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Using Notable Women in Environmental Engineering To Dispel Misperceptions of Engineers

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This paper describes an activity the author has carried out with 72 high school science teachers to enable them to overcome their stereotypical perceptions of engineers. The activity introduced them to notable women in environmental engineering, and raised their awareness of these female engineers' contributions to engineering and society. The results revealed that the activity was effective in countering high school teachers' misconceptions of engineers. 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 notable female engineers as role models to inspire their female students to become engineers.

Key Words: engineers, environmental engineering, outreach, role models, stereotypes, women

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 of all levels, from elementary school to college (Congressional Commission on the Advancement of Women and Minorities in Science, Engineering and Technology Development [CCAWMSETD], 2000; Knight & Cunningham, 2004; Scantlebury, Tai, & Rahm, 2007). While the media may, by chance or choice, promote this image, it is unfortunately not far from reality. For example, while women constituted 46.1% of the general workforce of the USA 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 engineering or a science career because they do not want to be the people so often portrayed in the media (Brownlow, Smith, & Ellis, 2002).

Stereotypical images of engineers and scientists have contributed, in part, to the existing gender gap in engineering and science (CCAWMSETD, 2000). This gender gap can be traced back to the educational choices made by young women. Statistics show that women in the Organisation for Economic Co-operation and Development (OECD) countries earn fewer Ba-

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chelor's degrees in most engineering and scientific fields as compared to men. For example, in 2003, women earned only 13.8% of all Bachelor's degrees in engineering in Switzerland, 18.7% of all Bachelor's degrees in engineering in UK, 21.0% of all Bachelor's degrees in engineering in USA, and 29.1% of all Bachelor's degrees in engineering in Sweden (National Science Foundation, 2006).

The gender gap in engineering and science has also been attributed to a number of other factors. Girls' rejection of engineering and science can be partially driven by parents, teachers and peers when they subtly, and not so subtly, steer girls away from informal technical pastimes (e.g. fixing bicycles) and science activities (e.g. science fairs) that too often are still thought of as the province of boys (Campbell & Clewell, 1999). Another reason is the shortage of female role models in engineering and science, and this is because female engineers and scientists are severely under-represented among senior positions in academia, government and industry. With this dearth of female role models, many girls do not see themselves as successful doers of engineering and science, and tend to view these disciplines as unsuitable careers and irrelevant to their lives (Catalyst, 2002). A similar reason is the shortage of female mentors in engineering and science. Having a mentor is critical to advancing into senior positions in corporations. However, it may be difficult for female engineers and scientists to find mentors through the same informal mechanisms used by men, especially since individuals tend to mentor people who are very much like them. Hence, female engineers and scientists are at a disadvantage in a predominantly male environment (CCAWMSETD, 2000). In addition, female engineers and scientists with children struggle to keep up with the fast-paced work environment. Unlike men, women remain primarily responsible for child care, elder care and other household responsibilities. Even in corporations with family-friendly policies, women are concerned that they cannot pursue their engineering and science careers and take family leave simultaneously without risking the perception that they are less committed to their careers than their male colleagues (Tack & Patitu, 1992). The gender gap in engineering and science can also be attributed to the lower pay scales and slower promotion rates for females as compared to males (Fox, 1995). Female engineers' and scientists' progress early in their careers may be impeded by their having to prove their technical credibility repeatedly. This may be the result of stereotyping of women's abilities by male supervisors as well as the perception that promoting women is riskier than promoting men. The perception that women cannot do engineering and science is one that female engineers and scientists have to battle constantly. The competencies and traits associated with success in engineering and science are generally viewed as male attributes (CCAWMSETD, 2000). Men and women have different styles of communication, and this may also affect how female engineers' and scientists' ideas are received by their male supervisors. Corporations tend to reward an aggressive style of speaking, and often discount language that is not certain. Women who exhibit an assertive style, however, run the risk of being seen as inappropriately combative (CCAWMSETD, 2000).

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 perception that engineering and science are unsuitable for girls (Anderson & Gilbride, 2003; Bodzin & Gehringer, 2001; Kahle, 1996; Mawasha, Lam, Vesalo, Leitch, & Rice, 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 and unbiased, many universities have recently organised outreach programmes to inform high school teachers about engineering, and hopefully, they would encourage their students to study engineering (Jeffers, Safferman, & Safferman, 2004). Some universities (e.g. Purdue University) have even set up an engineering education department for this purpose. The feedback from such programmes 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 among teachers, and to provide them with female role models from the various disciplines of engineering. To achieve these objectives, the author recently conducted a number of outreach workshop activities for 72 high school science teachers. The teachers were then charged with integrating what they had learned from the workshop into their classrooms.

This paper describes one of the workshop activities the author has carried out with high school science teachers to enable them to overcome their stereotypical perceptions of engineers. The workshop activity introduced them to notable women in environmental engineering, and raised their awareness of these female engineers' contributions to engineering and society. The results revealed that the activity was effective in countering high school teachers' misperceptions of engineers. Teachers and professors can use the examples of these notable female engineers as role models to inspire their female students to become engineers.

Method

The high school science teachers consisted of 41 males and 31 females. Their age ranged from 24 to 30. They were first asked to complete a "Draw-an-engineer" test to assess their perceptions of engineers. The test required them to draw a picture of an engineer at work (Knight & Cunningham, 2004). 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 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 groups were each assigned a female environmental engineer from Table 1 to research on. Table 1 contains 18 notable women in environmental engineering, and their major achievements. The participants were given one week to conduct their research, and were encouraged to use Internet resources for their research.

To familiarise the participants with the discipline of environmental engineering, a broad range of specialties were included in Table 1. These areas of specialisation were water and air pollution control, recycling, waste disposal, management of hazardous waste; designing municipal water supply and industrial wastewater treatment systems; minimising the effects of acid rain, global warming, automobile emissions and ozone depletion; protecting wildlife; and providing legal and financial consulting on matters related to the environment.

Each group was required to do a 20-minute oral presentation and submit a written report of the female environmental engineer assigned to the group. The participants were required to design and present various documents to give an overview of the environmental engineer's life, for example, birth certificate, educational certificates, marriage certificate, and resume for a hypothetical research post that the female environmental engineer wished to apply. They were also required to address the following items during the presentation: (a) Who inspired her to become an engineer? (b) What were her research interests? (c) What were her major

Table 1. Notable women in environmental engineering and their major achievements

1	Linda M Abriola She is a Professor in the Department of Civil and Environmental Engineering, and the Dean of the School of Engineering at Tufts University since 2003. Internationally renowned for her research on integrating mathematical modeling with laboratory experiments to investigate and elucidate processes governing the transport, fate, and remediation of non-aqueous phase liquid organic contaminants in the subsurface. Elected a fellow of the American Academy of Arts and Sciences, and a member of the US National Academy of Engineering (Tufts University, 2008).
2	Joan B Berkowitz She is the Managing Director of Farkas Berkowitz & Company since 1989. Specialised in environmental and hazardous waste management since 1972, when she contributed to the US Environmental Protection Agency's First Report to Congress on Hazardous Waste. Authored the first handbook on alternatives to landfill in hazardous waste management in 1978. Served as the Vice President of Arthur D Little Inc, where she directed the firm's environmental practices worldwide. Left Arthur D Little Inc to become the President of Risk Science International, an environmental consulting company, in 1986 (Farkas Berkowitz & Company, 2008).
3	Angela R Bielefeldt She is an Associate Professor in the Department of Civil, Environmental, and Architectural Engineering at the University of Colorado at Boulder. Contributed to research on the biodegradation and biotransformation of organic and inorganic pollutants in soil, water, and air. Co-recipient of two patents. Received the 1997 Rudolph Hering Medal from the American Society of Civil Engineers or ASCE (University of Colorado at Boulder, 2008a).
4	Sallie W Chisholm She is a Professor in the Departments of Biology, and Civil and Environmental Engineering at the Massachusetts Institute of Technology. Discovered the genus *Prochlorococcus* – the most abundant phytoplankton taxon in the ocean, and examined its physiological ecology at various scales, from the community down to the individual cell, and this has transformed our understanding of pelagic ecology, biogeochemical cycling, and microbial evolution in the ocean. Played a leading role in the integration of genomics into marine microbial ecology. Elected a fellow of the American Academy of Arts and Sciences (Massachusetts Institute of Technology, 2008).
5	Lisa Alvarez-Cohen She is the Fred and Claire Sauer Professor and Vice Chair of the Department of Civil and Environmental Engineering at the University of California at Berkeley. Internationally renowned for her research on the biotransformation and fate of emerging contaminants and the use of innovative molecular and isotopic techniques for studying the microbial ecology of bioremediation communities. Elected a fellow of the American Academy of Microbiology (University of California at Berkeley, 2008).
6	Geraldine V Cox Worked on several major environmental issues. Served as the Vice President and Technical

Table 1. *Contiuned.*

	Director of the Chemical Manufacturers Association from 1979 to 1991, where she developed policies for the chemical industry in energy, toxic substances, and hazardous materials. Served as the Vice President of Fluor Corporation (1991-1994), the Chairman of AMPOTECH Corporation (1994-1999), and the Vice President of EUROTECH Ltd (Drexel University, 2008).
7	Lorraine N Fleming She is a Professor in the Department of Civil Engineering at Howard University. Contributed to research on geo-environmental and geo-technical engineering, in particular experimental soil mechanics, waste material utilisation, and soil's response to environmental changes. Received the 1994 Faculty Fellowship for Research from the US Department of Energy's Office of Civilian Radioactive Waste Management (Howard University, 2008).
8	Efi Foufoula-Georgiou She is the Distinguished McKnight University Professor in the Department of Civil Engineering, and Co-director of the National Center for Earth-surface Dynamics at the University of Minnesota, Minneapolis. Internationally renowned for her research in the areas of space-time rainfall modeling, hydro-geomorphology, and scaling in hydrologic processes. Elected a fellow of the American Geophysical Union and the American Meteorological Society (University of Minnesota, 2008).
9	Susan Grimes She is the SITA/Royal Academy of Engineering Chair in Waste Management in the Department of Civil and Environmental Engineering at Imperial College London since 2005. Internationally renowned for her research on material recovery from waste, analysis of toxic pollutants in waste, and recovery of chemicals from waste to eliminate or minimise the hazardous component. Served as the Director of the Centre for Environmental Research at Brunel University from 1997 to 2005, where she supervised more than 60 PhD students (Imperial College London, 2008).
10	Shari B Libicki She is a Principal and Global Practice Area Leader for Air Sciences at ENVIRON Corporation. Has 20 years of experience in chemical fate and transport, including estimation and measurement of air emissions from industrial processes, and landfills. Elected a diplomacy fellow of the American Association for the Advancement of Sciences in 1987. Received the 1989 Meritorious Honor Award from the US Department of State (ENVIRON, 2008).
11	Nancy G Love She is a Professor and the Chair of the Department of Civil and Environmental Engineering at University of Michigan. Internationally renowned for her research on wastewater treatment at the cellular and molecular levels, focusing on the micro-organisms used in wastewater treatment and their responses to toxic pollutants. Received the 2002 Harrison Prescott Eddy Medal from the Water Environment Federation (University of Michigan, 2008a).
12	Debbie A Niemeier She is a Professor in the Department of Civil and Environmental Engineering, the Director of the John Muir Institute of the Environment, and the Associate Vice Chancellor for Research at

Table 1. *Contiuned.*

	the University of California at Davis. Contributed to research on quantifying the effects of transportation on air quality, improving the theory and methods of modeling used for estimate ing vehicle emissions, and developing regulatory responses for local and state agencies (University of California at Davis, 2008).
13	Lutgarde Raskin She is a Professor in the Department of Civil and Environmental Engineering at University of Michigan. Internationally renowned for her research on water quality control processes, focusing on the biological treatment of wastewater using a combination of novel molecular biological techniques and traditional engineering approaches. Contributed to an understanding of the relationship between system performance and microbial community structure in both aerobic and anaerobic waste treatment systems. Received the 2006 Walter L Huber Civil Engineering Research Prize from the ASCE (University of Michigan, 2008b).
14	Debra R Reinhart She is a Professor in the Department of Civil and Environmental Engineering, and the Executive Associate Dean of the College of Engineering and Computer Science at the University of Central Florida. Contributed to research on solid waste landfilling and groundwater remediation. Co-recipient of five patents. Appointed Vice President of the American Academy of Environmental Engineers in 2007. Received the 2002 Excellence Award for University Research from the American Academy of Environmental Engineers (University of Central Florida, 2008).
15	Kristy A Schloss She is the President and Chief Executive Officer of Schloss Engineered Equipment Inc, which designs and manufactures environmental treatment equipment in the wastewater, hazardous waste, and bulk-material handling industries. The firm has achieved remarkable international success under her leadership, and was named National Exporter of the Year by the US Small Business Administration in 1999. Co-authored "Keys to Engineering Success" – a textbook that is being used by first-year engineering students worldwide (University of Colorado at Boulder, 2008b).
16	Christine A Shoemaker She is the Joseph P Ripley Professor in the School of Civil and Environmental Engineering at Cornell University. Internationally renowned for her research on finding cost-effective and robust solutions to environmental and water resource management problems using numerical modeling, optimisation, and statistical analyses in the areas of groundwater remediation, hydrology, pesticide management, ecology, and prevention of eutrophication through watershed management. Elected a fellow of the ASCE. Received the 2001 Humboldt Research Award from the Alexander von Humboldt Foundation (Cornell University, 2008).
17	JoAnn Silverstein She is a Professor in the Department of Civil, Environmental, and Architectural Engineering at the University of Colorado at Boulder. A pioneer in the area of biological denitrification, in terms of a process for the treatment of wastewater and drinking water. Recipient of one patent. Received the 2000 Distinguished Engineering Educator Award from the US Society of Women

Table 1. *Contiuned.*

	Engineers (The Society of Women Engineers, 2006).
18	Anne C Steinemann She is a Professor in the Department of Civil and Environmental Engineering, and the Director of The Water Center at University of Washington. Contributed to research on water resources and environmental management; drought prediction, preparedness, and mitigation; climate variability and climate change adaptation; emerging contaminants in water supplies; exposure to pollutants and effects on health; and integration of forecast information into decision-making. Received the 1999 Hesburgh Award (University of Washington, 2008).

research findings, and how had they influenced the current knowledge then? (d) What were the difficulties she had encountered in her research or work, and how had she overcome them? (e) 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. The significance of differences in drawings before and after the intervention was assessed by McNemar's Test for the Significance of Changes (Institute of Phonetic Sciences of Amsterdam, 2008). 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 environmental engineers in terms of (a) Who inspired them to become environmental engineers? (b) What appointments did they hold? (c) What difficulties did they encounter at their workplaces? (d) How did they cope with both work and family life? A follow-up survey consisting of one forced-choice item was administered six months later *via* e-mail to find out whether the participants had carried out the activity with their students.

Results

The author observed that the female engineers featured during the oral presentations successfully 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. 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 90.3% 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 60.9% after the intervention ($p < 0.01$). Similarly, the percentage of female participants who depicted engineers as men decreased from 90.3% before the intervention to 32.3% 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 39.1% whereas that of female participants decreased by 58.0%.

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 65.9% before the intervention to 4.9% after the intervention while that of female participants decreased from 74.2% to 3.2% ($p < 0.01$). Conversely, the percentage of male participants who depicted engineers engaged in planning or designing increased from 26.8% before the intervention to 90.2% after the intervention while that of female participants increased from 19.4% to 90.3% ($p < 0.01$).

The post-activity survey revealed the following. 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. It was also noted that the female engineers held senior positions in academia, government or industry. 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, male supervisors' stereotyping of women's abilities, differences in communication style between male supervisors and female engineers, difficulties in coping with both family and career, and lower pay scales and slower promotion rates for females as compared to males. The participants also noted that the female engineers 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.

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.

Discussion

The results showed that the activity was effective in countering the participants' perceptions of the nature of engineering jobs. 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 rather than manual work.

It was noted that female engineers 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 might suggest that organising outreach programmes directed specifically at parents or teachers might help to narrow the gender gap in engineering.

It was also noted that the female engineers held high positions in academia, government or industry. 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 engineers featured here could therefore be used to overcome existing stereotypes of female engineers.

It was also noted that the female engineers had encountered difficulties at their workplaces. The participants felt that although these difficulties truthfully reflected the experiences of the 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 (Clewell & Campbell, 2002). The participants felt that while it was important to raise young women's awareness of the unfriendly environment that might exist in engineering, it was even more important to highlight the improvements made in producing more inclusive workplaces in engineering.

It was also noted that the female engineers were able to cope with both work and family life. 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.

The follow-up survey showed that a majority of the participants had carried out the activity with their students. This result indirectly showed that the participants found the activity useful for dispelling their misperceptions of engineers. 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, Ross, & Martin, 2007).

Participants in this or any similar study cannot be guaranteed to give responses which demonstrate their genuine thinking. The "Draw-an-engineer" test would certainly bring results with male-dominated figures anywhere in the world, just as "Draw-a-nurse" test would deliver mainly female pictures. After the intervention, people know what is expected and why they are being asked. Hence the results are not then necessarily genuine reflections of their feelings. They still have other experiences. Some will draw females, believing that is what the researchers want, without changing their true ideas. Others will deliberately not draw females because they know that most engineers are male even though they have accepted that some top engineers are female. Using only the very narrow evidence of this directed research (only environmental engineers and only females), the inference would be that all engineers are female, which is of course not true.

Conclusion

This paper describes an activity that can be used to correct misperceptions of engineers among high school teachers. The results showed that the activity was effective in countering misperceptions of engineers among high school teachers. 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. The activity could also be used for elementary and middle school teachers – this might enable them to correct misperceptions of engineers 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 environmental 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 amongst girls and young women that a career in engineering is not suited for them. Teachers and professors need to take every opportunity to assure girls and young women that females can contribute as significantly as males to engineering, as illustrated by the notable 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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Appendix 1. Post-activity survey questions

(1) Who inspired the female environmental engineers featured in the oral presentations to become engineers?

- ☐ Parents
- ☐ Peers
- ☐ Relatives
- ☐ Teachers
- ☐ Others. Please specify ________________________________

(2) What appointments did the female environmental engineers featured in the oral presentations hold?

- ☐ Professor
- ☐ Senior position in the civil engineering industry
- ☐ Senior position in the government
- ☐ Laboratory assistant
- ☐ Others. Please specify _________________________________

(3) What difficulties did the female environmental engineers featured in the oral presentations encounter at their workplaces?

- ☐ Absence of female role models, mentors and colleagues
- ☐ Inadequate physical strength
- ☐ Male supervisors' stereotyping of women's abilities
- ☐ Differences in communication style between male supervisors and female engineers
- ☐ Difficulty in coping with both family and career
- ☐ Lower pay scales and slower promotion rates for females compared with males
- ☐ Others. Please specify _________________________________

(4) How did the female environmental engineers featured in the oral presentations cope with both work and family life?

- ☐ Quitting and resuming career some years later
- ☐ Pro-family workplace policies
- ☐ Having a supportive and understanding husband
- ☐ Having an efficient domestic help
- ☐ Others. Please specify _________________________________

Appendix 2. Follow-up survey question

The follow-up survey consisted of one forced-choice item. Below is the item.

Have you carried out the activity with your students during the last six months?

Yes -- ☐
No -- ☐

Appendix 3. A Representative sample of the participants' drawings of engineers

Female engineer engaged in building or repairing

Female engineer engaged in planning or designing

Male engineer engaged in building or repairing

Male engineer engaged in planning or designing