Draw an Engineer Test (DAET): Development of a Tool to Investigate Students' Ideas about Engineers and Engineering

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Abstract

The public has an incomplete understanding of engineers and engineering as a profession. In discussions about the public's understanding of engineers, many have referenced the "conventional" stereotype of engineers as train operators. Though this stereotype may exist among students as well as the public, few investigations to date have focused on students' ideas about engineers and engineering. The recent introduction of engineering into the K-12 curriculum in Massachusetts has increased interest among educators in assessing students' knowledge of engineering as a result of intervention and outreach. The "Draw a Scientist Test" (DAST) has been widely used to assess students' attitudes about scientists. To help assess students' ideas about engineering before and after intervention, we are developing a "Draw an Engineer Test" (DAET). This analysis focuses on the results of the pilot study of students' written and drawn responses to the question "What does an engineer do?"

Introduction

Images shape the way individuals view the world, thus, understanding the image students have of engineers and engineering is extremely important. The public has an incomplete understanding of engineers and engineering as a profession [1, 2]. In discussions about the public's understanding of engineers, many reference the "conventional" stereotype of engineers as train operators [3, 4]. Though this stereotype may exist among students as well as the public, few investigations to date have focused on students' ideas about engineers and engineering. The recent introduction of engineering into the K-12 curriculum in Massachusetts has increased interest among educators in assessing students' knowledge of engineering.

Though we are surrounded by the products of engineering in our everyday lives, students often don't understand what engineers do [2]. Few students come in contact with working engineers, thus students' ideas about engineering are formed from other sources, such as the media. In his review of the depiction of engineering in popular culture, Vaughan outlined the degeneration of the image of the engineer in modern society from the heroes depicted in books such as Jules Verne's *Mysterious Island* to the modern day caricatures in *Revenge of the Nerds* [5]. The depiction of engineering in the media is unstable, and can vary widely depending on what the current headlines say about emerging technologies.

The image of engineering is also negatively affected by its close association with science [4]. Thus, it is useful to look at the research in science for information on potential reactions to engineering. Girls and boys develop ideas about science and who is qualified to be a scientist early in their education, often based largely on messages they receive outside of the school walls [6]. In order to effectively address students' ideas about science, it is important to understand the nature of those ideas [7, 8, 9]. Similarly, in order to address students' ideas about engineering, it is important to understand what ideas students have about engineering.

The Impact of Images

Images are a powerful form of communication, thus exploring and understanding images has important theoretical and practical implications. Humans create images in order to make sense of their everyday experiences [10]. A commonly accepted image can become metaphorical, equating one concept with another, such as "nerd" and "engineer". Once these images become part of a generally accepted vocabulary of popular culture, they transcend their origins.

> *While images always maintain some connection to people, places, things, or events, their generative potential in a sense gives them a life of their own, so that we not only create images, but are also shaped by them.* [11] (p. 21)

Though the concepts are theoretical, the implications are concrete. The messages students gather from years of socialization influence their attitudes about science and math, their self-efficacy beliefs, their choice of coursework, and even their future career plans. Girls begin to form negative attitudes about their abilities in science, especially physical science, as early as second grade [12]. Sex role stereotypes have negative impacts for both men and women. Men who choose non traditional careers in nursing and elementary school teaching often are regarded with a critical eye. Similarly, women who continue onto careers in non-traditional fields such as science and engineering are negatively stigmatized [13]. A student who is interested in engineering but does not want to be considered a nerd may shy away from expressing her interest to avoid the negative association. Images associated with a field become part of the identity of the people within that field.

The "Draw a Scientist Test" (DAST) has been widely used to assess students' attitudes about scientists [7, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31]. To help assess students' ideas about engineering before intervention, we are developing a "Draw an Engineer Test" (DAET). The purpose of the survey is to have students describe their knowledge about engineers and engineering through written and drawn responses. The questionnaire contains the following five questions on one page: "In your own words, what is engineering?", "What does an engineer do?", "Draw a picture of an engineer at work." (above a 2.5" x 7.0" rectangle for drawing), "Do you know any engineers?" (Yes/ No) "If yes, then who are they?". This analysis focuses specifically on students' answers on two of the five questions: "What does an engineer do?", and "Draw a picture of an engineer at work".

Methods

Teachers who work with the Center for Engineering Educational Outreach at Tufts University were asked to have their students fill out the one page questionnaire as part of an in-class assignment. Teachers were asked to do this at the beginning of the school year, preferably before they began any unit on engineering. Though specific information on ethnicity and socioeconomic status was not collected as part of this study, demographic information about the participating schools indicate that this population of students represent a wide range of ethnic and socioeconomic diversity.

Students were given 15 minutes to complete the questionnaire. Respondents were encouraged to write what they thought about engineering and not be concerned about whether their thoughts were correct. Teachers had the option to have a class discussion about engineering after the questionnaires were collected.

Written responses to questionnaires were entered into a Microsoft Access database. Pictures were translated into words by the researchers. All responses to the question were reviewed, and recurring themes were developed into codes. These codes were associated with each response, and queried for basic tallies. Tallies were translated into percentages using Microsoft Excel.

Results

These results are the basis of a pilot study investigating students' ideas about engineering. Different survey designs and question formats were tested during the pilot study. Initially, students were asked to answer the question "What is an engineer" in words, and did not ask students to draw pictures. Later, the survey was adapted to combine both written and drawn responses. The written data from all of the pilot studies was compiled for the analysis of written responses.

Table 1: Demographics of Written Responses to "What is Engineering" Survey

	All Grades	Percentage	Grades 3-5	Grades 6-8	Grades 9-12
Total	384	100%	60	189	135
Males	175	46%	25	92	58
Females	209	54%	35	97	77

Only surveys with both gender and grade information were used for data analysis. A total of 384 written surveys included gender and grade, with 46% of the respondents were male, and 54% were female. Almost half of the respondents (49%) were from students in grades 6-8, 35% of the respondents were from grades 9-12 and 16% of the respondents were from grades 3-5.

Written Responses

Students were asked to respond to the question "What does an engineer do?". Each response was coded for the activities of engineers that were mentioned by the student. If a student mentioned that engineers build houses and engineers build car engines, the individual's response was coded only once for building. Though students offered many ideas, about 30% of the students responded that building and fixing are the activities they associate with engineers. Creating and designing were also associated with the field of engineering. The common idea that engineers drive trains was only mentioned by 9% of students. The frequency of each category was similar for both male and female students, as detailed in Table 2.

Table 2: Top Ten Activities of Engineers

	All N=107	Male N=50	Female N=57
Builds	30%	27%	26%
Fixes	28%	23%	26%
Creates	17%	11%	18%
Designs	12%	13%	9%
Drives (trains)	9%	5%	9%
Don't know	6%	8%	3%
Improves	4%	4%	2%
Calculates	3%	2%	4%
Invents	3%	3%	2%
Studies	2%	2%	2%

Data was also disaggregated by the respondent's grade level and gender for the top five categories: builds, fixes, designs, creates and drives, as outlined in Table 3. Though building is a common response among all grade levels, older students are more likely to say that engineers design things than younger students. A significant number of students in the middle grades mentioned that engineers fix things. Additional examination of the students responses indicate that students described repair-type activities, such as repairing car engines (auto mechanics), computers, even plumbing—traditionally blue collar and male-dominated fields. The middle school years are crucial for an individual's planning for high school course taking and potential career paths; the perception that engineers are car mechanics could discourage female students from considering engineering as a possible career.

Table 3: Engineering Activities Disaggregated by Grade Level and Gender

	3-5 male N=25	3-5 female N=35	6-8 male N=92	6-8 female N=97	9-12 male N=58	9-12 female N=77
Builds	44%	31%	28%	23%	41%	17%
Fixes	28%	20%	33%	32%	9%	26%
Creates	8%	17%	10%	16%	17%	22%
Designs	16%	6%	10%	4%	17%	19%

Drives (trains)	8%	11%	7%	18%	3%	0%

Drawn Responses

During the pilot study, one participating teacher asked her students to express their thoughts about what engineers do through both words and drawings. These pictures contained interesting data, so all subsequent iterations of the survey have asked students to draw as well as write their responses. The demographic breakdown of the drawn responses is depicted in Table 4.

Table 4: Gender and Grade Level of Respondents who Submitted Drawings

	Total	Percentage	Grades 3-5	Grades 6-8	Grades 9-12
Total	253	100%	73	41	139
Males	106	42%	30	18	58
Females	147	58%	43	23	81

Gender

About 42% of the respondents who submitted pictures were male, and 58% were female. Many researchers have analyzed students' depictions of gender in their drawings of scientists. When asked to draw a scientist, both male and female students are more likely to draw men. The majority of the drawings that were analyzed for this study did not contain discernable evidence of gender; about half of the drawings that contained people were little more than stick figures. Of the 64 drawings with evidence of gender, 61% were male characteristics (short hair, square shoulders, necktie), and 39% were female (long hair). As with the draw a scientist test, females were more likely to draw females than males. The fact that 25 drawings depicted a female engineer is unusually high—most of these drawings were from a classroom in which two female undergraduate engineering students from Tufts had been working with the students for a few months before the survey was given. When asked whether they knew any engineers, many of the students specifically listed the names of the undergraduates, indicating that they had a significant impact on the students' ideas about engineering.

Table 5: Occurrence of Images of Gender in Respondents Drawings by Gender of Respondent

	N=253	Percentage	Female	Male
Unknown Gender	125	49%	67	58
Discernable Gender	N=64	Percentage	Female	Male
Female	25	39%	21	4
Male	39	61%	22	17

Images of Engineering

Each picture was analyzed for the images and artifacts contained in the pictures. As with the written responses, each occurrence of an artifact, such as a picture of a hammer, was coded once per respondent. If a respondent drew a picture with both a hammer and a wrench, the code "tools" was only assigned once, not twice. The most common images found in the respondents' drawings are listed in Table 6.

Table 6: Common Images in Students' Drawings of Engineers At Work

Image	Total N=253	Female N=147	Male N=106
Tools (e.g. hammer, wrench)	23%	25%	22%
Cars	19%	29%	12%
Computers	17%	29%	8%
Hard Hat	13%	24%	5%
Building/ House	11%	13%	9%
Trains	9%	13%	5%
Desk	6%	7%	6%

To gain a better sense of the overall themes in students' drawings, the images were grouped together into themes. These themes were created based on both the students drawing and the students' written responses to the survey. If a student responded that engineers build things or fix things, the student often drew a picture including tools or a workbench. If a student responded that engineers design things, the picture often included a person at a desk holding a pen or pencil. Table 6 lists the total occurrence of the different themes across the entire sample by code. If an individual's picture contained both tools and a hard hat, each code was counted once, counting for 2 occurrences of "images of building" in the overall sample.

Table 7: Frequency of Images of Engineering Grouped by Themes

Thematic Grouping	Images Included in Group	Occurrence of Image
Images of Building/Fixing	Tools, Hard Hat, Workbench, Safety Glasses, Heavy Machinery	133
Images of Designing	Desk, Plans or Blueprints, Pen/ Pencil, Models, Computers	81
Images of Products of Engineering - Mechanical	Cars, Engines, Machines, Rockets, Airplanes, Robots	73
Images of Products of Engineering - Civil	Bridges, Roads, Buildings, Houses	42
Images of Trains	Trains, Train Tracks, Train Engineers	22

Images of Laboratory Work	Test Tubes, Beakers	5

Similar to the written responses, students' drawings of engineers showed considerable evidence of building and fixing. These images were present not only in artifacts of building and fixing (such as tools, hard hats and safety glasses) but were also expressed through the products of engineering (cars, buildings, and bridges). These images suggest that many students think of engineers as the people who are fixing cars (car mechanics) and building houses and bridges (construction workers).

Quite a few pictures also included evidence of engineers in the process of designing. Often, these pictures included a person seated at a desk holding a pen or pencil, or a person in front of a computer.

Many pictures included images of the products of engineers. Products associated with mechanical engineering (machines, cars, engines) appeared 73 times in the sample of drawings, while products associated with the work of civil engineers (bridges, buildings and roads) appeared 43 times. The authors chose to group these products under "civil" and "mechanical"; none of the students specifically mentioned civil or mechanical engineering in their responses.

Finally, images of trains, train tracks and train engineers appeared about 22 times in the sample, indicating that a few students still equate engineers with trains. Images of laboratory work such as test tubes and beakers appeared only 5 times in the sample.

Discussion

The results of this pilot study indicate that the students in this study have preconceived ideas about engineers and engineering. Many students, especially younger students, think that engineers use tools to build buildings and fix car engines. Some of the students written responses indicate that this could be a vocabulary problem. When asked to describe what an engineer does, some students wrote statements such as "Engineer has the word engine in it, so I guess engineers must work with engines". Children seem to equate engines with car engines, thus they relate engineers with car mechanics. Similarly, the word "mechanic" is similar to "mechanical engineer". Older students are more likely to think that engineers are involved in designing things such as buildings or machines. When gender characteristics are included in students' drawings, they are male characteristics, indicating that students think of engineers as men. The traditional association of engineers with trains was not prevalent in this sample of students.

Student's images and stereotypes about engineers and engineering are important, since perceptions of careers are closely linked to whether students feel they can enter into those careers. The image that that all computer science majors are narrowly focused hackers, an image Margolis and Fisher refer to as "geek mythology", discourages students from studying computer science [32, 33]. The image of engineering as a "male" profession supports the idea that women can not "do engineering" [4]; thus, female students are less likely to consider engineering as a career [34]. Perception of ability is important; among college engineering majors, a student's perception of her ability plays a more important role in determining persistence in the major than her actual ability [35]. Clearly, though stereotypes and perceptions are “just beliefs”, they are powerful beliefs, and are worthy of investigation and analysis.

Limitations

The data for this study was collected with the assistance and cooperation of teachers, graduate students and undergraduate students who work with the Center for Engineering Educational Outreach at Tufts University. Since many people were involved in gathering the data, students may have been given different instructions, which could influence the results. Previous research has shown that changing the instructions the draw a scientist test can affect what students draw [27]. To minimize this potential, a standardized instruction sheet was given to the survey administrators, but there is no guarantee that the instructions were followed. Since the classrooms include teachers that are interested in including engineering in their curriculum, the students in these classrooms may have had more exposure to engineering than other students.

Asking students to draw a picture of an engineer may produce stereotypical results. Critics of the Draw a Scientist Test (DAST) have noted that students may have multiple models of scientists that may not be represented by a single drawing [23]. Students may actually have a more complex understanding of scientists than one drawing can communicate. As a result, some researchers have designed their studies to gather more than one drawing from the students [36, 37]. However, the purpose of this study is to investigate students’ stereotypes about engineering. Additionally, gathering a combination of written and drawn response allowed students to express more than one idea about engineers.

Future Research

The purpose of this research is threefold. First, understanding students’ ideas about engineering may give some clues as to why so few students, especially female and minority students, elect to go into engineering majors. The results of this study indicate that this may be linked to students’ misconceptions of what engineers do—if students believe that engineers are car mechanics and construction workers, then certain groups of students (such as female students) are less likely to consider engineering as a career. Informing those students that engineering is not just “fixing cars” may cause more students to consider engineering as an option.

Second, by taking these conceptions into account, intervention and outreach programs can directly address these ideas, and engage the students in discussion in order to form more accurate understandings of the role of the engineer. In science education, considerable research has shown that student’s preconceived notions are difficult to change unless the notions are directly addressed during discussion [8, 38]. Similarly, by understanding that students see the word “engine” in “engineer”, and think “car” when they see the word “engine”, then we can engage in a conversation about what role an engineer might play in the development and testing of a car engine. This can lead into a discussion about other types of engineering which may appeal to a wider range of students.

Finally, since engineering and technology are inextricably linked, we contend that students' ideas about engineers and engineering reflect their attitudes towards technology. Not every student will want to go into a technical career such as engineering. However, in an increasingly technological society, every student should have an understanding of and appreciation for technology, what some have called "technological literacy". Technological literacy includes knowledge about technology, ways of thinking and acting in order to understand new technologies, and having the basic capabilities to use technology [39]. Having an understanding of how engineering is related to the development of technology is an important component of technological literacy.

We have continued to gather data on students' ideas about engineering through additional written surveys as well as one-on-one interviews with students about their responses to the test. We are developing questions to link high school student's images of engineers and engineering with their perceptions of whether engineering is a positive career option and their willingness to consider engineering as a possible career. Preliminary analysis indicates that many students do not consider going into a career in engineering because they do not have clear understanding of the field, a contention that is supported by the literature [2]. Thus, educating students about engineering as a career option could have an impact on the number of students who consider majoring in engineering and going into such careers. We will continue to conduct research to determine whether and how students' images of engineers and engineering impact their own career paths.

We are also developing questions to allow students to demonstrate additional knowledge about engineers and engineering that the current questionnaire may not gather, such as the broad nature of the field of engineering, and to determine how students' images of engineering effect their ideas about technology.

Acknowledgements

The authors would like to thank the staff, GK-12 undergraduate and graduate students, PCET graduate students, and participating teachers for their assistance in collecting the data for this pilot study. Specifically, we would like to thank Paul Arenburg, Paul Ajemian, Patricia Brandl, Roberta Brown, Althea Brown, Katie Cargill, Patric Dunfrey, Mimi Forg, Ben Gemmill, Brian Gravel, Charlie Low, Merredith Portsmore, Melissa Pickering, Erica Wilson.

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Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition