AC 2007-449: MULTI-DIMENSIONAL AND INTERACTIVE LEARNING MODEL FOR INTRODUCTION TO MECHANICAL ENGINEERING

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Multi-dimensional and Interactive Learning Model for Introduction to Mechanical Engineering

Introduction

Many engineering curricula around the world traditionally include a course on introduction to engineering at the freshmen level. In most engineering schools such a course covers a general introduction to all engineering disciplines.

This year for the first time we admitted freshmen into our new mechanical engineering program at Washington State University Vancouver. Furthermore, mechanical engineering is the only engineering program on our campus. As a result, it was necessary to develop Mech 101 "Introduction to Mechanical Engineering" course. A multi-dimensional and interactive learning approach was taken in teaching this course. The method integrated the following components:

- *Multi-instructor teaching;* several faculty members held lectures and lab sessions to introduce sub-disciplines of mechanical engineering; including: thermal/fluid engineering, control, automation, and robotics, materials and manufacturing, computer-aided engineering, and machine design.
- *Engineering software skills;* an introductory software called Working Model 2D, was taught and practiced in class in order to be used for solving real-world engineering problems, and to be used in individual or group design projects later in the semester.
- *Design project competition;* a design project, entitled "Water-Powered Vehicle", with a competition at the end was used as a motivation tool to instill critical thinking and creativeness. The twenty one enrolled students were divided into seven teams and each team was given a one-liter bottle of drinking water to use it as the only source of input energy to run the vehicle as far, fast, and straight as possible. Student teams first designed their prototypes using the Working Model software and later built and test them for the competition.
- *Engineering problem solving;* about one-third of the course schedule was spent on solving real-world engineering problems in different sub-disciplines of mechanical engineering through case-studies; including: systems of units, unit conversions, forces in structures, stress and strain, fluidic systems, thermal systems, motion, power transmission, design of machines.
- *Soft-skills in engineering;* each faculty member introduced ethical and contemporary issues related to their sub-discipline as part of their lectures. Furthermore, these subjects were discussed throughout the semester in lively class discussions.
- *Industry tours;* in order to provide a real-world picture of mechanical engineering practice, industry tours were scheduled. Companies were selected to showcase a spectrum of activities from small-size device manufacturing to heavy equipment manufacturing, to demonstrate the broad field of mechanical engineering.

In this paper, first the course strategies and outline are described. Then, details of the course activities as well as other social and informative activities are presented. Finally, conclusions and the lessons learned are described.

1. Course Outcomes

The Mech 101 is a 2-credit course with two 50-minute lectures per week. No textbook was required but some were used as references in the course [1, 2]. Topics covered included mechanical engineering as a profession, sub-disciplines, computer-based modeling, engineering problem solving, ethics and contemporary issues in engineering. Also, a design project was assigned after introducing the mechanical engineering disciplines within a month into the semester so that the students would have about 10 weeks to finish their projects.

The following are the course outcomes based on the ABET accreditation criteria:

Students will

- review the fundamentals of physics and mechanics (criterion a),
- teamwork to build a mechanical system based on the required specifications and constraints (criterion c),
- evaluate the ethical issues while practicing and solving the real-world mechanical engineering problems (criterion f),
- deliver a well-organized oral presentation, including good explanations when questioned, for the design projects at the end of semester (criterion g),
- evaluate the impact of engineering solutions in a global context; in their design projects or in solving the real-world mechanical engineering problems (criterion h),
- track the continuing education opportunities in mechanical engineering (criterion i),
- evaluate the impact of contemporary issues, such as environmental, economic, emerging technologies, etc (criterion j),
- use a mechanical engineering software, such as Working Model, for analyzing their design projects (criterion k).

2. Mechanical Engineering Disciplines

The first objective in this course was to introduce the mechanical engineering professions and disciplines to the freshmen students. The best way to achieve this goal was to do collaborative work with other faculty members who could give lectures on their field of expertise in different disciplines of mechanical engineering. Five ME faculty members gave two lectures each, as described below. After these sessions, each faculty member prepared exam questions on their lectures. These questions were provided to the main instructor of the course to be used later in the final examination.

2.1. Thermal/fluid engineering

The thermo/fluids sequence of the ME curriculum, includes three fundamental courses, Thermodynamics (Mech 301), Fluid Mechanics (Mech 303), and Heat Transfer (Mech 404), and one capstone design course, Thermal Systems Design (Mech 402). One lecture was used to explain this curriculum path, and to review fluid engineering and thermal systems. The first lecture session was followed by a lab session.

Fluid engineering: Various examples of fluid systems were presented. The basic fluid parameters, such as pressure and velocity, were then introduced. The fluid engineering problems were in general divided into two categories: fluid statics and fluid dynamics. In fluid statics, the concepts of hydrostatic pressure and buoyancy were introduced. A few real-world examples, such as the force balance on a submerged submarine in still position, were discussed in class. In fluid dynamics, several concepts and real-world examples were practiced, for example: (1) a simple view of the Bernoulli's equation was given for the water flowing through pipes with variable cross-sectional area, (2) transition from laminar to turbulent flow around a golf and tennis balls were discussed, and (3) the drag forces against the motion of a bicycle and airplane were introduced and explained.

Thermal systems: In this section, the definitions of work and heat were reviewed and the laws of conservation of mass and energy were then introduced in a simple format. Typical applications of energy systems, such as hydraulic and thermal power plants, internal combustion engines, solar power generation systems, and jet engines were explained. Diagrams and tables were presented about the source of power generation in the United States as well as the amount of energy consumption by different industrial and residential units. Typical mechanical and thermal efficiencies of different machines and equipment were presented while emphasis was given on the importance of saving energy through the design of engineering systems.

Lab activities: In the second lecture period, the class met in the thermal/fluid lab. Some groups used a water tunnel to adjust the flow velocity and observe the flow patterns around few objects, such as cylinders, spheres, and airfoils. Other groups worked on the heat transfer where they could adjust the power of an electric heater and plot the temperature gradient through a metal bar.

2.2. Control, automation, and robotics

The dynamic systems and control stem of the ME curriculum contains two junior-level required courses, Instrumentation (Mech 304) and System Dynamics (Mech 348). The curriculum also provides a mechatronics option area which consists of three elective courses including Microcontrollers (Mech 405), Automation (Mech 467), and Robotics (Mech 468).

The field of robotics is exciting for the students. Therefore, robotics was chosen as a vehicle to introduce the dynamic systems sub-discipline of mechanical engineering and the course sequence mentioned above. A lecture was first provided as an overview of the field of robotics. Historic development of industrial, walking, and mobile robots was reviewed with reference to technical challenges and by highlighting the underlying dynamics and control problems whenever appropriate. Furthermore, examples of contemporary uses of the robotics technology, such as robot-assisted surgery, the mars rover, robotic prosthetics, etc., were used to provide a sense for where the future applications of robotics may go. In the next lecture period, students met at the robotics laboratory. After a brief introduction about how to program a robot, each student was given a chance to teach a couple of task positions for a simple robotic pick-and-place task. They programmed the robot to pick up wooden blocks to spell the acronym for the university. Students were very excited about programming the robots.

2.3. Materials and manufacturing

In the area of materials and manufacturing, the curriculum has two junior-level required courses, Introduction to Engineering Materials (Mech 309) and Introduction to Design and Manufacturing

(Mech310), and two senior-level elective courses, Introduction to Manufacturing Systems (Mech425) and Advanced Manufacturing Engineering (Mech 476).

Knowledge on materials and manufacturing is a core technical competency in manufacturing firms where most mechanical engineering graduates are employed. Two lectures were designed to: (1) introduce freshmen students to fundamentals in materials and manufacturing, (2) expose them to advanced materials and 21st century manufacturing system, (3) involve them in hands-on activities, and (4) encourage them to pursue degrees and careers in mechanical engineering. The first lecture was focused on material processing while the second one on contemporary issues in materials and manufacturing.

In the first lecture, the students were introduced to the modern manufacturing systems starting from marketing to delivery. Then, all students pretended to run a manufacturing company called "Cougar Emblem Manufacturing (CEM) Co." The mission of CEM Co. was to manufacture the best quality plastic cougar emblems on time. The instructor demonstrated the procedure of making plastic cougar emblems. Each student was assigned as a manager, process engineer, quality engineer, sales engineer and R&D engineer. The instructor was the customer. First, the manager checked the status of resources they had and assigned jobs to process engineers. Then, process engineers mixed liquid pre-polyurethane and curatives and poured the liquid mixtures into various silicone molds. After the parts solidified, the quality engineer inspected some of their plastic products for defects. The R&D engineer conducted surveys to find out the causes of defects. Finally, the sales engineer brought the products to the customer and explained why they would meet his needs. It took about 5 to 7 minutes to complete one plastic part, so the students made about dozen parts during the first lecture. In this hands-on activity, the students could experience polymer materials, molding process, and manufacturing systems.

The second lecture was focused on contemporary issues in materials and manufacturing. The instructor explained 4 different types of solid materials; metals, ceramics, polymers, and composites. Then, contemporary issues on materials engineering such as semiconductors, multifunctional materials and nano-engineered materials were discussed. Next, modern manufacturing processes such as non-traditional processes (laser, waterjet, electrical discharge machining, etc) and CNC systems were introduced. During the last 20 minutes, the class went to the materials lab and watched a demonstration of material testing.

2.4. Computer-aided engineering

In the area of computer-aided engineering, the curriculum has one freshmen-level required course, Engineering Graphics (Mech 103), one junior-level required course, Engineering Analysis (Mech 313), and one senior-level elective course, Computer-aided Engineering (Mech 485). The elective course Mech 485 is also one of the three option courses offered in the design and manufacturing concentration area in the curriculum.

The lecture started with an introduction to Computer-aided Design as a way of replacing the traditional inefficient method of mechanical drafting. Importance and benefits of using computer-aided technologies in engineering product design was illustrated by examples ranging from military equipment to daily life engineering products. Students realized that, as engineering products are becoming more complicated assemblies, mechanical engineers rely more heavily on sophisticated software for creation, visualization, and simulation of a 3D design. Importance of computer-aided engineering was illustrated by examples such as cell phone drop test simulation and vehicle crash test simulation. Through these examples, students learned that, over the life cycle of a product, many engineering changes might have been made to the original design idea based on simulation results of a design's mechanical behavior. They understood the importance of engineering analysis prior to product manufacturing and the benefits of computer-aided design and engineering in reducing cost and time for a company to provide a competitive edge in the market. A lab session was also held using the computer-aided design software SolidWorks. Students formed small groups and practiced how to virtually assemble a universal joint in SolidWorks following a tutorial. They showed great interest in this hands-on practice. The competition among groups to finish the assembly task first through team collaboration also added fun to their learning.

2.5. Machine design

In the design sequence of ME curriculum, the students start with the basic freshman Engineering Graphics (Mech 103) and proceed with a junior level course Design Process (Mech 314), followed by the senior Machine Design (Mech 414). These constitute the preliminary background to prepare them for the capstone senior design project.

In the first lecture, the concept of simple machines and mechanisms were introduced, in particular hand operated and mobile machine such as shears and vise grips. From design point of view of these devices, the significance of having multiple links between the input and the output members of a machine was discussed via examples. It was emphasized that these multi-force members, located between the input and output links, would magnify the input and therefore increase the mechanical advantage of the system. Several alternative designs were presented, all with the intention of force amplification. Two existing designs, a simple pliers and a compound-lever snips, were analyzed to prove the concept. In both cases, the input force and the overall length of both devices were identical. The objective was to see how the output force is amplified in the case of the compound multi-member snips. Students enjoyed learning about the effect of adding extra links in-between the input-output members. They learned how alternative design solutions might result in making the mechanical systems lighter, more compact, and efficient.

In the second lecture the main focus was on machine design. The main principles behind the mechanical engineering design, such as creativity, simplicity, and iteration, were explained and discussed. Machine elements, such as shafts, bearings, different types of gears, pulley-belt system, etc. were then introduced to the students.

3. The Importance of Engineering Software

The use of engineering software in simulating, solving, and optimizing the real-world engineering problems are becoming an essential education tool in many mechanical engineering curricula.

Several engineering software were evaluated to be used in Mech 101, and among them, the Working Model 2D was found as most appropriate software for the freshmen level. The idea of selecting such software was to use it as a tool to simulate engineering problems that freshmen students might not be able to solve due to their basic engineering knowledge just in the first semester.

A couple of sessions at the beginning of the course were used to provide tutorials and hands-on experience with the software. Later, they were given an open-ended assignment to find and simulate a mechanical system. Students found many creative examples such as locomotive in motion, pendulum, ball game using mass, spring and actuators, golf club simulator, golf ball collector, piano key, conveyer system, crates transporter, bicycle in motion, boat trailer, car door, Pelton turbine, tugboat and barge, wrecking ball for destruction, motorcycle suspension system, and an interesting jumping pogo stick, as shown in Figure 1.

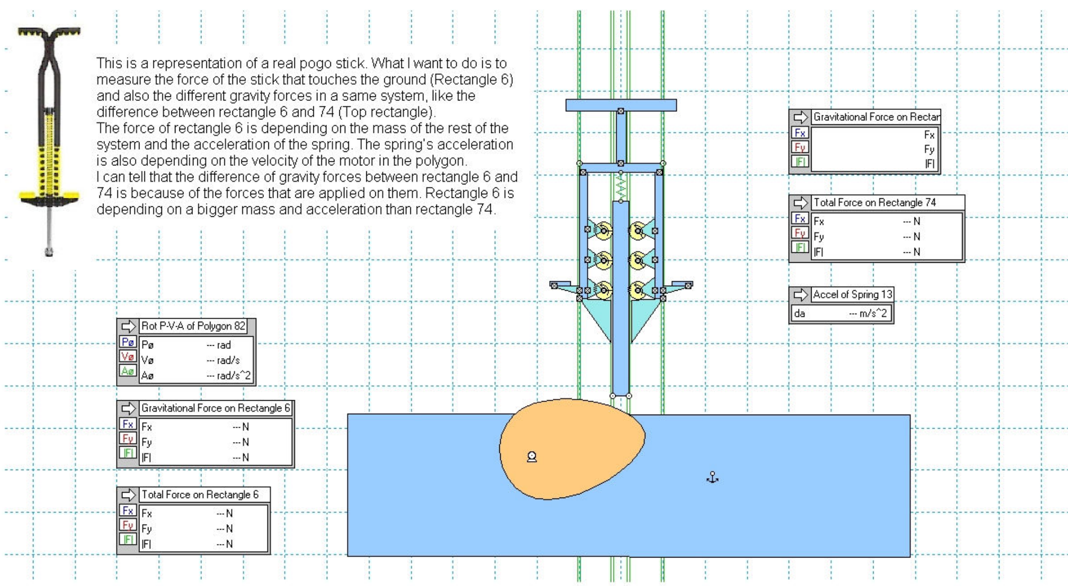

Figure 1. A jumping pogo stick that was modeled by one of the students using the Working Model software.

There was also a major design component in this course, as described below, where the students needed to design and build a vehicle that used a bottle of water as the only source of input energy. The goal was to have them first simulate alternative designs, using the Working Model software, before building the car.

4. Design Project

In order to get the freshmen excited about mechanical engineering and to allow them to practice their new skill in using the simulation software, we assigned a design project. The 21 students enrolled in the course were divided into 7 groups to design, build, and test a Water-Powered Vehicle. As much as possible, we tried to form the teams with uniform distribution across academic level, age, and gender. The design project ended with a design competition.

4.1. Project description

Each team was given a one-liter bottle of drinking water (33.8 oz Refresh Spring Water) to use it as the only source of input energy to run the vehicle. They could use the whole bottle or just water inside the bottle. They could also use a remote control system to direct their vehicles provided no additional sources of power other than the bottle of water were used to propel the vehicle.

The primary goal was to design and build a vehicle that could go as far, fast, and straight as possible. To accomplish this goal the students needed to share information and responsibilities with their team members to finish the project within the specified constraints and schedule. Constraints were:

a) The overall size of the system should not exceed Height: 8.0 ft, Width: 3.0 ft, Length: 5.0 ft
b) Due to the budget limitation, each team should keep the overall cost of project less than $80/team.

The project was assigned about one month after the semester began. In the meantime, the students had sufficient time to learn the simulation software to use it in their design.

4.2. Scoring the projects

The projects were judged in two sections: presentation and competition. For presentation, all team members had to participate in giving a 10-min. oral presentation to the class. Three faculty members judged all the presentations in one day and gave their individual scores to each team. An average was then taken as for the presentation score.

For competition, each team ran their vehicle twice in the main hallway of the engineering building. Scores were given to the vehicles for each run and later averaged using:

SCORE=15L+10V-5D-10C+20P

where:

- L: distance, measured from the start point to the end point in one direction, inch (0.1" increments)
- V: velocity, measured distance over the recorded time in one direction, inch/s (1 sec increments)
- D: deviation, lateral distance measured from the straight line, inch (0.1" increments)
- C: cost, overall cost of the project approved by the instructor, including all the materials used in building the system regardless of the source of funding, $ (0.1 US dollar increments)
- P: presentation, quality of the design and oral presentation scored by three judges, 5 points maximum

Interesting results observed from this hands-on design project; some designs were impressive while the others ordinary, as typically shown in Figure 2.

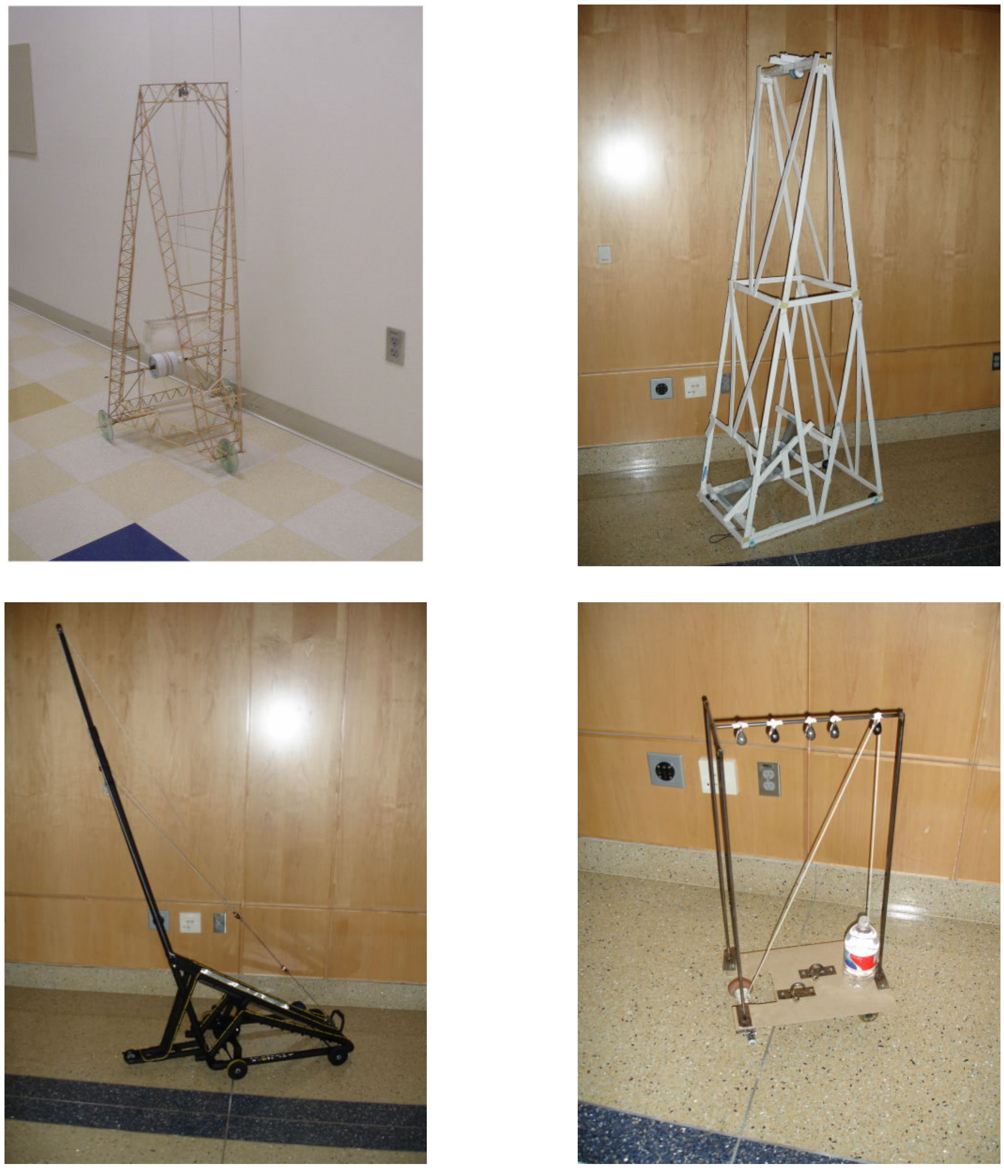

Figure 2. Sample of water-powered-vehicle designs.

5. Soft-Skills in Engineering

In this course, as mentioned previously in course strategies and outline, the goal was to teach and practice on four engineering soft-skills including: (1) engineering ethics, (2) impact of engineering solutions in a global context, (3) continuing education opportunities in mechanical engineering, and (4) impact of contemporary issues, such as environmental, economic, emerging technologies. These soft-skills correspond to the ABET criteria f, h, i, and j, respectively.

The five faculty members collaborating on this course introduced these skills and discussed them while giving lectures on their fields of expertise. For instance, in the thermal/fluid lecture we talked about a local power plant that provides electric power to our community while using the river as a source of cooling for the condenser of the plant. It was explained that if thermo-hydrodynamic aspects of the condenser are not considered and carefully calculated, exceeding the exit temperature to the river from allowable ranges may danger the fish life negatively impacting the big fishing industry in this region. Such examples consist of several engineering soft-skills to think about, such as engineering ethics, environment, economics, etc. A separate session was also focused on ethics in engineering. The famous ethical engineering story of the "New York Citicorp Tower" [3] was discussed in class.

In order to inform students about the continuing education opportunities in mechanical engineering, the American Society of Mechanical Engineers (ASME) and its relevant activities were introduced. Some junior and senior officers of our ASME chapter were also invited to the class to talk about their experience. At the end of these sessions, 15 freshmen decided to join the ASME student club.

6. Other Course Components

Several other in-class and out-of-class activities were done to increase students' knowledge and enthusiasm to mechanical engineering, as described below.

6.1. Networking and club activities

One of the main goals of this course was to familiarize the freshmen with the upper-division students as well as the faculty and staff members of the program. The engineering freshmen students mostly are taking fundamental science and general education courses. The Mech 101 is the only chance they can learn about their future department. An advantage of using multi-instructors in this freshmen course was that the students could get to know the faculty members of the program in person and communicate with them closely.

In order to let the freshmen get in touch with other students in the department, the HPV group of the ASME chapter was invited to the class to encourage them in joining the group. Some of the active HPV members showed up in class with last year's HPV entry. They presented the fun aspects of the project and explained their plan for going to the competition again with a new vehicle this year. At the end of session, 15 freshmen registered as new HPV/ASME members.

6.2. Local industry tours

A few industry tours from the local companies were setup and scheduled to enhance viewpoint of the students and open their eyes wider to mechanical engineering applications. By visiting these typical manufacturing companies, the students could see different mechanical engineering products ranging from small-scale devises, such as micro-pumps smaller than a shirt button, to much bigger machines, such as cargo trucks. These visits seemed quite interesting and helpful to students as indicated by their feedback.

6.3. Other informative lectures

A librarian was invited to the class to give specific information on engineering resources, such as the engineering data bases, and how the students can use them in their research and design projects. In another session, the engineering technician provided safety instructions on using the machine shop.

7. Course Assessment

The course outcomes were assessed at the end of the semester through two different methods; student survey and instructor evaluations. Students were given a survey with the course outcomes as the questions, listed in Section 1. They were asked to rate their level of accomplishment of each outcome after having completed the course. The response to each question was rated from 5 (strongly agree) to 1 (strongly disagree). Results were tabulated and plotted, as presented in Figure 3.

Additionally, the main instructor assessed the course outcomes separately by measuring each outcome through targeted questions on homework problems, projects, exams, and other class activities. A cover sheet on each assignment showed the mapping of the questions in that assignment to the course outcomes. Grades for each question were then tallied towards their corresponding outcomes. At the end of the semester cumulative grade earned by each student on each course outcome was computed. This final grade was then converted into a score for each student on each outcome on the scale of 1 to 5. Figure 3 presents both the instructor evaluations and the self-evaluations of the students through the survey on each of the course outcomes.

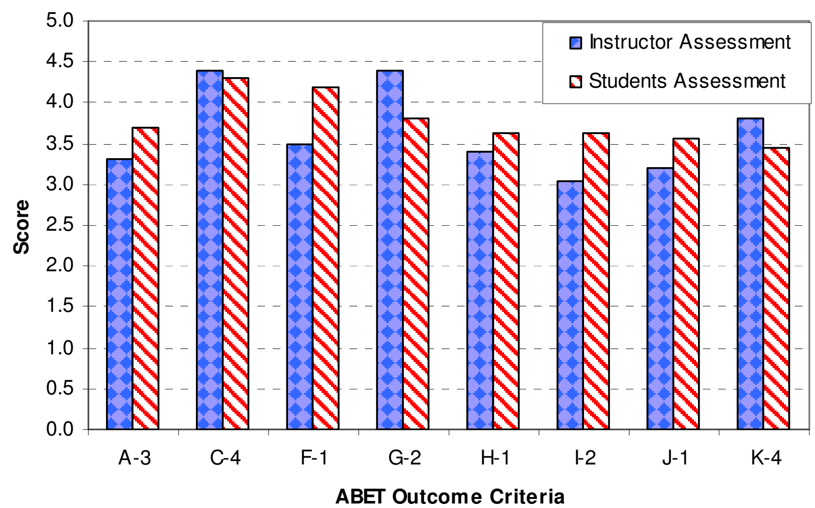

Figure 3. Assessment of the course outcome criteria.

The program faculty agreed that a minimum score of 3 on a course outcome would be considered satisfactory. As seen in Figure 3, all course outcomes are above the minimum and are satisfactory. Furthermore, there is relatively good agreement between these two separate course assessment methods where the maximum difference is about 18%. The assessment of the course outcomes will continue over the next few years using different methods, such as, senior exit survey, alumni survey, employer survey, focus group, and design panel. The students' comments also showed their excitement and joy of taking this course and their willingness to stay in the ME program.

Conclusions

The transitioning of the freshmen students from high school to college is always a concern to educators. The engineering students have an especially tough transition since they have to take several math and science courses in their first year and not much in terms of engineering.

In order to expose freshmen students to the mechanical engineering field and to improve our chances of retaining them, we developed a new "Introduction to Mechanical Engineering" course. Five faculty members of the mechanical engineering program collaborated and took a multi-dimensional and interactive approach to teaching this course for the first time. Each faculty member with different expertise in mechanical engineering disciplines spent two class sessions to explain their fields of expertise, using hands-on lab experiences and giving real-world engineering examples. Engineering soft-skills, such as ethics, contemporary issues, etc. were also introduced. An improvement on teaching this course for the following years is to invite alumni and professionals from industry to give lectures on the mechanical engineering practice.

The Working Model 2D software was used to simulate engineering systems. A water-powered-vehicle design project was used to excite the students about mechanical engineering while giving them a chance to practice what they learned.

The students were also integrated with the upper-division students in the school through a few social events, and by participating in building a human powered vehicle (HPV) for the ASME student chapter. A few industrial tours were also scheduled to broaden the students' understanding of mechanical engineering.

The course proved to be a productive and fun environment. They could get a big picture of mechanical engineering as their field of interest while enhancing their skills on engineering software, hands-on experience, team-work, soft-skills, and engineering problem solving. Such an early exposure to what is in the ME curriculum further down the road, and the exciting field of mechanical engineering in general, would hopefully help the school retain most of the first freshmen class in the program.

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