Development of Engineering Design Modules for Middle School Students: Design principles and Some initial Results

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This paper reports on the initial development of a program that uses engineering design challenges with middle school students to facilitate STEM learning and interest. We present the goals and design features of the modules and compare them to other successful approaches. We also present data showing differences in how students who worked with the modules perceive engineering. The results are discussed as they relate to the continued successful design and development of the modules.

Major issues Addressed

Education in science, technology, engineering, and mathematics (STEM fields) is often discussed as important to economic growth. The project described here emerged from such a community concern for workforce development in a medium size city. The work was spearheaded by the local education foundation. Before the foundation began its work, the focus on engineering was initially was sparked by a high school that developed an engineering themed curriculum to boost enrollment. The foundation started by developing engineering clubs and camps for elementary school students. Then the project moved into middle schools to help build opportunities for theses students. Along with this expansion has come funding to pursue further design and development.

The centerpiece of the project is a set of modules that use engineering design challenges. Students work on these design challenges each quarter during their middle school years. The goal of the modules is provide students with experiences that help them learn and motivate their interests in STEM. There are many potential benefits to the design challenges that suggest that they may enhance STEM learning and motivation. First, they provide a meaningful context for learning of science and mathematics. Second, given that the challenges involve meaningful applications, students are more likely to see the value of math and science. Third, students often have misconceptions about how engineers work. Practice working in collaborative groups to solve engineering problems provides a context that mimics the actual practice of engineers and may reduce student misconceptions.

Potential significance of the work

While in the past engineering challenges have been used in k-12, most of the time they have not been required in the curriculum (Brophy, Klein, Portsmore, & Rogers, 2008). So, one potential significance element is that the project involves the design of engineering challenges for all students. A second significant element is that the modules involve work in both mathematics and science classes. Thus, as we study the modules, we can potentially learn about how to integrate these engineering related themes across the two content domains. A third significant element of this project is that the modules are being developed so that students get a glimpse of the communities of practice of engineers. Finally, a fourth significant element is that the long term goal of this project is motivation and interest in STEM fields, not just student learning that occurs in the modules. Thus, there are potential insights that might be gleaned concerning the building long-term motivation and interest.

Theoretical Approach

As the modules are being designed and revised we are using elements of design from anchored instruction (CTGV, 1997), Learning by Design (Kolodner, et al., 2003), and the How People Learn Model to guide our work (Bransford, Brown, & Cocking 1999). Also, since one of our goals is motivational, we also are designing the modules with theories of interest and motivation in mind (e.g., Hidi & Harackiewicz, 2000). Our goal is to explore how we can develop and improve modules from these existing models.

Methodological Approach

The project is designed to examine both the development of the modules, and outcomes for students, teachers, and parents. For this poster, we focus on two different elements. First, we report quantitative data showing differences in student perceptions of engineering from the school that was used to develop the preliminary versions of the modules. Second, we analyze the currently designed modules in light of classroom observations, and through comparing them to other successful programs.

Major Findings and Conclusions

First, in analyzing the modules in comparison to other initiatives, we learned that our modules are not as thematically tight nor are the units as long as those of other programs. The concepts covered across the different challenges involve different types of engineering and different aspects of science, and typically do not last more than one week or two. However, they all have the in common idea of designing something in a collaborative group to solve a problem. The diversity of topics is intentional. First it was done to fit within current math and science standards (the modules were meant to enhance not replace the curriculum). Second it was done to provide students with evidence of the diversity within fields of engineering. Third, an important element of design for the modules is that the modules are set up so that the work takes place in science and math class. We believe that this feature has potential for helping students recognize the value of mathematics. If they just worked in science class they might not as easily see the importance of mathematics to these challenges. An initial analysis of a videotape of the implementation of the first module suggests that one issue that needs to be considered is whether the math class involves a continuation of the design process or whether the goal of activities in math class is to expand the concepts and facilitate transfer. For example, in a wind-turbine module, the science part of the activity involved working in groups to design and test the turbines, whereas the mathematics part of the activity involved working with a computer-based simulation of wind turbines. The teacher reviewed turbine concepts, and then the students and the teacher filled out a worksheet that asked students to make estimates from graphs, fill in charts, and do other calculations.

An additional feature of this project is that it has a strong community–based focus. We use the community focus in ways suggested by Bransford et al. (1999). First, engineers in the community have volunteered to help with the modules and visit classrooms. For example, an aerospace engineer was present for part of the wind turbine challenge. He told the students about his career and helped the students work on developing their turbines. Hence, there is involvement of the professional community in supporting the work. Second, the issues addressed by the modules are ones that are important to the community. For example, the community is located along a coastal area so a soil erosion challenge was built. Third, there is a pathway to continuing the emphasis on STEM fields in specialty high schools.

Finally, as noted earlier, an important element to the modules is an emphasis on the design process each time students engage in working on a module. The "design" rituals are reinforced and time is taken to help them focus on how the design process is present throughout the modules. This focus on the design process along with the connection to engineers of different types from the community provides students who work on the modules the opportunity to learn that engineering is a collaborative process. Part of the data for the project involves examining ideas students have about engineering. We asked students whether they agreed, disagreed, or did not know about statements concerning what engineers do. Students from the school that worked on the modules were more likely to believe that engineers mainly worked with other people to solve problems, were more likely to believe that engineers designed things that helped the world, and were more likely to know that engineers can choose different kinds of jobs than students from a matched comparison school. They were more likely to disagree with the statement, "engineers work on things that have nothing to do with me." Hence, there is some initial evidence that the beliefs of students may be influenced by the modules.

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