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Guest Editorial

Engaging Children in Engineering Design Through Popular Media

We submit that there is currently an urgent need to educate the public about engineering and attract talented people to the profession. Further, we argue that such efforts are most effective when they reach young children, and that popular media most be employed to have the desired national impact. These ideas have motivated a major new effort whose central element is a television show for public broadcasting. The television program will feature teams of high school students engaged in solving engineering challenges posed by other kids and adults. Three prototype episodes have been filmed and two of these have undergone focus group testing and analysis. These early tests indicate that the proposed format can engage an audience while reinforcing key lessons about engineering. Collaborative opportunities are currently being sought with engineers, professional societies, and K–12 educators. [DOI: 10.1115/1.2181867]

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1 Motivation

The products of the engineering profession have had a revolutionary impact on our lives. Consider the technological advances of the past century, including telephones, automobiles, household running water, and electrification [1]. People all over the world are deeply dependent on these products and infrastructures. This trend will continue and deepen as engineering is needed for "continued economic development...in a manner that will sustain both the planet and its growing population...and everything else that makes modern society function," explained Joseph Bordogna, speaking as Deputy Director of the National Science Foundation [2].

Despite a growing reliance on technology, most citizens do not understand how modern technologies work or how they are used in everyday products. For example, a 13 question quiz on science and technology was administered to over 30,000 respondents in the United States and Europe [3]. The question that most clearly related to technology literacy (as distinct from science literacy) was "lasers work by focusing sound waves," to which respondents chose "true," "false," or "I don't know." On this question, fewer than half of Americans and Europeans knew the right answer. (The statement is false.) Everyday, people go to the store, scan their items at the checkout, and see the lines of red light cascading across their groceries. This survey suggests that people are generally uninformed about the technology involved in this familiar transaction. At some level, our society's declining technology literacy will adversely affect the level of public discourse on matters of national policy. A democratic society is unlikely to make wise choices about technically complex issues if its voters lack a basic familiarity with technology.

Paradoxically, technology literacy may decline further as technology advances. For example, because today's cars have computerized control systems enabling higher mileage and lower emissions, fewer parents have their children help them perform basic engine maintenance. Reflecting such trends, the National Academy of Engineering committee on technological literacy noted "Most people have very few direct, hands-on connections to technology, except as finished goods. They do not build the devices they use, tinker with them to improve their performance, or repair them when they break. Because of this lack of engagement, people today learn relatively little about technologies through direct experience" [4].

The divergence between technological advancements and technology literacy may fuel a divergence between engineering jobs and engineering education. From 1980–2000, science and engineering jobs in the U.S. increased by more than a factor of two [5]. During the same period, the enrollment in undergraduate engineering programs has been nearly constant. Other nations do not seem to be experiencing the same divergence between demand and supply of engineering talent. Approximately 30% of all Bachelor's degrees in the U.S. are in science and engineering as compared to 60% in China. The trends in graduate education are similarly discouraging. Enrollment of U.S. citizens and permanent residents in graduate science and engineering programs fell by about 20% from 1980–2000. The modest growth in overall graduate enrollment is due to enrollment of temporary residents in U.S. colleges and universities. The divergence between our nation's need for engineering and availability of an adequate engineering workforce has been characterized by leaders in government, industry, and academia as a serious impending problem for the economy, environment, security, and health.

A related problem is the persistence in inequities in engineering education. In 1999, only 20% of the students at engineering schools were women [5]. In that same year, of those employed in a science and engineering occupation, Asians, African-Americans, Hispanics, and American Indians combined were only 18%. Delon Hampton, past president of the American Society of Civil Engineers, draws a link between these inequities and the public's perception of engineering: "...It seems that many Americans, especially women and minorities, don't consider engineering as a field where they can achieve to their maximum potential while utilizing their talents to serve society in the areas they most care about today—the environment, public health and safety, a better quality of life. We must do better at conveying that message if we're going to maintain the qualified engineering workforce we need for our future prosperity" [2].

Reinforcing this view is a 1998 survey which showed that the U.S. public feels uninformed about the engineering profession and revealed a strong tendency to underestimate the role of engineers in research, technology development, and social welfare [6]. Compounding the difficulties are other aspects of public perception. For example, mechanical engineering is frequently associated with imagery, such as construction equipment, that has historically appealed more to boys than to girls. This may contribute to an especially acute imbalance in the mechanical engineering workforce which, in 1999, was over 92% male [7]. Perhaps most importantly, engineering is perceived by much of the public as inaccessible, boring, and staid, and engineers are perceived as nerdy and socially inept. Both the perceptions and the objective reality can be changed through concerted effort. At its base, engineering is dynamic, creative, and rich with existential pleasures [8]. The challenge is to bring these positive aspects of the engineering profession to light.

The need for better technology literacy, for improved understanding of the engineering profession, for greater diversity, and for outreach to K–12 are all widely understood in the community of engineering educators. For example, these were common topics of written commentary [9–12] and discussion at the 2003 Mudd Design Workshop. However, what has not been adequately emphasized among engineers is the need to engage popular media in addressing these issues, as will be discussed in the next section.

2 The Role of Popular Media

Popular media should play a major role in the solution to the problems outlined in the previous section. The majority of the public's information about science and technology currently comes from television and the Internet. Television is cited as a source of science and technology information more than twice as often as newspapers, and more than ten times as often as either books or family and friends [3]. This trend is frightening to many, but it is a reality to be acknowledged as we seek solutions to problems related to public perception. Because television has such a broad reach and deep influence on our culture, it is a powerful means to improve the engineering pipeline. In a session of U.S. Congress on national competitiveness, the Dean of Engineering at MIT, Tom Magnanti, was asked by U.S. Representative Tom Price what could be done to inspire students and ignite a "spark" in our culture. Magnanti replied "You may be familiar with the television program 'L.A. Law.' Somewhat facetiously, I suggest that we need one called 'Detroit Manufacturing.' We need some public expression that celebrates math, science, and engineering in a way that young people find exciting" [13].

While Dean Magnanti imagined an engineering-related program for adults, we propose that even more leverage is possible with younger audiences. The idea of reforming children's programming was called for by the National Academy of Engineering: "Saturday morning television, movies, and other popular media should be strongly pursued to incorporate engineering, math, and science messages. The full resources of the engineering profession...should be brought to bear on this action" [14].

In response to the problems described here, and in response to the calls for action by various leaders, the authors and their collaborators are now developing a children's television program about engineering. This show will probe "under the hood" of modern technology, reach a broad audience, and present an image of engineering as enjoyable, accessible, creative, humane, socially relevant, and personally fulfilling.

3 The Concept of the Program

To have the desired impact, this show much reach its audience before misperceptions of engineering become the norm. By eighth grade, many patterns are already established such as the relatively low percentage of students aspiring to math and science careers (less than 10%) and the significantly lower interest among girls as compared to boys (less than one girl for every two boys) [15]. Therefore, the new show will be designed for kids aged 9–12 (who are typically in middle school). To reach the target audience, WGBH will cast players aged 14–17, relying on the remarkable way kids emulate and imitate other kids, especially slightly older ones. In addition, the show will provide role models for girls and minorities by casting children from a range of racial, ethnic, and socio-economic backgrounds. When viewers watch, they will see kids like themselves actively involved in engineering.

In order to provide an "under the hood" exposure to engineering, the television show must have substantive and sufficiently advanced content. Viewers will see other children taking raw materials, and with very little adult intervention, transforming them into workable solutions. The projects will have a scale and complexity that will excite the viewing audience. Unlike other children's series, where most of the activities use low-tech materials (such as scissors, tape, and cardboard), this show will use modern technology (such as computers, sensors, and actuators) to solve bigger challenges. As the footage of the design process is filmed and edited, the directors and producers will seek opportunities to compose the program so that it will:

- Foster a positive public image of engineering, especially among girls and minorities.
- Emphasize the inherent rewards and enjoyment of creative, technical work.
- Illustrate physical principles behind the engineering solutions.
- Present role models exhibiting intelligence, persistence, teamwork, and gracious competition.
- Illustrate effective skills for design, such as convergent and divergent questioning, estimation, planning and analysis of experiments [16].
- Accommodate the variety of learning styles that are likely to be reflected in the viewing audience [17].

In order for this project to fully attain its goals, the television show cannot stand alone, but must integrate with other efforts. The best learning outcomes are generally attained by active engagement through pedagogies of cooperative and problem-based learning [18]. These pedagogies cannot be implemented fully if children watch passively. Therefore, the new television show will be a part of a multimedia project. For example, the website associated with the show will provide kids with simplified versions of the show's challenges that they can do at home. An Educator's Guide will provide after-school care providers with a 12-week curriculum containing three engineering challenges adapted from the television series. Volunteer engineers and public television stations will host public engineering events around the country. As a demonstration of feasibility, the team has already hosted design/build activities at the 2005 meeting of the National Society of Black Engineers.

4 Formative Assessment

The process for developing this television program was iterative. Prototype episodes were filmed and edited and then subject to formative assessment from potential viewers and from a group of expert advisors. The feedback was then used in developing another prototype, and the cycle was repeated. The two cycles of development and evaluation are presently complete, and three cycles will be completed before filming the first season of 13 episodes in the summer of 2006.

For each prototype episode, focus group methodology was used to elicit feedback from viewers in the target demographics. Two episodes have been evaluated so far. Each episode was viewed by children in groups of three to five. Observations were made as the children were viewing and detailed discussions with the children were conducted afterward. Dozens of such focus groups were conducted in Cambridge, MA and Stamford, CT, so that, in total, over 100 children viewed each of the first two prototype episodes.

The evaluations indicated that the show strongly appealed to kids of both genders across all the ages sampled. The research participants (kids 9–12) exhibited enthusiasm while viewing and during discussion afterward. They showed high interest and formed opinions about the engineering designs and what would work best. Participants admired the skill and teamwork of the contestants making comments such as "Erin was really, really good and really smart. She made the..." and "George came up with the plans—he figured out how to test the... ."

In addition to testing the appeal of the program, an effort was made to assess the educational effectiveness of the program. Focus groups revealed that participants understood the scientific/technical concepts presented. For example, children vividly remembered the fact that a servomotor was used in a design and that it provided rotary motion. With another prototype episode, children formed opinions about preferred techniques for sealing joints. For both episodes, children were able to articulate different parts of the engineering design process.

Despite generally positive reactions, some weaknesses were revealed. For example, viewers wanted more detail in some technical areas, especially what components were being used and where they came from. In addition, kids felt that the working title of the show, "Design Squad," did not fit. Many kids objected to the word "design," mentioning an association with home design or decoration rather than invention or technology. In the opinion of the authors, this underscores the need for public media to be involved in shaping the national dialogue. The very concept of *design*, so central to engineering, in being lost to us because other professions are using the term in publicly visible ways and we are not. We need to show the world what *design* means to us, as engineers.

5 Next Steps

To help solve the interrelated societal problems of declining technology literacy, inadequate pipelines to the engineering profession, and poor public perceptions of engineering, WGBH has launched a major multimedia project to engage middle school children in engineering design. Major funding has been provided by the National Science Foundation and the Intel Foundation. Additional funding has been provided by the Noyce Foundation and the American Society of Civil Engineers. The first season will be filmed in the summer of 2006. In parallel, we will continue to develop the outreach materials while building partnerships among educators, engineers, and media professionals.

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