BOARD # 315: A Customizable Engineering Outreach Program for Elementary through High School Students (EDU/DRL)

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A Customizable Engineering Hands-on Outreach Activity for Students from Elementary through High School (EDU/DRL)

The implementation of NGSS in the United States has incorporated engineering practices in science education. Elementary and secondary science teachers must find ways to expose students to engineering in ways that are accessible and age-appropriate. In order to attract more students to engineering as a field of study and career path, it is important to offer outreach programs that are both educational and inspirational. [1], [2], [5] The activity discussed in this paper introduces students to fundamental engineering concepts through the design, implementation and optimization of a smart nightlight. The activity is designed to be customizable for students in grades 4 through 12 and further tailored to the learning skills and available time of the participating groups. Furthermore, the activity emphasizes hands-on learning while integrating engineering principles such as the engineering design process, electrical circuits, basic programming, and microcontroller programming. At the end of the activity, students assemble a functional smart nightlight with four distinct operational modes, reinforcing their understanding of the practical applications of engineering.

This activity is part of the efforts in outreach for the K-12 community offered by the Electrical and Computer Engineering (ECE) Department at Stony Brook University on Long Island, NY. Recruitment is done by email contact with local school districts and with teachers that participate in professional development offerings conducted through the department's outreach efforts. The ECE department also maintains a website that teachers can access to view all offerings. The outreach efforts include a variety of offerings of students' activities with different durations and modes of instruction. Some teachers choose to bring their classes to a dedicated lab at the university, offering an opportunity for students to experience a university setting and to learn to solder safely. Others may choose to have the activity at their school as an in-school field trip, which reduces the cost and difficulty of logistics for arranging transportation. During the COVID pandemic, the activities were run remotely with kits delivered to the schools and instruction conducted through Zoom. Although this option remains accessible, schools have shown a growing preference for in-person instruction. Schools may choose to offer the in-school field trip as a one-day experience, while some districts, in close proximity to the university, offer it as a multi-day in-school experience, taught as a unit of instruction. Furthermore, the program's duration can be adapted, ranging from a 3-hour introductory session to a more in-depth 6-hour workshop, providing educators with the flexibility to integrate the program into their curricula or as a stand-alone experience. All options have been implemented and have proven to be highly successful.

The activities may also be modified to fit the needs of the school in terms of time available and age of participating students. For students from fourth grade and up to those enrolled in Advanced Placement (AP) physics, the program may be adapted to include the engineering design cycle through the development of a prototype and simulation of a smart nightlight. Possible topics include the construction of simple circuits, introduction to circuit components such as resistors, sensors, LED lights, color control in LEDs, prototyping with breadboards, as well as the use of programming of microcontrollers to establish communication between the circuit components. [3] Students in middle school and up that attend the program at the university may learn to solder the components directly onto the printed circuit board (PCB) to create the final product. Classes involving younger students or those conducted in-district come with pre-soldered PCBs, performed by staff and teaching assistants from the outreach programs, that participants can simply insert the components into. Kits of materials are assembled prior to instruction and delivered to the district when conducted in-person or remotely.

In all versions of the program, participants begin by exploring the engineering design process by learning how engineers identify problems, brainstorm solutions, design prototypes, and use the iterative process to improve their designs. This process is woven throughout the program as students use it to guide the creation of their nightlights. The addressed problem is motivated by considering how street lights are turned on at dusk and off at dawn. This leads to a discussion of the use of sensors, electrical conductors, and insulators. Students build a simple circuit using Play-Doh, an LED light, a resistor, and batteries. The idea that Play-Doh conducts electricity is a source of engagement for students, and teachers, of all ages. The students then proceed to build a nightlight circuit using an online simulator. The function of photoresistors, as well as methods of programming a microcontroller are introduced during the simulation. After successful completion of the simulation, students build a prototype of the circuit using a breadboard, LED, microcontroller, resistors, photoresistors, and wires.

The focus then turns to ways of improving the design of the nightlight. The timing of the light turning on and off is related to LED light brightness control, which can be used not only on the nightlight, but also on smartphones as ways to reduce the brightness of the screen and to save power. This brightness control experiment may be done using the online simulation if time allows. After the brightness of the light is discussed, further improvements to the light include how to change the color of the light. RGB LEDs are discussed, and an online simulation is used to explain how the mixing of the colors spans the full color spectrum.

While most lessons use a pre-programmed microcontroller to control the nightlight, there is an option, dependent on time and student ability, to learn how a block-based programming language can control the behavior of the microcontroller using the online simulation. Depending on the students' grade level, programming may be incorporated into the instruction and may range from simple light-triggered responses for younger students, to more complex programming for older participants. A modified version of the lesson, for students as young as 6th grade, uses Python to program the microcontroller providing an opportunity for students to use their programming knowledge in practice. When using this version, students are able to choose to have their nightlight glow a specific color by using an online simulation to blend the red, blue and green LEDs. This flexibility in options ensures that the program is both challenging and age-appropriate, regardless of the students' prior knowledge.

The final stage of the project is the construction of the smart nightlight using a PCB. Whether or not students solder the PCB or program the microcontroller themselves, they will have a nightlight with four distinct functions, controlled by a pushbutton that they get to take home. The nightlight is controlled by a push button to turn on in a dark room and off in a well-lit room, to dim according to ambient light and to change color between red (when the room is dark) and blue, (when the room is bright). A fourth function includes color rotation with brightness changing; the light is on with all colors rotating when the room is dark and off when the room is light.

While conducting the activity remotely has been done successfully, this option does present some logistical challenges. When done in-person, the instructor and teaching assistants are able to directly address any potential problems, but this is more challenging to do when working remotely. During the COVID pandemic, we were able to build a successful modified mode of instruction of the activity. In a typical remote session, there would be some short instruction for the entire group, followed by the use of breakout rooms of 4 to 6 students and one teaching assistant, working on the procedure outlined in the large group instruction. Students working remotely each had their own device and headphones for the breakout rooms. When a problem arose, the small group allowed for the teaching assistant to find a solution. [4] Students were able to hold their project to the camera to be viewed by the teaching assistant and other students and led to group discussions of how to fix the problem. In some cases, the teacher would take a photo of the project and email it to the teaching assistant for a closer view.

Students that complete the program are asked to complete a brief survey, using a Likert scale about their experience. The survey includes questions about how the activity helped them to understand electrical circuits, the use of resistors, the function of microcontrollers, the engineering design process and any other topics specific to their activity, such as understanding of block-based coding. Students are also asked if the activity has increased their interest in engineering and how much they enjoyed each aspect of the activity. In almost all cases, the responses have been overwhelmingly positive. Over 80% of the students surveyed selected 4 or 5 on the Likert scale for their understanding of all aspects and 79% selected a 6 or higher (on a scale of 1 to 10) as an increase in their interest in engineering. These results are consistent across all grade levels and modifications in the activity.

In summary, this program offers students a comprehensive introduction to engineering through an engaging, hands-on activity. By constructing a smart nightlight, students gain practical experience in the engineering design process, electrical circuit assembly, block-based programming, and microcontroller programming, while cultivating their problem-solving and critical thinking skills. This adaptable program is well-suited for a variety of educational settings and timeframes, making it an accessible and enriching opportunity for aspiring young engineers. This work was funded through the NSF Division on Research in Learning Grant Number DRL# 1850116.

References

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