

## **Learning Experience in Mechanical Engineering First-Year Students**

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# Learning Experience for Mechanical Engineering First-Year Students

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**Abstract** - Retention of engineering students continues to be a major challenge affecting engineering Schools across the nation and unsuccessful experiences in freshmen engineering and science courses are some of the driving factors contributing to this problem. This paper presents details of a reformed freshmen course offered in the mechanical engineering (ME) program at Washington State University-Vancouver (WSU-V). It is a semester long two-credit course with a primary purpose of giving the students an opportunity to explore the mechanical engineering discipline topics that they are going to learn in their four-year study. This course has been offered for the past ten years with various teaching approaches. It is mostly a project-based course combined with lectures across the mechanical engineering topics, such as force/stress analysis, material properties, motion, fluids, etc. In the first few offerings, ME faculty members were invited as guest speakers to present their areas of research to the students. Based on their availability, mechanical engineers from local industry were invited as guest speakers to talk to the students about “a day in an engineer’s life.” These approaches have had various outcomes and instructors have varied methods to meet the needs of students. In the new approach, in addition to covering the engineering fundamentals and problem solving, the students are engaged in two group projects enhancing their creativity and hands-on skills. One is a term project, similar to the ones assigned in previous years. The additional project proposed at the freshman level was on reverse engineering. The paper provides details of how the course was organized, topics presented in the course, and the types of projects assigned to the students. Results on the student learning outcomes and experience throughout the course conclude the paper.

*Index Terms* – First Year Mechanical Engineering Students, Reverse Engineering, Retention of Engineering Students, Term Projects

## INTRODUCTION

This paper presents the impact of some key strategies that were implemented for improving retention and student success for mechanical engineering undergraduates at Washington State University-Vancouver (WSU-V). The first engineering course taken by entering freshmen offers an opportunity to lay the foundation for forthcoming years. At

the University, the first course is “Introduction to Mechanical Engineering”, two credit hours, in which the focus is to introduce the students to the broad discipline of this major and the topics they will be studying in their next four years. Historically, the majority of the freshman come directly from local high schools, while a small percentage return from the work-force.

Reported numbers vary from one source to another, but a national average of about 55% is in reasonable agreement with the sources identified [1]-[7]. The first group of freshman mechanical engineering students were admitted to our program in Fall 2006. This course was intended to introduce what the mechanical engineering discipline is and what mechanical engineers do once they join the work-force. The course was developed as a group effort, then rotated among ME faculty with diverse research interests [8].

In the first few offerings, more emphasis (up to 50% of the grade) was on a group project to make the course fun, so that the students coming with diverse backgrounds in terms of science and math, do not face an overwhelming school work load in their first year of engineering experience.

The course was set up so that in addition to covering some fundamentals by the course instructor, one session was devoted to another faculty member to talk about a particular topic, such as fluid mechanics. In addition, the faculty speaker was introducing himself to the students by further talking about his/her area of research. This gave students an opportunity to get to know the faculty, their area of expertise, and foresee a chance to develop a relationship for potential undergraduate research opportunity during their four-year study. This strategy worked well, but was not effectively covering all the materials outlined in the course syllabus, and resulted in falling short of time at the end of the semester.

The focus of the course has changed from the first few offerings to the latest offerings in which more emphasis is placed on the materials to be covered according to the syllabus and a change in types of design projects in which students work as a team has taken place.

With the amount of material to cover in a two-credit course, there has always been a challenge to cover class material, while trying to make the course appealing to the students. Thus, in the most recent offerings, the faculty presentations were eliminated from the schedule to allow more time to cover the required topics in detail. Inviting a guest speaker from industry was limited to one, but still implemented.

## COURSE OVERVIEW

The mechanical engineering faculty at Washington State University-Vancouver recognizes that graduating engineers will be expected to function effectively in multidisciplinary teams where effective skills related to team work, collaboration, and communication will be necessary and valued. The “Introduction to Mechanical Engineering” course is intended to expose students in their freshman year to engineering problem solving and design that emphasizes team work, communication, and the interdisciplinary nature of solving engineering problems. At the same time, the program faculty want to expose the students to the different focus areas that will later be offered in the program.

The instructors attempt to generalize the teaching to motivate and educate diverse students. Most students were exposed to science and math at adequate levels in high school. The engineering principles allow the instructors to make connections and draw analogies and demonstrations across different areas. The course description and objectives are presented in Appendix A.

Although all objectives were implemented during the past decade of offering the course, some minor changes were adapted throughout the years with the intention of improving the students’ engagement in and motivation toward the engineering program, in return improving retention.

As described previously, one of the main elements of this course is a group project assigned to the students to engage their creativity and developing teamwork skills. In the new version of the course, two group projects were assigned.

## PROJECTS ASSIGNED

### *Project Module 1:* Engineering Design Project

The primary objective of this Project is to introduce students to the iterative nature of engineering design. Students gain experience working with constraints and criteria, and how these must be satisfied and balanced during a product design.

The project is to design and build a vehicle that uses a source of mechanical energy (springs, rubber bands, etc.) to start from a slope on a ramp and travel a certain distance as shown in Figure 1. The scores assigned to the design are itemized as creativity, workmanship, distance and time travelled, and overall cost of the product. A formula was developed to calculate the overall score portion of the students design. The details of the formula are presented in Appendix B.

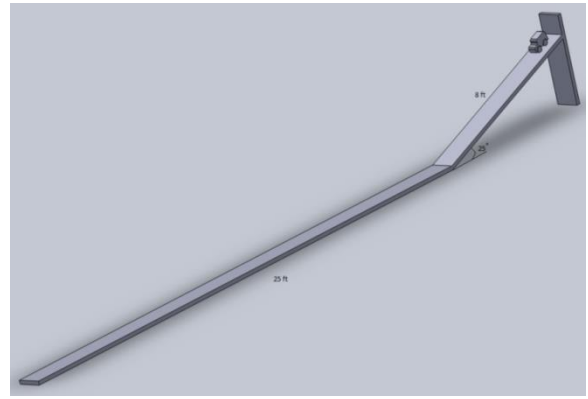


FIGURE 1  
DESIGN PROJECT - CAR ON A RAMP

Several creative designs were proposed and built by the students for the purpose of competition at the end of the semester. Two examples of these designs are shown in Figure 2.



FIGURE 2  
TWO DIFFERENT DESIGN OF RACE CAR

### **Project Module 2: Reverse Engineering Project**

Reverse engineering is the practice of taking products apart (product dissection) to discover how they work and gain insight into why a product was made the way that it was. This is a common practice in the industry and an important part of the product development cycle.

In this project, students select a product, such as a wind up flash light, a Nerf Dart gun, a Vintage Bell alarm clock, or a bicycle shifting mechanism. In all these various products, the idea is to disassemble the system, understand the physical principle behind them, and come up with at least one idea for how to improve the current design.

The goal is for the students to learn the engineering principles through disassembly, including how product components were manufactured and assembled, material properties of components, and interrelationship among components and subsystems within the product. Student teams then provide their findings through a project report.

Product dissection has been used in a variety of ways to successfully engage engineering students in their learning. Intellectual and physical activities such as dissection help to anchor knowledge and practice of engineering in the minds of students<sup>[7, 8]</sup>. Two examples of the products students did reverse engineering on follow.

**Nerf Dart Gun** – One of the reverse-engineered products was a Nerf Dart Gun shown in Figure 3 along with the components when disassembled.



a) THE GUN



b) DISASSEMBLED PRODUCT

FIGURE 3  
A NERF DART GUN

Two possible areas of improvements are either to enlarge the piston and cylindrical housing while keeping the nozzle the same size, or replacing the compression spring with one that exerts a larger force. The main improvement proposed however is to replace the compression spring with one having the same dimensions, but a higher strength and stiffness in order to store more potential energy to release the dart.

**Bicycle Shifting Mechanism** – The other system was the bicycle shifting mechanism shown in Figure 4 which illustrates the shifting mechanism and the components when disassembled.



a) THE SHIFTING MECHANISM



b) DISASSEMBLED PRODUCT

FIGURE 4  
BICYCLE SHIFTING MECHANISM

There are two, barrel adjusters; one on the handlebar portion, another on the lower shifting portion of the assembly, used to fine tune the tension in the cable, both made of a hard plastic. The barrel adjuster on the lower end of the assembly had some visible signs of wear. The product could be improved by using a stronger material for this part such as a stronger plastic like FR-4/G10 which is a composite material made up of woven fiberglass cloth and an epoxy resin". This is a lightweight material that is close to the strength of steel.

The product could also be improved by creating more accessibility to the inner workings of the lower shifting mechanism. The current design uses permanent pins to hold



the derailleur body together with the return spring inside. There is no way to access this interior for maintenance or in case of spring failure. Upon gaining entry to this portion of the assembly by removing one of the permanent pins, it was apparent that debris had been collecting around the spring, which will eventually limit its functionality. To solve this problem one of the permanent pins could be replaced with a removable one using a C-clip. The use of a removable pin would allow the assembly to still pivot as needed while also allowing the inner components to be accessible.

### STUDENT SURVEY AND THEIR LEARNING OUTCOMES

One of the main focuses of the new approach to teaching the course this time was to examine the effectiveness of the implementation of *team-based* learning in the course.

The course had 39 students in Fall of 2016, from which 76% were admitted directly from local high schools, and the rest were students either changing majors or coming back to school from the work-force.

At the end of the semester, a survey consisting of seven following questions was posed to the students finishing the course. The questions used a 5-option symmetric disagree-agree scale. A score from one to five is assigned to each point on the disagree-agree scale with one being “strongly disagree” and five being “strongly agree”. For example, for the question “Team-based learning activities are fun”, the student answer “strongly agree” gets five points and the answer “strongly disagree” gets one point. The survey questions to students at the end of the semester:

1. The team-based learning activities were a much better way to learn.
2. Team-based learning really did assist my learning in this class.
3. I enjoyed team-based learning.
4. I learned from project-based course as well as the materials covered in class.
5. I love group work it makes everything easier to understand.
6. The group work really stimulated the learning process. Group work made the course a lot more interesting and fun.
7. I like most about this course is learning how to work as a team.
8. Team-based learning activities are a waste of time.

Depending on the wording of the questions, some questions require a reverse score from five to one being assigned to disagree-agree scale. For example, the question “Team-based learning activities are a waste of time” uses a reverse score with five points assigned to “strongly disagree” answer and one point assigned to “strongly agree” answer. The results of the survey are presented in Figure 5.

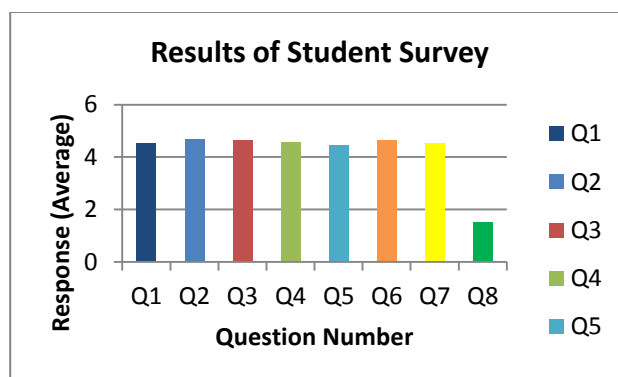


FIGURE 5  
STUDENT SURVEY RESULTS ON THE NEW APPROACH WITH TWO PROJECTS

Examination of the results presented in Figure 5 shows a clear preference by students who elect to stay in mechanical engineering for “design challenge”, “design-based projects”, in addition to the fundamentals covered in the course, the majority of the students, nearly 78% were in favor of the new approach.

### CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE STUDIES

Redesigning the introductory freshman course in the Mechanical Engineering Program at WSU-V provides entering engineering students with an important first-semester college experience. The course has been designed to address several learning objectives important for student success. The approach taken in re-designing the course involves four steps: (1) define course learning objectives, (2) develop course content based on learning objectives in the presence of constraints, (3) assess degree of achievement of learning objectives and effectiveness of content, and (4) utilize assessment data to implement changes, which increased effectiveness and efficiency of resources.

In the new approach to teaching the course, major changes were applied to the previous offerings which included class lecture, one design project having 50% of the total students grade, faculty, as well as engineers practicing in industry as guest speakers.

In the most recent offering in Fall 2016, the time used for ME faculty presenting their area of expertise and research was effectively devoted to covering the course materials in more depth, assigning two design projects, including a reverse engineering project, while inviting at least one guest speaker from local industry.

At the end of the semester, a survey was given to the students to ask about their learning experience and the result shows a very positive feedback. However, the outcome from one-time offering is not indicative of a definitive conclusion on the student learning experience. The author intends to use the same strategy in the next offerings to be able to have adequate data and to compare the student performance and success.

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## APPENDIX A

**Course Description:** Introducing mechanical engineering profession; engineering problem solving; computers in engineering; design process and methodologies.

### Course Objectives:

In this course, the students:

1. define mechanical engineering problems and propose alternative solutions,
2. participate in a team-work class project to design and build a prototype with design constraints,
3. learn on engineering ethics, continuing education, contemporary issues, global context, etc.,

### Topics Covered in this Course:

1. Overview of Mechanical Engineering Profession
2. Engineering problem solving
3. Forces, Materials, and Stresses
4. Fluids Engineering
5. Thermal and Energy systems
6. Motion and Power Transmission
7. Design Projects
8. Guest speaker

## APPENDIX B

Design Project Competition Score:

$$H = 5L + 30S + 10N + 10W + \frac{200}{T}$$

$$SCORE = H + \frac{100}{min} \left( \frac{\log C}{C} \right)$$

where,

- L:** Distance traveled on the pond (in feet)  
**S:** Whether it stopped at the end or not (1=stopped, 0=did not stop)  
**N:** Novelty of the design (Average of the scores (on a 1 to 3 scale) given by the judges)  
**W:** Quality of the workmanship (Average of the scores (on a 1 to 3 scale) given by the judges)  
**T:** Time it took for the boat to complete its travel (in seconds)  
**C:** Overall cost of the design

**min:** A constant coefficient determined based on the project with lowest cost.

$$min = \frac{\log(\text{lowest cost})}{\text{lowest cost}}$$