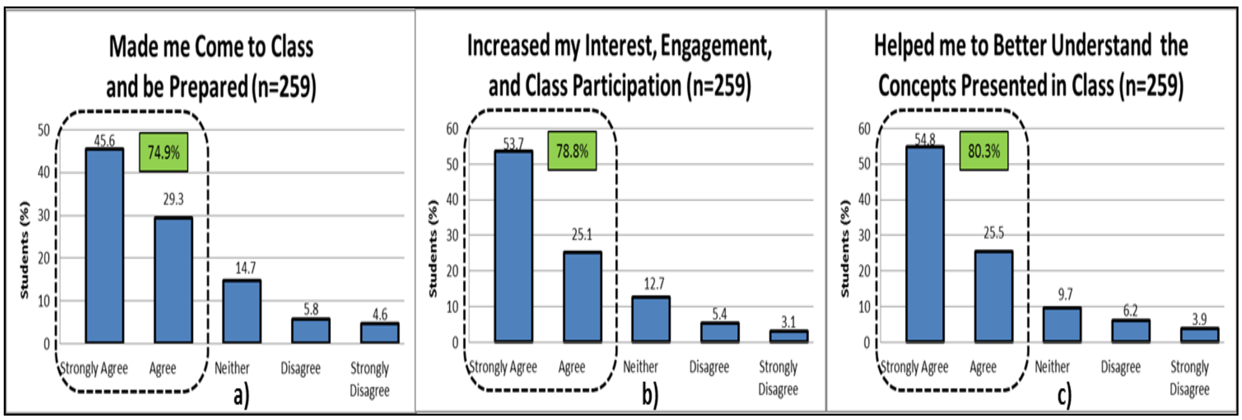

Figure 5. Students' Opinions about Unannounced Class Activities

Collaborative Project Based Homework (PBH)

This is a HIP active learning strategy used and researched by the author for several years. Full analysis, data, demographics, implementation, and results will be presented during the 126th annual ASEE conference. In this paper, a brief description, one example, results, and SPI's are shown. The mid-term results corresponding to the different topics of the class were summarized for several semesters with the intention of identifying the most challenging concepts for the students. Initially conceived as an extra-credit, the students were given the opportunity of working in pairs to create a physical model that reproduced one problem (selected by the instructor to match the previously identified critical topics) from their regular online/traditional homework (Figure 6a).Then, a comparison of their hand calculation results and the experimental measurements must be prepared and explained in a 5 minutes video (Figure 6b). Results of the mid-term exam question related to this topic showed that students participants performed between 60% and 84% better that those students that only turned in the traditional homework (Figure 7a). In addition, students reported their engagement in the class increased (Figure 7b) and they understood better the concepts (Figure 7c).

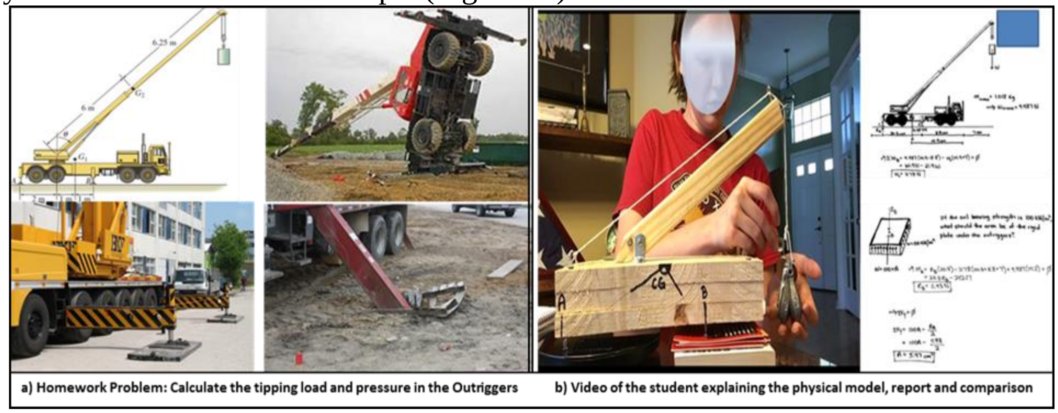
a) Homework Problem: Calculate the tipping load and pressure in the Outriggers
b) Video of the student explaining the physical model, report and comparison

Figure 6. Example of Collaborative PBH

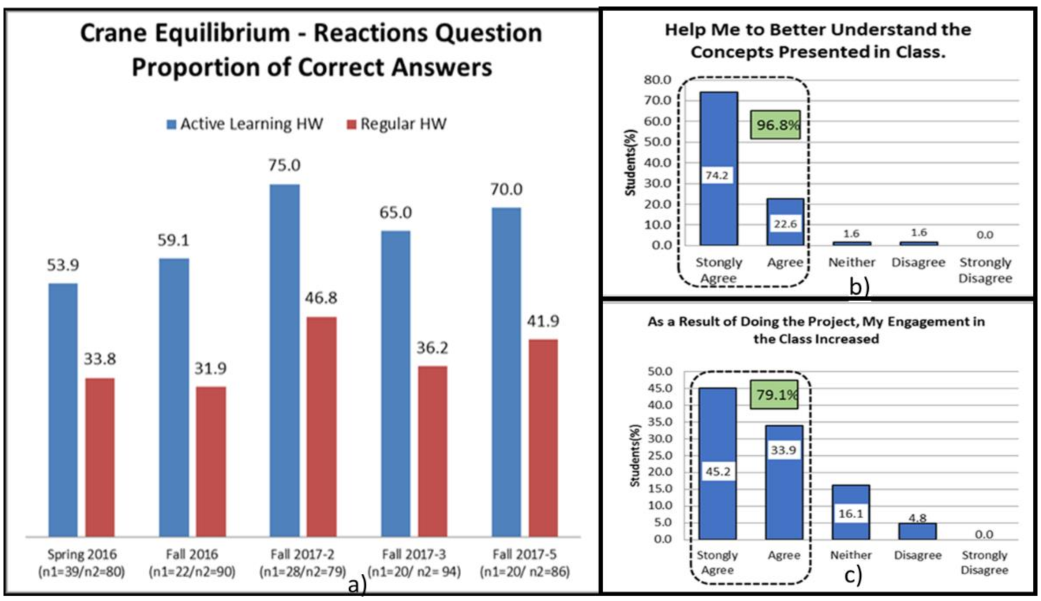

Figure 7. Comparative results of the incidence of PBH

Semester Long Experiential Learning Project (IDEAS Showcase)

The Interdisciplinary Display for Engineering Analysis Statics (IDEAS) was developed and organized with the objective of promoting creativity, team-work, and presentation skills for undergraduate sophomore and junior students, as well as exposing them to the fascinating world of scientific/technological research based engineering. A comprehensive description IDEAS and results corresponding to students' success, retention, graduation rates, and students' perception of instruction was presented in [2] during the 125th ASEE Annual Conference. For IDEAS, the students are asked to form groups and work on a final project. They select a topic, preferably related to their majors, and conduct research involving some of the concepts learned in Statics. The projects involve creation of physical models, designing experiments, testing, measurements, and comparison of the experimental data with the theoretical calculations. Also, the students write papers and prepare posters, which are presented on the day of the showcase. Professors and graduate students judge these projects. First places are awarded with medals and every student receives a certificate of participation upon completion and presentation of their projects (Figure *8*). Online copies of the proceedings with all the abstracts are made available to the community. Around 2800 students have participated and defended their findings in front of judges, producing more than 850 models, projects, papers, and posters.

Figure 8. One of the IDEAS Showcases

The percentages of IDEAS students successfully completing Statics and advancing to other courses was substantially higher than the non-participants (between 44% and 81% higher for the participants). The retention in the college for the participants was also significantly higher (ranging from ~11 and ~13 percent points greater for the participants). The overall graduation rate reached up to 13 percent points higher for the participants[2].

Discussion of the results.

This paper presented several active learning strategies and their effect regarding students' success, class engagement, and students' perception of instruction. A sample of 259 students expressed their perception about Socratic Lectures and Class Discussions: 76.1% of the sample said these activities increased their interest, engagement, and class participation; 79.6% expressed that this type of discussions helped them to better understand the concepts. For "Open ended questions and Brainstorming": 85.3% of the same sample agreed in the benefits regarding engagement and class participation while 84.6% expressed they were able to make better connections with previous courses' knowledge and with real life engineering situations. Regarding "Graded unannounced group class activities (group quizzes)": 74.9% of the students expressed that because the activities were "unannounced" they had to come to class and be prepared, 78.8% said their engagement and participation increased, and 80.3% agreed on their understanding of the concepts was better because of it. An example of "Collaborative Project Based Homework" was presented. For this, a sample of 558 students spanning 3 semesters was studied. Out of the 558 students, 129 decided to participate. During the mid-term examination, one question was prepared to evaluate the mastering of the concepts related with this topic. Results showed that PBH participants performed between 60% and 84% better than the non-participants. In addition, 96.8% said this activity helped them to better understand the concepts and 79.1% thought their class engagement increased. The last of the discussed active learning strategies was a "Semester Long Experiential Learning Project (IDEAS Showcase)" results from this project showed that the percentage of success was between 44% and 81% higher for IDEAS students with a bigger retention within the college (~11 and 13 percent points higher) and a higher graduation rate (around 13 points higher for the participants).

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