The Role of Gender in Pre-college Students' Perceptions of Engineering

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Abstract

The study reported in this paper is motivated by a larger study to broaden pre-college students' perceptions of engineering by engaging them in engineering activities that broaden the context of engineering. The goal of broadening perceptions through broad contexts is to appeal to a more diverse group of students, underrepresented minority groups. This paper presents analysis regarding gender and perceptions of engineering. The work presented here shares the analysis of how students from both genders perceive engineering and then relate it to their own personal interests. For this exploration, data was collected from a summer engineering workshop conducted for approximately 175 students ages 8-14 who were all from a mid-sized Midwestern city and who all qualified for the free or reduced lunch program. Students were interviewed prior to engaging in the engineering activities and asked to share their personal interests (i.e., what do they do for fun, extracurricular activities, favorite school subjects) as well as what they thought engineering was. Additionally, the research team observed these students as they engaged in the engineering activities to gather further understanding of their personal interests and whether they connected them to the engineering activity. The analysis of the interview transcripts and videotaped observations led to the identification of various themes across the participants. In this paper, we chose to compare and contrast the themes with relation to gender and knowledge of engineering. We compared the responses from males and females as well as detected for the gendered language embedded in both male and female responses. Future work based on this understanding may include how children describe role models in engineering and if the under representation of women in engineering affecting the view of an engineer in this age group.

Introduction

Numerous reports commissioned by the federal government have called for increasing the enrollment of women in science, technology, engineering and mathematics (STEM) as less than 20 percent of those earning bachelor's degrees in engineering are women [1]. According to the Congressional Joint Economic Committee, about 14 percent of practicing engineers are women [2]. Multiple organizations and governmental agencies have invested in STEM education programs to research the gender disparity. Possible reasons that have been raised regarding low female and minority engineering rates include misconceptions of what engineers do [3], lack of role models in engineering [4], and a shortage of engineering experiences for girls in early education [5]. In spite of informal STEM programs out of the classroom, there has been small progress towards a gender shift in STEM or to indicate acceleration of female and minorities in the engineering career fields [6].

The focused conversation and examination of underrepresentation of minorities (African American, Hispanic, and Native American), women, and people with disabilities have occurred for over thirty years with increased interest in the 1990s [7–9]. Nevertheless, the number of minorities, women, and people with disabilities in engineering has remained stagnant. Because of the need to offer an equal opportunity for all involved, there is a robust desire to advance the variety of perceptions contributing to engineering. In the absence of diversity, experiences can

be restricted, and because of this, future designs are never formed, constructed, or even invented [10]. In addition to the importance of providing equal access to all, helping students relate their personal interests to engineering solutions can create innovation based on untapped curiosity and awareness of engineering.

A primary educational goal of this project is to present engineering design activities in broad contexts that intentionally integrate more humanistic or social dimensions of the problem context. After a brief on the background of this project, we explain the theories about the importance of interests for learning and development, and person and thing orientations that we adopt to understand our participants' social or object oriented orientations of their personal interests. We then explain the research methods we adopt given our context and participants and present our findings and discussions. The research team divided the discussions into the themes of 1) broadening the perception of engineering 2) humanistic perception of engineering, and 3) male-dominated perceptions of engineering.

Background

Engineering has emerged as a critical post-secondary education and profession for the success of the US and nations throughout the world. Recently, the US has placed increasing emphasis on engaging students in engineering before college with hopes to attract more students into engineering majors and professions [11,12]. The publication of the Next Generation Science Standards [13] and pending adoption across the US creates a timely opportunity to implement engineering curricula and continue to research their effectiveness. One key research gap in K-12 engineering education is in appealing to underrepresented populations. The proposed work seeks to explore the nature of grades 5-8 students' interests and how they relate to engineering. By concentrating on engineering activities on students' interests, it is anticipated that more students will self-identify with engineering by relating engineering work with their personal interests. Considering the wide-ranging work of engineers from designing environmental doings to video-games, there are many opportunities to make meaningful associations between students' interests and what they could design as engineers.

Framework

The main focus of this research study conveyed in this paper is increasing the interest of students in engineering and other STEM disciplines. Much work has been done over the last decade to welcome pre-college students to engineering through various hands-on activities. Nevertheless, there has not been a substantial change in diversity and inclusion when considering who is becoming an engineer [9]. In analyzing the thought process, we theorize that most current engineering activities may be situationally interesting and not as personally interesting. Renninger, Hidi, and Krapp [14] make a distinction between these two types of interests, people or thing orientation. Person-thing orientation research investigates preferences for either social environments (person orientation) or physical environments (thing orientation) and how this orientation influence interests, motivation, and choice (especially vocational choice) [15,16].

Using the person-thing orientation framework, the study analyzed students' attention to the physical environment (the designed artifact and associated tools and materials) and the social

environment (the team/classmates). Considering the focus of engineering education on the mastery of technical skills to design artifacts (physical and virtual) as solutions to problems, engineering is predominantly a thing-oriented career. Research in fact shows that engineers are more thing-oriented than person-oriented and that women who do choose to go into engineering are either more thing-oriented, which is counter to the predominance of person-orientation among women, or have found another personal interest that motivated them to persist in engineering [17]. These findings suggest that engineering as it is currently portrayed and perceived is not appealing to women and potentially to people of more person-oriented cultures. However, engineering should take place in a social context to help students draw upon their knowledge and ability to navigate interpersonal relationships within their team, understand the client or end users, and be conscious of their own values, beliefs, and skills as they carry out a design.

Setting

The participants of this study were enrolled in a free 5-week day-camp offered for underserved children in the summer of 2016 to promote service learning and leadership for students aged 8-14. 175 of the participants from this five-week day-camp engaged in an engineering focused activity for 40 minutes over the course of 9 days. The activities used their interests to encourage them to participate in engineering and laid emphasis on the person-oriented (social and humanistic) aspect of engineering. They solved problems that they were interested in solving themselves, for example, making sports safer, personal accessories, and faster transportation. Throughout the process, the participants were encouraged to think about the people they were solving the problems for, practice teamwork, and also bring forth their personal knowledge, beliefs, and interests. The students were ushered into an interactive classroom setting for the course of 40 minutes on each of the 9 days. In the classroom the students sat with their respective teams, and designed and fabricated prototypes for the engineering challenge. This activity is detailed further in the intervention section.

Participants

For this exploration, data was collected from a summer engineering workshop conducted for approximately 175 students ages 8-14 who were all from a mid-sized Midwestern city and who all qualified for the free or reduced lunch program. Of the 175 students, 40 consented to be a part of our study of which 21 were male and 19 female. All students were also part of the larger 5-week summer camp and thus were familiar with one another before attending the 9-day engineering activity this paper reports on. The teams that the participants worked in were deceided before they started the engineering activity by the activity instructors.

Intervention

The engineering activity consisted of the participants working in teams of 3-5, on an open-ended engineering challenge that related to their's and other's lives at camp. The intended learning outcome of this activity was for the participants to implement various facets of

engineering design practices. Briefly, theough the 9 days the student carried out the following engineering design practices:

- Identifying and scoping a problem to be solved using engineering design
- Identifying various relevant user and stakeholder groups for their identified problem
- Brainstorming solutions to the identified problem, taking into consideration the user and stakeholder groups involved
- Practicing concept reduction by identifying pros and cons of solutions
- Fabricating a prototype of the solution
- Testing and evaluating the solution
- Communicating the final solution to applicable users and stakeholders

Participants implemented all of the aforemention in their teams with assistance from camp volunteers and activity instructors. During the instruction, strong emphasis was laid on the humanistic aspects of engineering by way of laying importance on stakeholders, consideration of other's perspectives in decision making within the team, and feedback from others and users (when possible) during testing and evaluation.

Methodology

Of the 175 students students who participated in the engineering activity, 40 consented to participate in the research and were interviewed prior to participation in the engineering focused activities regarding their engagement of personal interests (i.e., what do they do for fun, extracurricular activities, favorite school subjects) as well as their thoughts regarding engineering. After their participating in the engineering workshop, the students were asked the same questions to which the research team identified patterns that connected the student's personal interests with their engineering experiences. The researchers analyzed the pre and post interviews by an open qualitative coding scheme. The participants' personal interests and their perception of engineering were coded as person-oriented, thing-oriented, or both. The team of researchers first separately coded the interview transcriptions, and then coded together, discussing any differnces and reaching a concensus. As in all qualitative research, the researchers were aware of the personal bias they bring into the research study, and often interrogated and checked their bias within the group of researchers during coding. The three themes presented in this paper are derived by asking similar questios before and after the intervention, and the data comprising of quotes and percentages from content analysis is presented in the findings nad discussions.

This paper presents three themes that emerged from analyzing the student interviews from before and after the engineering focused activity. Since traditional perceptions of engineering relate to males and thing-oriented practices, the first two themes identified by the researchers focus on the broadening of students' perceptions about engineering, and the inclusion of humanistic perceptions of engineering. The theme of broadening perceptions is informed by student narratives that changed and became more inclusive over the course of the activity. The theme of humanistic perceptions emerged from student narratives of engineering being not just a thing-oriented, but a humanistic person-oriented profession. The third theme exposes prevalent male-dominated stereotypes and perceptions of engineering, and is informed by the students' use of male gendered terms to depict engineers and engineering.

Findings & Discussion

Three themes emerged from the study: 1) broadening the perception of engineering 2) humanistic perception of engineering 3) male-dominated perceptions of engineering. These themes begin to shed light on the importance of well-intentioned interventions in engineering education in P-12 settings. The data presented in this study is limited to one 9-day long workshop. However, the insights gathered can be useful for educators and researchers aiming at being cognizant of the role of gender in broadening perceptions of engineering, and inculcating humanistic aspects of engineering in their practice and research. This section provides a brief on the three aforementioned themes:

Theme 1: Broadening perception of engineering

The field of engineering is constantly evolving and is comprehensively sufficient to include person-focused contexts. In further support, the National Accreditation Board [18] (ABET) calls for engineering graduates to be able to navigate through social, environmental, and economic global issues. Even though our research team received mixed results from the student interviews regarding the workshop's effects on shifting understanding to include the humanistic side of engineering, there were encouraging strides towards expanding the meaning of engineering. Before and after the workshop, the research team asked students the following open-ended questions:

Pre-workshop	Post-Workshop
What is engineering?	What is engineering?
How would you explain engineering to someone at school?	What kind of people become engineers?
Are you interested in engineering?	So now that you have gone through this camp, how would you explain engineering to your friends at school?
Do you think your interests are related to engineering?	Are you interested in engineering?

In response to the pre-workshop questions above, only twenty-five percent were able to associate engineering while using person-specific phrases (i.e. 'help society,' 'working with people'). However, over ninety percent of students were able to give more person-specific responses post-workshop (i.e. 'think what could happen in the future to help people,' 'make the world an easier place for people'). These figures show an increase in the awareness of engineering and opportunities in engineering and as Hira & Hynes [19] position, "over time as they (students) gain the required disciple/application specific knowledge, they (students) can apply the process to specific problem-solving contexts." Evaluation of pre and post-workshop knowledge and attitudes showed heightened interest and knowledge of engineering for most participants. This exposure is imperative because of student's exposure to the environments to SME (science, mathematics, and engineering) in K-12 strengthens student's perseverance and successes in these disciplines as they get older [20]. Although the results had many limitations, there is a clear depiction of the need to continue to reinforce engineering to pre-college children.

Theme 2: Humanistic perceptions of engineering

After engaging in the engineering activity, some students' perceptions of engineering changed from a thing-oriented perception of engineers building and fixing things, to that of engineering being a more people-oriented profession as well. Both female and male participants began understanding engineering as helping people and working with other people. The following direct quotations are appropriate representations of responses during the pre and post interview process:

Female A

Pre: do stuff like science and make stuff together and put stuff together

Post: is stuff where you make stuff so that people can use

Female B

Pre: making cool things and being imaginative and creative and all that

Post: isn't just making stuff. It is how being with other people and working with other people to reach your design and feedback and all that

The female student responses above were used as examples as their responses were similar to describing thing to understanding both thing and person orientation. In this context, both females in the A&B samples were able to expand their interpretation of engineering to include the association of people.

Male A

Pre: To make electronic devices and stuff and how to fix your own things, so you don't have to call people.

Post: Making stuff to make other things better or making stuff to help us out.

Male B

Pre: engineering is like building, no not building like making 3-d models of what you want to build.

Post: Fun and lifesaving (it can save people's lives)

Thus, the male students who perceived engineering as a thing-oriented profession with no relation to people began realizing the person-oriented humanistic nature of engineering. We can see this to be true in the Male B example. Male B focused on building things in the pre-interview and by the end of the workshop was able to articulate engineering as a profession that can save people's lives in the post-interview. While there is truth in the responses above, Male B's response shows an increased awareness of the impact engineering has on people's lives.

Theme 3: Gender perceptions of engineering

During the pre-interviews, the need for more gender diversity in engineering was apparent. Pronouns like "he" or nouns like "my dad" were used 100% of the time to describe

known engineers from females and males. In one example, a male student explained that his father is a doctor but was probably an engineer previously. Even though there were female engineer researchers present, the perception of an engineer did not change for females and males. Baylor [21] states "improving young women's perceptions of the stereotypical engineer could lead them to see engineers as the type of people with whom they would want to work, which may increase interest in pursuing engineering" (p.530). These findings highlight the importance of creating a more diverse field of engineering.

Recommendations

Based on this inquiry to explore the role of gender in pre-college students' perception of engineering we propose recommendations for engineering activities in P-12 settings. Firstly, we propose making students more aware of who engineers are and what they do. This awareness would support broadening the reach of engineering in school-going children. Secondly, we propose engineering activities and other instruction to emphasize the humanistic nature of engineering. Emphasizing the humanistic nature of engineering would help appeal to not just thing-oriented, but also person-oriented interests of students of both genders. Thirdly, we propose spreading awareness about female engineers along with their accomplishments. This gender awareness would help combat male-dominated perceptions of engineering among both female and male students, and bring to the forefront positive role models for P-12 students. These recommendations apply to a formal setting that introduces and encourages students to practice engineering within the formal school, and also informal after-school environments such as museums, and Makerspaces.

Conclusion

Throughout this work, we have shown the importance of applying a humanistic side of engineering and connecting engineering to student's personal interests when teaching as a way to improve gender bias and inclusion in P-12 environments. We showed this by indicating the importance of expanding perceptions of engineering at a young age, associating engineering to both thing and person orientations, and the necessity for changing the gender language of engineering to include females. However, this study alone is not enough evidence to show the importance of such changes and encourage other educators and researchers to explore such claims.

Acknowledgements

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