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Experiences with Inquiry-Based Learning in an Introductory Mechanics Course

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Abstract

Inquiry-based learning is an educational approach that allows the student to take ownership over the education process by self-identifying a problem and formulating their own solution. The application of this method of teaching was explored in an introductory mechanics course taken by both engineering and engineering technology students. Students were tasked with applying the principles of fundamental static equilibrium analysis to objects found in their normal surroundings. The deliverable for this assignment consisted of a photograph of an object they found to be in static equilibrium and a short description of how the state of the object could be described mathematically. Student submissions for this task exhibited a wide range of quality and imagination. Examples of student work are presented along with discussion of lessons learned and recommendations for the use of this method in the future. The overall student response to this task was positive and thus these efforts will be expanded.

Introduction

Inquiry-based learning is an educational approach that has received widespread support in the engineering education community and has a strong foundation within the cognitive neuroscience literature[1]. At its core, this method of learning (or teaching) attempts to allow the student to identify a problem or question and formulate their own solution. It has been shown that this process leads to greater concept retention and ultimately better performance on assessments.

Additionally, it has been demonstrated that students perform better on assessments when using an inquiry based or active learning method during preparation[2,3]. The application of this method can take many forms as, in general, inquiry-based learning shares several common features with other active learning educational approaches such as project based learning[4]. The literature suggests that through these methods students engage higher-order thinking tasks which in turn promote stronger development of necessary problem solving skills[5]. Students who learn by these methods have been found to have better overall achievement as well as improved critical thinking skills[4]. These skills thus better prepare the student for life-long learning when compared against a traditional lecture-only approach. By asking students to complete an assignment where they had to identify a system or object in static equilibrium, it was intended for the student to begin to look beyond their textbook and relate the course material with their surroundings. Similar work by others has demonstrated success in getting students to make the connection between the classroom and the "real world"[6]. The initial pilot study presented here was conducted in order to gage the base level of student participation in order to better inform and help shape the direction for the use of these methods in the future.

Methods

The application of this method of teaching was explored in an introductory mechanics course taken by students from both an engineering program and an engineering technology program. As this course is generally taken early in a student's undergraduate program, they often experience difficulty grasping the concepts presented and connecting them with real world experiences. To help promote a deeper understanding of these concepts, students were tasked with taking a look at their surroundings while considering the fundamentals of static equilibrium. The deliverable for this assignment consisted of a photograph of an object they found to be in static equilibrium and a short description of how the state of the object could be described mathematically. While the assignment did contribute to the student's course grade, it carried little weight and thus students had only minor grade-based incentive to do more than the minimum requested. In this way it is possible to establish a baseline level of student participation in the task.

This assignment was scheduled immediately after course lecture content covering the topics of static equilibrium, free body diagrams, particles and rigid bodies, and 2D/3D analysis of particles and rigid bodies in equilibrium. The task description provided to the students was kept intentionally brief, as shown in Textbox 1. The goal was to provide students with a set of instructions that were open to interpretation. In this way, it becomes possible to qualitatively establish a baseline for how students would approach this sort of task. By assigning the task in this manner, it was expected that there would be a wide variety in the quality and completeness of student submissions.

> Find an example of an object that demonstrates particle or rigid body equilibrium around campus. Capture a photograph of it. Write a one paragraph explanation of the photograph that includes at least an explanation of how many forces are acting on the object, whether you would need to perform 2D or 3D analysis of the object, and where you took the photograph.

Textbox 1. Text of the task description provided to students.

Student Submissions

A total of 78 student submissions were gathered over two semesters of the introductory mechanics course. As expected, the submissions for this task gathered from the students exhibited a wide range in terms of quality and imagination. A high-level analysis of the submissions revealed that the majority, 77%, of students selected structures for which analysis could be conducted in two dimensions. Further, systems consisting of simple loading scenarios such as gravity and a single reaction load were common. Students seemed to actively seek out the simplest possible structures they could find. An example photograph from a student submission is shown in Figure 1. This example consists of a light pole with an attached banner. This particular structure was popular among the students most likely due to its relative simplicity and the frequency with which it appears on campus. While the basic structure shown in this example allows for significant simplification of the underlying mechanics, it was noted that several students wrote about the various loading scenarios that could arise even for this simple structure, such as wind loading or alternative types of connections that might be used. This suggests that students were thinking about the problem in ways that may not be immediately captured by a photograph of the structure alone.

Figure 1. Sample photograph of a student submission comprised of a simple structure.

While the majority of students selected simple structures, approximately 23% of students submitted photographs of structures which would require three-dimensional analysis to be adequately described. An example of such a submission is shown in Figure 2, which consists of a sculpture found on campus. The geometry of this structure suggests that the use of three-dimensional analysis would be necessary to completely describe the mechanics present. For submissions of this level, the student descriptions tended to be more thoughtful and complete. By assessing each student submission with a quality score on a basis of accuracy of information conveyed and on a point scale ranging from 1 to 4 with 4 being high-quality, it was found that 52% of two-dimensional submissions achieved a score of 3 or 4, while 89% of three-dimensional submissions scored a 3 or 4 as shown in Figure 3. This indicates that the students who decided to tackle a more difficult problem tended to have a better grasp on the course content and were able to more clearly present this understanding through the assigned task.

Several students also demonstrated the iniative to take the assignment a step further by constructing an example of a system under static equilibrium out of the materials around them. The student's analysis is included in Textbox 2 which was used to described the submission shown in Figure 4.

Figure 2. Sample photograph of a student submission showing a more complicated 3D structure.

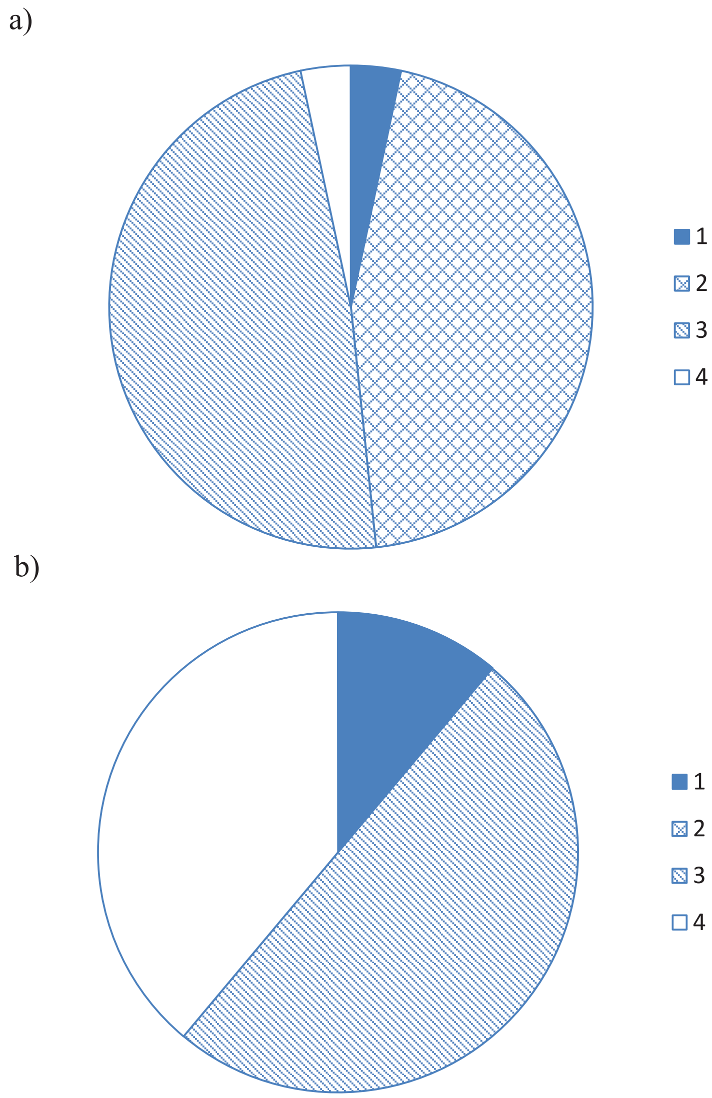

Figure 3. Assessment of student submission quality on a 1 to 4 point scale with 4 being high-quality and 1 being low-quality for (a) two-dimensional submissions and (b) three-dimensional submissions.

I determined that the center of mass of the book was hanging over the edge of the desk, and because gravity is creating a downward force the book should tilt and fall. There is also a moment balance, at the point where the edge of the desk and book meet. The moment is the force being applied in the downward direction (weight of the book) multiplied by the distance it is from the focal point. There was a second force that provided enough force to keep the body in equilibrium. This second force was the jar of pencils. The jar had a downward force on the book, however, had enough force to in the negative direction overcome the reaction on the book to keep it from tilting and falling. It was sufficient enough to analyze this object in 2D.

Textbox 2. Example of student description of system in static equilibrium.

Finally, it was found that several student submissions contained additional analysis beyond what was requested, typically in the form of a free body diagram or force vectors to enhance their presentation. An example of this is shown in Figure 5. Here again the student constructed a situation using available materials. Their photograph was accompanied by their interpretation of the situation in free body diagram form. While their interpretation may not necessarily be complete, it is useful to have a visual representation of their interpretation of the conditions present in the problem.

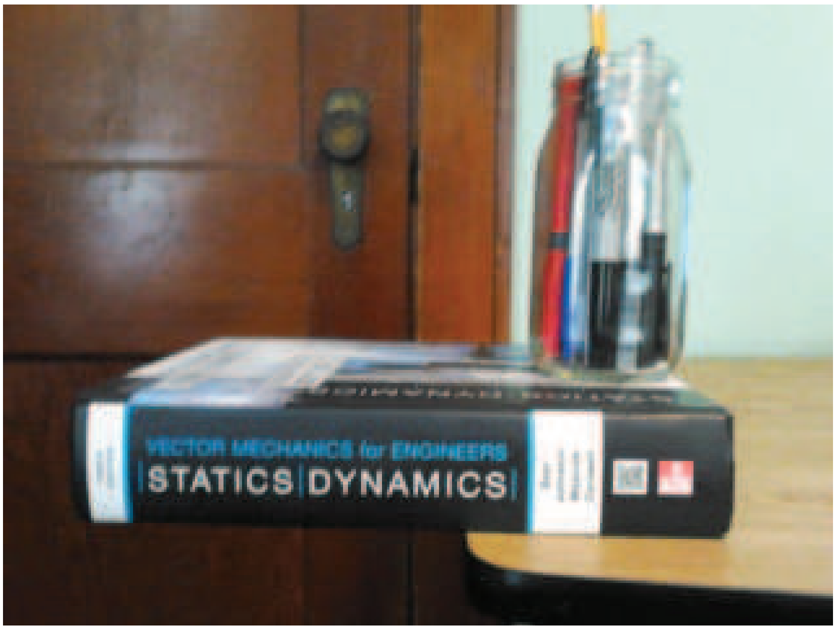

Figure 4. Student submission showing a self-constructed static equilibrium example.

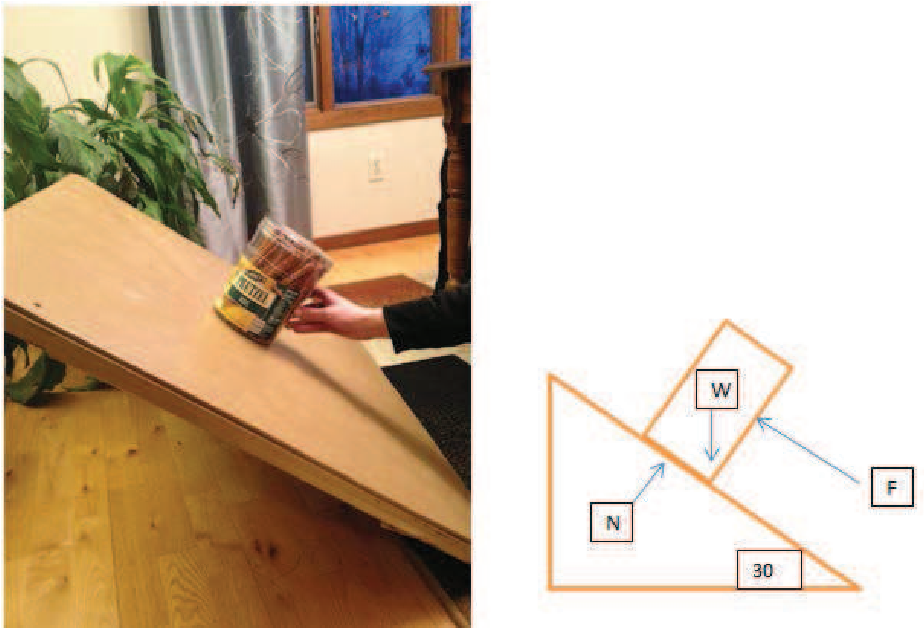

Figure 5. Student submission showing thoughtful analysis through construction of a free body diagram.

Summary

The use of an inquiry-based learning task in an introductory mechanics course was found to be helpful for both the students as well as the instructor. Informal qualitative feedback gathered from the students through classroom conversations after completion of the task suggested that in general students found it useful to try to relate the course material to their surroundings. Completing this task required them to use thought processes that differ from those employed during the completion of traditional homework.

From the instructor's point-of-view, it was helpful to collect a less formal assessment of the student's conceptual understanding of static equilibrium. This provided the opportunity for discussion about what the students had found and how they drew their conclusions. Because the students had selected the problem they chose to analyze themselves, they were more invested in the discussion, which resulted in a more productive conversation. One conclusion resulting from these discussions which was not captured in the student's submissions was the passive analysis performed by the student while selecting a problem. During the process of completing the assigned task, the student was forced to look around and perform at least a brief analysis of several structures or systems before selecting the one to be analyzed. A future iteration of this assignment will be modified to capture that information possibly through a more journaling based approach, similar to what has been presented in the literature[6].

The use of this form of student assignment was a positive experience for both the students and the instructor. Therefore, it is planned to expand its use throughout the term using a form of short-form journaling with regular documentation of how the students are finding the course material relevant to their surroundings and the events in their lives. Additionally, it is planned to assess the effectiveness of these methods on enhancing student learning. This will be done through the use of control and treatment groups as well as pre- and post-deployment of a concept inventory to allow for comparison of student concept retention between the groups.

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