A Study of Secondary Teachers' Perceptions of Engineers and Conceptions of Engineering

Emel Cevik, Texas A&M University
Dr. Michael Johnson, Texas A&M University

Dr. Michael D. Johnson is a professor in the Department of Engineering Technology and Industrial Distribution at Texas A&M University. Prior to joining the faculty at Texas A&M, he was a senior product development engineer at the 3M Corporate Research Laboratory in St. Paul, Minnesota. He received his B.S. in mechanical engineering from Michigan State University and his S.M. and Ph.D. from the Massachusetts Institute of Technology. Dr. Johnson's research focuses on engineering education; design tools; specifically, the cost modeling and analysis of product development and manufacturing systems; and computer-aided design methodology.

Dr. Bugrahan Yalvac, Texas A&M University

Bugrahan Yalvac is an associate professor of science and engineering education in the Department of Teaching, Learning, and Culture at Texas A&M University, College Station. He received his Ph.D. in science education at the Pennsylvania State University in 2005. Prior to his current position, he worked as a learning scientist for the VaNTH Engineering Research Center at Northwestern University for three years. Yalvac's research is in STEM education, 21st century skills, and design and evaluation of learning environments informed by the How People Learn framework.

Jennifer Whitfield,

Dr. Jennifer Whitfield received her Ph.D. in Curriculum and Instruction with an emphasis in Mathematics Education in 2017. Her M.S. and B.A are both in Mathematics. She joined the Mathematics Department at Texas A&M University as a Senior Lecturer in 2001. Dr. Whitfield has taught 13 different undergraduate and three graduate mathematics courses. She helped develop the Personalized Precalculus Program, has overseen the operations of the Math Placement Exam, is the Associate Director of the Center for Technology Mediated Instruction, Director of aggieTEACH, and has been instrumental in developing online math courses. Dr. Whitfield's research focuses on secondary mathematics teacher preparation and the effects of scholarships for high school science and math teachers. She has received over $2.2 million in external funding from the National Science Foundation and over $3.6 million in funding from other state, university, or private agencies. Dr. Whitfield has co-authored two peer-reviewed journal articles, one book chapter, and is the co-editor of a book. She has chaired six masters' committees and served on four others. Dr. Whitfield has received ten awards including the Distinguished Ph.D. Honor Graduate in 2017, Texas A&M Chancellor's Academy of Teacher Educators Award in 2014, and was an A&M Fish Camp Namesake in 2013.

Dr. Mathew Kuttolamadom, Texas A&M University

Dr. Mathew Kuttolamadom is an associate professor in the Department of Engineering Technology & Industrial Distribution and the Department of Materials Science & Engineering at Texas A&M University. He received his Ph.D. in Materials Science & Engineering from Clemson University's Int'l Center for Automotive Research. His professional experience is in the automotive industry including at the Ford Motor Company. At TAMU, he teaches Mechanics, Manufacturing and Mechanical Design to his students. His research thrusts include bioinspired functionally-graded composites, additive/subtractive manufacturing processes, laser surface texturing, tribology, visuo-haptic VR/AR interfaces and engineering education.

Dr. Jay R Porter, Texas A&M University

Jay R. Porter joined the Department of Engineering Technology and Industrial Distribution at Texas A&M University in 1998 and is currently the Associate Dean for Engineering at Texas A&M University - Galveston. He received the BS degree in electrical engineering (1987), the MS degree in physics (1989), and the Ph.D. in electrical engineering (1993) from Texas A&M University. His areas of interest in research and education include product development, analog/RF electronics, instrumentation, and entrepreneurship.

Dr. Joseph A. Morgan, Texas A&M University

Joseph A. Morgan has over 20 years of military and industry experience in electronics and communications systems engineering. He joined the Engineering Technology and Industrial Distribution Department in 1989 and has served as the Program Director of the Electronics and Telecommunications Programs and as the Associate Department Head for Operations. He has served as Director of Engineering and Chief Technology Officer in the private sector and currently a partner in a small start-up venture. He received his BS degree in electrical engineering (1975) from California State University, Sacramento, and his MS (1980) and DE (1983) degrees in industrial engineering from Texas A&M University. His education and research interests include project management, innovation and entrepreneurship, and embedded product/system development.

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Abstract

People's personal beliefs and perceptions can be explored and interpreted by investigating the mental images that they draw with regards to a specific subject. With this in mind, many researchers utilize the Draw-An-Engineer Test (DAET) instrument to evaluate students' and teachers' perceptions of engineers and engineering through drawings. Previous research shows that teachers' perceptions and attitudes toward engineers and engineering can play a substantial role in affecting perceptions and stereotypes of students related to engineering. Because the teachers' perceptions are correlated with their students' perceptions, understanding and improving how teachers perceive the concepts of engineers and engineering can be used to enhance students' perceptions toward the same concepts and improve the number of students who choose Science, Technology, Engineering and Math (STEM) fields as their future careers.

In this study, twenty-four STEM teachers participated in a two-week-long engineering-focused professional development (PD) program in 2017 and 2018. The STEM teachers learned about innovative engineering technologies and designing appropriate lesson plans to incorporate the newly learned content into their curricula. The purpose of this study was twofold. First, the authors aimed to understand the characteristics of the mental images teachers had regarding engineers and engineering. Second, the authors focused on understanding how participant teachers' perceptions changed regarding engineers and engineering after the two-week-long PD ended.

The participating teachers in the study were administrated the DAET followed by a survey including 5 open-ended questions. Teachers drew an engineer and then answered the open-ended questions in two occasions; once before the PD activities and once after the PD activities. The pre- and post- drawings were evaluated using the DAET rubric and analyzed using the descriptive and inferential statistics, the pre-post open-ended question responses were analyzed by using the constant comparative method. Findings from the qualitative and quantitative data analyses are reported.

Introduction

Science, technology, engineering, and mathematics (STEM) fields are considered fundamental to the nation's economy [1]. In today's world, it is critical to attract and retain more students in STEM fields [2]. With this in mind, teachers are sources of knowledge for students, and they inevitably have a significant influence on a student's self-image and perceived interests and abilities [3]. For these reasons, teachers who hold more accurate views and images of engineers and engineering tend to send more positive messages about who can be an engineer and who can be involved in STEM fields as future career choices. Rosenthal [4] notes that when teachers have negative stereotypes of science, scientists and engineers, their views and images are transferred to their teaching in a negative manner. This can cause students to develop negative views and images towards STEM. Since the teachers' perceptions are strongly related with their students' perceptions, understanding and improving how teachers comprehend the concepts of engineers and engineering can be used to improve students' perceptions toward the same concepts and improve the number of students who choose STEM fields as their future careers.

One effective way of understanding people's personal beliefs and perceptions is to investigate the mental images that they draw concerning a particular subject [5]. For example, the "Draw a Scientist Test" (DAST) has been developed [5] to understand students' attitudes toward scientists through students' drawings. Many researchers effectively and extensively have used this instrument in their research [6-8]. Similarly, many researchers utilize the Draw-An-Engineer Test (DAET) instrument [9] to evaluate students' and teachers' perceptions of engineers and engineering by analyzing their drawings [10-13]. These drawings could be used to help education researchers and other stakeholders in recognizing these potential misconceptions [14] and can be utilized to measure the effectiveness of the teacher professional development programs.

Carreño, et al. [11] examined the conceptions of engineers and engineering among Mexican teachers. Their findings revealed that while the number of teachers who were knowledgeable about engineers and engineering was very limited, the common misconceptions about engineers were widespread among these teachers. Similarly, Ergün and Balçın [13] conducted a study to determine the perceptions and attitudes of fifth and sixth-grade students towards engineers and engineering. Results of their study indicated that students conceived engineers as construction workers, rebuilders, supervisors, or designers; and that they had stereotypical images about their gender. Moreover, this study reported that most students were not interested in choosing engineering as their future profession [13].

In other research, Carr and Diefes-Dux [15] examined elementary students' conceptions of engineering before and after a curriculum intervention. This study indicated that the students' drawings at the beginning of the school year were similar to previous literature where students perceived engineering as fixing and constructing. The results of the end-of-year drawings have shown that over half of the participants' conceptions were design-related instead of the manual labor notion [15].

While the DAET instrument can easily be implemented to large samples, the usage of DAET has some limitations since participants' drawing skills could heavily impact the results [13]. To overcome these challenges and to understand better the students' and teachers' drawings, many researchers supported DAET results with interviews, or open-ended questions [16, 17].

The purpose of this study was twofold. First, the authors aimed to understand the characteristics of the mental images teachers had regarding engineers and engineering. Second, the authors focused on understanding how participant teachers' perceptions changed regarding engineers and engineering after the two-week-long PD ended. Two research questions were asked: 1) What were the characteristics of the mental images teachers had regarding engineers and engineering; and 2) What were the changes in teachers' perceptions of engineers and engineering after completing a two-week-long engineering-focused PD workshop?

Methods

This study has been designed to identify the characteristics of the mental images teachers had regarding engineers and engineering and the changes in teachers' perceptions of engineers and engineering after completing a two-week-long engineering-focused PD workshop. Teachers participated in data collection at the beginning and at the conclusion of the summer workshop.

Teacher Professional Development

This two-week STEM focused summer workshop took place at Texas A&M University. The workshop ran eight hours per day for two weeks. This summer workshop used the transformational and exciting technology of connected devices, commonly referred to as the Internet of Things (IoT) and the application of building automation to promote STEM interest using authentic experiential design activities. In this teacher professional development workshop, the participating teachers gained background knowledge about the engineering design process, connected devices, and building automation. These teachers also had the opportunity to engage in authentic experiential design activities using connected devices and, they were provided all the resources to become a STEM education champion at their campus.

Participants

Demographic information of the participants can be seen in Table 1. In this study, twenty-four STEM teachers participated in a two-week-long engineering- focused professional development (PD) program in 2017 and 2018. All twenty-four teachers participated in this research study. While fifty-eight percent of the teachers were female, forty-two percent of the teachers were male. Teachers' age ranged from 20 to 58 (M = 40.08, SD = 12.06). While fifty percent of the participant teachers were relatively new in teaching profession, the rest of the population had a teaching experience ranged from 6 to 25 years (M =8.36, SD =8.23). 66.6% of the teachers had bachelor's degrees, 25% of them had master's degrees, and 8.4% of them had doctoral degrees.

Table 1. Demographic Information of the Participants

Criteria	**Categories**	**Total**
Gender	Male	10 (42.0%)
	Female	14 (58.0%)
Ethnicity	White	10 (41.7%)
	Black	6 (25.0%)
	Hispanic or Latino	4 (16.7%)
	Asian	3 (12.5%)
	Two or more races	1 (4.1%)
Age	20-35	10 (41.7%)
	36-49	8 (33.3%)
	50+	6 (25%)
Education	Bachelor's Degree	16 (66.6%)
	Master's Degree	6 (25%)
	Doctorate Degree	2 (8.4%)

Teaching Experience (years)	1-5	12 (50%)
	6-10	7 (29.1%)
	11-19	2 (8.4%)
	20 and up	3 (12.5%)
Teaching Grades	6-8	15 (62.5%)
	9-12	9 (37.5%)

Note: Numbers within parentheses are participant demographic percentages

Procedure

The participating teachers in the study were administrated the DAET followed by a survey including 5 open-ended questions. Teachers drew an engineer and then answered the open-ended questions in two occasions; once before the PD activities and once after the PD activities. The pre-test and post-test drawings and open-ended questions were scored and analyzed by one of the researchers in the study. She read and reread the text to identify the pattern and themes that emerged from the data using content analysis [18]. Content analysis is described as any technique used to interpret written data [18]. Drawings and teachers' responses were organized into several categories. These results were summarized using descriptive statistics. Pre and post quantitative data were also arranged for certain drawing aspects and responses. The pre- and post- drawings were evaluated using the DAET rubric [9] and analyzed using the descriptive and inferential statistics, the pre-post open-ended question responses were analyzed by using the constant comparative method [19, 20].

DAET (Draw an Engineer Test)

The Draw an Engineer Test (DAET) has been used to evaluate students' and teachers' ideas about engineer and engineering [9]. In this survey, participants "drew an engineer at work." The survey also included several questions and prompts, which were as follows:

1. Describe what the engineer in your picture is doing.
2. What tools does the engineer in your picture use?
3. What does the engineer in your picture do on a typical day?
4. What skills does the engineer in your picture have?
5. Is your knowledge of engineers accurate? How do you know?
6. How could you find out more?

DAET is an instrument, which requires only blank paper and pencil or colored markers/crayons, participants are provided these materials and are simply asked to draw an engineer at work. No other guidelines or restrictions were given. After teachers finished their drawings, they were also asked to respond to the five open-ended questions.

Results

Analysis of question one and drawings showed that teachers have mixed opinions about engineers' occupations (Table 2). While the most popular answers were "designing" and "thinking/working" in pre- test drawings, the most popular answers in post-test drawings were "designing, "coding/programming", "thinking/working" and "problem solving". After the summer workshop, most of the participant teachers described engineers as being "problem solvers". While there were not any teachers who included engineering design process in their drawings prior to the summer workshop, three of them included in engineering design process in their drawings after the summer workshop.

Table 2. Question One

Describe what the engineer in your picture is doing?		
Type of Action	**Pre**	**Post**
Designing	5	7
Creating	3	2
Improving	0	1
Building	2	1
Doing Research	2	2
Coding/Programming	1	5
Problem Solving	1	8
Thinking/Working	6	6
Following Engineering Design Process	0	3
Supervising a Construction Site	2	0

Teachers' responses to question two were categorized based on the keywords that teachers used in the text and teachers' drawings. Before the summer workshop, teachers indicated that engineers were using mostly hand tools; however, after the summer workshop, there was an increase in engineers using electronic tools and software/hardware as well as hand tools.

Table 3.Question Two

What tools does the engineer in your picture use?		
Type of Tools	**Pre**	**Post**
Hand Tools	9	14
Electronic Tools	9	23
Software/Hardware	4	12
Own Skills	4	8
Laboratory Equipment	5	1
Blueprints/Models	4	3

Analysis of question three and drawings indicated that there was an increase in the number of teachers' responses with regards to "type of skills" that engineers have. The results are presented in Table 4. Before the summer workshop the most cited answers were "math", "science" and "technology". After the workshop the teachers' most cited answers were "math", "science" and "technology as well as "computer programming/coding", "collaboration/communication skills" and "critical thinking skills".

Table 4. Question Three

What skills does the engineer in your picture have?		
Type of Skills	**Pre**	**Post**
Math	7	12
Science	7	5
Technology	5	7
Computer Programming/coding	1	10
Design	2	4
Perseverance	3	4
Building	2	3

Creativity	3	3
Collaboration/Communication	4	8
Work Ethics	0	1
Electrical/Mechanical	2	3
Critical Thinking Skills	3	5
Problem Solving Skills	4	4

Results from question four focused on understanding the teachers' confidence level related to knowledge about engineers. While the number of teachers who described themselves as "not sure" decreased significantly at the end of the summer workshop, the number of teachers who describe themselves as "sure" increased at the end of the summer workshop. These results are shown in Table 5.

Table 5. Question Four

Is your knowledge of engineers accurate?		
Confidence Levels	**Pre**	**Post**
No response	5	0
Sure	7	18
Not Sure	12	6

As indicated earlier, while fifty-eight percent of the teachers who participated in the summer workshop were female, forty-two percent of the teachers were male. However, the majority of the drawings that included people were stick figures. Occurrence of images of gender in teachers' drawings can be seen in Table 6.

Table 6. Occurrence of Images of Gender in Teachers' Drawings

	Pre-test (%)	Post-test (%)
Female	15.7	25.9
Male	31.5	22.2
Unknown	52.6	51.8

Examples of pre-test drawings and post-test drawings are presented in Figures 1, 2, 3,4, and 5.

While many of the engineers who featured in the pre-test drawings were mostly alone in a working environment (e.g. see Figure 1 and Figure 2), in the post-test drawings, most of them were depicted in a collaborative working environment by the teachers (e.g. see Figure 3 and Figure 4). Similarly, although most of the engineers depicted in the pre-test drawings were related to some level of lab work (e.g. see Figure 2), in the post-test drawings the depicted engineers were related to mostly engineering tools and equipment (e.g. see Figure 5).

Figure 1. A Pre-test Image Drawn by a Teacher DAET

Figure 2. A Pre-test Image Drawn by a Teacher DAET

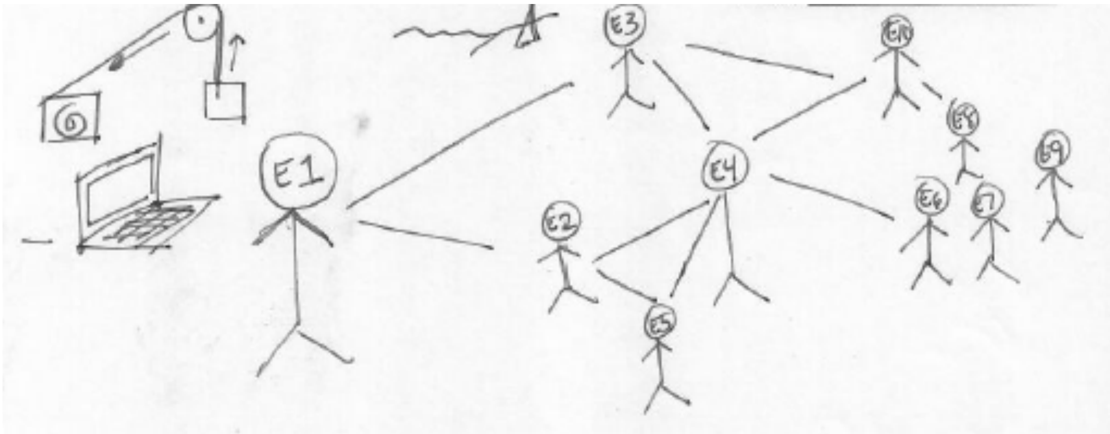

Figure 3. A Post-test Image Drawn by a Teacher DAET

Figure 4. A Post-test Image Drawn by a Teacher DAET

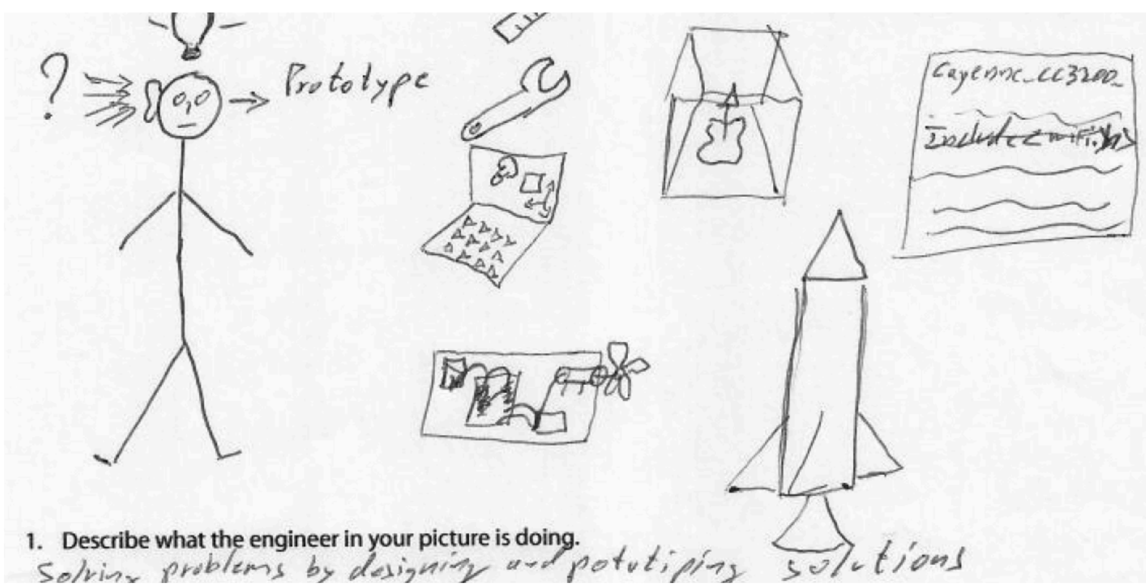

Figure 5. A Post-test Image Drawn by a Teacher DAET

A paired-samples t-test was conducted to determine whether there was a significant difference between teachers' pre- and post- perceptions of engineers and engineering after completing a two-week-long engineering-focused PD workshop. For that purpose, we analyzed the mean difference in Table 2, Table 3, and Table 4. Descriptive statistical analysis showed a significant mean difference between groups within those categories. A paired samples t-test revealed that there was a statistically significant increase in the number of teachers' responses with regards to "type of skills" (Table 4), ($t(24) = -2.63$, $p = .022$). On the other hand, there wasn't any statistically significant increase in the number of teachers' responses with regards to "type of actions" that engineers present (Table 2) and, in the number of teachers' responses with regards to "type of tools" that engineers use (Table 3).

Conclusions

There is growing concern in the US about the lack of interest and aptitude in science, technology, engineering and math (STEM) disciplines. While most teachers are well versed in math and science through their formal education, very few have experience and/or educational backgrounds in engineering and technology. A significant report noted the lack of engineering education at the K-12 level [21]. Incorporating engineering into the K-12 classroom is getting national and international attention [22]. Engineering is can be viewed as the application of math and science for the betterment of humanity. Understanding teachers' views of engineering and engineers and how certain activities can impact those views can have significant affects on the ability to increase the number of students that pursue engineering degrees and careers.

This work examined the effects of a two week summer program on teachers using the Draw an Engineer Test (DAET) [9]. The results among a diverse group of teachers showed increased awareness of the activities engineers engaged in such as computer coding and problem solving. The teachers seemed to get a better awareness of the tools engineers used such as electronics and hand tools as opposed to lab equipment more equated with science. The teachers also seemed to gain a better understanding of the skills necessary for engineering, including programming and collaboration. The teachers also improved their confidence of their understanding of engineering. The representations of the drawn engineers (that showed a gender) were also less male after the two-week program as compared to those before the two-week program. Overall, the two-week program seemed to have an appreciable impact on the participants' understanding of engineering. Future work will examine the effects of this change on their students' beliefs and understanding of engineering.

Limitations

There were several limitations in this study. Participants were chosen from a population of teachers who applied to the summer workshop. Because of this limitation, the sample size of participant teachers was limited by the number of teachers who participated in the study. This summer workshop was somewhat short (two weeks of lessons), and this may deliver only limited information about teachers' perceptions related to engineering and engineers. In addition, since the workshop was relatively short, the data analysis may only demonstrate slight instant changes in teachers' conception of engineering and engineers. Finally, only one researcher conducted the data analysis. With this in mind, there is a possibility that results might be susceptible to researcher bias. To overcome this challenge and to gain deeper understanding regarding the results, we requested teachers to explain their drawings by answering open-ended questions at the end of the DAET. In future, expanding the number of researchers who conducted the analysis would improve the inter-rater reliability of the study. Finally, it should taken into consideration that participants might provide positive results after the intervention because of being in a research study and receiving attention from the researchers [23].

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