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Five-Minute Demonstrations: Minimal Faculty Investment for Maximum Learning Impact

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Five-Minute Demonstrations: Minimal Faculty Investment for Maximum Learning Impact

This work examines a systematic approach of designing five-minute course demonstrations for use in large engineering lectures for active learning and course concept retention within a traditional engineering second year course. A one-page demonstration design question flow-chart was created and followed in formation of the five-minute demonstrations. These tangible brief activities, which students can physically operate during the lecture based course, are structured for students to develop a better engineering feel for the importance of theoretical concepts paralleled in the same lecture. With the need for innovative methods for engaging future engineers, these hands-on demonstrations are structured with the goal of realization of practical applications of mathematical based engineering course concepts [1]. Students have opportunity to individually actuate the demonstrations shown by the instructor as they are passed around the lecture hall to optimize students seeing, hearing, and physically experimenting briefly with the goal of improved retention of knowledge [2]. The demonstration design process and related flow chart can be used by faculty for demonstration construction within a variety of engineering service courses. Students in the lecture course are surveyed for qualitative and quantitative feedback on the impact of the hands-on five-minute demonstrations.

Demonstration Creation Flow Chart

A series of five progressive questions are used in the demonstration design process to create builds to complement each traditional lecture. Demonstrations are created maintaining key characteristics of: a) ease of build by faculty using inexpensive parts, b) portability to the lecture hall in a laptop bag, c) durability for passing around to all students in lecture to test themselves, and d) clearly reinforcing engineering concepts in physical practice of the theory paralleled in same lecture.

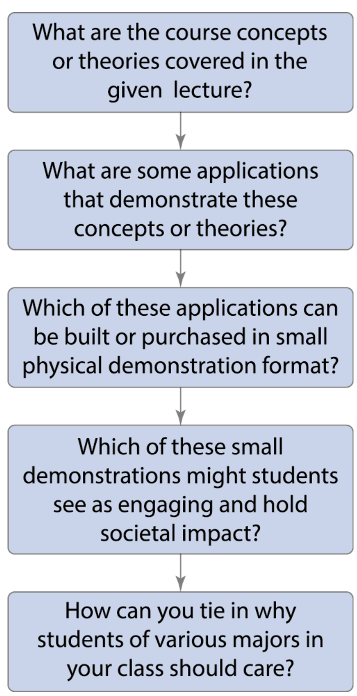


Figure 1: Five-minute demonstration creation flow-chart.

Highlighted Five-Minute Demonstrations
Three demonstration designs are highlighted, including the supplies and related lecture theories used in a 375 student ‘circuits for non-majors’ course at a public land-grant university. This course is overseen by the University of Florida Herbert Wertheim College of Engineering Institute for Excellence in Engineering Education, and not by specific department. The faculty member in charge of the course has a formal Mechanical Engineering educational background, with current research specialty in the area of Engineering Education. The largest fraction of students in the ‘circuits for non-majors’ course are Mechanical Engineering students, and demonstrations are designed to emphasize applications as well as building a foundation for basic electronics knowledge expected in subsequent major courses. These tangible brief demonstrations, that students can physically operate during the lecture based course, are structured for students to develop a better engineering feel for the importance of theoretical concepts paralleled in the same lecture, with the goal of realization of practical applications of mathematical based engineering course concepts.

The classroom in which this course in instructed has four teaching tools common in most engineering lecture halls: chalkboard, computer, stylus screen, and a document camera. The size of demonstrations is structured for portability to the classroom in a standard laptop bag, as well as for fitting underneath a document camera (standard 8.5” by 11” piece of paper footprint). Each demonstration is held on a small Montessori tray (simple tray with handles for early-childhood active learning). The Montessori tray format facilitates portability to classroom, sticking to a size profile for use under the document camera, and most importantly after the instructor demonstrates under the camera, each tray is passed around the large lecture hall so all students in attendance can physically interact with the demonstration they just saw explained and actuated by the professor. While these demonstrations may seem simple, even toy based in some cases, their structure optimizes the combined goal of impact on students of applications of theory they are learning, as well as the portability/durability for passing around to hundreds of students.

Sample Demonstration 1: Potato Clock – Batteries in Series to Recycle Waste Food
The first demonstration highlighted is the one voted most appreciated by surveyed course students for “What was the most memorable or your favorite course demonstration?” The theory that surrounds the in-class demonstration includes understanding what a simple battery cell is comprised of: anode, cathode, and acidic environment for electron exchange; how assumed current flow direction in circuit equations opposes actual electron flow, and how two “potato batteries” in series add effective voltage for application use. The societal impact discussion highlights a research project at the Hebrew University of Jerusalem using boiled potato slices to greatly improve the operational life of using food or food waste to create batteries and potential impact for power in third world countries and using food waste an an alternative power source.

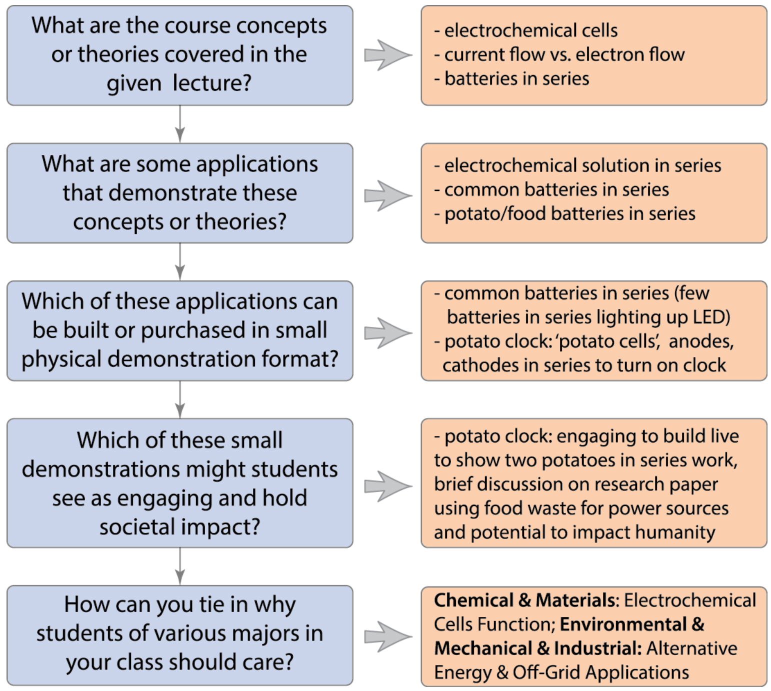


Figure 2: The demonstration flow chart as applied to Potato Clock demonstration.

The potato clock kit used is found for less than $12 on Amazon, the brand being "Green Science Potato Clock", along with the kit, two potatoes, and a standard multi-meter is used to complete the hands-on five minute demonstration. The two potato clock circuit is created live, the voltage drop across the two potato cells in series is measured, and students are shown general multi-meter use to measure voltage. The whole setup is then passed around the lecture hall for student experimentation.

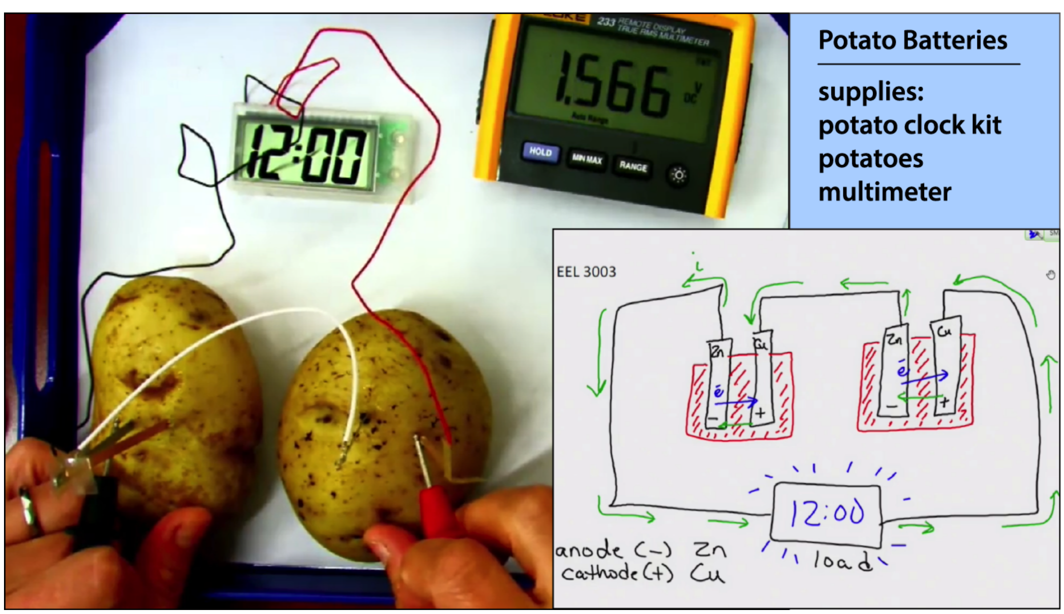


Figure 3: Potato Clock document camera view and stylus board current versus electron flow.

Highlights of qualitative student feedback relating to the Potato Clock demonstration on **"What was the most memorable or your favorite course demonstration and why?"** are included:

"The most memorable demo for me was the potato circuit demo because it demonstrated alternative ways to get energy using non conventional sources and I thought that was really interesting."

"My most memorable and favorite course demonstration in the video was the potato clock. The reason for this is it reminded me of something I was shown as a kid that got me interested in science in the first place."

"The Potato clock without a doubt. It combined the essence of electrical engineering with the carbohydrate we all know and love. It also demonstrated how the practical application of circuits can be integrated without the worlds most advanced technology."

"I really enjoyed the demonstration with the potatoes and how you can generate power from them. I know the demo seems elementary because of how often it is done across the country in middle and high schools, but it is a very helpful and innovative way to get power out of something that is much cheaper than traditional sources."

"My favorite course demonstration is the potato clock! I really liked this demonstration because even though it is simple, it is a great way to show electric cells in action and how they are similar to batteries. It was just really cool to see how the current flowed through everyday items to power something as simple as a clock. I feel like these simple demonstrations are just cool to know in general in easy to re demonstrate to other people to show basic principles of circuits."

"I really enjoyed the Potato Circuit Demonstration. I did not know that vegetables could be part of a circuit and I really enjoyed learning about the Israeli research group optimizing Potato Voltage."

"This was the first time I had ever seen someone use food in order to power something else. It opens up a new channel in my mind for ways to conduct experiments or be resourceful."

"I enjoyed the potato clock demonstration. It is a classic science experiment that I have heard of many times before but never really understood how it worked. It was nice to see how it applied to the material that we learned in class."

"My favorite was the potato battery. It's something that we have all seen before but perhaps didn't really take the time to understand. I think it interested me the most because of the research that was brought up about students who are maximizing the battery use of a potato. I like when I can see the applications of this class reach to the applications in research projects."

"My favorite course demonstration was the potato clock. This concept is something everyone has heard of before, but with this demonstration we are taught the theory behind why it works using anodes and cathodes."

"I liked the demonstration of the potato clock because it shows the connection of what we are learning about to real world application, and using food waste to generate power and develop more efficient ways to power things."

"My favorite course demonstration was the cell made from the zinc/copper electrodes and the potatoes. I enjoyed how it brought in concepts from a science-fair-esque experiment we have known about for a long time, but not necessarily thought about more deeply than simply showing that you can power a clock with a potato. Additionally, the tie-in to how the concept can be used in the larger world was interesting, especially in relation to the group that was able to greatly increase the voltage output simply by preparing the potato in a different way."

"I liked the potato-battery demonstration because it provided a new avenue of personal research and study into biological energy storage. If stored in a proper environment (cool and dry), potatoes have a long shelf-life, even among vegetable peers, making them a good choice for biological batteries."

"The demonstration where you showed that potatoes and limes could be used as some sort of power source. It really shows that the mass amounts of food waste America has can be used for something other than dump filler."

"My favorite demonstration was the how a cell works demonstration with the potato and the limes. This is because the demonstration took a concept which we were introduced to as children and brought it to reality and then went one step further to explain the research going on that can solve real world problems using the basic theories which we learned with the potato."

Sample Demonstration 2: AC-DC, Transformers, & Power Distribution
The second demonstration highlighted is structured to physically show the difference between alternating current (AC) and direct current (DC), how transformers will only function using AC, and the impact of AC on long distance power distribution. The course lecture theory includes physical configuration of transformers, deriving transformer step-up and step-down equations, highlighting the functional differences between AC and DC, and discussing the reduction of losses over long distances of non-contacting AC power distribution using electromagnetic induction across transformer coils. The impact of this demonstration is for a physical understanding of the difference between AC and DC. The societal discussion includes the power distribution network and AC distribution infrastructure. Discussion includes the ideas of alternative energy sources of AC power and local independence options for off-grid living or third world power applications.

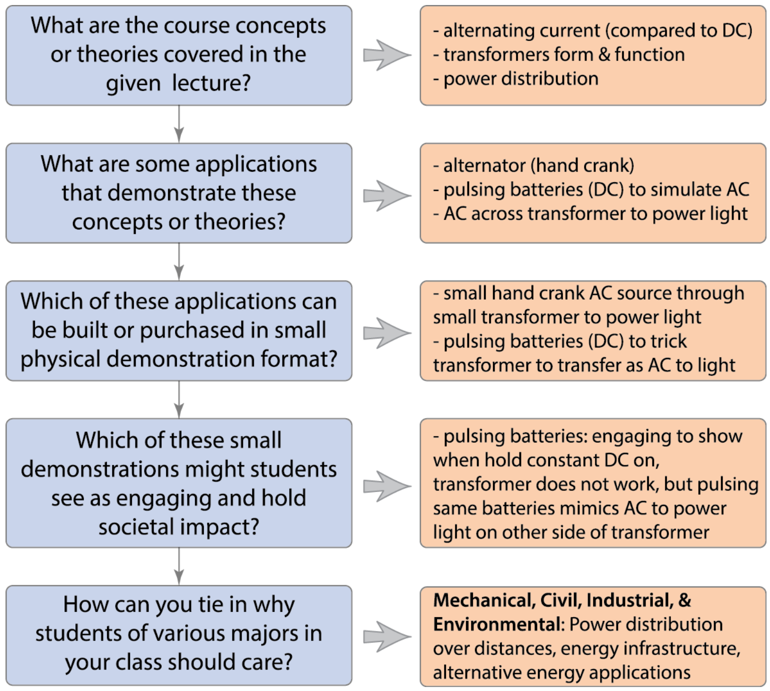


Figure 4: The demonstration flow chart as applied to AC-DC and Transformers.

The demonstration selected uses a commercially available Snap-Circuits set SC-750R (retails less than $130). While this one build is highlighted, the kit itself is quite large, with many basic circuit components, and is utilized numerous times throughout the semester for brief build demonstrations alongside theory based lectures. This snap circuits set is ideal for the nature of demonstration in this course due to the durability for passing demonstrations around a large lecture hall, portability to the lecture hall, base build plate fitting within a standard sized 8.5” by 11” piece of paper for use under the document camera, and for ease and variety of physical circuits construction by the instructor for multiple demonstrations. This particular build was chosen to show theory because in a single circuit, both AC and DC can be physically demonstrated by pulsing a DC source to trick the transformer into thinking it is AC. When the switch is held on only the light on the same side as the DC batteries work. When the push button is pulsed, simulating an approximate AC square wave, current is induced across the magnetic field of the transformer, and the red LED on the other side of the transformer and current meter light up and read a signal.

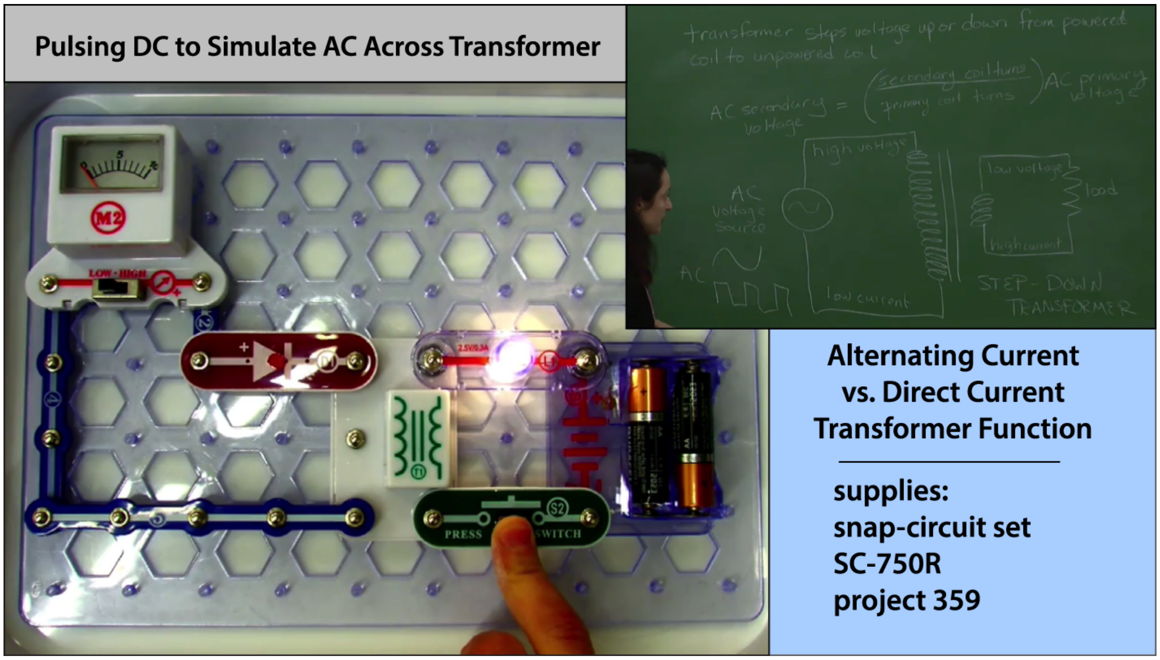


Figure 5: Pulsing DC to make AC Transformer Demo and chalk board based transformer theory.

Highlights of qualitative student feedback relating to the AC-DC Transformer demonstration on **"What was the most memorable or your favorite course demonstration and why?"** are included below:

"The most memorable demonstration for me was the demonstration of AC current. The reason for this is because I felt like it was the most relevant to everyday living as AC power is required for use in the transformers that allow the power grid to operate."

"The most memorable demonstration for me was the AC and DC transformer demonstration. This is because I was having an issue understanding the difference between the two. The demonstration was very straight forward and easy to follow."

"The most memorable of the course demonstrations for me was the transformer demonstration. I enjoyed seeing a transformer functioning in a real life situation. I also enjoyed when Dr. Dickrell showed how rapidly engaging the current can make an AC current source from a DC source."

"My most memorable course demonstration was on the transformers & AC-DC. It was most memorable to me because I was kind of confused about transformers, so it helped me get a better understanding of the topics. I liked the visual demonstrations we saw in class."

"The one on transformers/ AC power and how electricity is transferred from the position of power generation to distribution and finally to the home. It was an example that was the perfect intersection of course material and a "real-life" example."

"Using the DC power as sort of an AC source by flicking the button simulating a square wave. I liked this demonstrating because it really showed how simple AC can be."

"I liked the demonstration that showed how AC current and transformers worked to power the small light bulb in the circuit. The reason being that I knew what a transformer was, but not how it worked or what its actual purpose was. This demo clarified not only what they actually do, but how they do it."

"I found Transformers & AC-DC to be the most important demonstration to me throughout the semester. This was the most memorable demonstration for me because I was having trouble understanding the actual difference between DC and AC circuits. This demonstration along with Dr. Dickrell's clear explanations helped me grasp the concept of AC circuits."

"Your demonstration of AC current by flipping the switch repeatedly to power the lightbulb. It was the first time I truly understood what AC current was because of the physical demonstration."

"The transformer demonstration was the most interesting to me. It uncovered the mystery behind how transformers work and it was interesting to see how a DC source could replicate an AC source by rapidly switching it on and off."

"The transformers demonstration was the most memorable in the course because it provided substantial aid in understanding how transformers work. Beforehand, AC circuits seemed to be a relatively abstract concept, however, the demonstration made the subject must less intimidating, especially when visualizing how DC circuits can induce AC sources."

Sample Demonstration 3: Flex Sensor - Voltage Divider, Series, & Variable Resistors
The third demonstration highlighted is structured to show physical engineering applications of a variable resistor with voltage divider equations derived as part of lecture theory. While there were multiple choices to show variable resistors (potentiometer, dimmer switch, photo-resistor, etc.), in this particular demonstration a flex sensor is highlighted to control a servo motor. Other demonstrations using potentiometer, dimmer switchers, and photo-resistors are highlighted in other lectures throughout the semester. The flex-sensor and servo motor pair were chosen because the physical bending of the flex sensor makes a tactile interaction for students as the demonstration is passed around the lecture hall. The pairing with the servo motor highlights: a) immediate visual controlled feedback of variable resistor as a voltage divider (bend flex sensor, resistance changes, different amount of voltage goes to servo signal, controls rotation amount), and b) the function of a servo motor (fine rotational position control, have students hold the black box and feel the gears moving inside as change rotation, see three wires for power, ground, and control signal). The application and societal discussion include the use of flex sensors in prosthetics to better mankind (Mechanical, Biomedical, Materials Science), as well as using flex sensors in manual dexterity controlled robotic applications for remote environmental uses (Nuclear, Mechanical, Aerospace). Additionally, the design and composition of the flex sensor is discussed in relation to electronic materials (Materials Science, Chemical).

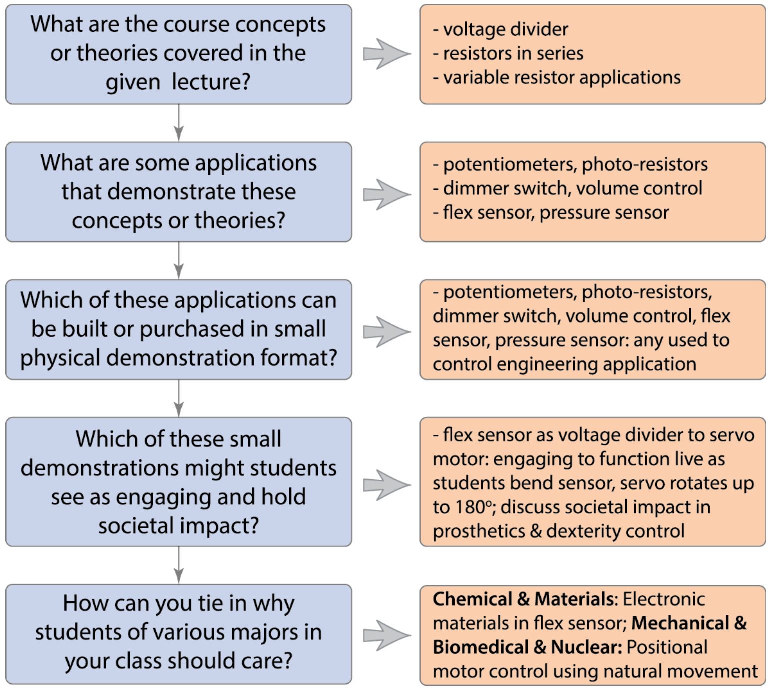


Figure 6: The demonstration flow chart applied to voltage divider, series, and variable resistors.

The demonstration constructed uses a commercially available Arduino based breadboard kit, the SparkFun Inventors Kit V3.2. This kit sells for less than $99, and includes all the sensors, motors, electronics, breadboard, wiring diagrams, Arduino based board, and Arduino codes for 16 circuits. The "inventors guide" that comes with the kit has a full color manual, including educational items for each circuits along the way (analog versus digital, what is pulse width modulation, etc.). This kit was chosen because of the ease of use, size, included Arduino codes (no time or knowledge needed in programming if new to Arduino), and making the step up from educational toys to real sensors and computer controlled breadboard applications.

The full computer controlled circuit is highlighted under the document camera starting from the voltage divider equation for resistors in series, the flex sensor as a variable resistor, the analog-in signal from the voltage divider flex sensor to the Arduino board, and the basics of pulse width modulation (PWM) and that type of signal to control the rotational position of the servo motor.

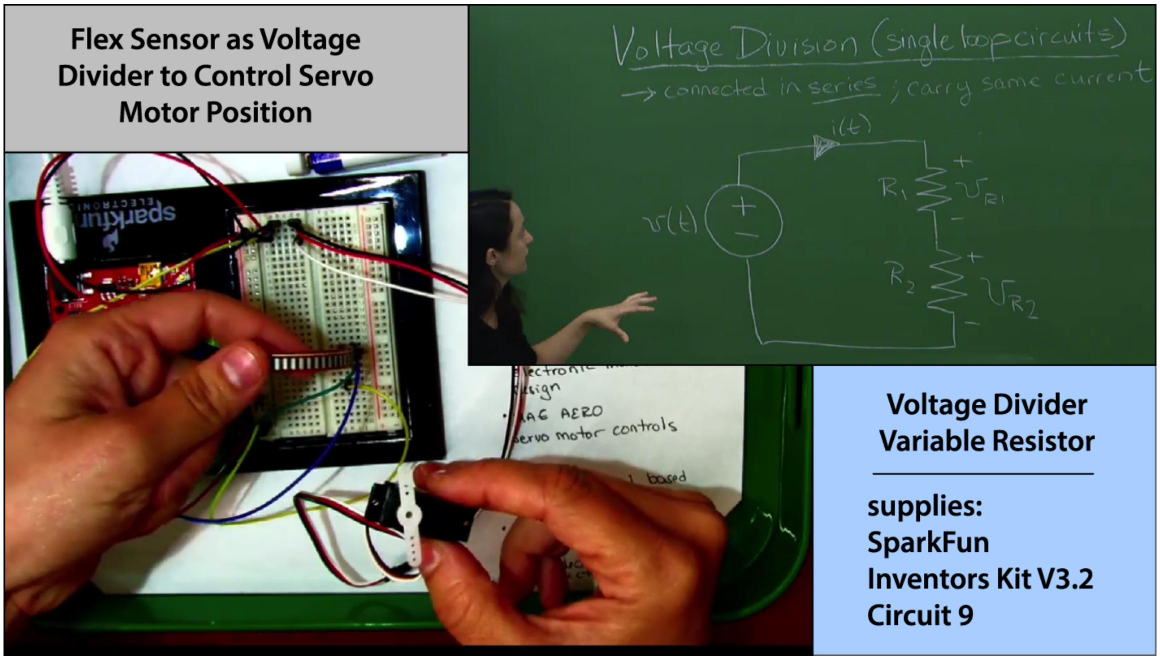


Figure 7: Flex Sensor as Voltage Divider & Variable Resistor to Control Servo Motor.

Highlights of qualitative student feedback relating to the Flex Sensor/Variable Resistor and Servo Motor demonstration on **"What was the most memorable or your favorite course demonstration and why?"** are included below:

"My favorite demonstration was the one with the flex sensor since I didn't know about those and it gave me some ideas on what I could use that for. For instance, if a surgeon could operate on a smaller scale using robotics then the flex sensor could be a major part of how a robot could be controlled precisely."

"The flex sensor was the most memorable because I liked how you actually had to bend the sensor to vary the resistance, and it pertains to my future field."

"The most memorable demonstration in the video was the flex sensor because of its functionality. Bending the sensor more leads to a higher resistance due to the spacing between the conductors."

"The most memorable demo highlighted in the video is the one of the flex sensor. Flex sensors are so cool! I've considered medical school and, thus, find biomedical applications to be very interesting. Flex sensors can be used in gloves, for instance."

"I love the flex sensor, I think its possible applications in robotics, prosthesis and as a control device are super freaking cool. Just being able to think of different Bio-med applications was pretty fun."

"Flex sensor with servo motor because it relates to my major as a Mechanical engineer with sending signals to automated systems."

"The most memorable in class demonstration was showing the flex sensor and the servomotor. As you bend the flex sensor you can control the conductive items and change the resistance through physical motion. This demo included such a small piece on the circuit board, but gave a real visual for how resistance is varied and calibrated through physical touch. It paints a different picture than the common switch tool to vary resistance, especially when Dr. Dickrell spoke of the electrical glove and its nuclear/mechanical applications."

"My most memorable demonstration would be the demo where Dr. Dickrell explained the mechanics of a flex resistor. I really found this concept interesting and it helped me to see that the principles of circuits can be manipulated to best suit the intended application."

"The flex sensor with the servo motor was the most memorable. I think this was the best visualization to see the effects of a resistor as opposed to just a simple LED connected to a resistor."

"The most memorable demonstration was the flex sensor and servo motor because it was something slightly unusual which can be used in numerous engineering applications. Applying the concepts of variable resistors and voltage dividers and tying this into how they are used in numerous engineering fields gave more direct insight into how this course can be applied. I found it to be the most memorable because it was something unique I had not seen before."

"I enjoyed the flex sensor demonstration the most for a few reasons. As a mechanical engineer, I feel this demonstration was relevant to my field but also outlined the importance of a solid electrical engineering foundation, and how other majors in the engineering field all interact. Mechanical engineering is essentially the field of either turning a source into energy, or using energy and turning it into some usable form, and this demonstration showed a small glimpse of how that lead to new developments in technology. I felt that the flex sensor demonstration was a simple but effective way of illustrating this concept. It also tied in what different possibilities are currently out there, and at the same time introduced a component which I had never heard of before that lecture."

"The flex sensor was my favorite demonstration because it was an interesting way to show a variable resistor. It applied the concept learned in class to an object that I didn't know existed, so I felt like I was really learning something."

"The flex sensor demonstration was very interesting. Starting with the initial input (mechanical bend), the signal travels through a voltage divider and is then converted into an analog input which software can read. Sensor technology in general seems innovative to me. I find it amazing that a physical change in the environment can be converted and manipulated into producing another desired change (in this case, rotation of the motor)."

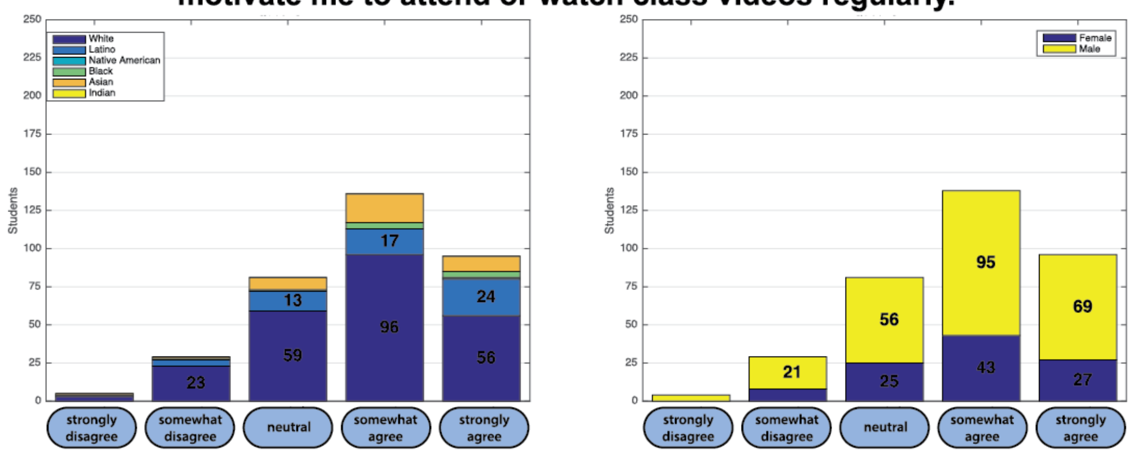
"My favorite demonstration was the flex sensor demonstration. I enjoyed this demonstration because of its various applications in things I'm relatively interested in (e.g., costume design, virtual reality, smart clothing, wearable technology, etc.)"

This specific SparkFun Inventors Kit that includes the flex sensor and servo motor as well as components for 15 other circuits builds was selected as a “textbook” requirement for students in subsequent semesters, so each student will complete a number of the Arduino based circuit builds as homework assignments. This “circuits for non-majors” lecture course does not have a laboratory with it, as the engineering students taking it have other major-specific labs the credits are needed for. The future inclusion of the kit will elevate the active-learning level for individual ownership and hands-on education. Since this is not a programming course, the fact that the Arduino code for 16 labs is included as part of the kit makes using it easy for faculty, as there is minimal student programming assistance required. However, the code is documented well enough and makes suggestions about modifications that students inclined towards maker-culture or self-learning could easily dive into Arduino based electronics further. There will be a subsequent educational study to this work about this individual kit ownership model impact.

Quantitative Feedback & Conclusions

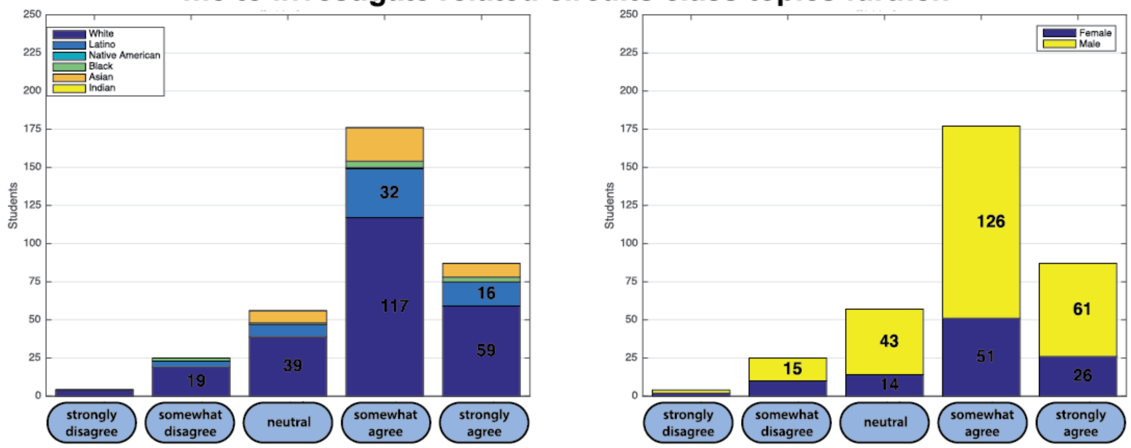
Students in the course were given a highlight video of 11 select course demonstrations from throughout the semester as a refresher of some of the theory-application pairs they had seen over the previous months. Following reviewing the highlights video, the students were asked Likert scale quantitative questions about the impact of the five-minute demonstrations. Data was examined as both a function of self-reported ethnic background and self-reported gender.

Question 1: These type of hands-on lecture demonstrations shown in class motivate me to attend or watch class videos regularly.



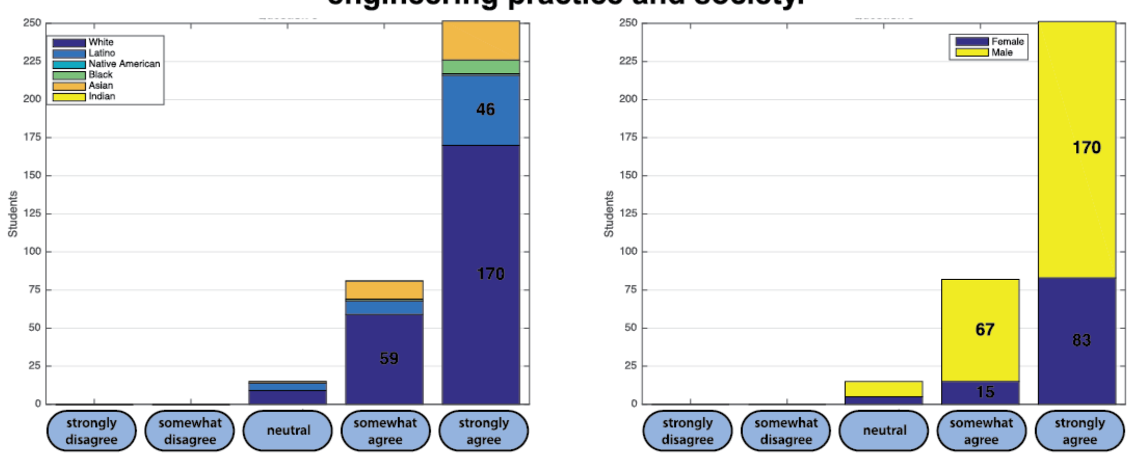
A first goal of the addition of five-minute course demonstrations is an increase in course lecture attendance and/or regular completion of watching course lecture videos. The first Likert question shows that across various ethnic backgrounds and genders, there was a general response of “somewhat agree” to attend or watch course video lectures regularly because of the in-class demonstrations. This is motivating as one goal is to increase retention within second year engineering undergraduate students. The more students are motivated to attend or watch class regularly using hands-on demonstration inclusion, the more likely they will be successful within their engineering studies and not choose to transfer to a non-engineering major [3].

Question 2: The inclusion of these types of course demonstrations motivate me to investigate related circuits class topics further.



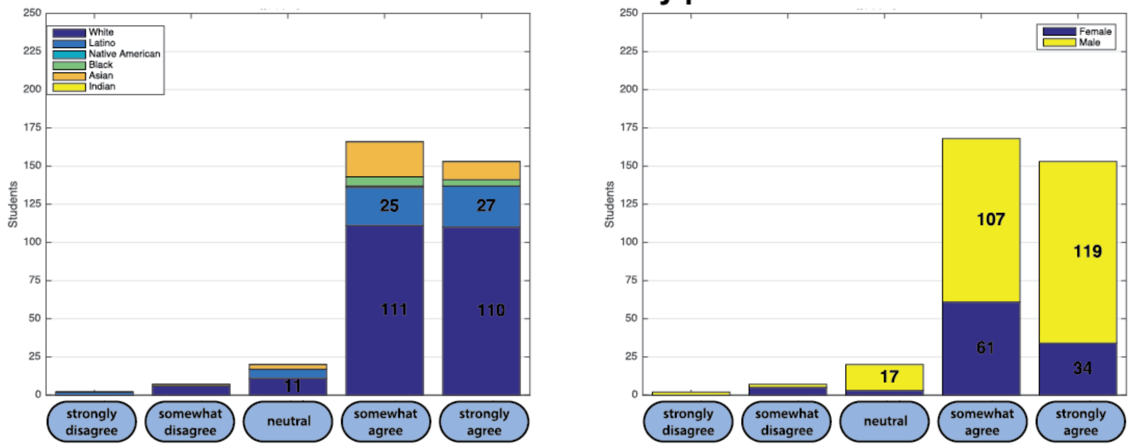
A second goal of the inclusion of demonstrations is to motivate students to be self-educators and life-long learners. The second Likert question shows that across various ethnic backgrounds and genders, there was a stronger response of "somewhat agree" that these types of course demonstrations motivate students to investigate related circuits course topics further. Given none of the student majors in this "circuits for non-majors" course are required to take higher level electronics courses in their engineering studies, this was motivating that students who do not necessarily need to study further circuits on their own to graduate, might be motivated towards self-learning to make them more complete engineers or further personal curiosity.

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



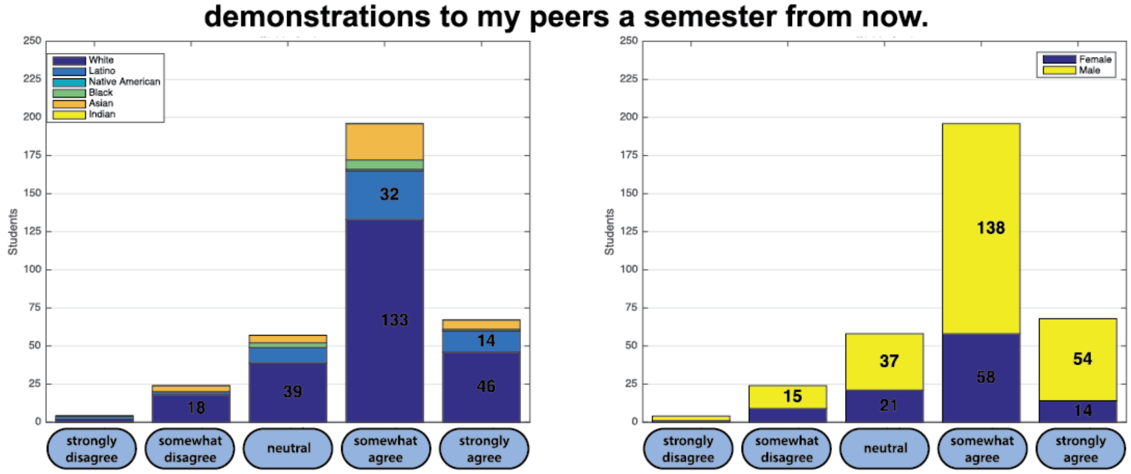
A third goal of the inclusion of demonstrations is help students understand the applications that engineering practice has on society and humanity. The third Likert question results were surprising showing an extremely large fraction of responses as "strongly agree" across various ethnic backgrounds and genders. This was most encouraging, that students feel what they are studying, even if they do not have to take any subsequent engineering courses in that subject, has a strong purpose towards what engineers do as part of society. Generally, student retention within engineering majors is strengthened if they feel there is real reason for knowing the math and theory they are learning, and that purpose is applicable to practice and society.

Question 4: I feel that I could explain the basic principles involved in the demonstrations to my peers.



A fourth measure of the impact of the inclusion of the five minute demonstrations is if students understand the principles highlighted. One measure of this is if students would feel confident explaining the principles in the demonstration to their peers. The fourth Likert question results returned that the majority of students either “somewhat agreed” or “strongly agreed” that they could explain the principles to their peers. One interesting note in this data was while across various ethnic backgrounds the distributions were the same, across genders the female students seemed slightly less confident in their ability to explain the principles to their peers.

Question 5: I feel that I could explain the basic principles involved in the demonstrations to my peers a semester from now.



A fifth measure of the impact of the inclusion of the five minute demonstrations is if students retain understanding of the principles highlighted. One measure of this is if students would feel confident explaining the principles in the demonstration to their peers a semester from now. The fifth Likert question results showed a shift towards more “somewhat agreed” than “strongly agreed" as compared to question 4. The response categories were evenly distributed across various ethnic backgrounds and genders.

Conclusions & Future Work

This work resulted in the formation of a systematic flow diagram approach to adding five minute demonstrations to supplement traditional lectures. This flow diagram can be used across multiple second year core engineering courses to bring some practical application instances into a traditional lecture course for students across multiple engineering majors. While the demonstrations themselves in class take five minutes to show to students, conducting the flow diagram approach to add a demonstration does take some time by the faculty member. Each lecture demonstration took about two hours of planning, ordering, construction, and testing the first semester they were used. However, in subsequent semesters a small library of course demonstrations have been built using a few standard kits that enables the course instructor to plan about 30 minutes before class to bring with a five-minute lecture demonstration for most standard lectures.

The qualitative impact based on students' comments has been generally very positive, especially when it comes to understanding societal applications of a traditionally mathematics based course, and why they should care about the class. Quantitatively using the Likert scale surveys, students showed the greatest "strongly agree" response to the five-minute demonstrations helping them understand the applications and societal impact of the course lecture materials. Students also both mainly "somewhat agreed" and "strongly agreed" to the five-minute course demonstrations increasing their course attendance (or video watching), self-motivation to investigate course topics further, and ability to explain course concepts to their peers.

Future work from this study includes increasing the level of active-learning through a course "textbook" requirement for individual student hands-on Arduino based kit ownership and use, in addition to maintaining the five minute hands-on demonstrations within lectures.

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