Engineering in the Classroom: A Low-Tech, Local Approach

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Each group took a vastly different approach to the problem.

When one mentions the word engineering, most people think immediately of high-tech items such as computers, or large-scale projects such as bridges, buildings, and roads. While these products represent the products of engineering, there are clear challenges to having students work directly on any of these projects in the context of a science classroom. As a ninth grade physical science teacher at an urban high school with a high dropout rate and few resources, the possibility of including engineering in my classroom seemed even less likely. However, after participating in a summer workshop on engineering, I found a way to introduce and engage my students in engineering design in a local and low-tech way. In this project, my ninth grade science students interviewed and observed the special education classes at Holyoke High School, then designed and constructed Assistive Technology devices for the special education classrooms out of everyday materials. Not only did my students learn about engineering design, they also learned a great deal about science, teamwork, and how to use what they learned to help other people.

Holyoke is located in central Massachusetts, just north of the city of Springfield. The demographics of Holyoke High School reflect the population of Holyoke; over 50% of the students are non-native English speakers, with a majority of these students coming from Puerto Rico. The high school has few resources; as a ninth grade physical science teacher, I was teaching science in an English classroom, with slanted desks attached to the chairs. I did not have access to a sink or to a supply closet and had to carry all of my science materials on a cart.

Despite these obstacles, I am always looking for ways to engage my students. In the summer of 2003, I participated in a summer professional development workshop at Tufts University called the "Pre-College Engineering for Teachers"
The main focus of the PCET project was to familiarize teachers with the engineering design process. It did this by focusing workshop activities on two main themes: water treatment and assistive technology. The United States Government defines an assistive technology as an "item, piece of equipment, or product system... that is used to increase, maintain, or improve functional capabilities of individuals with disabilities." (29 U.S.C. Sec 2202 [2])

Assistive technologies can be commercially manufactured "high-tech" items, such as electronic hearing aids and motorized wheelchairs, or homemade "low-tech" items, such as customized pencil grips or booster seats. During the PCET workshop, we learned about and tried different "low-tech" design projects that we could use in our classrooms. The group visited the Assistive Technology Lab at Perkins School for the Blind. I was impressed with how the director, Molly Campbell, and the volunteers used everyday materials such as corrugated cardboard, clay, paint, glue, tape, and inexpensive items to create custom-designed chairs, games, and other helpful items for the Perkins students.

At the end of the PCET workshop, each teacher was asked to create an "engineering design project" to implement during the subsequent school year. Teachers were given support in the form of $200 to purchase project materials and the assistance of a PCET fellow, an engineering graduate student from a university who could help in the classroom. Bree Carlson, a graduate student from the University of Massachusetts in Amherst, worked with me during the workshop and the school year.

We decided to introduce our students to the fundamentals of engineering design by asking them to create an "assistive technology" device. The project requirements were simple: We asked students to design and build a device that would help the special education students in our school. Holyoke High has a large population of severely physically impaired students who attend class in two basement "Special Education" classrooms. Not surprisingly, the Special Education teachers often complain that these students are too isolated from mainstream students. Part of our project would allow my ninth grade students to visit these classrooms and learn more about the needs of the special education teachers, para-professionals, and students.

We had three main goals for this project. Our primary goal was to increase our students' understanding of engineering and the eight-step engineering design process in the Massachusetts Science and Technology Frameworks. Another important goal for this project was to introduce our "mainstream" students to the "unseen" portion of the school's population—the students in the contained special education classroom. Finally, we wanted to introduce our students to the ideals of good citizenship.

During the first year, we incorporated this project into three classes but only engaged a small subset (fewer than five) of students in each class. Students' names were chosen randomly out of a hat. Since I was uncertain how the project would be received, students with behavior problems were not allowed to participate in the lottery. The groups would work on the project periodically throughout the course of the year with Bree, while the other students in the class would learn more about engineering by discussing issues such as the challenges of building a Mars rover and designing a more useful backpack.

The project was primarily "inquiry-based" in that it was a student-driven project. After students were given the initial parameters of the project, they were primarily responsible for choosing how they would address the problem. Bree, the PCET fellow, facilitated the process and tried to keep the groups on task. The eight-step engineering design process that my students followed is shown in Figure 1.

The first and second steps of the engineering design process are to identify the problem and research possible solutions. In order to identify the needs of the special education students, Bree escorted my science students to the basement rooms to interview the special education teachers, aides, and their peers with disabilities, and to observe the types of games and activities that were currently being used in the Special Education classroom. Even though they never left the school building, these students collected firsthand data that they would use to develop their project. The students returned to the science classroom marveling at their interactions with the "basement kids." As the project proceeded, students expressed thoughts on how this population could be better served by the school. They were suddenly concerned about a group they had only ogled previously.

The third and fourth steps of the engineering design process are to develop many possible solutions and then select one solution. The physical science students discussed their ideas with their peers and with Bree and determined which of
their ideas were feasible as group projects. Each group took a vastly different approach to the problem: The first group decided to create a talking educational cube, the second group decided to create a memory game, and the third decided to create a communication board. The success of our students in completing their projects corresponded to the difficulty of the project. The first group wanted to build a cube that would be a talking word bank, but did not consider that a word bank requires a programmable computer chip. Although many of the students had experience with electronic toys, they had never previously thought about how one might be put together. The group became more frustrated as the project continued, and eventually abandoned the project. The second group also never completed their project, due to their overly simple design. Instead of feeling challenged by the “Memory Challenge Game” and being compelled to complete it, they lost interest and abandoned the project. The third group, however, found the right balance between designing a project that was challenging, but not overly so, and was able to divide the tasks so that each student could be fully engaged throughout the entire process. The “communication device” was designed to help students with limited vocal ability communicate with other students and the teachers and para-professionals in the classroom. This was an important lesson to me as a science teacher; inquiry-based lessons need to be well matched to the abilities of the students participating in them.

After deciding on the project, the students proceeded to construct a prototype (Step 5). The students started this step by creating drawings of the activity board. Even this seemingly simple step took a great deal of time to complete, as Bree and I reminded the students that this “paper” design had to be translated into an actual device. Bree helped gather the materials for the project, including going to the Salvation Army to purchase a few electronic toys to take apart so the students could see how they worked. Bree also
supervised the creation of the project. The students designed the board using simple circuits, lights and switches, duct tape, and “triple ply” corrugated cardboard (cardboard glued together to make it sturdy, described in Campbell’s book Creative Constructions).

After the students completed their device and tested it in their classroom (Step 6), they took it to the special education classroom to share it with the students and teachers (Step 7). This experience is an example of “real-life assessment,” in which the students’ work was being evaluated by the actual audience for which it was created. The students were able to observe their design in use and redesign parts of their device before completing the project (Step 8).

The resulting design was a 60 cm by 60 cm box with a series of pictures, a column of words describing what the user might need (such as “snack” or “bathroom”), and a corresponding switch that would power a light next to the picture. Although communication boards are available for purchase, they are expensive (a few hundred dollars) and are easily broken. The design the students created was inexpensive and could be fixed by the students if it was broken, since they knew how it worked (DeForge 2004).

The classroom time spent completing the project was extensive, but valuable. The project solidified and extended students’ knowledge of circuits as they figured out how to create a light next to a picture when the corresponding switch was turned. They learned how to create a sturdy structure for the device that could withstand everyday wear. They learned the importance of planning and staying within the PCET materials budget. They learned the challenges of working in a team with their peers, from deciding which project idea to work with to the frustration of failed attempts. They recognized the importance of working with other experts like the paraprofessionals and special education teachers, trying out “crazy” ideas, and failing and trying again. They also learned that they could do something in school to help other people. “Why do we need to know this?” was replaced by “How does that work?” and “Why not try it like this?”

I continue to do this project with my students year after year. Instead of merely observing the special education students, my students have started to interact with them socially. Some students eat lunch with the special education students, and friendships have developed.

One of the greatest challenges for a teacher at Holyoke High School is to convince students that knowledge is an important tool that is useful and meaningful in their lives. There is no better way to teach this lesson than to give students a concrete goal rather than an abstract assignment. By tackling a local problem in a low-tech way, my students gained a better understanding of science, of engineering design, and of their peers of all abilities.

References


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