



Changing gender perceptions in elementary STEM education

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Changing gender perceptions in elementary STEM education
(Research to Practice)
Strand: Engineering across the K-12 Curriculum:
Integration with the Arts, Social Studies, Science, and the Common Core

Abstract

The enrollment of women in science, technology, engineering and mathematics (STEM) continues to be a problem across most post-secondary institutions in North America. In 2009, American universities reported 17.9% female enrollment in engineering¹, while Canadian universities reported 17.7% in 2010². While concerns around enrollment encompass numerous issues, many students, particularly females, lose interest in STEM domains as early as grades 4/5/6^{3,4,5}. In this paper, we demonstrate how integrating STEM classroom content and cross-curricular aspects using creative, engineering design techniques can change student perceptions of gender within STEM fields.

We designed a series of creative projects that combine mandated science, mathematics, technology, English, social studies, physical education and fine arts courses with basic electrical engineering concepts. These projects were led across five schools by one of the female researchers⁶. Over 350 local grade 5 students participated in the projects. Impressions held by students towards STEM were measured through quantitative surveys and qualitative interviews, both before and after the completion of the projects. These results are summarized in Table I.

Table 1: Comparison of student percentages who responded “agree” or “strongly agree”

Survey Question	Before	After
Men are less creative than women	75%	26%
Math is more difficult for women to learn than men	75%	7%
Science is more difficult for women to learn than men	75%	8%
Only nerds love math and science	74%	9%
Males are more professional than females	75%	12%
It is hard for women to become engineers in the workplace	75%	15%

Both the qualitative and quantitative data showed that cross-disciplinary activities enhance student perception of STEM. Prior to participating in the projects, 75% of students agreed or strongly agreed that men are less creative than women, and that math/science are more difficult for women to learn than men. Following the project series, those percentages fell significantly to 26%, 7%, and 8% respectively. All genders improved their opinions of STEM subject areas, with 74% falling to 9% of students agreeing or strongly agreeing that only nerds love math and science.

Other significant results were seen regarding perception of engineering. Before starting the projects, 38% self-identified as performing best in math or science, split closely between males and females. While these students were strong in the pre-requisite subjects for more advanced STEM courses and later careers, 60% stated that they would not consider engineering at all, very little, or a little, as a future career. Only 25% of females strong in math and science were interested in engineering, as opposed to 62% of the males. Of the entire sample population,

only 6% of students were female, good at math and science, and interested in pursuing engineering. Following the projects, students were asked again about their perceptions towards engineering. Overall, 74% of students stated that they were now more interested in electrical engineering as a possible career. When ranking a list of potential careers, males and females exhibited an equal level of interest in electrical engineering. Females also gained an appreciation for engineering inventions, with 87% now agreeing or strongly agreeing that engineers design cool things, as opposed to the earlier 69%.

By offering students a chance to explore engineering in the context of their other subjects, both genders changed their perceptions towards the engineering profession. These effects may remain as the students continue through school, and impact their future career decisions when they enroll in post-secondary.

Problem Statement

Across post-secondary institutions in North America, engineering enrollment continues to be dominated by male students, with less than 20% of first year classes reported as female. In 2009, American universities reported 17.9% female enrollment in engineering¹, while Canadian universities reported 17.7% in 2010². Concerns around enrollment encompass numerous issues, but past research has shown that many students, particularly females, lose interest in science, technology, engineering, and mathematics (STEM) domains as early as grades 4/5/6^{3,4}, consequently impacting their decision to follow STEM-based career paths, such as engineering.

The Norwegian ROSE (Relevance of Science Education) project demonstrated significant gender differences in attitudes towards science and technology on an international scale⁵. Girls in first world nations, such as Japan and countries of Northern Europe, are more likely to be negative or ambivalent towards science and technology than boys. They are also more likely to agree that their school science is less interesting than other subjects, and to agree that school science has not opened their eyes for new and exciting jobs. Young males expressed an interest in technical problems, while females preferred environmental and health related areas. Girls also indicated a preference for future careers that involve helping and working with people, and were not interested in a career in science and technology. This discrepancy may be due to the fact that young women do not identify traditionally technological subjects, such as engineering, as career fields that involve interactions with people and society.

The purpose of this study is to demonstrate how integrating STEM classroom content and cross-curricular aspects using creative, engineering design techniques can change student perceptions of gender within STEM fields, such as engineering.

Research Methodology

The first stage of this study was to analyze the perceptions held by post-secondary students who have already chosen to enter the field of engineering. The purpose behind this goal was to determine the views that engineering students hold towards their future career, and to examine their perceptions of gender within engineering education. 144 first year students responded to an anonymous survey distributed through an email link, with 36.8% of the students

being female. Engineering students consistently ranked math and science as their top two best subjects, as well as the subjects they enjoyed the most in both grades 4/5/6 and high school. These students who have already chosen engineering as a future career, expressed an interest in math and science at an early age, rather than later in their grade school education. In general, the students indicated positive views towards engineering, including how engineers are viewed in society. The students reacted very strongly to gender-related engineering questions, even offering extraneous comments about the sexism suggested by the questions. The majority of students disagreed that women have a harder time learning technology, science, and math than men, and also disagreed that men are less creative than women.

The second stage of this study adapted the post-secondary survey to a grade five reading level, and the new questionnaire was answered by 306 fifth grade students, with 58% of the respondents being female. The purpose of this second survey was to determine the pre-conceived notions that elementary students have about engineering, and math and science in their classroom, prior to beginning any engineering coursework. Like the post-secondary students, the grades fives were asked about their hobbies, interests, thought on STEM coursework, and their views on gender in engineering. Only 35% of students identified math or science as their favourite subject, and only 22% also indicated math/science as the subject they perform the best in. Just over half of the students best in math and science selected another subject as their favourite, suggesting a lack of enthusiasm for STEM despite academic success. 60% of these students also stated that they would not consider engineering as a future career at all, very little, or a little (62% of the males, and only 25% of the females). 75% of all students agreed or strongly agreed that only nerds love math and science, showing either a perception that passion for STEM subjects is only for the academically elite, or a disinclination to identify themselves as “nerds”.

The grade five students also indicated troubling perceptions of gender relating to engineering skills. Despite nearly all of the students believing that they are creative themselves, 82% of males agreed that men are less creative than women, with 69% of female believing the same. 75% of the students, regardless of gender, agreed that science and math are more difficult for women to learn than men, that it is hard for women to become engineers in the workplace, and that males are more professional than females. These perceptions are reinforced by the lack of interest and confidence reported by the female students. Out of all the students, only 6% of the fifth grade students were female, self-identified as good at math and science, and interested in pursuing engineering as a career.

The differences between the post-secondary and elementary students revealed interesting issues for the current state of engineering education in K – 6. Elementary students who are both interested and perform well in math and science are those who may choose to enter engineering at the post-secondary level. However, with inaccurate perceptions about creativity, ability and gender in STEM subjects, many potential engineering candidates may be lost to career paths that are traditionally more arts-based. The third stage in this study addressed this issue through the creation of cross-disciplinary STEM projects for grade five students that aim to encourage interest and engagement in engineering.

Curriculum Development

Among both post-secondary students and the elementary students, sports and fine arts were identified as the most popular hobbies and interests. Even students who enjoyed math and science showed a preference for traditionally creative and expressive activities. To increase student engagement in STEM classroom content, six cross-disciplinary projects were developed and incorporated into a program series called *Exploring Electrical Engineering*⁶. Mandated curriculum learning concepts from across all of the Alberta grade five subject areas were combined into hands-on, exploratory lessons and corresponding activities for teaching electricity and electrical engineering. Combining math, science, technology, English, social studies, fine arts and physical education concepts allows elementary teachers to incorporate engineering into their lesson plans without taking away from the time needed to cover mandated learning outcomes. In addition to cross-disciplinary concept combinations, the projects were also designed to incorporate engineering graduate attributes, as outlined by the Canadian Engineering Accreditation Board. Including attributes such as professionalism, critical thinking, and teamwork skills allows students to experience the foundational attributes of the engineering profession, and helps to develop their understanding of how engineers contribute to society.

Implementation and Results

The project series was implemented across several local schools, involving over 350 grade five students and teachers. Students were introduced to electricity and electrical engineering over the course of three module components: Concept Learning, Applications, and Creative Design. Each of the projects was led by one of the researchers, with the regular classroom teachers available for any classroom management issues and additional student help. Following the completion of the project series, students and teachers were asked to give feedback via interviews and surveys. Both male and female students were the most responsive to creative design, with over three-quarters of the students agreeing or strongly agreeing that they would like to see more art, design, and creativity in their regular science class.

Students were also asked to answer an exit survey that repeated many of the previous questions about engineering perceptions. The purpose behind this survey was to discover if their views and impressions about engineering and gender in STEM changed after participating in the *Exploring Electrical Engineering* program.

Changes in Gender Perception

Students demonstrated a dramatic change in how they perceived scientific and mathematical ability depending on gender, depicted in Figure 1. Before participating in the program, 75% of students agreed or strongly agreed that math and science are more difficult for women to learn than men. While this belief was held by 82% of the males, a surprising 69% of female students felt the same way. After participating, only 7% of students felt the same way about women in mathematics, and only 8% felt the same about women in science. Female students gained confidence in their own gender's abilities to learn math and science, with 69% falling to 4% (math), and 3.5% (science). Male students also demonstrated a large shift in opinion, falling from 82% to 11.9% (math) and 14.6% (science). In contrast, only 18% of

students agreed or strongly agreed that technology is more difficult for women to learn than men, likely due to the fact that youth interact with technology on a regular basis in their academic and personal lives, regardless of their gender. Nearly no change was detected regarding this opinion.

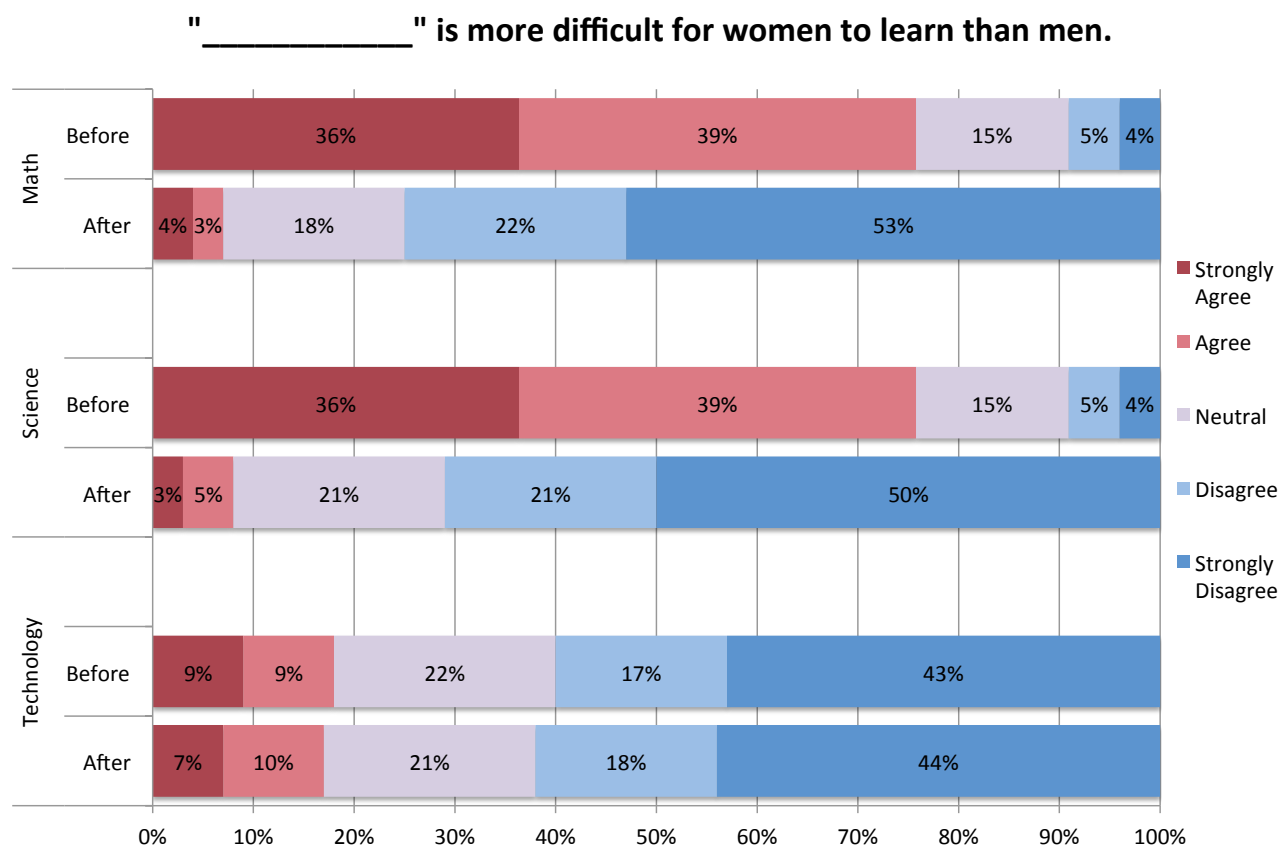


Figure 1: A comparison of how grade five students view gender ability in STEM subject areas before and after participating in the *Exploring Electrical Engineering* program.

A change in perception was also demonstrated in other gender-related answers. 75% of students agreed or strongly agreed that it is harder for women to become engineers in the workplace, and that males are more professional than females. After participating in the programs, those values dropped to 15% and 12% respectively, shown in Figures 2 and 3. Females in particular gained a new respect for professional women, with 69% dropping to 4% of students who believe males are more professional than females. Lastly, despite nearly all of the students identifying themselves as creative people, 75% agreed or strongly agreed that men are less creative than women, with 86% of males believing their gender is not as creative. Following their completion of the program, only 10% of male students felt the same, and overall only 26% of students believed that men are less creative than women, demonstrated in Figure 4.

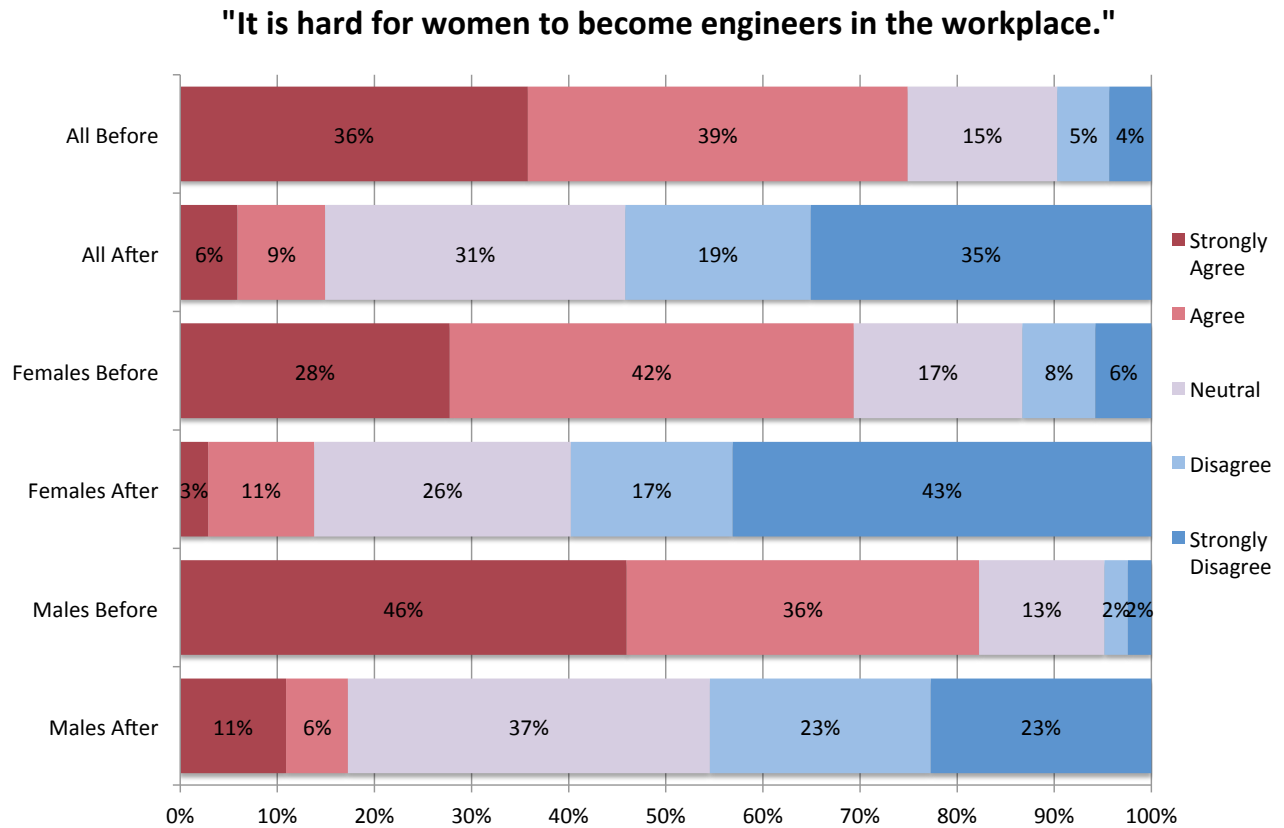


Figure 2: A comparison of how grade five students view female engineers in the workplace before and after participating in the *Exploring Electrical Engineering* program.

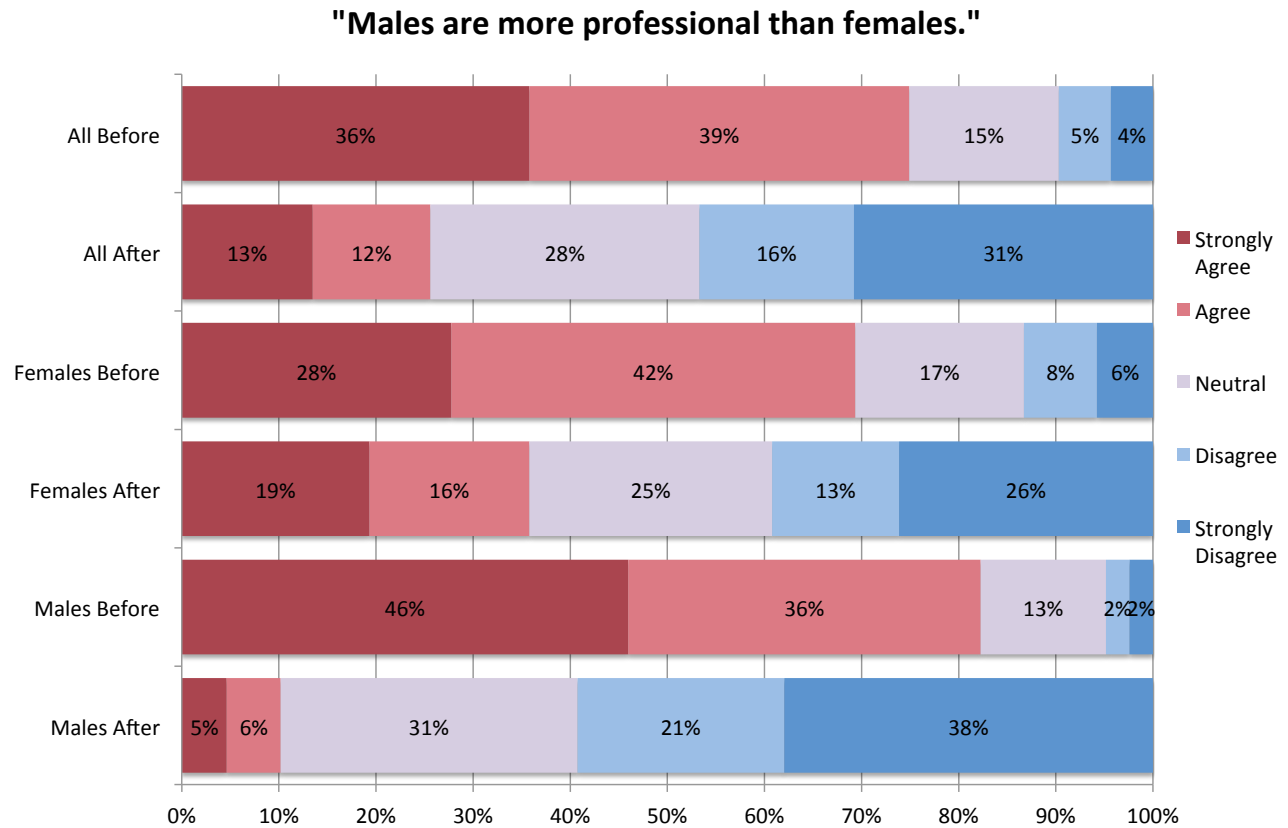


Figure 3: A comparison of how grade five students view gender professionalism before and after participating in the *Exploring Electrical Engineering* program.

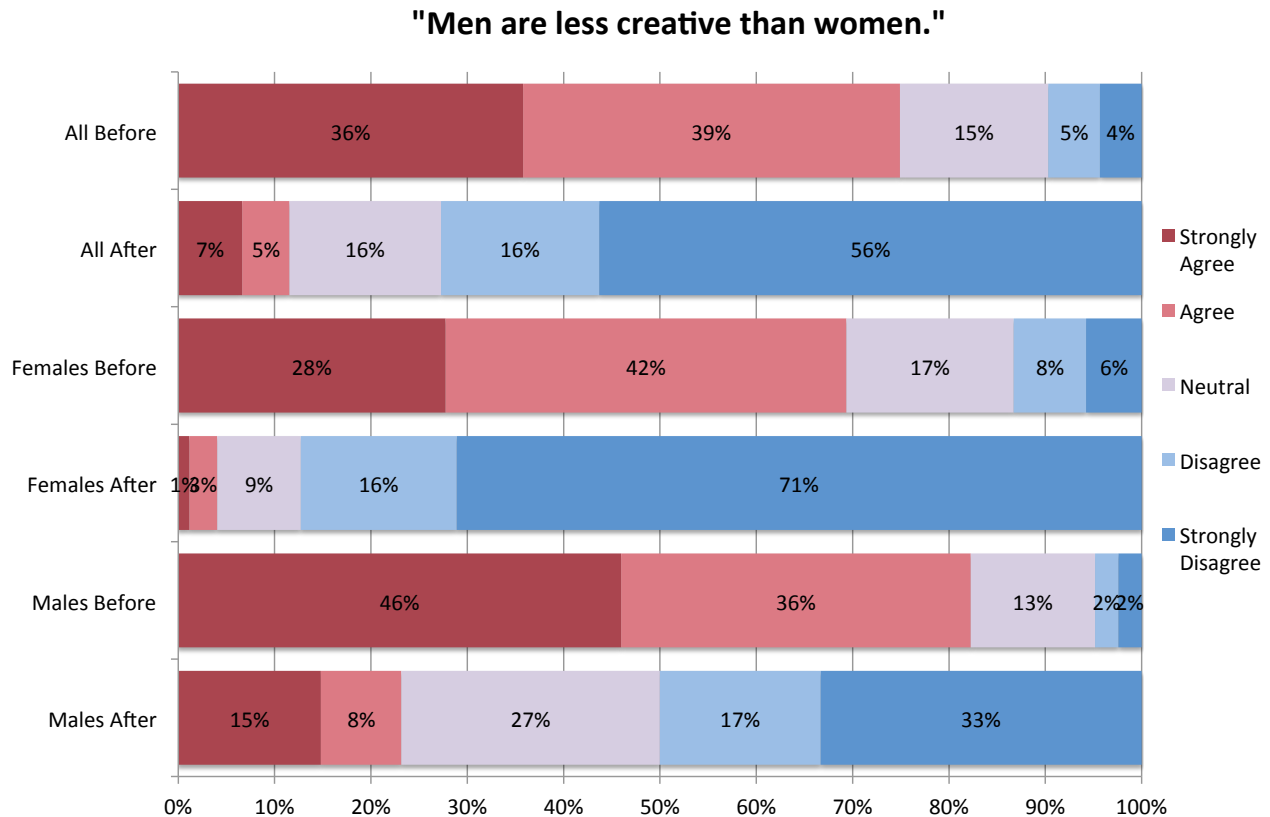


Figure 4: A comparison of how grade five students view gender in creativity before and after participating in the *Exploring Electrical Engineering* program.

Other Perceptions of Engineering

Through participating in the *Exploring Electrical Engineering* program, students also expressed a change in their attitudes towards math, science, and engineering. Before the program, 74% of students agreed or strongly agreed that only nerds love math science. When interviewed, students demonstrated negatively in association with being labeled a “nerd”. However, after completing the program, only 9% felt the same way. Males were more likely to agree, but the gap between the responses of the genders shortened from 13% to 5%. These results are shown in Figure 5.

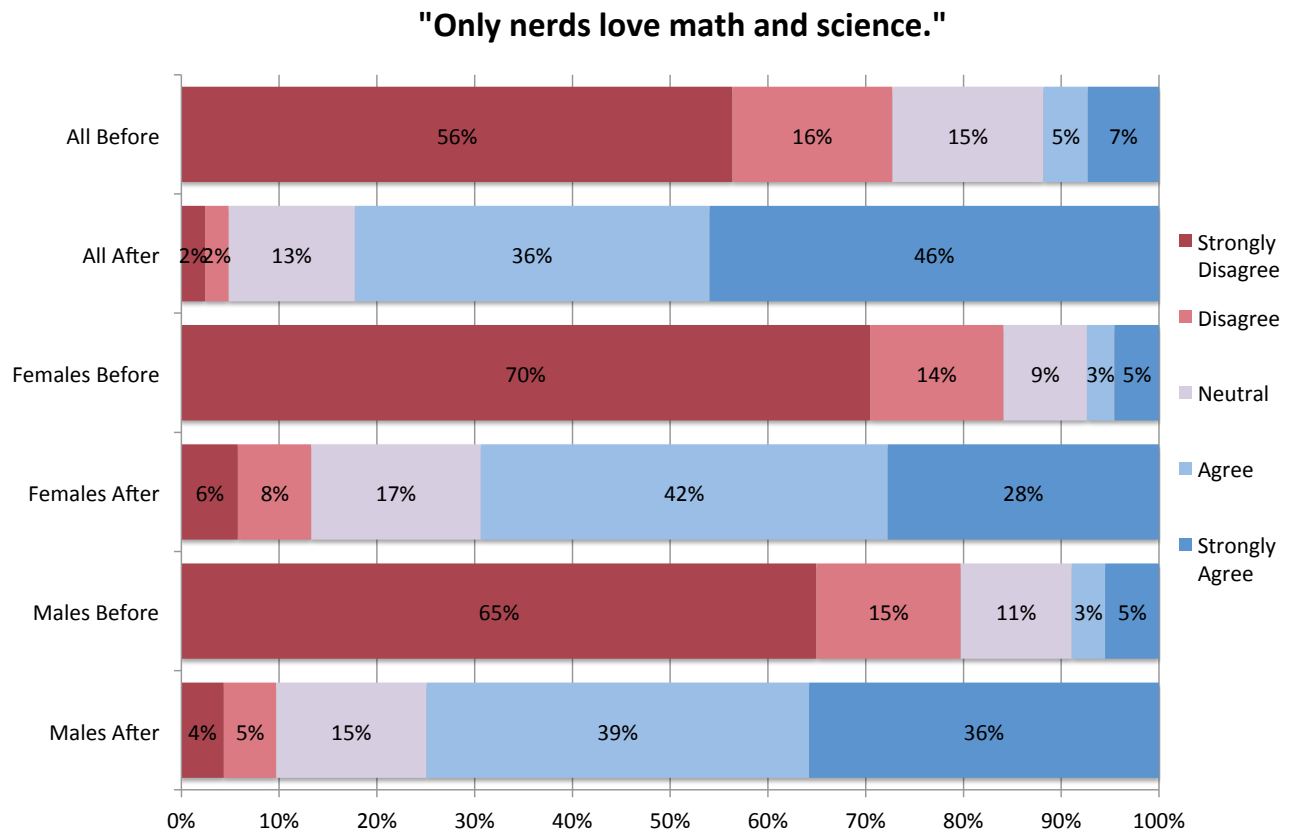


Figure 5: A comparison of how grade five students associate “nerds” with math and science before and after participating in the *Exploring Electrical Engineering* program.

Discussion

An analysis of the complete set of program results reveals a significant change in the attitudes to grade five students towards gender roles within the discipline of engineering. The creative and exploratory projects developed in the *Exploring Electrical Engineering* program encouraged student engagement, and allowed students to make discoveries regardless of their academic ability. This may have increased student confidence, and showed students their own potential in technical domains such as engineering, regardless of gender or perceived difficulty of a subject. Students may also have been influenced positively by the instructional lessons given by a female engineer, providing the students with a technical female example.

Following their completion of the program, 74% of students said that yes, they were more interested in electrical engineering as a possible career. Nearly half (45%) of all participants were both female, and now more interested. The encouragement of female students to pursue engineering requires STEM curricula to be taught in an engaging manner that appeals to both genders. The results of this research also demonstrates how pre-conceived notions about gender and STEM subjects can negatively affect how a students views the engineering profession, and the importance of encouraging creativity and cross-disciplinary thinking in future engineers.

In conclusion, this paper discusses the design of a program for teaching electricity at the grade five level, while examining the perceptions of elementary students surrounding STEM subjects and gender abilities. Through creative, hands-on projects, students were given the opportunity to explore different facets of engineering, and consequently improve their opinions about the capabilities of women in technical subjects, and of men in creative roles.

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