Measuring Engineering Perceptions of Fifth-grade Minority Students with the Draw-an-Engineer-Test (DAET) (Work In Progress)

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Introduction

Research continues to combat the national decline in STEM fields through motivational strategies that can be applied in teaching students [1,2,3,4]. Next Generation Science Standards (NGSS) underscore the importance of making engineering education available to all students, especially minorities in STEM [5]. NGSS creates a holistic approach to understanding engineering by blending scientific and engineering practices [5]. This is important, because of engineering's relevance to daily life and contribution to critical thinking [6,7]. However, improvement of science standards alone is not sufficient to improve students' understanding of engineering. A strong engineering curriculum also plays a major role in improving students' perceptions and encouraging them towards STEM [8].

One curriculum that parallels goals of NGSS is the Museum of Boston's Engineering is Elementary (EiE) curriculum. EiE strives to introduce students to engineering at the elementary level. Through EiE units, students solve real world engineering design challenges and are exposed to engineering experiences [9, 10, 11]. Another critical outcome of each engineering project is learning EiE's cyclical, five-step engineering design process (EDP). The EDP guides students through asking questions, imagining, planning solutions, constructing their designs, and improving their collective work before the end of the unit. EiE introduces the EDP through leveled stories that introduce the type of engineer and the real-world relevance of the challenge. The unit then breaks into three lessons. Each lesson builds on the next with activities that help students understand the steps of the EDP and how engineers work as a team to create and improve technology. The motivation of EiE is that all students can learn engineering, including minority students [10, 12].

The NGSS shares EiE's goal of engineering education for minority groups [5]. From an epistemological view, the NGSS appreciates the contributions of other cultures in engineering. Pedagogically, NGSS shows engineering has a potential to be applied to everyday life. Global perspectives are shown through the NGSS with relevant engineering instruction that may motivate students to pursue engineering careers [5]. Minority students who experience engineering challenges at the pre-collegiate level, may see the relevance of science and engineering to their lives.

To improve engineering education in elementary, it is important to examine students' but also teachers' perceptions of engineering. The Draw An Engineer Test (DAET) is a reliable, widely-used assessment of students' and teachers' views of engineering [9, 13, 14, 15]. Results of the DAET show students and teachers hold incomplete or naive engineering perceptions [16, 17, 18]. Moreover, DAET revealed that students characterized engineers as fixers or laborers [9, 14, 15]. Other research revealed teachers held misconceptions of engineers as construction workers or laborers who work with machines [16]. In a similar vein, research stated that teachers and students improved their engineering perceptions after experiencing engineering professional development or curriculum [19].

Developing engineering perceptions has been prioritized in engineering education, however at

the elementary level, research is limited [20, 21, 22]. Furthermore, this rare research on elementary perceptions is lacking attention on student gender and minorities' views of engineering and engineers [23, 24]. Elementary misconceptions like, only men are engineers, are some of the most critically important issues of equity in engineering education [9, 25]. Additionally, relatively few researchers investigated the effect of meaningful elementary engineering curriculum [20,26]. Thus, there is a need to investigate students' shift in perceptions based on gender after experiencing meaningful engineering curriculum. Although aforementioned studies reveal students' incomplete engineering perceptions with the DAET, further research is still needed to investigate the effectiveness of engineering curriculum on minority students' engineering perceptions. This Work In Progress will further understanding in three areas: (a) elementary, (b) gender, (c) minorities in STEM. Authors used the DAET to examine fifth grade minority students engineering perceptions after the EiE unit, *Making Work Easier,* was accomplished by the students. The following research questions guided our study: (a) To what extent are fifth grade minority students' perceptions of engineering changed after a unit of EiE curriculum? (b) How does gender influence fifth grade students' perceptions of engineering?

Methods

Participants in this study are enrolled in a Title 1, 100% free and reduced lunch, K-12 public charter school in the southwestern United States. This school is the most diverse in its district with students representing more than 15 different countries and languages. The 26 students in this research sample consists of 13 female students and 13 male students ranging from 10 to 12 years of age. 70% percent of the class is first generation refugees, and 90% of the class are minorities in STEM. The teacher in this study is co-author of this WIP. She has completed EiE training prior to instruction and has worked with the curriculum for three years. An intervention was given after the Pre DAET. During this intervention, the EDP and what engineers do was taught through the EiE introduction story and the *Making Work Easier* lessons. Knight and Cunningham (2004), did inspire some of the categories used within this WIP, "*build/fix, create,* and *design*"[14], however we also wanted the terms to occur *in vivo* according to Capobianco et al. (2011) suggestions [9]. The intervention lasted two weeks and concluded with a class demonstration of their compound machines.

Data Analysis

All questions in the EiE DAET were organized by pre, and post and then cross-analyzed by gender. Pre- and post- student responses were added to a matrix to simplify visual analysis. Although the DAET was given to the entire class, one student did not wish to participate, so this data was not included in the analysis. During analysis of the DAET, pictures and students' descriptions were organized into nine categories. For clarity, when discussing Female pretest, and posttest the abbreviation FPre and FPost will be used. Additionally, Male pre- and post- test results will be MPre, MPost.

Table 1. Q1. What type of job or jobs do you think you might want to do "when you grow up"?

	STEM		Non-STEM	
Gender	Pre	Post	Pre	Post
Female	7	8	6	5
Male	3	4	10	9

Question 1 analysis was completed to track student expectations towards a STEM career (see in Table 1). Authors defined "STEM" job as any career that uses scientific knowledge. Some examples were engineers, doctors, nurses, and computer scientists. Authors defined "Non-STEM" as any career that does not require a scientific degree. The students' responses of writer, professional athlete, firefighters, or police officer would be examples of a Non-STEM career. FPre to MPre, female students showed a greater inclination toward STEM careers than male students.

Table 2. Q2. When you hear the word "engineering", what do you think about?

	Laborer (build)		Mechanic/Technician (fixes)		Designer (makes/create)		Uncategorized	
Gender	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Female	3	1	3	2	4	5	3	5
Male	3	1	5	3	2	7	3	2

Question 2 responses were based on keywords from student sentences, e.g. "build" was classified as "laborer", "fixes" was classified as "Mechanic/Technician", and "make" or "create" was categorized as "Designer", and a final classification, uncategorized, was added for responses that could not be understood or were completely unrelated to the question (see in Table 2). FPre to FPost results show a decrease in associating engineer with someone who builds (Laborer) and fixes (Mechanic/Technician). Similarly, MPre to MPost decreased for engineering associated with building and in associating engineering with fixing. Both female and male students showed an increase in aligning the word engineer with someone who makes or creates (designer). However, male students showed a greater increase in this area.

Table 3. Q3. Have you ever thought about being an engineer?

	YES		NO	
Gender	Pre	Post	Pre	Post
Female	4	3	9	10
Male	5	5	8	8

Results for Question 3 tracked the number of students by gender who were motivated towards a career in engineering firstly. While no growth was seen for MPre to MPost, a decrease for FPre to FPost was seen in students who wanted to be engineers (seen in Table 3).

Table 4. Categories and Category descriptions for Q4-5

Category	Description	Category	Description
1. Fixing	Mechanics, Technician, Laborer, in the description it says repair or fixing	5. Gender_F	Person or people have feminine characteristics: dress, hair, written description from student
2. Creating	Designers, Engineers, people making items, people making plans, math and science equations, improving an item	6. Gender_M	Person or people have male characteristics: dress, hair, written description from student
3. Object	No person or people, something that was created, doesn't count for any other categories	7. Alone	Person is fixing or creating alone

4. Tools	Any item used by the people or person in the drawing that helps fix or create an object	8. Team	Person is fixing or creating with other people
9. Unrelated	Drawing was unclear, or about a topic unrelated to other categories, doesn't count for any other categories		

Question 4 and 5 required the students to "Draw a picture of an engineer at work" and then describe their picture. Instead of authors predetermining image themes, categories naturally developed as the drawings were analyzed [9]. After several revisions, based on the student responses and illustrations, the pictures were finally divided into nine categories (see in Table 4). "Tools" was added as a category because it helped to define whether or not the person in the picture was fixing or creating. "Unrelated" was created due to the need to classify images that did not fall into the other eight categories. If a category was shown in the picture, a point was given by subgroup, therefore total points may equal more than the number of student participants.

Table 5. Q4. Draw a picture of an engineer at work.

Female			Male		
Categories	Pre	Post	Categories	Pre	Post
Fixing	9	3	Fixing	3	3
Creating	1	5	Creating	7	9
Object	1	2	Object	0	2
Gender_F	3	2	Gender_F	1	0
Gender_M	8	7	Gender_M	10	10
Alone	6	6	Alone	4	9
team	4	2	Team	6	1
Tools	7	4	Tools	6	8
unrelated	2	1	unrelated	3	1

Based on these categories, students' drawings were analyzed. Categories 1 through 3, relate to the idea that engineers fix objects, create objects, or engineers are the objects themselves. "Creating" increased from the pre-test to the post-test for female and male students. Female students showed more growth, and male students, beginning with a relatively high understanding of engineers as "Creating", increased in the posttest. FPre to FPost scores for the category "Fixing" showed a decrease from nine students to three students. MPre to MPost scores stayed consistent at three students for the category "Fixing". (Table 5).For categories 4 through 7, the pre-test to the post-test show little to no students drew engineers with female characteristics. Additionally, for both female and male students' images of people working in a team decreased from four to two for FPre to FPost and six to one for MPre to MPost. Male engineers were drawn in most of pre- and post- images. For category 6, people working alone, FPre to FPost stayed at six images, while MPre to MPost increased from four to nine images (see in Table 5).

Discussion

In response to our first research question, we analyzed the effects of an engineering curriculum. The uncategorized responses could be attributed to the large number of English Language Learners in the class. Additionally, many reasons students gave for not being an engineer

stemmed from misconceptions about what engineers do, however the intervention was effective in connecting engineers to people who create things. Similar to other studies [13,14], the participants in this WIP shared the misconception that engineers fix things. To improve this engineering perception by elementary, longer than a two-week intervention is required. Even so, perhaps this understanding that engineers create can be the first step towards motivating students towards STEM careers, specifically engineering. Also, the engineer in the EiE unit was a male engineer and no female examples were shown to the students during this intervention. Knight and Cunningham (2004) also found that students linked engineering as a male dominated career. However, it's important to note that most of the female engineers drawn, were by female students not male. Additionally, the increase in engineers working alone demonstrates a need for explicitly teaching the importance of collaboration. Finally, the students who drew "tools" created a visual progression of understanding of the EDP that may be developed for future work. In response to our second question, although some questions or categories showed increases when comparing gender, for the most part, there is very subtle differences between genders at this age level. Therefore 5th grade students, female students especially, may be less influenced by stereotypical images of engineers, and may be prone to change their attitude towards engineering as a career. Before giving the late test at the end of the year, the students will complete three more EiE units. We look forward to these results after a year's intervention.

Recommendations

While researching for this WIP, we found many variations on the DAET that would provide more detailed information for future work. One variation required students to name their engineers. This allowed researchers to better assess the engineer's gender when students were only able to draw stick figures. Other studies provided crayons and extended the time to complete the DAET to make it more engaging for the participants [9]. Researchers also interviewed students about their responses after the DAET to receive a more complete understanding of elementary students' views [9,14].

In addition to these recommendations, there are improvements that we noticed during the course of our study. For future work, we propose changing the Q4-5 wording to "Draw an engineer or engineers at work". By providing a choice, this wording may provide a more accurate depiction that engineers work collaboratively. Secondly, we suggest changing the word Test, in the DAET, to Task. This may eliminate any anxiety for the student. We further suggest visits from engineering professionals of both genders and similar ethnic groups so that students may break gender and minority biased misconceptions. Finally, we recommend explicit teacher training in engineering standards and curriculum before instructing students at any academic level.

Limitations

Since our research was based on scheduling of the co-author of this paper, time constraints on our study existed. While interviews would have provided a deeper look at students' views of engineering, the time for interviews was not available. Another limitation in the consistency of the data was the fact that many of the students were English Language Learners or below grade level. Many discrepancies involving vocabulary in Questions 1-3 may be the result of a lack of writing ability or vocabulary. For future work, vocabulary, writing, and reading will have greater influence during the units.

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