The perception that engineers and scientists are intelligent Caucasian men who are socially inept and absent-minded people is prevalent among students of all levels, from elementary school to college (Congressional Commission on the Advancement of Women and Minorities in Science, Engineering and Technology Development [CCAWMSEDT], 2000; Knight & Cunningham, 2004). While the media may, by chance or choice, promote this image, the reality is that most engineers are men. For example, while women constituted 46.1% of the general workforce of the U.S.A. in 2000, they represented only 25.4% of the engineering and science workforce (National Science Foundation, 2006). 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 cannot be the people so often portrayed in the media (Brownlow, Smith & Ellis, 2002).

Fortunately, research has shown that strategies such as 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 (Anderson & Gilbride, 2003; Bodzin & Gehringer, 2001; Mawasha et al., 2001; Moreno et al., 2001). 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 (Advocates for Women in Science, Engineering and Mathematics, 2000).

In order to reach out to students at an early age when they are still impressionable, many universities have recently organized outreach programs to inform high school teachers about engineering, and hopefully, these teachers will encourage their students to study engineering (Jeffers, Safferman & Safferman, 2004). Some universities (e.g., Purdue University) have set up an Engineering Education Department for informing high school teachers about engineering. The feedback from such programs has been encouraging.

For this work, the author wanted to inform teachers about the applications of engineering 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 author recently conducted a number of outreach workshop activities for 80 high school biology teachers. The teachers were then charged with integrating what they had learned from the workshop into their classrooms.

This article describes one of the workshop activities the author has carried out with high school biology teachers to enable them to overcome their stereotypical perceptions of engineers and engineering. The workshop activity introduced them to outstanding women in bioengineering and raised their awareness of these female bioengineers’ contributions to engineering and society. Biology teachers and professors can use the examples of these outstanding female bioengineers as role models to inspire their female students to become bioengineers.

**Method**

The high school biology teachers consisted of 45 males and 35 females. Their ages ranged from 25 to 40. 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 (Knight & Cunningham, 2004). The drawings were analyzed as follows. Drawings of engineers with short hair and broad shoulders were regarded as male while those with long hair and narrow shoulders 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. Those working with computer, blueprint, pen, model, and/or desk were regarded as engaged in planning or designing, while those working with test tube and/or beaker 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 bioengineer from Table 1 to research. The Table contains 20 outstanding women in bioengineering and their major achievements. The participants were given one week to do their research and were encouraged to use Internet resources. To familiarize the participants with bioengineering, bioengineers specializing in different areas were included in the Table. These areas of specialization were bioinstrumentation, biomaterials, biomechanics, clinical engineering, rehabilitation engineering, and systems physiology.

Each group was required to do a 20-minute oral presentation and submit a written report of the female bioengineer assigned to the group. The participants were required to design and present various...
Table 1. Outstanding Women in Bioengineering and Their Major Achievements.

<table>
<thead>
<tr>
<th>Name</th>
<th>Achievement</th>
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<tr>
<td>Frances H. Arnold</td>
<td>She was the Dick and Barbara Dickinson Professor of Chemical Engineering and Biochemistry at California Institute of Technology. Internationally renowned for pioneering methods for directed evolution to optimize enzymes and to engineer biosynthetic pathways and genetic regulatory circuits. Held 19 patents. Elected a member of the U.S. NAE and the U.S. Institute of Medicine (California Institute of Technology, 2008).</td>
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<tr>
<td>Sangeeta N. Bhatia</td>
<td>She was the Director of Laboratory for Multiscale Regenerative Technologies at the Division of Health Sciences and Technology, Harvard-Massachusetts Institute of Technology. Internationally renowned for her research on hepatic tissue engineering and biologic micro-electro-mechanical systems. Held three patents. Elected a fellow of AIMBE (Massachusetts Institute of Technology, 2008).</td>
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<tr>
<td>Susan M. Blanchard</td>
<td>She was Professor in the Department of Bioengineering, and the Founding Director of the School of Engineering at Florida Gulf Coast University. Internationally renowned for contributions to cardiac electrophysiology and for innovations in biomedical engineering education. Elected a fellow of AIMBE, BMES, and IEEE (Florida Gulf Coast University, 2008).</td>
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<tr>
<td>Barbara D. Boyan</td>
<td>She was Professor in the Department of Biomedical Engineering at Georgia Institute of Technology and Emory University. Co-founded Osteobiologics, Inc., Orthotis Inc., and Biomedical Development Corporation. Internationally renowned for her research on the mechanisms of actions of hormones and growth factors on chondrocytes and osteoblasts, normal and pathological calcification, tissue engineering, and response of cells to biomaterials. Held 11 patents. Elected a fellow of AAAS and AIMBE (Georgia Institute of Technology, 2008).</td>
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<tr>
<td>Janie M. Fouke</td>
<td>She was Professor in the Department of Biomedical Engineering, and Senior Advisor to the President for International Affairs at the University of Florida. Internationally renowned for developing instrumentation critical to the understanding of the etiology of airway diseases. Elected a fellow of AAAS, AIMBE, BMES, and IEEE (University of Florida, 2008).</td>
</tr>
<tr>
<td>Martha L. Gray</td>
<td>She was the Edward Hood Taplin Professor of Medical and Electrical Engineering at Massachusetts Institute of Technology, and the Director of the Division of Health Sciences and Technology, Harvard-Massachusetts Institute of Technology. Internationally renowned for her research on ways to diagnose and treat arthritis, connective tissue physiology, imaging, and microfabrication. Held four patents. Elected a fellow of AIMBE (Massachusetts Institute of Technology, 2008).</td>
</tr>
<tr>
<td>Lydia E. Kavraki</td>
<td>She was Professor of Bioengineering and the Noah Harding Professor of Computer Science at Rice University. Internationally renowned for contributions to computational structural biology, bioinformatics, and computer-assisted drug design. Elected a fellow of AIMBE (Rice University, 2008a).</td>
</tr>
<tr>
<td>Rebecca Richards-Kortum</td>
<td>She was Chair of the Department of Bioengineering at Rice University. Internationally renowned for her research on the use of fluorescent imaging agents and high-resolution optical imaging for cancer detection, and the use of fiber-optic sensors for in vivo detection of cancer. Held 25 patents. Elected a fellow of AIMBE (Rice University, 2008b).</td>
</tr>
<tr>
<td>Jelena Kovacevic</td>
<td>She was Professor of Biomedical Engineering at Carnegie Mellon University, where she also served as Director of the Center for Bioimage Informatics. Internationally renowned for building automated systems for processing and interpreting biological images. Held 18 patents. Elected a fellow of IEEE (Carnegie Mellon University, 2008).</td>
</tr>
<tr>
<td>Ann L. Lee</td>
<td>She was Vice President for Process Development at Genentech, Inc. Internationally renowned for developing methods for large-scale, cost-effective production of vaccines that have saved lives worldwide. Held three patents. Elected a member of the U.S. NAE (Yale University, 2008).</td>
</tr>
<tr>
<td>Frances S. Ligler</td>
<td>She was Senior Scientist of the Center for Bio/Molecular Science and Engineering at the U.S. Naval Research Laboratory. Internationally renowned for inventing portable, automated biosensors for detecting pathogens, toxins, pollutants, drugs of abuse, and explosives. Held 19 patents. Elected a member of the US NAE (US Naval Research Lab, 2008).</td>
</tr>
<tr>
<td>Linda C. Lucas</td>
<td>She was Professor in the Department of Biomedical Engineering, and the Dean of Engineering at University of Alabama, Birmingham. Internationally renowned for developing and characterizing bioactive coatings for dental and orthopedic devices, evaluating the biocompatibility of biomaterials, and developing bone cement. Elected a fellow of AIMBE (American Institute of Medical and Biological Engineering, 2008).</td>
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<tr>
<td>Deirdre Meldrum</td>
<td>She was Director of the Center for Ergonomics, and the Dean of Engineering at Arizona State University. Internationally renowned for automating the processes for large-scale DNA sequencing, and for developing microscale devices with sensors for measurements in biological applications. Held two patents. Elected a fellow of AAAS, IEEE, and AIMBE (Arizona State University, 2008).</td>
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<tr>
<td>Banu Onaral</td>
<td>She was Founding Director of the School of Biomedical Engineering, Science and Health Systems at Rice University. Internationally renowned for developing mathematical models for complex physiological systems, clinical applications, and resuscitation therapies for burn patients. Elected a fellow of AIMBE, IEEE, and AIMBE (IEEE, 2008).</td>
</tr>
<tr>
<td>Laura M. Roa</td>
<td>She was Founding Chair of the Biomedical Engineering Research Group at the University of Seville, Spain. Internationally renowned for developing mathematical models for complex physiological systems, clinical applications, and resuscitation therapies for burn patients. Elected a fellow of AIMBE, IEEE, and AIMBE (International Council on Medical and Care Compumatics, 2008).</td>
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<tr>
<td>Esther S. Takeuchi</td>
<td>She was Chief Scientist for Wilson Greatbatch Technologies, Inc. Internationally renowned for developing silver vanadium oxide batteries for implantable cardiac defibrillators, and lithium-carbon monofluoride cells for implantable pacemakers. Held 135 patents. Elected a member of the U.S. NAE, and a fellow of AIMBE (National Academy of Engineering, 2008a).</td>
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<tr>
<td>Kathryn E. Uhrich</td>
<td>She was Professor in the Department of Biomedical Engineering and the Department of Chemistry and Biomedical Engineering at Rutgers University. She was also founder and Scientific Advisory Board Chairperson of Polymemix Corporation. Internationally renowned for research on the synthesis and characterization of biocompatible polymers for medical and dental applications. Held 13 patents. Elected a fellow of AIMBE (Rutgers University, 2008).</td>
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<tr>
<td>Jennifer L. West</td>
<td>She was the Isabel C. Cameron Professor of Bioengineering and Director of the Institute of Biosciences and Bioengineering at Rice University. She was also Co-founder, Director, and Principal Scientific Officer of Nanospectra Biosciences, Inc. Internationally renowned for her research on the medical applications of nanoshells, for developing techniques that could be used to grow replacement blood vessels in a patient’s own cells in vitro, and for developing polymers that could be coated on arteries and that could release nitric oxide. Held 14 patents (Rice University, 2008c).</td>
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<tr>
<td>Miranda G.S. Yap</td>
<td>She was Professor in the Department of Chemical and Biomolecular Engineering at the National University of Singapore, and the Executive Director of A*STAR Bioprocessing Technology Institute in Singapore. Founded Mertion Pharmaceuticals Pte Ltd and A-BIO Pharma Pte Ltd. Internationally renowned for her research on mammalian cell culture. Elected a foreign associate of the U.S. NAE (National Academy of Engineering, 2008b).</td>
</tr>
<tr>
<td>Jackie Y.R. Ying</td>
<td>She was Professor and Executive Director of the Institute of Bioengineering and Nanotechnology in Singapore, and an Adjunct Professor of Chemical Engineering at the Massachusetts Institute of Technology. Internationally renowned for her research on the synthesis of nanostructured materials for drug delivery, tissue engineering, biosensing, bioimaging, synthesis of pharmaceuticals, and energy applications. Held 11 patents (Institute of Bioengineering and Nanotechnology, 2008).</td>
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documents to give an overview of the bioengineer’s life, for example, birth certificate, educational certificates, marriage certificate, and resume for a hypothetical research post to which the female bioengineer wished to apply. They were also required to address the following items during the oral presentation:

- Who inspired the person to become a bioengineer?
- 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 that were unusually inspiring for young women studying bioengineering?

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 (MedCalc Software, 2009). 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 bioengineers in terms of:

- Who inspired them to become bioengineers?
- 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?

A follow-up survey consisting of one forced-choice item was administered one year after the activity via e-mail to find out whether the participants had carried out the activity with their students.

○ Results & Discussion

The author observed that the female bioengineers 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 way to make them become aware of their misperceptions of engineers and engineering. Figure 1 shows a representative sample of the participants’ drawings of engineers. 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) (Figure 2). 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 as compared to 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) (Figure 3). 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) (Figure 4). 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 ability and capacity for innovation and not so much manual work.

The participants noted that the female bioengineers 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 (Tilleczek & Lewko, 2001). Research has also shown that teachers play a critical role in young women’s decision to pursue careers in engineering and science (Schoon, Ross & Martin, 2007). All these suggest that organizing outreach programs directed specifically at parents or teachers can help to narrow the gender gap in engineering.

The participants also noted that the female bioengineers featured here held senior positions in academia, government, or industry. Many of them are members of the U.S. National Academy of Engineering (NAE) or fellows of the American Association for the Advancement of Science (AAAS), the American Institute for Medical and Biological Engineering (AIMBE), the Biomedical Engineering Society (BMES), the Institute of Electrical and Electronics Engineers (IEEE), or the International Academy for Medical and Biological Engineering Sciences (IAMBES). 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 (Steinke, 2004). The female bioengineers featured here could therefore be used to overcome existing stereotypes of female engineers.

The female bioengineers 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 the female bioengineers, such revelations could deter talented young women from pursuing careers in bioengineering. 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 (Clewell & Campbell, 2002). The participants felt that while it was important to raise young women’s awareness of the chilly environment that could exist in engineering, it was even more important to highlight the improvements made in producing more inclusive workplaces in engineering.

In addition, the female bioengineers 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 (CCAWMSETD, 2000). In order to encourage more young women to pursue engineering, it was thus important to highlight how female engineers successfully combined work and family.

All the participants took part in the follow-up survey. The survey findings showed that 83.8% of the participants had carried out the activity with their students. Further analysis of this result showed that the female participants were more likely to have done so as compared to the male participants — 91.4% of the female participants versus 77.8% of the male participants. This could be because the female participants were able to identify with the female engineers better than the male participants. All these results indirectly showed that the participants found the activity useful for dispelling their misperceptions of engineers and engineering. Indeed, it is important that teachers do not carry stereotypes with them to the classrooms because research has shown that stereotypes can shape girls’ attitudes in ways that limit their educational and vocational aspirations during the early years of adolescence (Schoon et al., 2007).

○ Conclusion

This article describes an activity that can be used to correct misperceptions of engineers and engineering among high school biology teachers. The results showed that this activity was effective in
achieving the goals of correcting misperceptions of engineers and engineering among high school biology teachers, and providing them with female role models in bioengineering. By providing detailed information about the personal lives and work experiences of the female bioengineers, the biographies can be useful in countering existing stereotypes of female engineers and initiating changes in perceptions needed to narrow the gender gap in engineering. The activity can also be used for elementary and middle school teachers-to enable them to correct misperceptions of engineers and engineering among their students. Furthermore, the activity can be carried out by professors with female undergraduate or graduate students so as to provide them with female role models. This can encourage them to pursue and excel in bioengineering 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 bioengineers 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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