EDUCATIONAL DESIGNER
JOURNAL OF THE INTERNATIONAL SOCIETY FOR DESIGN AND DEVELOPMENT IN EDUCATION

Designing Engineering Experiences to Engage *All* Students

Christine M. Cunningham and Cathy P. Lachapelle
Museum of Science, Boston

Abstract

New academic standards at the state and national level in the U.S. A. call for integrating engineering into K–12 education. As designers develop curricula to meet this new need, we must ensure that engineering instruction is inviting and engaging for all students, particularly those from populations that are underserved, underperforming, or underrepresented in STEM fields. Starting with the explicit goal of fostering equity, we designed an engineering curriculum for grades 1 - 5. In this paper we articulate the set of 14 inclusive design principles that guided the development of the Engineering is Elementary (EiE) curriculum, link them to relevant literature, provide examples of how they influenced our design decisions, and describe classroom outcomes.

Introduction

The recent introduction of a new discipline – engineering – into K-12 education in the U.S.A. comes with both opportunities and responsibilities. One particular opportunity for curriculum designers stems from the reality that few entrenched models of K-12 engineering instruction exist, so we can start fresh, with an eye toward best practices. At the same time, we have a responsibility to promote educational equity and work diligently toward closing the achievement gap (also called the opportunity gap); colleges, universities, and workplaces in the U.S.A. have an unfortunate (though unintended) track record of excluding certain groups from engineering instruction and employment (Burke & Mattis, 2007) [1].

Little research has been done on young children's interest in engineering. But research on children's interest in, and attitudes toward science can inform the design of an engineering curriculum because of the many similarities in concepts and skills used in engineering and science. Science education researchers conclude that it is important to address disparities in access and exposure to science at an early age because students' interest in science tends to decline after elementary school (Brotman & Moore, 2008; Catsambis, 1995; Clewell & Braddock, 2000; Reid & Skryabina, 2003). From the earliest school years, girls' attitudes toward science tend to be more negative than those of boys, and both boys and girls tend to show increasingly negative attitudes as they get older, with girls' attitudes becoming disproportionately more negative than boys' (Catsambis, 19

95; Reid & Skryabina, 2003). One exception to this pattern is African American girls, who tend to have more positive attitudes toward science than both African American boys and white girls (Hanson, 2009). Students from cultures and groups underrepresented in science, such as English-language learners and students from high-poverty areas, may have more trouble in navigating the differences between their home cultures and the culture of science than do students from well-represented groups. This can lead to difficulties with achievement even where interest exists (Aikenhead & Jegede, 1999; Lee, 2003).

Engineering is Elementary

In 2003 our team at the Museum of Science, Boston began to develop Engineering is Elementary (EiE)®, a curriculum that introduces elementary school-aged children to principles of engineering and technology. Over the past 13 years, EiE curricular units have been used in classrooms across the country; as of February 2016 approximately 10 million children and 110,000 teachers have used our materials. The impact of EiE has far exceeded our initial expectations. Research and evaluation data suggest that EiE materials are engaging for girls, children of color, children from low socioeconomic groups, and children with disabilities and have resulted in learning gains related to both engineering and science (Lachapelle, Cunningham, Jocz, Kay, Lee-St. John et al., 2011; Lachapelle, Cunningham, Jocz, Kay, Phadnis et al., 2011, Weis & Banilower, 2010). We believe these results can be attributed, in part, to the commitments we brought to our work.

Grounding our efforts was the belief in the benefits to individuals, engineering disciplines, and society when people engage in problem solving, innovation, inquiry, and engineering design. We resolved to design materials that would effectively reach *all* children, attracting and engaging underrepresented, underperforming, and underserved students, including girls, minorities in STEM, students from low socioeconomic backgrounds, students with individualized education plans, and English-language learners. From the beginning, we worked to identify design principles that would be maximally inclusive; in pilot tests and evaluations, we collected data on student demographics so we could examine the effects of the curriculum on different populations.

Briefly, we concluded that an equitable, inclusive engineering curriculum must demonstrate the relevance of engineering in the real world. It must actively engage students in engineering practices as they work on developmentally appropriate design challenges. It must include scaffolding to support students as they learn key concepts and practices and become fluent with the cultural norms of engineering. It must engender learning environments where students can contribute, collaborate, and develop their own sense of agency, expertise, and ownership. These criteria are similar to what others have advocated for science education (Brotman & Moore, 2008; Carlone, Haun-Frank, & Webb, 2011); however, engineering education affords unique opportunities heretofore unrecognized.

We also argue that project-based learning sets the stage for equitable instruction in engineering. Like educators who advocate for project-based learning in science (Krajcik & Blumenfeld, 2006), we view this approach as contributing to student motivation and engagement, to deeper learning of concepts, and to a broader learning of the practices, discourses, and culture of the discipline. The five key criteria for project-based learning are that students should (1) start with a problem they are challenged to solve; (2) explore the dimensions of the problem and possible solutions using guided inquiry; (3) work collaboratively to develop designs to solve the problem; (4) have their performance scaffolded so they can engage in new practices and participate at a deeper level than if left to their own devices; and (5) produce designed, iteratively improved solutions and share them with the classroom community or others (Blumenfeld, Soloway, Marx, Krajcik, Guzdial, & Palincsar, 1991). We applied these criteria to the design of the EiE curriculum.

With equity as the focus, drawing on educational literature and our experiences working in classrooms, we developed a set of 14 design principles for curricula and materials that guided the development of EiE. These principles can be grouped in four larger categories as illustrated by Table 1.