A product dissection project designed for student motivation and retention in an introduction to engineering course

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Abstract

Many engineering curriculum include introduction courses at the freshman level to motivate and retain students. Providing meaningful introductions to engineering at the freshman level, however, is very challenging because the students lack an engineering background. This paper presents a product dissection based project within an introduction to mechanical engineering course. The project allows students to explore engineering design concepts with little engineering background. In a group project that consisted of 5 total hours of in-class work over the course of several weeks the students studied a purchased product in terms of performance, reliability/safety, manufacturing, and cost. Additionally, students were guided through a study on how the mechanical engineering curriculum would prepare them to create similar design solutions. Feedback from students was collected and analyzed to determine the qualitative impact on student motivation and understanding of the mechanical engineering curriculum.

Keywords

First-year, Product-dissection, Hands-on, Retention

Introduction

With the increasing complexity of technology in the world, the need for engineering graduates continues to grow. However, a study by T. K. Grose[1] shows that recent enrollment in engineering programs in the US has not grown as fast as the population. Because of this, student retention has become a critical issue in engineering education. In fact, student motivation and retention has been a challenge for many years. Based on several studies in the literature, D. W. Knight, et al.[2] estimated engineering graduation rate to be 56% of the students entering engineering programs in the US. Engineering undergraduate curriculums are very challenging, and without proper motivation, there can be significant student attrition in the first and second years. Over the past decades, many engineering departments have offered introduction to engineering courses in an effort to improve student retention. The goal of these courses is to motivate capable students very early in their education, so that they have the perseverance to persist through the degree program with success. Providing meaningful introductions to engineering at the freshman level, however, is very challenging because the students lack an engineering background. A number of approaches have been used in introductory courses on engineering including project based learning (See Knight, et al.[2]) and seminars from engineers in industry and academia. Knight et al.[2] found that hands-on learning of engineering skills and developing a student learning community were two important factors for student retention. One interesting approach to project based learning are product dissection based projects. J. Lamancusa et al.[3] discusses a freshman level engineering course that is devoted entirely to

prepared dissection modules on a variety of complex engineering products. The course consist of students disassembling and reassembling each module, reading materials related to the product, and giving presentations and reports based on learnings.

This paper presents a smaller product-dissection based project within an introduction to mechanical engineering course. The project allows for some of the benefits of a product dissection project to be realized while still meeting some of the other course objectives such as bringing in speakers from industry, discussing ethical issues, and introducing engineering software. Additionally, by using fairly simple, inexpensive products, this project requires very little development time or cost. The students are responsible for the only cost which is the cost of the product to be dissected.

In a group project that consisted of 5 total hours of in-class work over a period of several weeks the students studied a purchased product in terms of performance, reliability/safety, manufacturing, and cost. Additionally, students were guided through a study on how the mechanical engineering curriculum would prepare them to create similar design solutions. Feedback from students was collected and analyzed to determine the qualitative impact on student motivation and understanding of the mechanical engineering curriculum. A total of 23 students participated in the project and survey.

Product Dissection Project Overview

The product dissection project discussed in this paper is one component within a required 'Introduction to Mechanical Engineering course at Mississippi State University for first semester engineering students. Each group of 4-5 students were required to analyze a purchased product with respect to market, function, performance, reliability/safety, manufacturing, and cost. Focusing on a consumer product gave the students access to a variety of design related issues without requiring them to have the engineering skills needed for design. The project was conducted during three class periods (1.5 hours each).

The students were first tasked with selecting a product at a cost of $30 or less. Example product ideas were provided to the students including an aquarium pump, a rice cooker, an electric pencil sharpener, a quadcopter, and a space heater. Ideally, the products should be fairly easy to take apart yet complex enough to be studied from a mechanical engineering design perspective. Additionally, each group was required to select a unique product so that a variety of insights could be gained and shared with the class.

Product Dissection Assignment: Segment 1

For the first segment of the in-class project, students were required to bring in the product as purchased and study it in terms of market, function, and design constraints. For example, in terms of market, students were tasked with using their computers to describe the target customers, competitors, and distinguishing features. In terms of function, the students were tasked with generating a basic functional block diagram that illustrated the relationship between the component parts of the product. Figure 1 shows an example of what was expected of the

students in terms of the functional block diagram. Students had the opportunity to add detail to these diagrams during subsequent segments of the project.

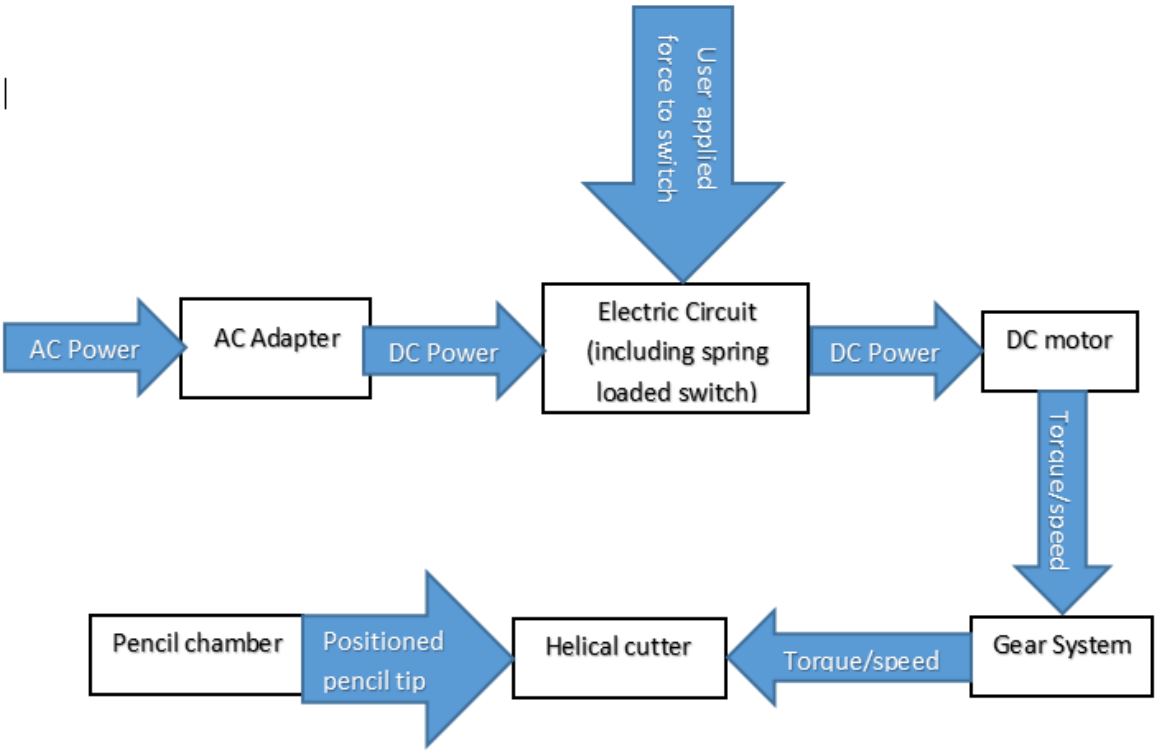

Figure 1. Functional Block Diagram for Pencil Sharpener

Next, the students were required to generate a list of critical design constraints for the product. This was an opportunity to create a set of approximate quantitative metrics that could be used as a specification for the product design. In an effort to generate a realistic specification, students were required to generate logical estimates of upper and lower bounds for constraints like dimensions, weight, material properties, and cost.

Then, the students were required to begin to explore how the skills and concepts learned in the mechanical engineering curriculum could be used to create a similar or improved product design. This can be a fairly difficult task for students who have taken little or no engineering courses. As a starting point the students were provided a handout that summarized the major topic areas in the ME curriculum as shown in Figure 2. This handout was discussed with several examples during one of the earlier lectures. Students were then expected to read through some of the course summaries and try to determine what elements from the courses in the curriculum could be helpful for designing their product. Initially, many groups were only able to list how the curriculum courses might be used to understand the physics of the products. During this part of the project, there is an opportunity for the instructor to provide some helpful coaching and

experience to reveal how some of the courses could actually be used to design the geometry and materials of the product in such a way that it meets the design requirements.

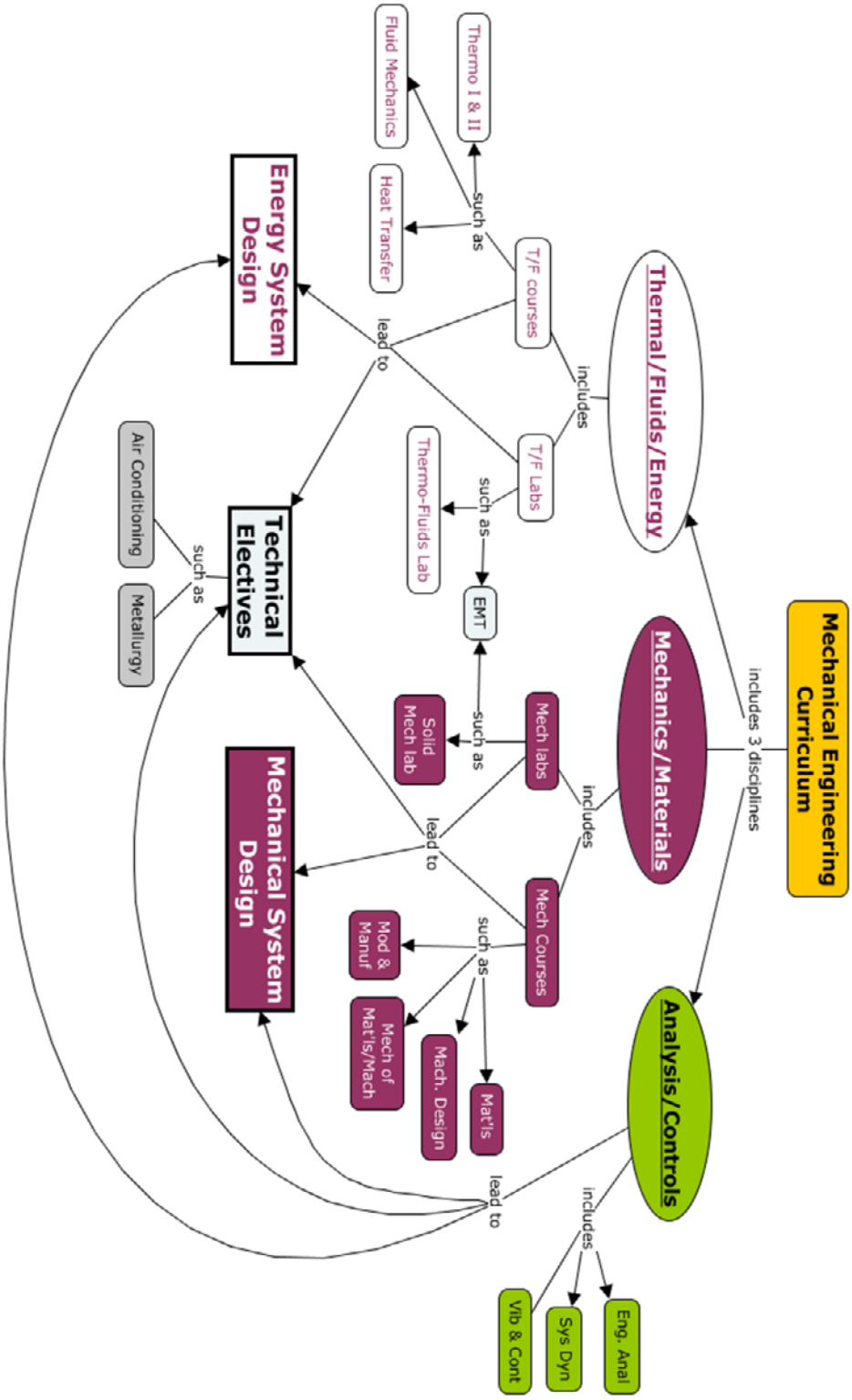

Figure 2. Mechanical Engineering Curriculum Summary for MSU

Product Dissection Assignment: Segment 2

The second segment of the in-class project focused on manufacturing and cost. The students were asked to describe the methods of connecting components and consider the advantages/disadvantages of these methods over other methods. The students were asked to do a similar exercise with regards to the material used for each component. Finally, the students were asked to think through product improvements.

In order for the students to complete this segment of the project, the students were required to dissect the product. Each group was required to arrive in class with their product dissected to the point that a minimum of two internal components could be identified. This limited definition of dissection was used because, the students were not provided any special tools for dissecting the products. An example, of a dissected pencil sharpener project is shown in Figure 3. In addition to understanding the manufacturing methods, students could also get a better understanding of how the device functions once the product had been dissected.

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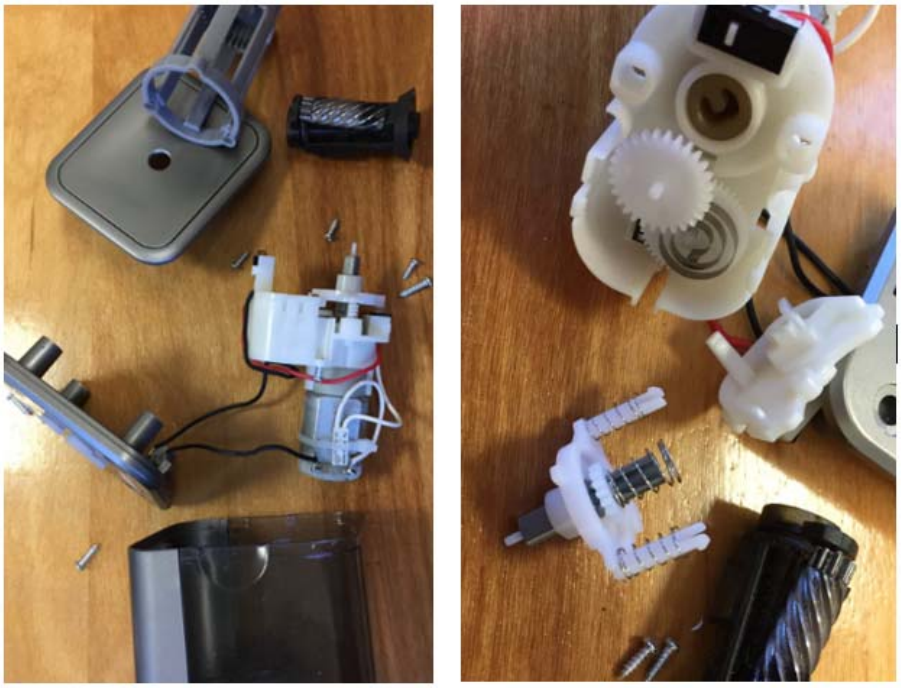

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Figure 3: Dissected electric pencil sharpener.

Product Dissection Assignment: Part 3

The third segment of the in-class project focused on safety and reliability. To study the products failure mechanisms the students were introduced to two tools from the Design for Six Sigma (DFSS) methodology which is in common usage in industry.

The first tool used was the parameter diagram which is used to list out the system inputs, desired outputs, potential error states and the “noise” factors that could lead to error states (i.e. failures to meet the product functions). An example P-diagram of a flashlight was presented in class. This exercise really gave the students an opportunity to really explore all of the possible failure types and failure causes of their product.

Next, the students were asked to use a second tool from DFSS: Design Failure Mode Effects Analysis (DFMEA). Specifically, the students had to select two of the worst error states (i.e. product failures) and list the three noise factors (e.g. dimensional variation, environmental factors, customer usage, etc.) that would be most likely to cause each error states. A full DFMEA would involve a more complete list of these combinations and a systematic rating exercise to identify the highest risk elements in the design. However, the exercise was simplified greatly because of the available time.

Again, the students required a lot of instruction and examples to enable them to complete this part of the assignment. Through this process many of the students were able to understand the role that an engineer can play in designing products for safety and reliability. This is critical for gaining an appreciation for the broad education required to effectively generate designs that benefit society.

Throughout the semester, student groups were asked to give informal presentations of their product. During this time, the instructor asked several questions and provided some guidance on other aspects of the assignment. Also, several students in the class were invited to participate in a discussion about what went into the design of each product and how the mechanical engineering curriculum could prepare the students to create similar design. This open discussion allowed the entire class to gain insights from each product and provided a rich environment for a discussion of the mechanical engineering curriculum.

Student response

Students were asked to fill out a survey to get an idea of their perception of the project. In general the students were very pleased with the project and felt that it gave them unique insight into their future engineering education and careers. Across the board, the students strongly agreed that the project opened their eyes to the complex set of issues that go into an engineering design. Many of the students were surprised to see the importance of considerations such as safety, reliability, manufacturability, and cost in the design process. They expressed anticipation about the challenge of being able to create designs which addressed such a variety of constraints.

Additionally, many of the students mentioned that they appreciated that the project was hands-on. However, some students actually expressed frustration about the level of depth of the hands-on aspect. Students gave several recommendations for improving the project such as dissecting more complex products, providing tools to dissect the products more thoroughly, and adding in activities where the students can actually design replacement components. Of course, some of these ideas are challenging from a cost and complexity stand-point, especially for students without any significant engineering or technical background. Still, there may be an opportunity to use some of these suggestions. Additionally, many of the students recommended that more time be dedicated to the project to allow the products to be studied in more depth.

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