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Demonstrations in Large Enrollment Courses: Designing for Impact

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Dr. Ira Jerome Hill, University of Florida

Ira Hill is a faculty member in the Institute for Excellence in Engineering Education at the University of Florida, which focuses on improving large-enrollment, introductory engineering courses. Dr. Hill currently teaches programming for engineers across all majors. His research interests include developing and incorporating engaging demonstrations into the classroom and faculty development. His educational background includes a B.S. in Mechanical Engineering from the University of Pittsburgh and a M.S. and Ph.D. from the University of Florida. He has experience in implementing robotics solutions for biomechanics applications, including a postdoctoral fellowship with the UF Orthopaedics and Sports Medicine Institute.

Dr. Philip Jackson, University of Florida

Demonstrations in Large Enrollment Courses: Designing for Impact

What impact do course demonstrations have on engineering students motivation and knowledge? Can the addition of a few core demos of engineering practical applications influence the effectiveness of course materials across students of different ethnic backgrounds and genders? This work investigates the design and effect of in-class demonstrations in three engineering service courses: Computer Programming for Engineers Lab, Circuits, and Dynamics, offered at a land-grant public university.

Within these service courses our college of engineering has set goals of improving retention and student self-motivation for active participation. This work outlines multiple in-class demonstrations; including physical demonstration structures and related core course learning outcomes for three service courses. Demonstrations are designed to show practical applications of course concepts for students across multiple majors. This work highlights each demonstration with pictures and the basic details of experimental setup for the benefit of other universities interested in developing their own related materials.

Following each in-class demonstration students are anonymously surveyed about their impressions and the impact of the in-course demonstrations. Student surveys include qualitative and quantitative feedback of the impact of the demonstrations on: student engineering topical interest, self-motivation to attend class, inspiration to learn demonstration related concepts further, and both immediate and longer-term retention of related course theory knowledge. Outcomes of student survey results are examined statistically in regards to results by: overall response of all students participating, impact of each specific demonstration, responses by student gender, and responses by student reported ethnic background; in order to evaluate the impact of demonstration inclusion across multiple audiences.

College Instructed Service Courses

The engineering faculty behind the courses in this study all have traditional Mechanical Engineering undergraduate and doctoral degrees, but their home department and research interests are within the Institute for Excellence in Engineering Education, which is part of the Herbert Wertheim College of Engineering, at the University of Florida. This study examines the impact of demonstrations within three courses: 1) Computer Programming for Engineers Lab (MATLAB and C++), 2) Circuits, and 3) Dynamics. The courses are traditionally courses with enrollments of students from a diversity of engineering majors taken during the second year of undergraduate studies.

'Computer Programming for Engineers Lab' is a laboratory course, held in a technology-enabled classroom (Figure1). Each laboratory section is capped at a maximum of 60 students, with each student bringing their own computer to the technology classroom, which is equipped with interactive group table seating. The structure of the laboratory course and classroom makes for an interactive experience for students. These laboratory courses serve students from Aerospace, Biomedical, Biological, Chemical, Electrical, Materials Science, Mechanical, and Nuclear Engineering. Additionally, some students wishing to learn programming as a technical elective from outside the college have participated from Astronomy, Geomatics, Physics, and Statistics.

Figure 1: Technology enabled interactive computer classroom used for Computer Programming for Engineers Laboratory instruction (MATLAB and C++). Dr. Ira Hill instructing students on sensors during Speed Gait Demonstration day.

‘Circuits’ in this study is the version of circuits for non-electrical engineers. It is a large enrollment service course, taught in a traditional lecture style, except it is held in a studio classroom. Students have the option of attending each lecture live, or watching the lectures online the same day the live lecture is held. Lecture videos stay online all semester, for students to review as needed. Course exams are held as live, large assembly written exams. This course fulfills the circuit content requirements for students from Aerospace, Biomedical, Chemical, Civil, Environmental, Industrial, Materials Science, Mechanical, and Nuclear Engineering majors.

‘Dynamics’ in this study is the version of dynamics for non-mechanical engineers. It is a large enrollment service course, taught in a similar studio classroom setting as ‘Circuits’; with attendance optional lectures, and live assembly exams. This course meets the dynamics requirements for student from Biological, Chemical, Civil, and Environmental Engineering majors. Figure 2 shows the typical view into the lecture based studio classroom used for teaching both Dynamics and Circuits courses surveyed in this study.

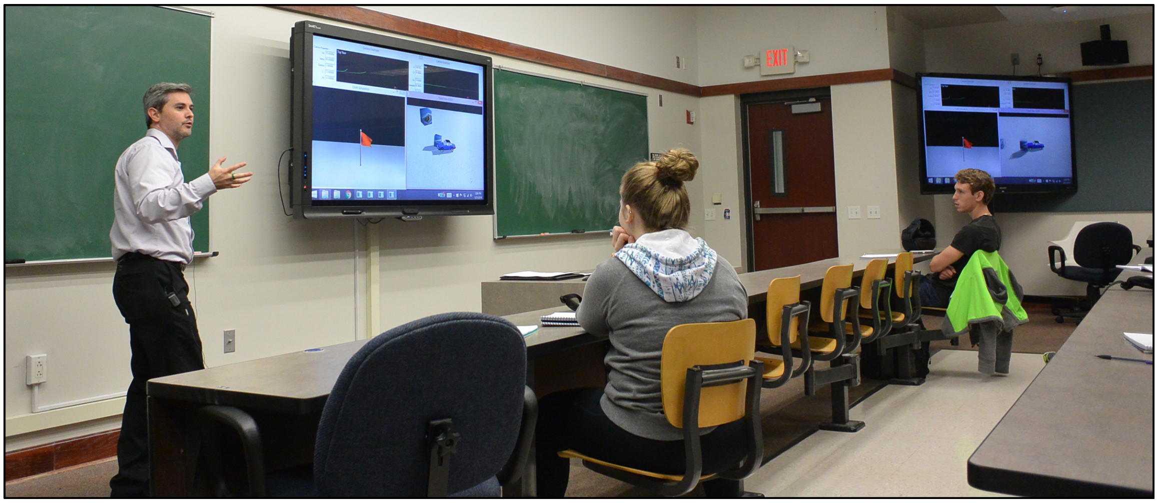


Figure 2: Dr. Philip Jackson instructing students during digital dynamics demonstrations in the lecture style studio classroom. The same type studio classroom is used for both Dynamics and Circuits, with an attendance optional model allowing a single live lecture time to serve a very large enrollment course in a single section, with online lecture videos available to all course students for the duration of the semester.

Demonstrations in Computer Programming for Engineers Laboratory

Two different demonstrations are examined in Computer Programming for Engineers Laboratory in this study. While some may not not consider the number of students in this lab 'large', the lab does have a parallel lecture course with it. Demonstrations developed in this laboratory are being considered for the large enrollment lecture sections of the associated programming courses.

Programming Demonstration 1: Roomba Exploration Robot: The iRobot Create 2 provides students an excellent platform for exploring robotics and programming. It includes numerous sensors such as infrared and motor encoders and is fully functional as is. This demo takes advantage of the Create 2 to give students a glimpse of the engineering challenges of controlling a robot over wireless communication to explore unknown environments. Students often have difficulty connecting introductory programming concepts to real-world applications, and this demo helps make that connection. The learning outcomes include the following:

- Give students hands-on-experience with robotics
- Motivate students to apply basic programming to robotics
- Expose students to working with sensor data, including infrared, contact, encoders, camera

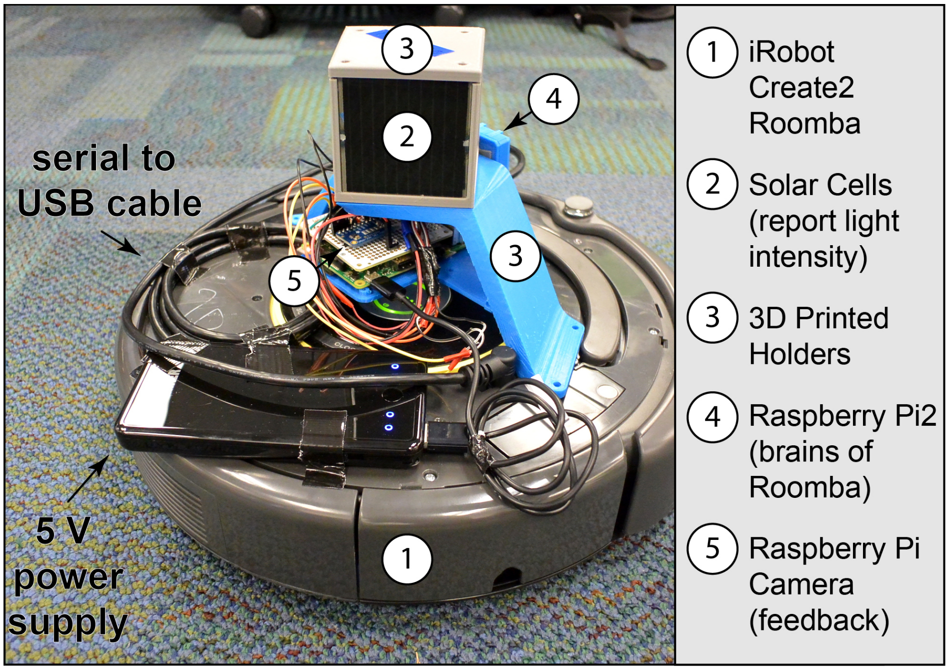


Figure 3: Roomba exploration hardware. Components include an iRobot Create 2 Roomba, Solar Cells (report light intensity as analog voltage), 3D printed holders, Raspberry Pi 2 (brains of Roomba), Raspberry Pi Camera, Raspberry Pi Prototype Hat (mounting surface fro electronics), USB Wifi adapter (students computer signals to Roomba), Anker 5V power supply, FTDI Serial to USB Cable, and an ADS1115 ADC (Convert analog solar cell signals to digital).

The challenge in having students wirelessly control the Create 2 is building the necessary software foundation that allows students to work with the robot in a reasonable time frame. iRobot provides several well-document tutorials, including using a Raspberry Pi as the brains of your setup. The Raspberry Pi connects directly to the Create 2 through a USB to serial cable, allowing students to send wireless commands to the Create 2 from their laptop using any traditional programming language. These commands let students drive around, play musical notes, or have the Create 2 return to its docking station. Furthermore, camera data from the Raspberry Pi is made available as a website that students can view for visual feedback.

Students are split into groups and presented with the challenge of exploring an unknown environment to find an object of interest. A comparable real-world example is having robots explore a dangerous environment for people who need assistance. With this in mind, students must use their robots to explore the hallways outside of class and locate a hidden target. As a group, they develop the necessary software to control and drive their robot. Furthermore, students cannot leave the classroom but instead must rely on the camera feedback while exploring. Students have completed their challenge once they show the hidden target centered in their camera view.

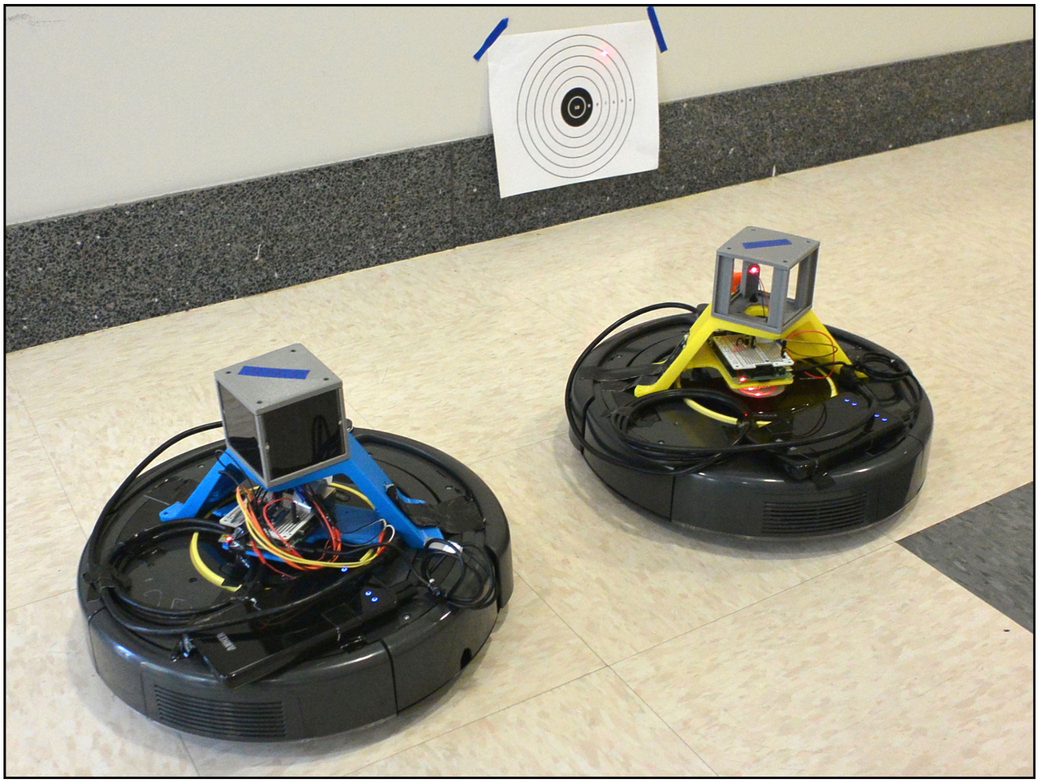
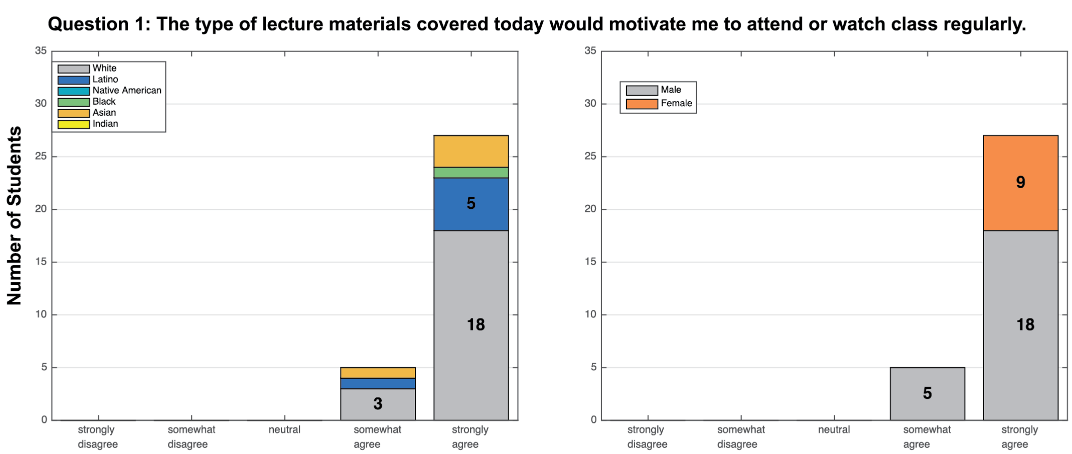
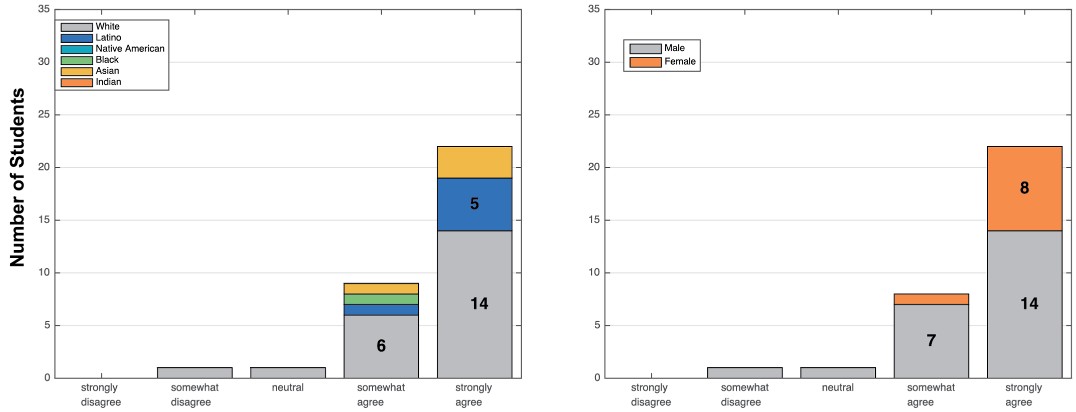


Figure 4: Roomba exploration robots in action during demonstration day.

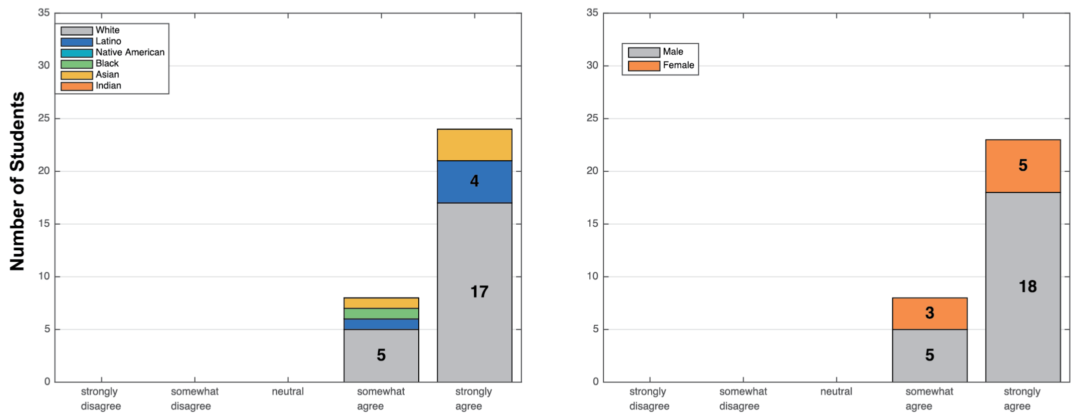
Student Survey Results: Roomba Exploration Robot: Following the demonstration the course students were anonymously surveyed on the impact of the in-class demonstrations. The survey results from each question are examined based on both self-declared gender and ethic background of students. The Roomba Robot was demonstrated in the C++ section of the laboratory class.



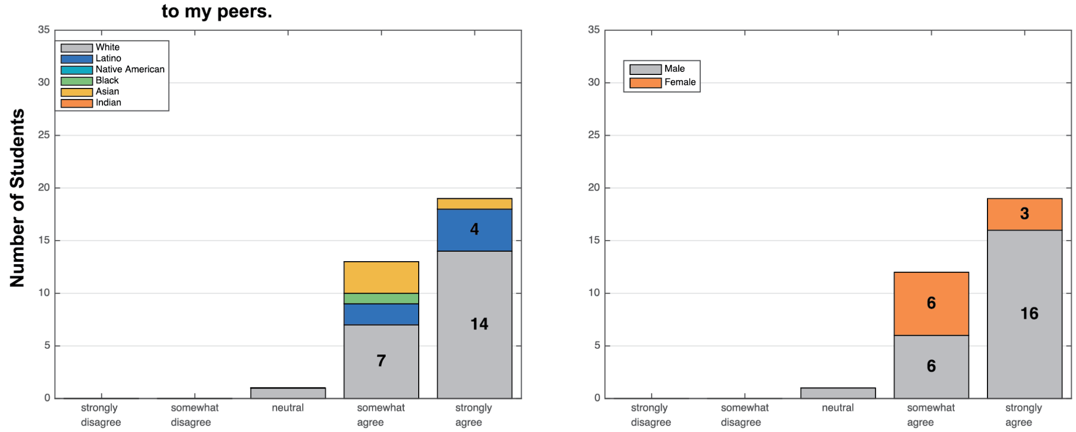
Question 2: This lecture motivated me to investigate related class topics further.



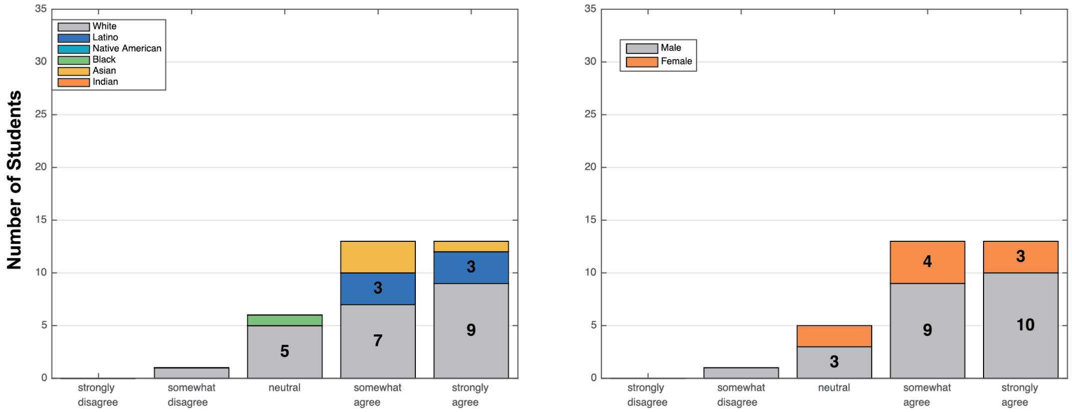
Question 3: The in-class demonstration of Roomba Robot and Dr. Hill's description helped me understand the application of course materials to engineering.



Question 4: I feel that I could explain the basic principles involved in today's demonstration of the Roomba Robot to my peers.



Question 5: I feel that I could explain the basic principles involved in today's demonstration of the Roomba Robot a semester from now.



Programming Demonstration 2: Speed Gait: The speed gait demonstration provides students with hands-on-experience developing a real-world programming application. Students brainstorm and develop an inexpensive system to measure the average walking or running speed of patients for a biomechanics lab. The strength of this demo is in its simplicity; students develop a useful tool from common engineering materials, achieving the following learning objectives:

- Expose students to real-world programming applications not seen in lecture
- Inspire students to connect programming and engineering design
- Instruct students on how to collect, process, and visualize data
- Help students appreciate the details in implementing a real-world application using fundamental programming concepts

To begin the demonstration, students are introduced to traditional equipment in a Biomechanics lab, such as camera-based motion capture, gait mats, and instrumented treadmills. While these instruments are useful in evaluating the biomechanics of patients, they are often costly and difficult to transport. Students are then organized into groups and challenged to develop a cost-effective alternative that only needs to measure gait speed. It is important that students consider the design with material cost along with an outline (or pseudo-code) of the programming involved.

Students share their designs with their peers, and the class discusses the advantages and disadvantages of each. Finally, students build one possible implementation of the design using solar cells and laser diodes. Volunteers help the instructor interactively build and test the system, including the software design. Finally, everyone determines his or her natural walking speed using the system.

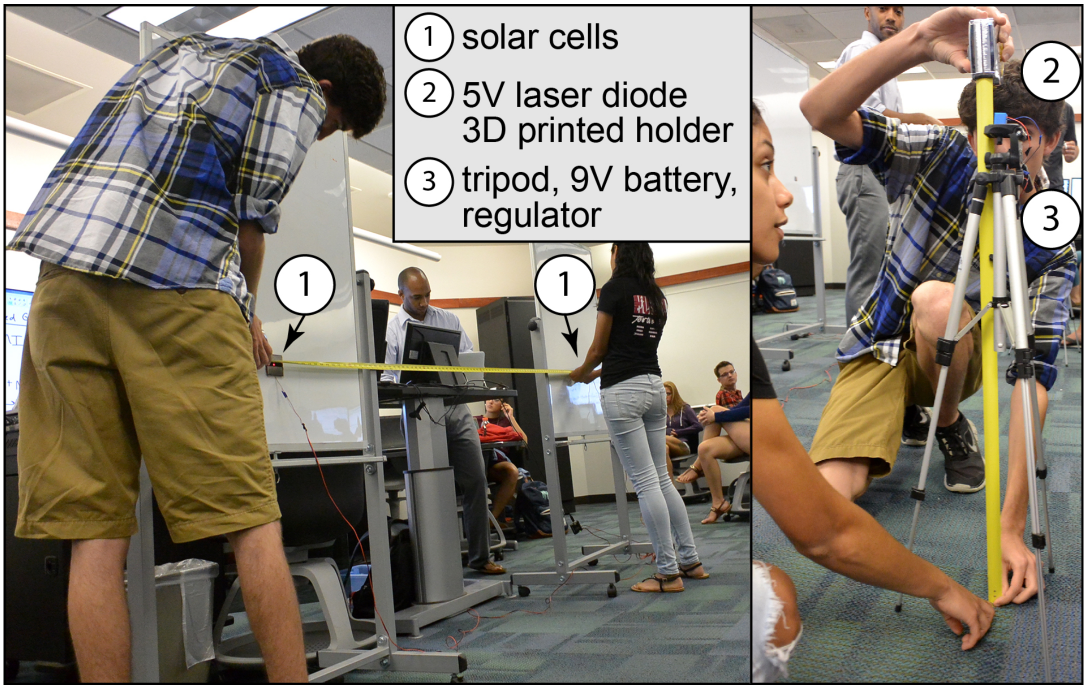
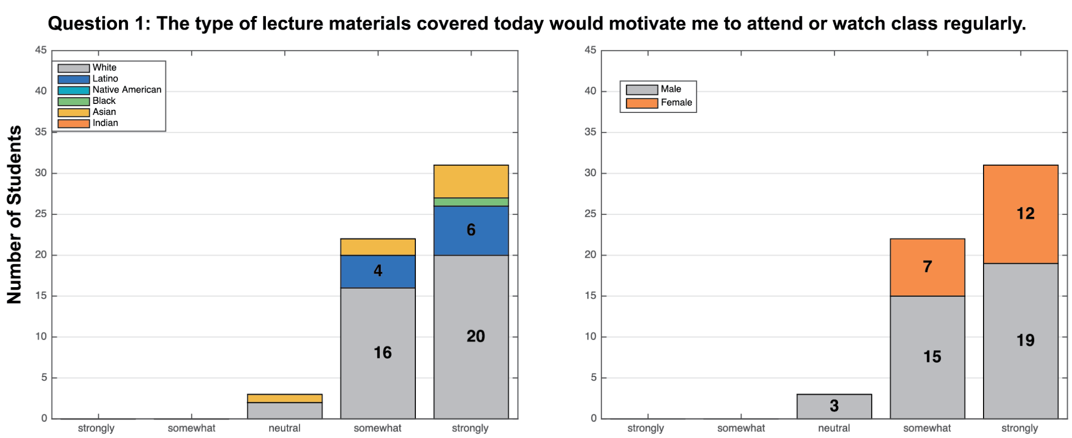


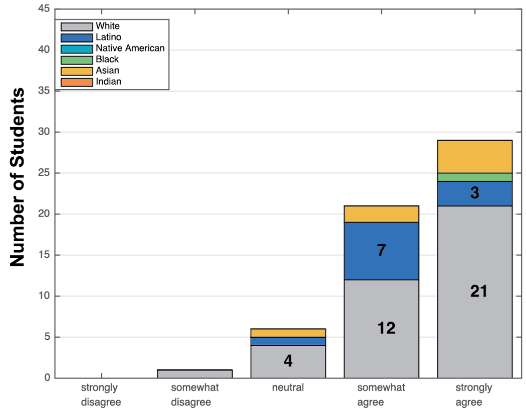
Figure 5: Speed Gait demonstration setup. Components include Solar Cells (report light intensity as analog voltage), 5V Laser Diode (trip mechanism for precise timing), Camera Tripods, 3D printer laser mount, USB Data Acquisition Device (measures solar cell voltage), and a 9V battery with regulator (laser power supply).

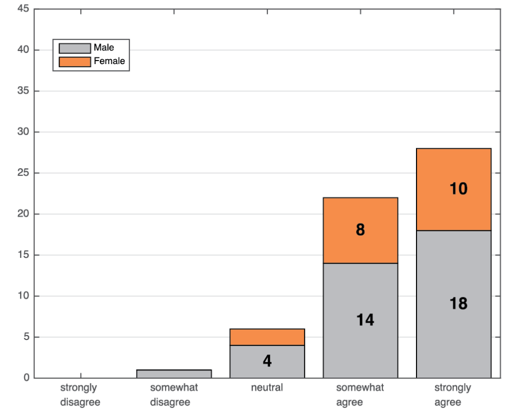
Student Survey Results: Speed Gait: Following the demonstration the course students were anonymously surveyed on the impact of the in-class demonstrations. The survey results from each question are examined based on both self-declared gender and ethic background of students. Speed Gait was demonstrated in both the MATLAB and C++ sections of the laboratory class, so there are two sets of survey results below.

MATLAB Speed Gait Survey Results:

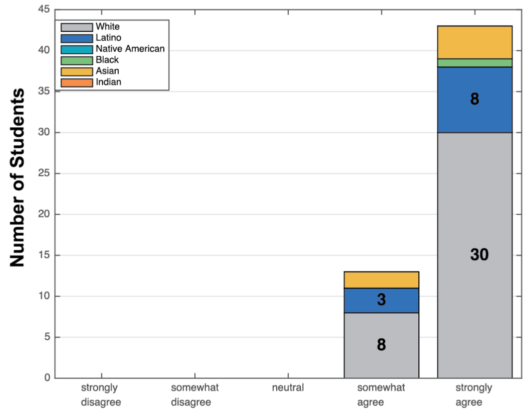


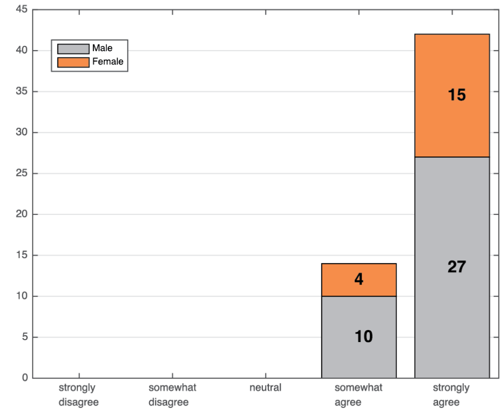
Question 2: This lecture motivated me to investigate related class topics further.



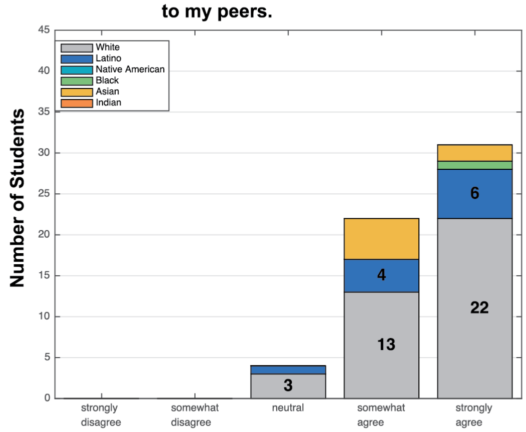


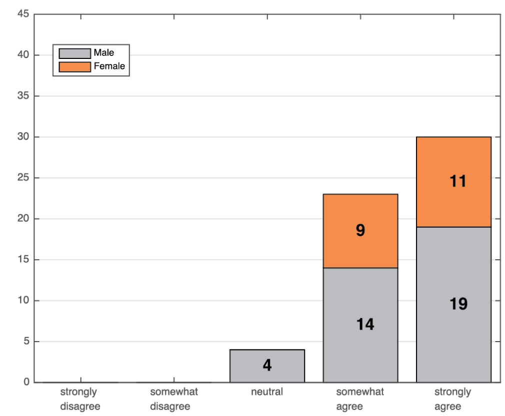
Question 3: The in-class demonstration of Speed Gait and Dr. Hill's description helped me understand the application of course materials to engineering.



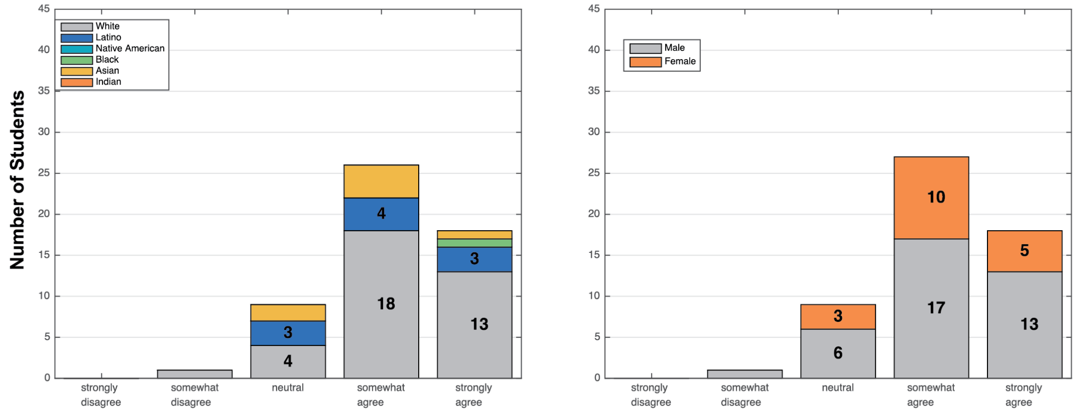


Question 4: I feel that I could explain the basic principles involved in today's demonstration of Speed Gait to my peers.



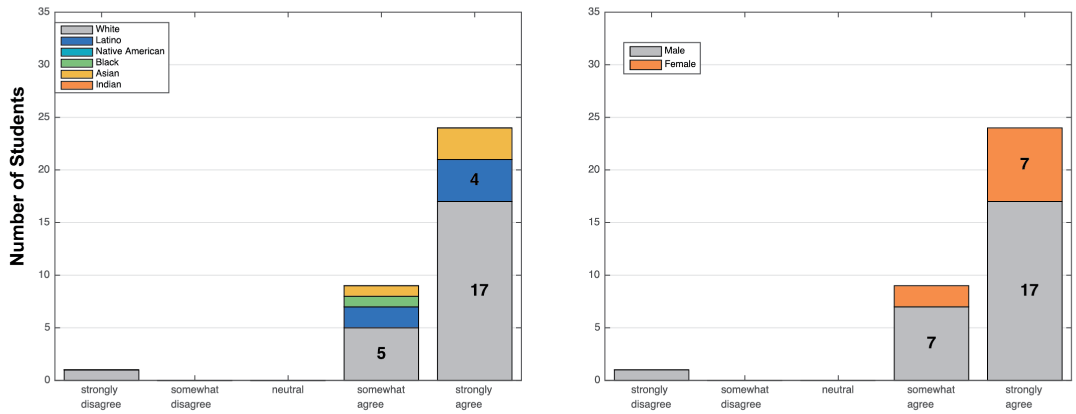


Question 5: I feel that I could explain the basic principles involved in today's demonstration of Speed Gait a semester from now.

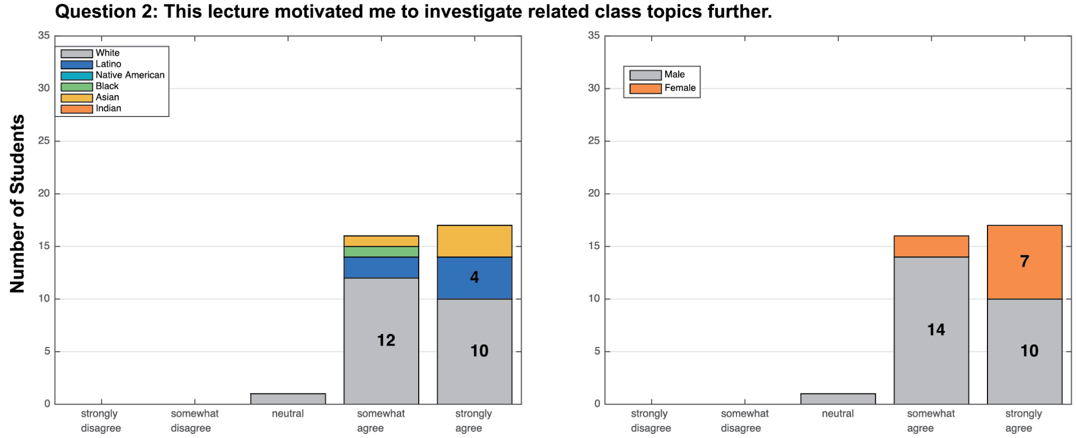


C++ Speed Gait Survey Results:

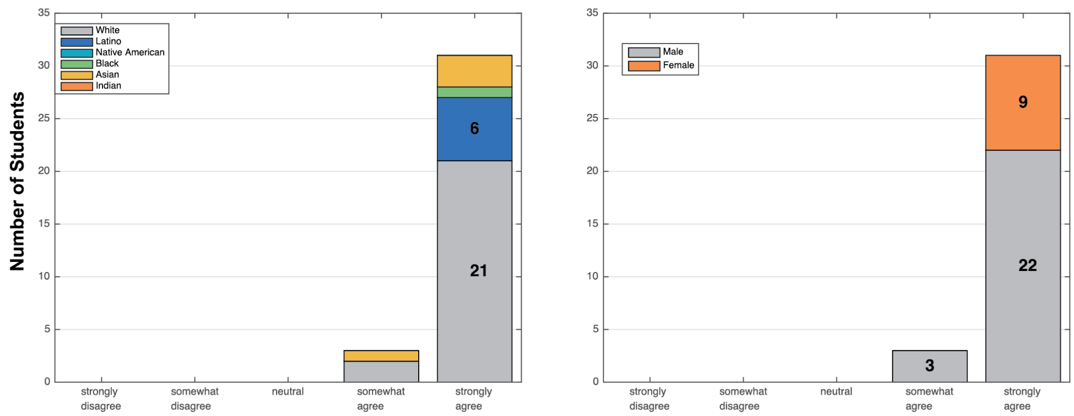
Question 1: The type of lecture materials covered today would motivate me to attend or watch class regularly.



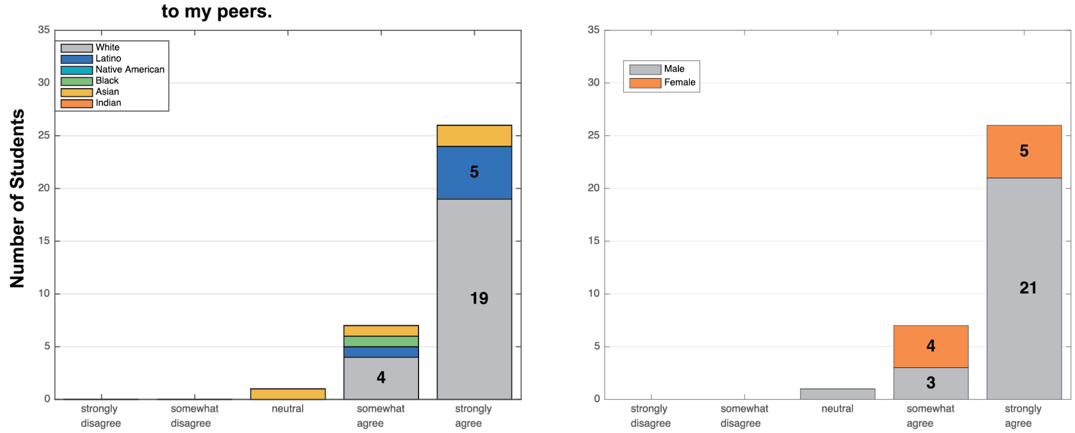
Question 2: This lecture motivated me to investigate related class topics further.



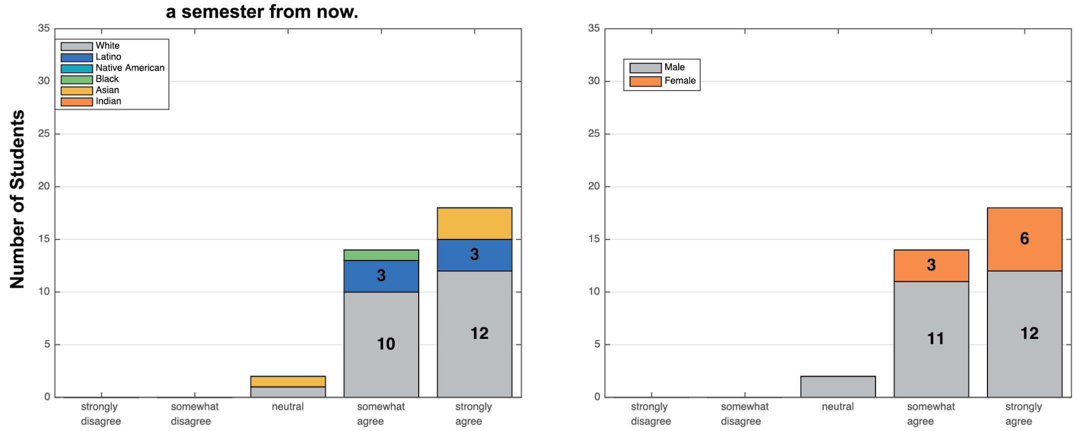
Question 3: The in-class demonstration of Speed Gait and Dr. Hill's description helped me understand the application of course materials to engineering.



Question 4: I feel that I could explain the basic principles involved in today's demonstration of Speed Gait to my peers.



Question 5: I feel that I could explain the basic principles involved in today's demonstration of Speed Gait a semester from now.



<u>Demonstrations in Circuits: All About Energy</u>

The version of Circuits examined in this study is for non-electrical engineering majors. It is a large-enrollment course, with regularly between 300-400 students in the single section of the course offered each semester. With the variety of students majors of

Aerospace, Biomedical, Chemical, Civil, Environmental, Industrial, Materials Science, Mechanical, and Nuclear Engineering, the main goal of course demonstrations is to tie in practical applications across many majors of fundamental core concepts instructed in basic circuits. The emphasis for practical applications center around the theme of energy, which is universal to the variety of majors within the course. Six small demonstrations were discussed on a single 'Energy Demo Day' to tie together course concepts to the variety of majors and potential applications students might see in engineering practice.

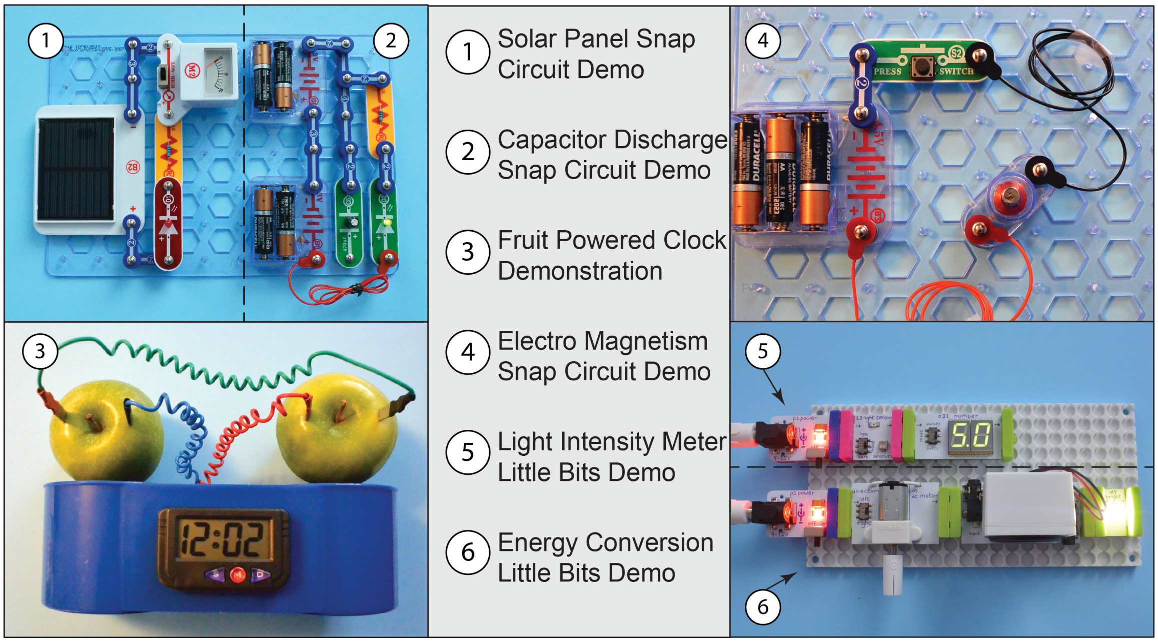


Figure 6: Energy Day Demonstrations used in Circuits to show practical applications of course materials to students in a variety of engineering majors.

Solar Panel Snap Circuit Demo: Using a Snap Circuits kits, a simple solar panel demo was constructed with an energy meter. Course discussion during the demonstration went into describing photovoltaics, efficiency, electronic materials, environmental impact of design, energy storage, and energy conversion.

Capacitor Discharge Snap Circuit Demo: Using a Snap Circuits Kit, a basic capacitor was charged and sued to power an LED light. Course concepts of capacitor charge and discharge rates and engineering applications were discussed during the demonstration. Current research into space applications of capacitors use for powering experiments in vacuum were discussed and a related journal paper sent to the students.

Fruit Powered Clock Demo: This demonstration began with a proposal of question to students "Do batteries grow on trees?" Students engaged in some related guesses leading up to the demonstration using a simple fruit clock kit. The related student discussion centered on chemical to electrical energy conversion, and articles on current groups doing research of alternative energy sources based on food waste and materials waste for anodes and cathodes.

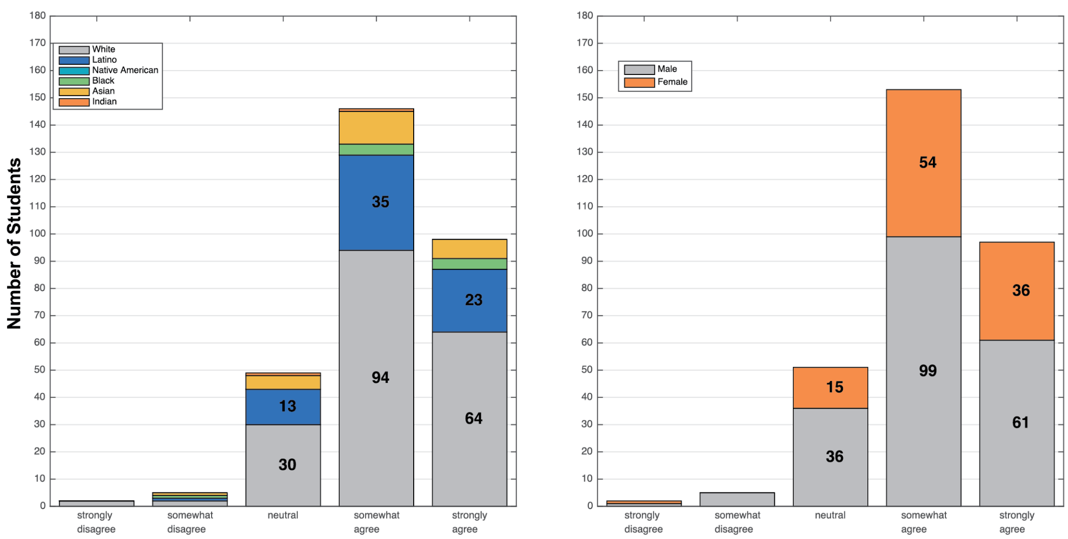
Electro Magnetism Snap Circuit Demo: Discussed how an electromagnet works and outlined related energy conversion and potential EM applications within industry for aerospace, biomedical, chemical, civil, environmental, industrial, materials science, and mechanical engineering students in class.

Light Intensity Meter Little Bits Demo: Using a Little Bits kit, outlined basics of low voltage sensors and use in various majors for knowing data operational ranges and uncertainty of meters.

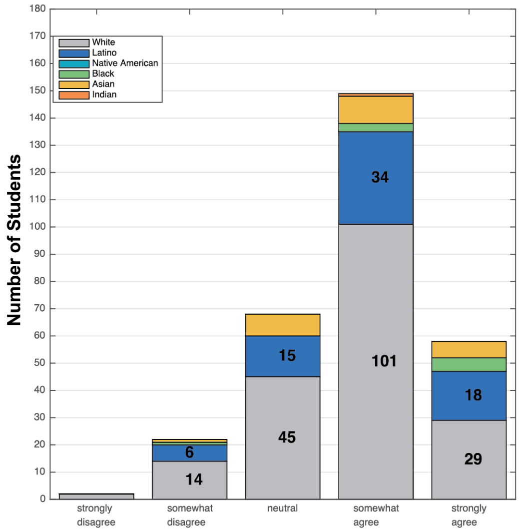
Energy Conversion Little Bits Demo: Using a Little Bits kit, demonstrated the various forms of energy with simple devices (battery-potential, motor-kinetic, speaker-vibrational, light-electromagnetic) and relation to circuits course materials and various engineering majors.

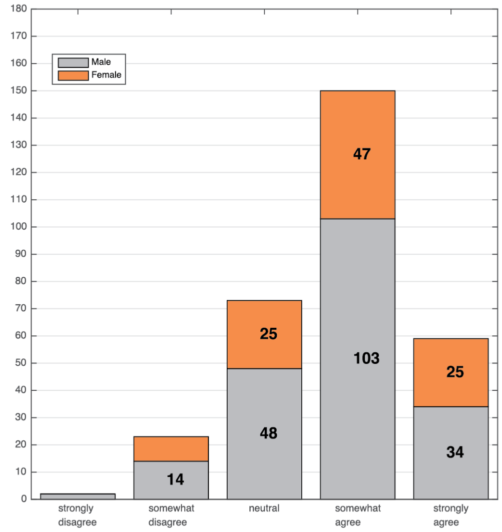
Student Survey Results: Energy Demo Day: Following the demonstration day the course students were anonymously surveyed on the impact of the in-class demonstrations. The survey results from each question are examined based on both self-declared gender and ethic background of students.

Question 1: The type of lecture materials covered today would motivate me to attend or watch class regularly.

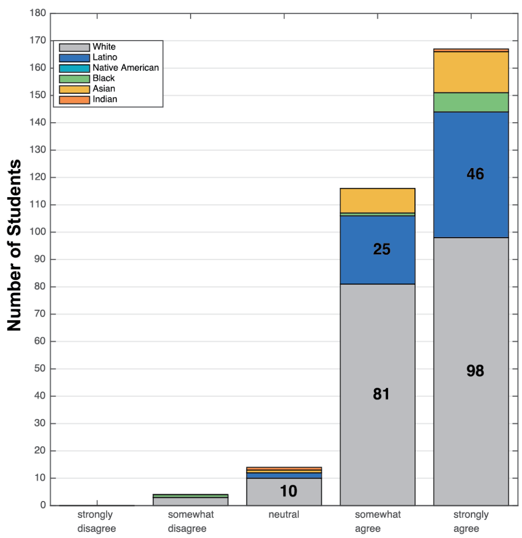


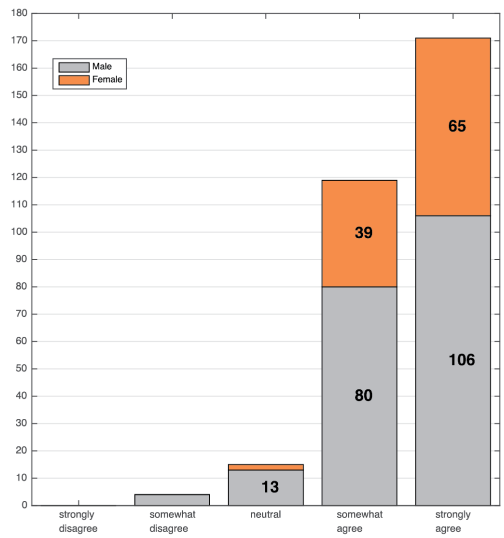
Question 2: This lecture motivated me to investigate related class topics further.



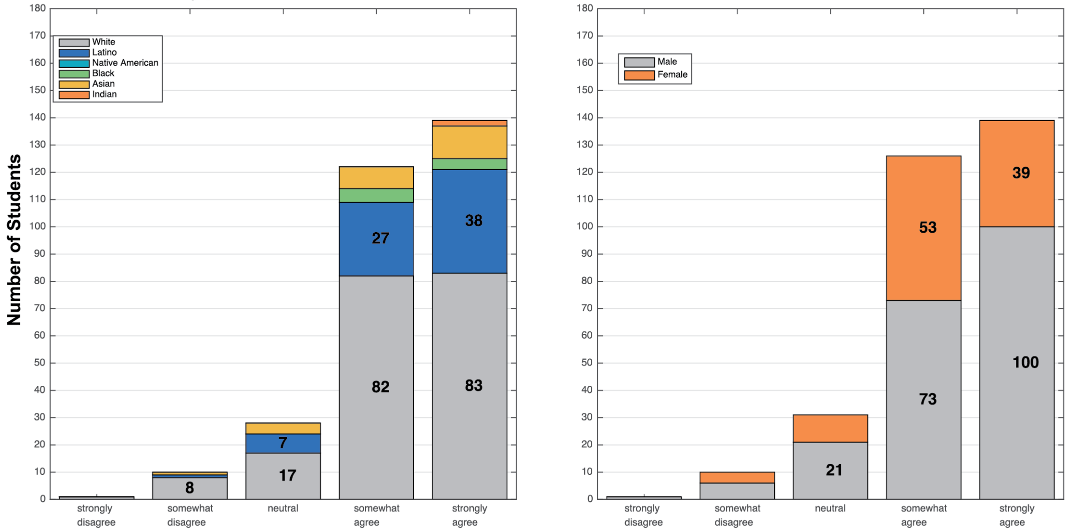


Question 3: The in-class demonstration of Circuits and Energy and Dr. Dickrell's description helped me understand the application of course materials to engineering.

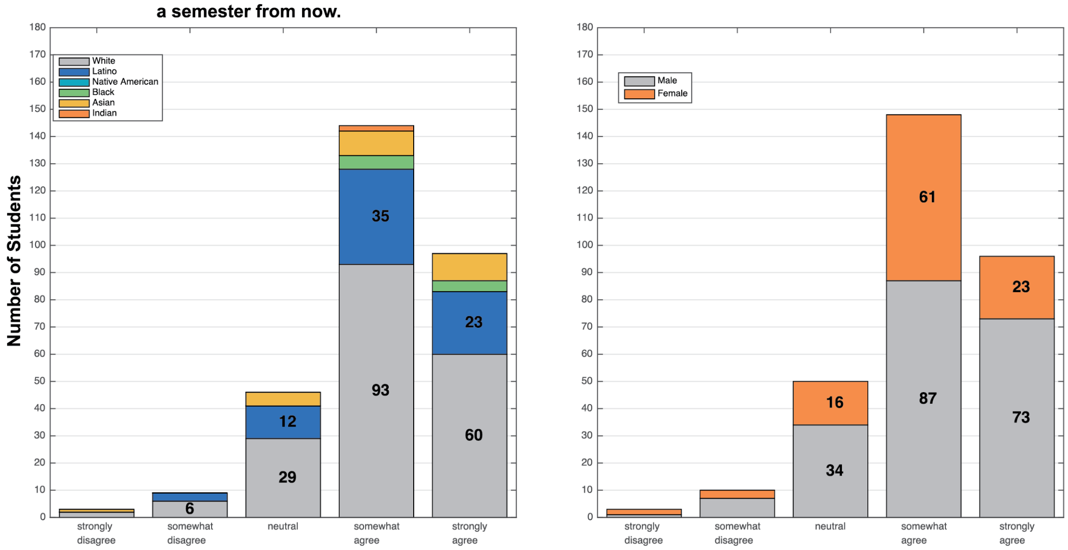




Question 4: I feel that I could explain the basic principles involved in today's demonstration of the Circuits & Energy to my peers.



Question 5: I feel that I could explain the basic principles involved in today's demonstration of Circuits & Energy a semester from now.



<u>Demonstrations in Dynamics: Digital Simulations</u>

Students are presented with several real-world examples of dynamics simulations in the form of animations taken from popular culture. Examples include the computer generated animation of spacecraft from science fiction films, computer generated characters from fantasy films, and the animation of human characters from popular video games. Next students are shown animations from various engineering presentations that show the simulated deformation of solid objects, the simulated flow of air currents in a weather model, and the simulated results of an automotive crash test. What all of these examples have in common is they are all visually appealing products of some underlying dynamics model.

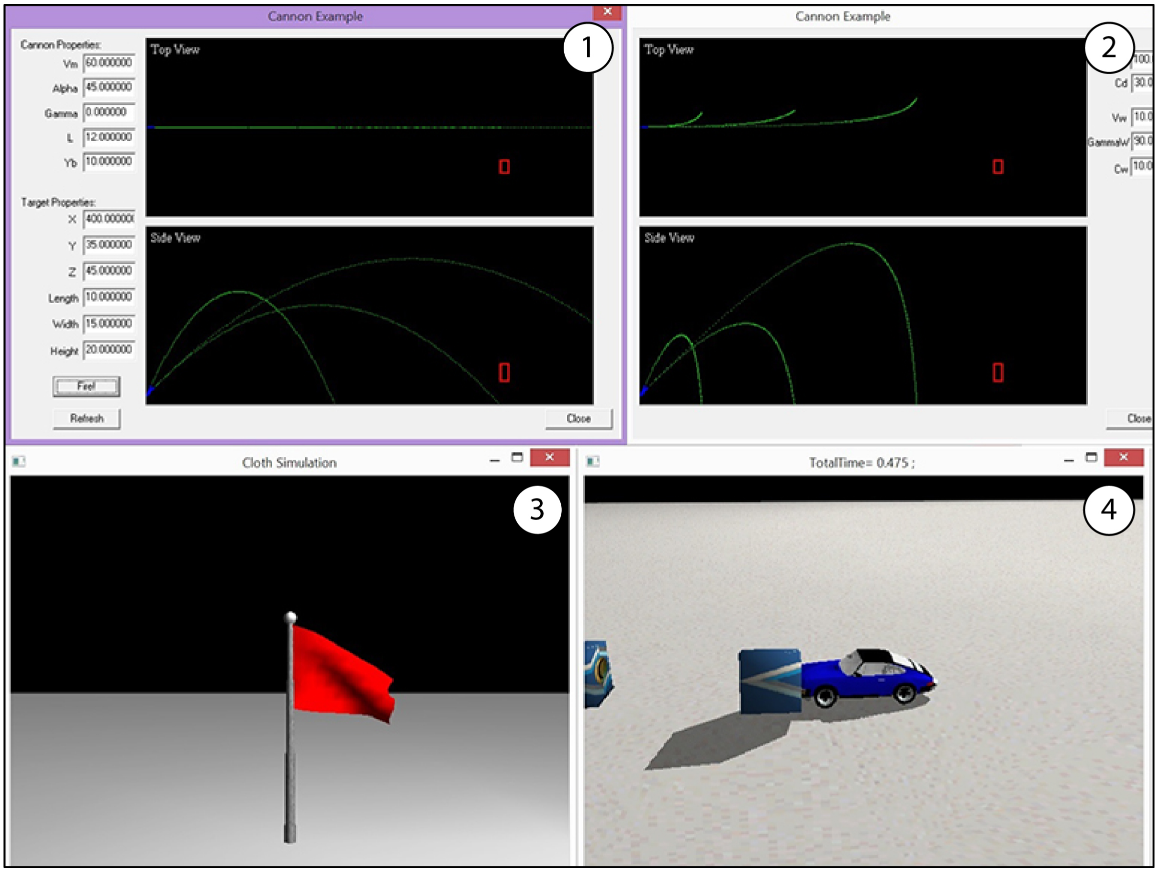


Figure 7: Digital Dynamics Simulations: 1) Simple projectile motion without wind resistance, 2) Projectile motion with a linear-velocity drag model, 3) Periodically driven real-time cloth simulation with 49 nodes, and 4) Three-dimensional conservation of linear and angular momentum simulation

Each demonstration begins with the use of the previous examples as context for the creation of original simulations that directly correlate to topics covered in class. Over the next fifteen minutes, students are presented with several example problems and exercises that have been used in previous lectures, implemented now as digital real-time simulations. These simulations illustrate many of the basic topics covered since the beginning of the course, such as two-dimensional projectile motion alongside more advanced dynamics concepts such as two-dimension projectile motion with drag, cloth dynamics, and three-dimensional rigid body collisions. The discussion that follows seeks to achieve the following:

- Provide students with practical applications of dynamics theory in engineering and non-engineering disciplines
- Demonstrate the applicability of two-dimensional particle dynamics
- Illustrate the complexity of three-dimensional rigid-body dynamics
- Motivate students to apply dynamics principles to real-world scenarios
- Motivate students to explore digital solutions to in-class and real-world problems

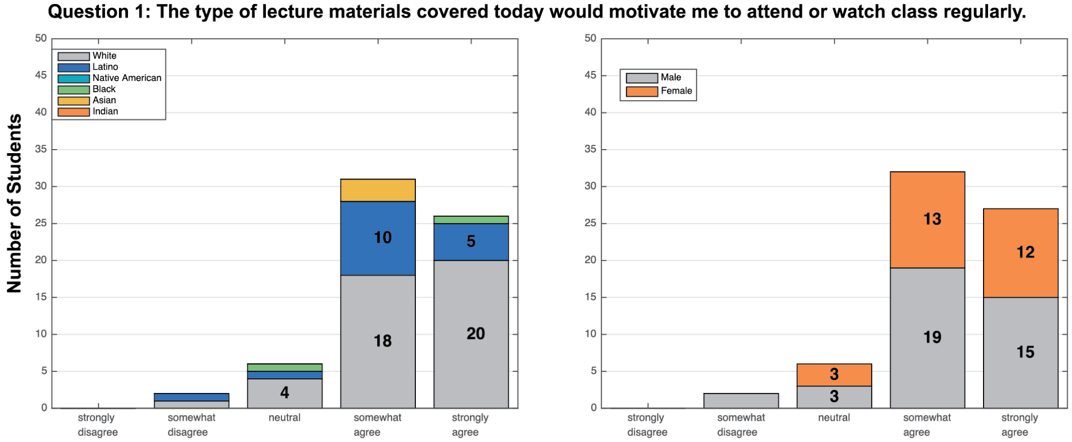
The digital simulations are implemented in C++ and all executable programs and source code files are provided to the students through the course website for download. Students with previous programming experience, or a desire to learn programming concepts, are encouraged to download and experiment with the source code using the published instructions and documentation for guidance.

Of particular interest is the two-dimension projectile motion simulation, as its underlying physics model is one in which the students have already calculated manually. The projectile motion simulation takes as inputs the parameters describing the initial conditions: the starting position of the projectile, the starting velocity, and the angle at which the projectile is launched. The simulation then animates the motion of the projectile in real time until the particle reaches the ground again. Values calculated by the simulation are then tested against calculations made in previous class examples.

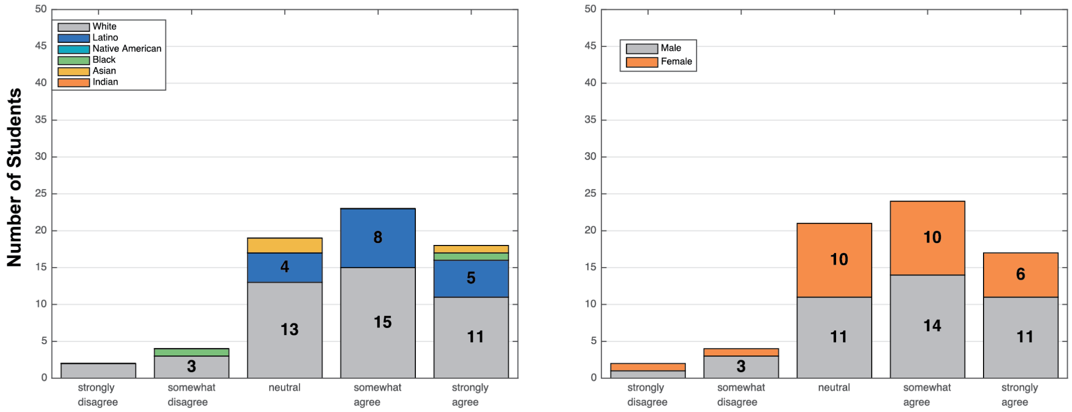
Students are then asked to solve the opposite problem. If the point where the projectile hits the ground is known, can we find the original velocity and angle of launch? Students are then instructed to use a trial-and-error method to guess the correct input values until the simulation achieves the desired range. Now, while this problem can be solved analytically, without the need for a trial-and-error solution, the power of the digital simulation is revealed. A physically accurate simulation may be able to iteratively find the solution to a dynamics problem regardless of complexity even if an analytical solution cannot be found.

Student Survey Results: Dynamics – Digital Simulations: Following the demonstrations the course students were anonymously surveyed on the impact of the in-class demonstrations. The survey results from each question are examined based on both self-declared gender and ethic background of students

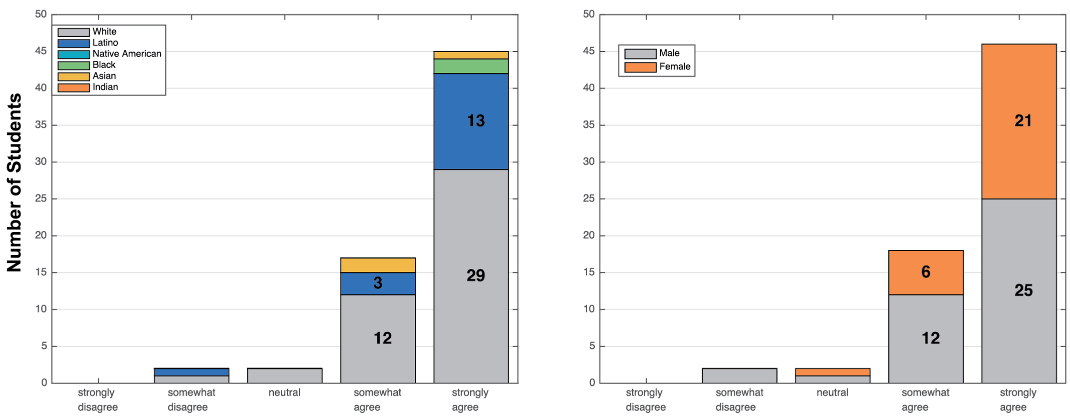
Question 1: The type of lecture materials covered today would motivate me to attend or watch class regularly.



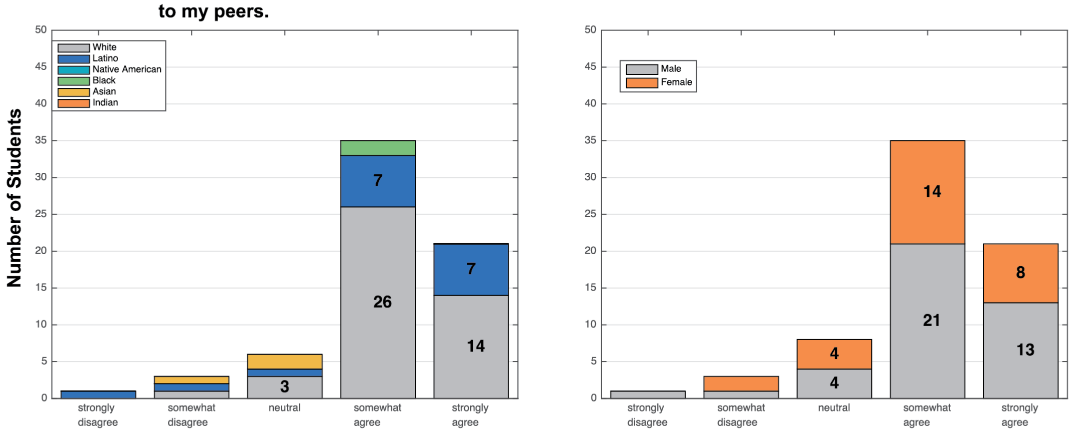
Question 2: This lecture motivated me to investigate related class topics further.

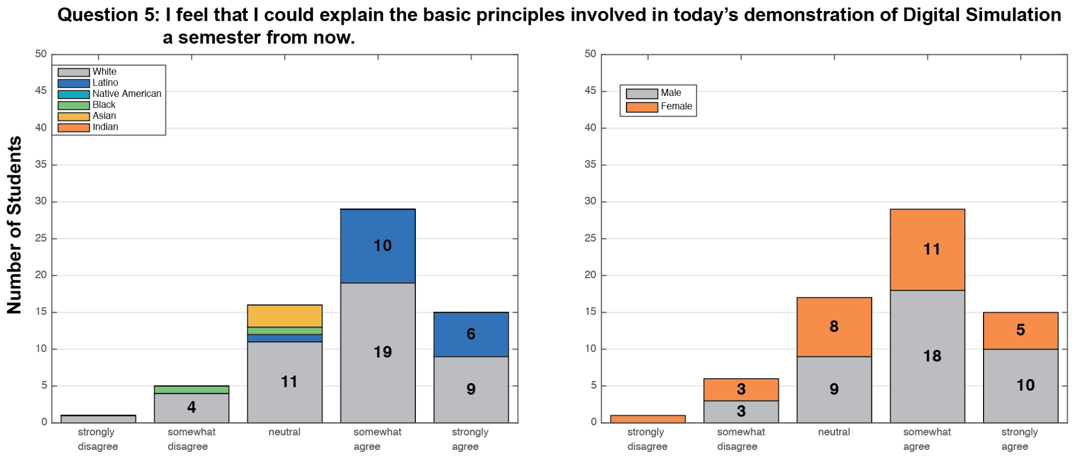


Question 3: The in-class demonstration of Digital Simulations and Dr. Jackson's description helped me understand the application of course materials to engineering.



Question 4: I feel that I could explain the basic principles involved in today's demonstration of Digital Simulation to my peers.





Discussion and Conclusions

This work examined both quantitative and qualitative feedback from student groups surveyed following in-class demonstrations. Analysis of these large data sets across multiple courses is examined on a question-by-question basis to analyze impact generally and across gender and ethnic background basis.

Question 1 Discussion: "The type of lecture materials covered today would motivate me to attend or watch class regularly." It is well known that it can be difficult with traditional lectures to keep students motived and attending class, especially in a large lecture setting [1,2]. Studies have shown there is a positive correlation between attendance and class performance; therefore changes to lecture that motivate students to attend are necessary [3]. The engineering education literature has shown several alternatives to the traditional lecture, including inductive teaching, problem-based learning, and active learning [4,5,6]. Our hypothesis is that incorporating demos based on realistic and engaging problems is another alternative to improving lecture. Demonstrations provide a useful break during the normal lecture and can help students connect subject fundamentals to a tangible problem. If students are excited about the class material, they will want to take ownership of their educational experience.

Across all courses surveyed, every demonstration had a positive impact on students' desire to attend class regularly, across genders and all ethnic groups. 84.36% of male and 88.89% of female students agreed to this question. Splitting the responses by ethnic group had a similar trend with approximately 80% of student agreement. The largest group to disagree was in a single class surveyed, the Black/African Americans at 7.14% but that was from a single student out of 14 responses. In general, these data support that the demonstrations were effective in engaging the students and propelling them to attend class.

Question 2 Discussion: "This lecture will motivate me to investigate related class topics further." Lecture attendance is important, but students should also be generally excited about the material they're learning. Traditional lectures can again fall short here, leaving students unsure or not motivated to explore the class material. Anecdotal evidence from student feedback has shown that they do not always see the point of the introductory material they are required to learn. This often leads to students doing the bare minimum to complete an assignment or study for an exam. Properly implemented demonstrations can help with this issue by challenging students with real-word applications. The key idea is to show students what is possible, peaking their curiosity, and encouraging them to explore on their own.

Similar to the first question, overall students felt the demonstration encourage them to explore a topic on their own. Having students attend lecture doesn't necessarily guarantee what students will do outside of class. 73.31% of male and 72.09% of female students agreed to this question, a slightly lower response than Question 1. Responses were still positive when split by ethnic group, with students agreeing between 73-85%. The key result here is that the correct demo can motivate students to do work outside of class.

Question 3 Discussion: "The in-class demonstrations helped me understand the application of course materials to engineering." The ability of students to understand why they are being taught concepts and how topics will apply to their field is critical for engaging students towards self-motivated learning. Structuring in-class demonstrations for students to clearly visualize or tangibly experience why mastering course concepts is important to engineering practice answers the all important question of many students of 'Why are we learning this anyways?" Faculty members in theory-heavy lecture courses can find students motivation and attention waning part way through the semester as more and more theoretical concepts and solution methods are covered. The addition of a few key in-class demonstrations to periodically remind students of the 'why' behind what they are learning can serve as boosters to student attention and retention within engineering courses.

Overall, students across all the courses examined found the in-class demonstrations helped them to understand the applications of the course materials they were learning, with 95% of students answering affirmative (62.5% 'strongly agree' plus 32.5% 'agree'). This positive affirmation of the effect of in-class demonstrations on the understanding of applications was seen across all genders and ethic backgrounds surveyed, showing positive impact for a diverse body of engineering students.

Question 4 Discussion: "I feel that I could explain the basic principles involved in today's demonstration to my peers." The effectiveness of in-class demonstrations can be shown in how they encourage students to engage in the course, in how they motivate students to learn more about course materials, and in how they provide concrete examples of real-world engineering. Perhaps most importantly, the effectiveness of in-class demonstrations may also be shown in how they directly affect the student's understanding and subsequent mastery of course topics [7,8]. Research has shown that participating in activities that break from traditional lectures can engage students in such a way that promotes increased performance in the course [9]. It has also been shown that a student's ability to instruct their peers is directly related to their understanding of material [10,11]. If participation in class demonstrations does indeed lead to improved class performance, then it may also influence their perception of their ability to excel at peer instruction.

The majority of students reported that they could indeed explain the basic idea behind each demonstration. Approximately 88% of students agreed to this question, a percentage that was closely mirrored across each ethnic and gender demographic. In general, the data supports the conclusion that in-class demonstrations have a positive effect on students' confidence in their understanding of class subjects.

Question 5 Discussion: "I feel that I could explain the basic principles involved in today's demonstration a semester from now." Not only may in-class demonstrations be useful for students to attain mastery of the course topics covered, but they may also contribute to the long-term retention of that information. Studies have shown that engaging in in-class activities tends to promote the storage of course material into long-term memory. Being able to explain the basic principles behind class demonstrations immediately after participating in the demonstrations may reflect their ability to understand and apply those principles. Being able to explain the same information after an extended period of time, however, may reflect the student's confidence in how close they are to attaining true mastery of the material.

It is, arguably, intuitive that one might expect that the confidence a student feels in their ability to explain demonstration concepts would decrease over time. Therefore one may expect that the percentage of students that agree that they can explain topics in a semester from now would be less than those that can explain the topics presently. This is indeed reflected in student responses with about 79% of students answering in the affirmative. As expected, this value is less than the 88% of students who could offer explanations in the present. In each course and in each demonstration, the number of students agreeing to Question 5 was less than the number agreeing to Question 4. Despite the decline, the overwhelming majority of students still agreed, suggesting that in-class demonstrations may be powerful tools in ensuring mastery beyond the current semester's commitment.

Qualitative Feedback Questions Discussion

In addition to the five quantitative survey questions discussed graphically, students were asked two free response questions for qualitative feedback on the in-class demonstrations. While the inclusion of all the quotes from students in these surveys would be length-prohibitive, three faculty-selected quotes from each course were included for each question that captured the essence of the motivation for in-class demonstrations in each respective course. While it is difficult to draw any quantitative conclusions from these selected student responses, the voices of these students summarize the intent of this work, to create meaningful experiences for students within traditional engineering courses by introducing in-class demonstrations designed for impact.

Qualitative Question 1: "What was the most memorable part of today's lecture?"

<u>Computer Programming for Engineers Responses:</u>

-"The way the lasers were able to read how you move when walking was interesting. I thought it was really cool how much data can be collected just by walking past lasers.

The most memorable part was that we were able to walk through the lasers and find out our speeds."
-*"The lecture was very interactive and woke everyone up. It was fun, racing each other and trying to beat the system. This is a large part of what made it memorable."*
-*"I think that every part of our in-class demonstration was incredibly interesting. Being able to actually see the real world applications to what we have been learning is amazing."*
Circuits Responses:
-*"The most memorable part of lecture was your ability, Dr. Dickrell, to tie such simple concepts to such complex problems. So often in my time here, professors and students alike get bogged down in details for an entire semester without remembering the breadth of applications. The most minute details and equations mean nothing if we don't know when or where to apply them. I have walked away from countless courses and quickly forgotten those details, but the subjects in which I am the strongest are the classes where professors focused on the "why" as much as the "how"."*
-*"Really the lecture as a whole was very interesting. It was enjoyable to see all these topics that we talk about in theory and get to see some of their real world uses. It's always helpful to see the applications because you learn more from it. There is an actual use that you can connect your knowledge of it to."*
-*"I enjoyed the background that went with all the examples, such as the use of capacitors on the space station and the inefficiency with solar panels. The real world problems combined with the functionality of the demos made it easier to visualize working with these types of energies and circuits."*
Dynamics Responses:
-*"The simulations were the most memorable part of the lecture. Seeing a simulation of what we will be calculating made me more interested in the material."*
-*"The beginning of the lecture was very intriguing for me because I am very interested in digital simulations. The technology and preciseness of these applications are astonishing. In my opinion this is exactly what many young engineers would love to get involved with."*
-*"The simulations used to help explain the topic. Having these simulations showed real life examples of what dynamics is used for, especially in industries that you never expected."*

Qualitative Question 2: "Was the lecture interesting, why or why not?"
Computer Programming for Engineers Responses:
-*"Absolutely! It was interesting to see a practical application of programming from different perspective (design, implementation, and demonstration)"*
- *"Absolutely, in the majority of my classes I feel so far removed from any of the applications of the material I'm learning. It was a nice change of pace to actually think about how what I'm learning can be applied to actual real life problems. At the same time for the first time in a long time, it actually felt like I was having any sort of fun in one of my classes and I was completely interested. If my classes involved demonstrations and introduction of technology like this, I would be way more compelled to attend and enjoy class."*

- "Yes. It was fun to first do brainstorming and then see a real application of different aspects of engineering."

<u>Circuits Responses:</u>

-"This lecture was very interesting because of the real-world applications of circuits. In a lot of engineering classes, the parallel between mathematical derivations and their applications is not clearly defined. However, this lecture made these connections apparent and thus had ample implications on my perspective of circuits."

-"The lecture was very interesting because, as a class, we were exposed to real applications, rather than theoretical problems that can be solved with pen and paper. Real applications peak our interest as engineers and makes us think of ways to solve the problems we face today."

-"The lecture was definitely interesting because of the demonstration, which applied the topics and concepts we were learning in class to a real life example. It is much easier to comprehend a topic when you are given demonstrations such as the ones presented in this lecture."

<u>Dynamics Responses:</u>

- *"Yes! More than anything, I thought it was really engaging because it applied to everyday life. Seeing the application of what we've been learning to movies was really great!"*
- *"Yes! I'm very interested in 3d physics modeling programs that are user friendly, and I have found a couple more programs to explore as a result of the lecture."*
- *"Yes it was. I find every lecture interesting, but the movie examples caught my attention even more and made me stay more focused. Knowing how the material can be applied in real life makes everything more interesting."*

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