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Using the biographies of outstanding women in electrical and electronics engineering to overcome teachers' misperceptions of engineers and engineering

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ABSTRACT: In this article, the authors describe an activity that they have carried out with 80 high school physics teachers to enable them to overcome their stereotypical perceptions of engineers and engineering. The activity introduced them to outstanding women in electrical and electronics engineering, and raised their awareness of these female engineers' contributions to engineering and society. The results showed that the activity was effective in dispelling the teachers' misperceptions of engineers and engineering. By providing detailed information about the personal lives and work experiences of the female engineers, the biographies might be useful in countering existing cultural stereotypes of female engineers and initiating changes in perceptions needed to narrow the gender gap in engineering. Teachers and professors can use the examples of these outstanding female engineers as role models to inspire their female students who are aspiring to become engineers.

INTRODUCTION

The perception that engineers and scientists are intelligent Caucasian men who are socially inept and absent-minded people seems to be prevalent among students at all levels, from elementary school to college [1][2]. While the media may, by chance or choice, promote this image, it is unfortunately not far from the reality. For example, while women constituted 46.1% of the general workforce in the USA in 2000, they represented only 25.4% of the engineering and science workforce [3]. These stereotypical images of engineers and scientists as Caucasian men have, in part, discouraged many young women from pursuing any interest they may have in an engineering or science career because they do not want to (and cannot) be the people so often portrayed in the media [4].

Fortunately, research has shown that strategies such as the presentation of female role models, distribution of career information, examination of gender-equitable materials, and participation in hands-on science investigations are effective in countering the stereotypical perceptions of engineers and scientists [5-8]. Research has also pointed to the presence of female role models in engineering and science as the most important factor in sustaining girls' interests in engineering and science [9].

In order to reach out to students at an early age when they are still impressionable, many universities have recently organised outreach programmes to inform high school teachers about engineering and, hopefully, to encourage their students to study engineering [10]. Some universities (eg Purdue University) have even set up an engineering education department for this purpose. The feedback from such programmes has been encouraging.

For this work, which was carried out at Nanyang Technological University in Singapore, the authors wanted to inform teachers about engineering applications, to demonstrate the problem-solving approach of engineers, to correct misperceptions of engineers and engineering among teachers, and to provide them with female role models from the various disciplines of engineering. To achieve these goals, the authors recently conducted a number of outreach workshop activities for 80 high school physics teachers. The teachers were then charged with integrating what they had learned from the workshop into their classrooms.

In this article, the authors describe one of the workshop activities that the authors conducted with high school physics teachers to enable them to overcome their stereotypical perceptions of engineers and engineering. The workshop activity introduced them to outstanding women in electrical and electronics engineering, and raised their awareness of these female engineers' contributions to engineering and society. Teachers and professors can use the examples of these outstanding female engineers as role models to inspire their female students who seek to become engineers.

METHOD

The high school physics teachers consisted of 45 males and 35 females. Their age ranged from 25 to 45. The participants were first asked to complete a *draw-an-engineer* test to assess their perceptions of engineers and engineering. The test required them to draw a picture of an engineer at work [2]. The drawings were analysed as follows:

- Drawings of engineers with short hair and broad shoulders were regarded as males while those with long hair and narrow shoulders were seen as females;
- Drawings of engineers working with one or more of the following items were considered as engaged in building or repairing: hard hat, workbench, heavy machinery,

hammer, wrench, car, engine, rocket, airplane, robot, bridge, road, building, train and train track;
- Drawings of engineers working with a computer, blueprint, pen, model, and/or desk were regarded as engaged in planning or designing;
- Drawings of engineers working with test tubes and/or beakers were deemed as doing laboratory work.

The participants were then randomly divided into groups of four members each, and the various groups were each assigned a female engineer from Table 1 to research on. Table 1 contains 20 outstanding women in electrical and electronics engineering, and their major achievements. The participants were given one week to carry out their research and were encouraged to use Internet resources for their research.

Each group was required to undertake a 20-minute oral presentation and submit a written report of the female engineer assigned to the group. The participants were required to design and present various documents to give an overview of the female engineer's life, for example, birth certificate, educational certificates, marriage certificate, and resume for a hypothetical research post that she wished to apply for. Other items to address during the presentation included the following:

- Who inspired the person to become an engineer?
- What was the nature of her work?
- What were her research interests?
- What were her major research findings, and how had they influenced the current knowledge then?
- What were the difficulties she had encountered in her research or work, and how had she overcome them?
- What were some issues in her life which were unusually inspiring for young women studying engineering?

Each oral presentation was followed by a five-minute question-and-answer session. After all the groups had presented, the *Draw-an-engineer* test was administered to determine the effectiveness of the oral presentations in dispelling the participants' misperceptions of engineers and engineering. The significance of differences in drawings before and after the intervention was assessed by McNemar's Test for the Significance of Changes [11]. A post-activity survey consisting of four forced-choice items was also administered, and this required the participants to indicate what they had noted about the biographies of the female engineers in terms of the following:

- Who inspired them to become engineers?
- What appointments did they hold?
- What were the difficulties they had encountered at their workplaces?
- How did they cope with both work and family life?

RESULTS AND DISCUSSION

The authors observed that the female engineers featured during the oral presentations really captured the attention of the participants. The participants seemed to show greater enthusiasm than anticipated, and they participated actively in the question-and-answer sessions.

The participants commented that administering the *Draw-an-engineer* test at the outset without them suspecting anything was a powerful method to make them become aware of their misperceptions of engineers and engineering.

The results showed that before the intervention, the perception of engineers as men seemed to be more prevalent among the male participants as compared to the female participants – all the male participants depicted engineers as men while 91.4% of the female participants did so. The results showed that the activity was effective in dispelling the participants' perceptions of engineers as men. The percentage of male participants who depicted engineers as men decreased from 100% before the intervention to 62.2% after the intervention ($p < 0.01$). Similarly, the percentage of female participants who depicted engineers as men decreased from 91.4% before the intervention to 31.4% after the intervention ($p < 0.01$). After the intervention, the male participants seemed to be more tenacious of their perceptions of engineers as men than the female participants – the percentage of male participants who depicted engineers as men decreased by 37.8% whereas that of female participants decreased by 60.0%.

In the drawings, the participants showed engineers engaged in building or repairing, planning or designing, or laboratory work. The results showed that the activity was effective in countering the participants' perceptions of the nature of engineering jobs. The percentage of male participants who portrayed engineers engaged in building or repairing decreased from 66.7% before the intervention to 4.4% after the intervention while that of female participants decreased from 74.3% to 2.9% ($p < 0.01$). Conversely, the percentage of male participants who depicted engineers engaged in planning or designing increased from 26.7% before the intervention to 91.2% after the intervention while that of female participants increased from 20.0% to 91.4% ($p < 0.01$).

Thus, prior to the intervention, a majority of the participants had the misperception that engineering jobs involved a lot of manual work and were physically demanding. The oral presentations enabled the participants to note that engineers were increasingly required to think, plan, design and communicate, and not do just manual work. In order to encourage more girls to pursue engineering, teachers need to highlight to students that in today's knowledge-based and innovation-driven economy, engineering requires intellectual abilities and the capacity for innovation, and not so much manual work.

The participants noted that the female engineers featured here cited the role of their parents or teachers in encouraging their pursuit of an engineering career. Research has pointed out the importance of parental support in fostering young women's interest in science-related careers [12].

Research has also shown that teachers play a critical role in young women's decision to pursue careers in engineering and science [13]. All these might suggest that organising outreach programmes directed specifically at parents or teachers might help to narrow the gender gap in engineering.

The participants noted that the female engineers featured here held senior positions in academia, government or industry. Many of them were members of the US National Academy of Engineering (NAE). They were different from those the participants had ever encountered and those found in many studies where most female characters were shown as pupils, laboratory assistants or science reporters [14]. The female engineers featured here could, therefore, be used to overcome existing stereotypes of female engineers.

Table 1: Outstanding women in electrical and electronics engineering and their major achievements.

1.	Eleanor Baum Previously appointed President of the Accreditation Board for Engineering and Technology (ABET), and President of the American Society for Engineering Education (ASEE). Appointed Dean of Engineering of the Cooper Union for the Advancement of Science and Art in New York City since 1987 [16].
2.	Edith Clarke Awarded a patent in 1921 for a *graphical calculator* that was used for solving electric power transmission line computations. Authored a two-volume reference book entitled *Circuit Analysis of AC Power Systems*, which became classics in the field [17].
3.	Esther M. Conwell Developed the theory behind the conduction of electricity in semiconductor materials used in transistors. Investigated the transport and optical properties of organic conductors, which were important components of xerographic copiers and printers. Held four patents. Elected a member of the US NAE [18].
4.	Denice Denton Researched micro-electro mechanical systems as an enabling technology, and in the arena of transformational change in higher education. Appointed the Dean of Engineering at the University of Washington in 1996, and the Chancellor of the University of California at Santa Cruz in 2005 [19].
5.	Mildred Spiewak Dresselhaus Established high-field magneto-optic spectroscopy as a tool for the study of the electronic structures of semi-metals. Modified the structures and properties of electronic materials, carbon fibres, fullerenes and bismuth nanowires. Appointed the Director of the Office of Science of the US Department of Energy in 2000. Elected a member of the US NAE [20].
6.	Mitra Dutta Developed unique optical characterisation and diagnostic techniques, which were used for the design of novel hetero-structures for optoelectronic and electronic devices of superior performance. Held 24 patents [21].
7.	Delores M. Etter Contributed to adaptive signal processing, digital filter design and biometric signal processing. Appointed Deputy Under Secretary of US Defense for Science and Technology in 1998, and Assistant Secretary of US Navy for Research, Development and Acquisition in 2005. Elected a member of the US NAE [22].
8.	Elsa M. Garmire Discovered the key features of stimulated light scattering and self-focusing. Demonstrated the key components of integrated optics in semiconductors. Invented a generic class of hybrid-electrical optical bi-stable devices, a technology pivotal in digital optical computing. Held nine patents. Elected a member of the US NAE [23].
9.	Evelyn L. Hu Developed microfabrication and nanofabrication techniques to facilitate the study of superconducting and semiconducting devices and circuits. Examined the processes critical for the fabrication and operation of superconducting, electronic and optical devices. Studied the formation of high-quality, heterogeneous interfaces, such as that between semiconductors and superconductors. Elected a member of the US NAE [24].
10.	Jennie S. Hwang Recognised as a pioneer and longstanding leader in the fast-moving infrastructure development of electronics miniaturisation and environment-friendly manufacturing, including Surface Mount Technology and environment-friendly lead-free electronics. Held nine patents. Appointed the President of the H-Technologies Group Inc and Asahi Technologies America Inc. Elected a member of the US NAE [25].
11.	Shirley Ann Jackson Recognised for her work on the polaronic aspects of electrons in two-dimensional systems. Her research in solid-state physics resulted in rapid improvements in the signal-handling capabilities of semiconductor devices. Spearheaded the formation of the International Nuclear Regulators Association. Appointed the President of Rensselaer Polytechnic Institute in 1999. Elected a member of the US NAE [26].
12.	Leah H. Jamieson Co-founded the Engineering Projects in Community Service programme. Contributed to research on speech analysis and recognition; design and analysis of parallel processing algorithms; and the application of parallel processing to digital speech, image and signal processing. Appointed the Dean of Engineering at Purdue University in 2006, and the President of the Institute of Electrical and Electronics Engineers in 2007. Elected a member of the US NAE [27].
13.	Betsy Ancker-Johnson Described plasma as a fourth state of matter after solids, liquids and gases, and discovered that solid-state plasmas could serve as microwave sources of radiation. Developed a high-frequency signal generator. Appointed Assistant Secretary of US Commerce for Science and Technology in 1973. Elected a member of the US NAE [28].
14.	Kristina M. Johnson Recognised for her contributions to holography, optical and signal processing, liquid crystal electro-optics, and using a novel variety of liquid crystals to create new types of miniature displays and computer monitors. Founded Colorado Advanced Photonics Technology Center, ColorLink, KAJ LLC, Colorado Microdisplay, and Southeast TechInventures. Held 43 patents. Appointed the Dean of Engineering at Duke University in 1999 [29].
15.	Linda P.B. Katehi Recognised for her contributions to three-dimensional integrated circuits and on-wafer packaging. Held 13 patents. Appointed the Dean of Engineering at Purdue University in 2002, and the Provost and Vice Chancellor for Academic Affairs at the University of Illinois in 2006. Elected a member of the US NAE [30].

16.	Cherry Murray Developed the optical fabric for the first all-optical cross connect for telecommunications networks, and 40 Gbit electronics for Lucent Technologies' optical products. Held two patents. Elected a member of the US NAE [31].
17.	Irene Carswell Peden Determined the bulk electromagnetic properties of Antarctic ice 7,000 feet thick using surface data. Developed analytical model for interpreting data from a probe lowered into deep ice, yielding the first direct measurements of VLF dielectric and loss properties. Elected a member of the US NAE [32].
18.	Manijeh Razeghi Initiated the design and implementation of epitaxial growth techniques. Developed a number of semiconductor structures for advanced photonic and electronic devices. Pioneered the growth of (Ga,In) (As,P)-based hetero-structures, thereby overcoming numerous material problems. Held 50 patents [33].
19.	Evangelia Micheli-Tzanakou Contributed to research on neural networks in biology and medicine, visual and auditory systems, and the modelling of neurological disorders. Established the first brain-to-computer interface using her algorithm ALOPEX. ALOPEX has also been used for digital signal processing, image processing and pattern recognition [34].
20.	Doris Kuhlmann-Wilsdorf Studied tribology and the mechanical properties of metals. Developed a theory of crystal defects, crystal plasticity and electric contacts. Invented metal-fibre brushes, which were critical parts of motors and generators. Held six patents. Elected a member of the US NAE [35].

The participants noted that the female engineers featured here acknowledged that they had encountered difficulties at their workplaces, such as the absence of female role models, mentors and colleagues, supervisors' stereotyping of women's abilities, differences in communication style and sexism, but they also mentioned recent progress made towards acceptance and equality. The participants felt that although these difficulties truthfully reflected the experiences of female engineers, such revelations might deter talented young women from pursuing careers in engineering. This is a significant point because research shows that young women are less likely to choose careers in science because of the difficulties associated with doing science [15]. The participants felt that while it was important to raise young women's awareness of the *chilly environment* that might exist in engineering, it was even more important to highlight the improvements made in producing more inclusive workplaces in engineering.

The participants noted that the female engineers featured here were able to cope with both work and family life because of pro-family workplace policies, and having a supportive, and understanding husband and efficient domestic help. This is an important point because concerns about how to balance work and family responsibilities appear to be a recurring issue in research on the factors that keep young women from pursuing engineering and science careers [1]. In order to encourage more young women to pursue engineering, it was thus important to highlight how female engineers successfully combined work and family.

CONCLUSION

In this article, the authors describe an activity that can be used to correct the misperceptions of engineers and engineering among high school teachers. By providing detailed information about the personal lives and work experiences of prominent female engineers, these biographies might be useful in countering existing cultural stereotypes of female engineers and initiating changes in perceptions needed to narrow the gender gap in engineering. The activity could also be used for elementary and middle school teachers – this might enable them to correct misperceptions of engineers and engineering among their students. Furthermore, the activity could be carried out by professors with female undergraduates or graduate students so as to provide them with female role models – this would encourage them to pursue and excel in electrical and electronics engineering as a course of study and as a profession.

It is hoped that more educators will use this type of activity to correct the myth among girls and young women that a career in engineering is not suited for them. Professors and teachers need to take every opportunity to assure girls and young women that females can contribute as equally as males to engineering, as illustrated by the outstanding female engineers featured here. As the world economy becomes increasingly reliant on a technologically literate workforce, the world cannot afford to overlook the talent and potential contributions of half of the population. If it does, societies, nations and our world will suffer.

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