AC 2008-1731: SIXTH GRADE STUDENTS' IMAGES OF ENGINEERING: WHAT DO ENGINEERS DO?

Faik Karatas, Purdue University

Amy Micklos, Purdue University

George Bodner, Purdue University

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Abstract

There has been a growing interest in teaching engineering in the K-12 context. It is therefore somewhat surprising to find that there have been few investigations on students' views of engineering and the nature of engineering (VNOE) at this level. This project is based on the assumption that understanding students' VNOE has as much potential for impact on engineering education as the views of the nature of science investigations have had on the field of science education. The overall goal of this study was to investigate 6th-grade students' perceptions of the nature of engineering (NOE), and to understand the experiences that have shaped students' perceptions of the field of engineering. The results of twenty 6th grade students' drawings of an engineer or engineers at work with associated interviews related students' own drawings from two mid-west middle schools are presented. Results indicated many students held common mis- and naïve conceptions about engineering, engineers, and what engineers do; specifically that engineers drive trains, fix cars, build houses, and work alone.

Introduction

One of the main goals of science education is to prepare scientifically literate students. The Nature of Science (NOS) and the Nature of Technology (NOT) were inserted as central components of scientific literacy in 'Science for All Americans,' 'Benchmarks for Scientific Literacy,' and 'National Science Standards' documents[1,2,3] because NOS/NOT serve as a base for understanding capabilities, power, and effects of technology.[4,5,6] An understanding of the NOS/NOT helps today's civilized societies make more informed decisions about developing and using new technologies more responsibly and rationally as well as evaluating the effects of technology on the environment and society.[6]

Research in science education has shown that students' learning is influenced by their ideas regarding the NOS.[7,8] Some science educators have claimed that an informed view of the NOS will improve students' attitudes towards science, help them internalize science, and eventually enhance their science learning.[9,10] The same argument could be appropriate for and can be applied to the engineering field. In other words, an understanding the nature of engineering (NOE) could improve students' learning outcomes of engineering and technology. It could also affect how engineers see and conduct their professional lives after they graduate.[11]

Research has shown that the attitudes of high-school students toward engineering become more favorable as their knowledge of engineering increase.[12] The International Technology Education Association (ITEA)[6] has asserted that an increasing knowledge of engineering may increase the number of students who choose engineering and technology as their future career. This is especially crucial because the number of students enrolling in engineering and technology has been constant or declining in recent years. At the same time, the need for engineering and technology related school graduates is higher than ever.[13] There has been a growing interest in integrating engineering curriculum at the K-12 level as a result of the higher demand of engineers and technicians.[6,14,15] Science education research has shown that conceptions and misconceptions of the target population should be integrated into curriculum development efforts in order to establish inter-subjectivity between students and course material. In spite of this, there have been few studies of students' views of engineering and the nature of engineering (VNOE) at this level.[15-19]

Research has shown that university engineering students indicated that they generally become aware of engineering at the age of 11 (around 6th grade); a time at which these students began to shape their career choices.[20] Therefore, investigating 6th grade students was a good starting point to better understand what students think of engineering and of what engineers do.

This study is based on the assumption that understanding students' views of engineering has as much potential for impact on engineering education as the results of the views of the nature of science have had on the field of science education. The overall goal of this study was to investigate 6th-grade students' perceptions of the nature of engineering, and to understand the experiences that have shaped students' perceptions of the field of engineering based on previous research in the field. However, we only discuss one aspect of the study in this paper. The results of twenty 6th grade students' drawings of engineer/engineers at work with associated interviews related to students' own drawings will be presented.

The main research questions that have been sought to be answered are:

- What images of engineering do 6th grade students' hold?
- What do 6th grade students think engineers do?

Methodology

A qualitative research method was adopted in the process of this study. Phenomenography was the theoretical framework that was chosen for this study.[21] The goal of this approach to educational research is to define the different ways in which people experience, interpret, understand, perceive, and conceptualize a phenomenon, or certain aspects of reality.[22] The main results of phenomenographic research are categories of description of the various conceptions of a phenomenon. Phenomenographic research, however, does not only report these different conceptions but also involves identifying conceptions and looking for underlying meanings and relationships between them.[23]

Phenomenography was chosen as the theoretical framework for this study because the main goal of this study was to investigate 6th grade students' images of engineering that were constructed as a result of different experiences. Phenomenography allows researchers to probe others' experiences and understand what they gained from these experiences. We expected that the students in this study would have had different experiences that shaped their views of the phenomenon of engineering.

Setting and participants

Two middle schools from a small mid-west town were selected for this study. One school was running an engineering curriculum for 7th and upper grades while study was conducting. A researcher from a major engineering school gave an hour lecture/seminar about engineering to the target population at the same school long before the study began. As seen in Table 1, total of 370 students enrolled in 6th grade in these schools. Participants were 20 Caucasian 6th-grade students that were 11-12 years old. An equal number of male and female students was purposefully selected among the volunteers in the study. In phenomenographic studies, a sample size of 15-20 with maximum variation is traditionally believed adequate to investigate the phenomenon. In this study, variation was sought only for gender. Ethnicity and economic status was not part of our selection process because of ethnic homogeneity among the volunteers and privacy concerns.

Table 1. Demographics of selected schools

	Enrolment		Ethnicity			Economic (Lunch)	
	6th Grade	Total	African-American	Hispanic	Caucasian	Free	Reduced
School 1	180	550	N/A	1%	99%	16%	12%
School 2	190	590	2%	8%	89%	35%	10%

Data collection and analysis

The methodology appropriate for use with phenomenography is qualitative interviews. However, other methods of data collection are also suitable. In this study, we conducted approximately 20 45-minutes long (35-70 minutes) audio-recorded individual interviews which were semi-structured. Two researchers together conducted interviews. During the interviews, each student was asked to draw "an engineer or engineers at work" on a white paper with provided crayons and then talk about their drawings. This approach was employed with the underlying assumption that drawings provide more explanatory data and a broad picture of the thinking of 6th grade students.[24]

The data from the interviews were analyzed by identifying qualitatively distinct categories or clusters. Two researchers were involved in the analysis process. The analysis process began with open coding, a form of inductive data analysis[25] because there were no pre-determined categories. The first level of analysis involved examining five students' responses by looking for similarities and differences among them. At the end of this level, the two researchers came together and discussed their initial codes and categories. The data were then subjected to a second, deeper analysis that helped us develop categories that were more general. At the end of the second step, the researchers came together again and shared their categories and ideas about the data. There was almost perfect overlap between the researchers' categories. In a version of the hermeneutic circle[26] that underlies research methodologies such as phenomenography, the data were then subjected to further analysis by collecting students' answers for each question together. One of the goals of this process was internal consistency within each category. Another important goal was the development of as few general categories as were needed to describe all of the participants' views. After more rigid categories were developed, they were applied to the rest of the data without forgetting to look for other categories of description.

Results

In this section, the results of the interview and student drawing analysis are reported. Students' oral responses to the interview questions and their drawings were analyzed to discover what students think about what engineers do.

What do engineers do?

Almost every response to the questions we asked naturally touched what engineers do. All participants pointed out one or more artifacts that engineers either 'make' or 'build.' However, they mentioned different ways and stages that engineers involve in these making and building processes. Three main artifacts were considered by students that engineers make or build, including vehicles-machines, structures, and electronics. A typical vehicle that the participants thought that engineers make was automobiles and planes as well as trains, roller coasters, and space shuttles. The last three vehicles that students mentioned in interviews were actually the objects that we utilized to probe students' views about engineering. As illustrated in Table 2, fourteen participants indicated that engineers make or build vehicles. Eleven students stressed that engineers put vehicle parts together, weld them or assemble them as engineering work (Here SMXX represents male students, SFXX represent female students, and RX represents researchers).

> SF17: Uh, instead of just doing building they do cars too. Engineers working on cars and stuff.
> R1: What would they do with the car?
> SF17: I think when they're putting the car together and everything, I know factories do it now, but engineers work the machines and stuff, but like I think of frames every time.
> R1: So, they put together the frame of it again. Okay.
> R2: Who put the seats into the car?
> SF17: Um, I guess engineers cause. I don't know.

Four students (two of whom did not mentioned that engineers assemble vehicles), on the other hand, stated that engineers also have to figure out where and how to assemble parts in addition to putting them together.

> SM20: I am telling that it is very complicated job because you have to like mapped out and get the right parts and put them in the right place so it… but if he messed it up, everything is gonna go wrong.

In addition to making vehicles or machines, as seen in Table 2, 13 students indicated that engineers build structures, including roads, railways, buildings, tunnels, and amusement parks. Four of the participants especially focused on "mega structures" and skyscrapers.

> R1: You said they could build things, so what type of things do they build?
> SF19: Like the streets, um like rollercoasters, and then they can also help build like really tall towers.
> R2: How about the short ones?

SF19: Yeah, they can help with that too.

Table 2. Detailed students' views of what engineers do

What do engineers do?		**Number of students (N)**
Make-build	Vehicles	14
	Structures	13
	Electronics	3
Fix	Vehicles/consumer electronics /things	10
Test/check		10
Calculate/estimate		5
Design	Structures	5
	Vehicles	4
	Consumer Electronics	3

Except for five students, the participants who indicated engineers build structures meant engineers construct them as if they were construction workers. A students' drawing in Figure 1 illustrates students' views of what engineers do clearly. The figures that have a star over them were specifically indicated by the participant when directly asked whether they are engineers or not.

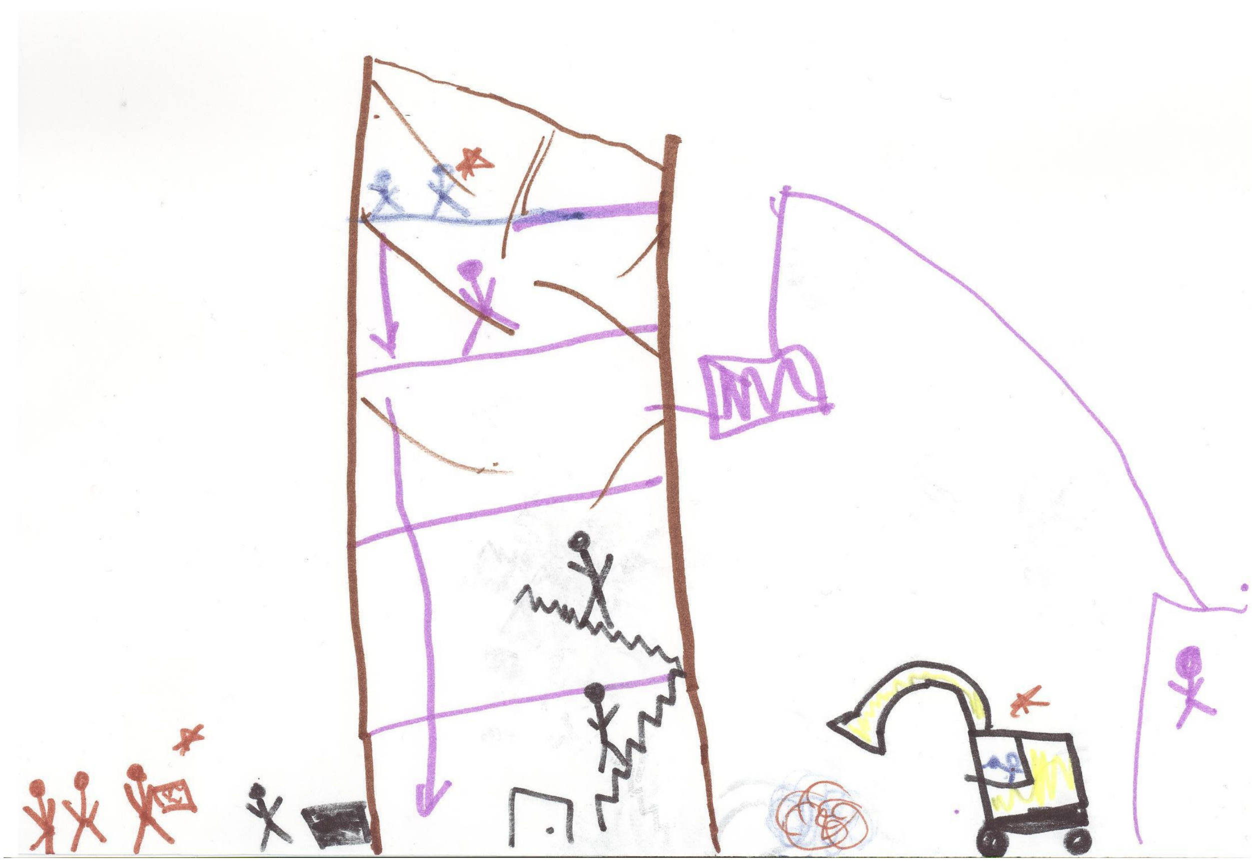

Figure 1. A student drawing that indicates engineers construct buildings

On the other hand, as seen in Table 2 five students explicitly indicated that engineers design a structure. Students also considered there is a chain of command in the process of building a structure and engineers are responsible for how it should be build.

> R2: What kind of engineer?
> SM05: A construction engineer.
> R2: What do construction engineers do?
> SM05: They… like make the lay out for the roads and the highways and like the ways you get around.
> R2: Do you think they work (outside)?
> SM05: No. They probably work in an office.
> R2: Office. Do what?
> SM05: Umm… Create the things and then tell… Like create 'em in their mind then jot it down and then tell the other people to go…
> R2: What kind of other people?
> SM05: Like the workers… They tell the foreman and foreman tells the workers.
> R1: Chain of command, right?
> SM05: Yeah

One student also indicated tools that engineers use to do their job. The term "tools" is used here as any form of equipment or material that engineers use to do their job.

> R1: What does the engineer do in particular about planning that?
> SM09: Make all the roads so they don't get all… well they make them so they won't having thing wrong so they don't didn't crashes. So make the roads…
> R2: Do you think engineers build those roads? Actively involved in construction?
> SM09: No. Designed it.
> R2: How?
> SM09: With, models, blueprints, charts and…

In addition to making vehicles and building structures, a few students also indicated engineers are responsible for making or designing electronic consumer products, including iPods, computers, and video game hardware. Half of the students also stated that engineers not only make and build things, but also fix them. An illustration of a student drawing is in Figure 2 with her explanation of what the engineer is doing in this picture.

> SF18: These are little IPODs, that's what they are. And that's supposed to be a machine that builds them. Like you know, okay, um, now there are, there has to be engineers 'cause say if a machine broke down then they'd have to fix it. But the engineers aren't always one's building the product. A lot of times they fix what's building them. So, we're not here, there's more machining building what they are, but there's still people that fixing machines.

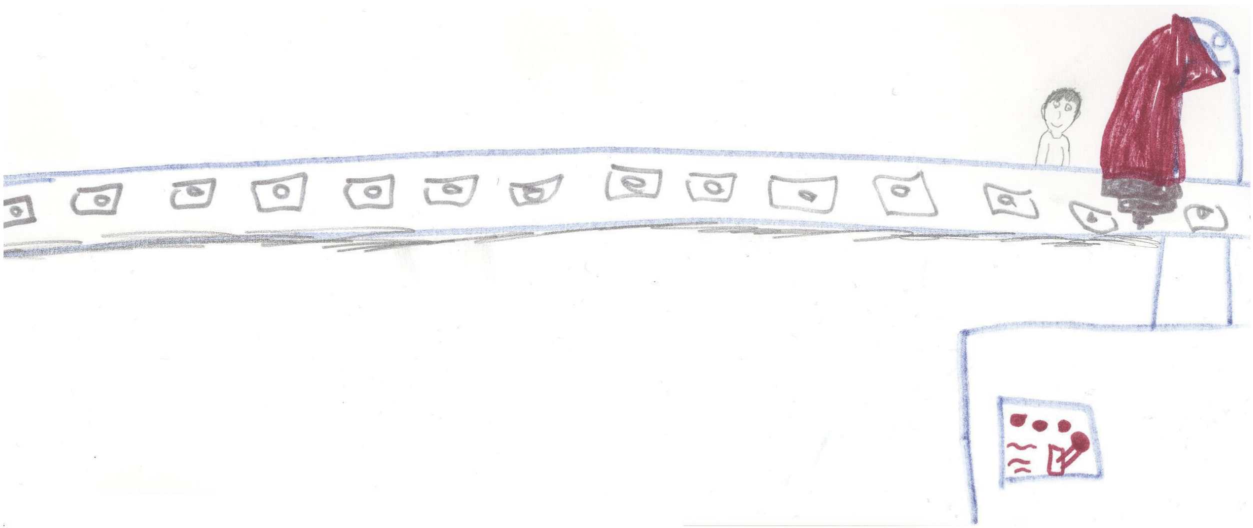

Figure 2. A student drawing that indicates engineers fix machines

Almost half of the students' responses also pointed out another engineering job: engineers also test products to check whether they function right, are built in accordance with blue-prints, provide enough safety, etc. Students especially stressed whether all parts of a machine work properly and safety issues for roller coasters. A couple of students also vocalized that engineers are the ones who are responsible for controlling any damages on the space shuttles.

> SF14: Because like the other thing that we just saw (roller coaster), they have to design it and make sure all the parts are right and then there are people that build it and make sure it works right.

As seen in Table 2, a few students (N=5) anticipated engineers need to calculate and/or estimate how much money they spend, how large the product would be and how long it is going to last, or how fast a roller coasters goes to operate safely.

> R1: OK. What might they do for a job?
> SM09: Umm… Design it, that design rollercoaster or maybe… calculate how fast it goes or something…

> SF11: …they have to think about how much money it's going to cost and what supplies they need?

As illustrated in Figure 3, three students, thought that engineers drive trains. Even one of them over generalized this idea and claimed everyone who drives a vehicle is an engineer.

> SM01: An engineer is someone who will be able to fix things or drive things. When I think of engineering I think of someone who drives a train.
> R1: A locomotive engineer.
> SM01: Yeah, that was what I was thinking of.

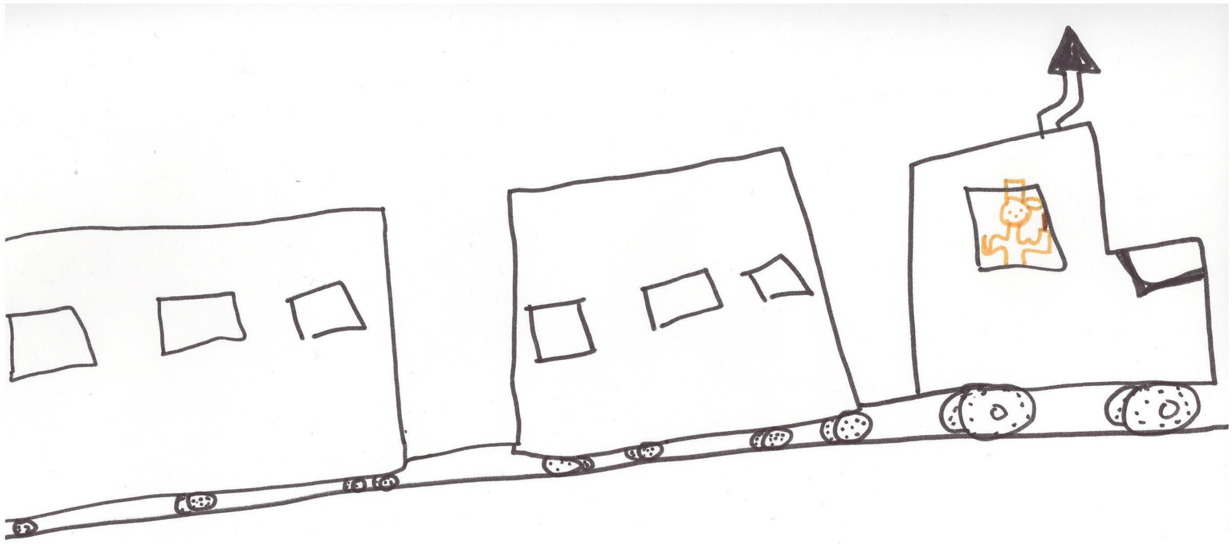

Figure 3. A student drawing that indicates engineers drive trains

Another three students believed that engineers paint or make figures on products. One of them, for example, indicated that engineers paint TVs or draw pictures on it. She also associated this with design. Another student's views of what engineers do were similar regarding space shuttle:

> SM06: I was… think like… about like it sitting on the ground and have them painting it and putting USA and the flag on it (space shuttle).

Wrong attribution of engineering to other occupations

There are many incidences that the participants believed some other occupations or professions are responsible for a certain domain of work that is actually part of engineering work or vice versa. Most frequently, students confused the work of architects, factory and construction workers, scientists, locomotive engineers, mechanics, and carpenters with the work of engineers. In total, nine students confused architecture with engineering. Even though few students pointed out that architects design mechanical devices or machines, many confused the role of engineers and architects in designing buildings and other structures.

> R2: … What is the difference between architecture and engineering?
> SM08: (Pause…) Architecture is basically the…
> R2: Or is there any difference?
> SM08: Kind of…
> R2: OK. Then tell me what is the difference?
> SM08: Engineering like… mostly architectures design it and a lot of people that are engineers or architectures are sometimes are engineers and they do both.
> R2: They do both? So, an engineer could be an architect too, an architect could be an engineer?
> SM08: They do a lot of the same things.
> R2: OK. What is the difference between them if there is any difference?

SM08: Engineering… they think of the new technology I guess and they design it and usually architect just design it.
R2: They don’t think new technology just design it?
SM08: Yeah, I think they just design it.
R2: Based on what? What do they design?
SM08: Cars, roads, houses…
R2: Architects can design this?
SM08: Yeah.
R2: How about this shuttle?
SM08: Umm… I don’t know, maybe.
R2: How about that car?
SM08: Yeah.
R1: So, an architect can design just about all three those things that he just showed you.
B: Yeah.

Students also assign roles of engineers to factory or construction workers. They thought workers or operators do what engineers are supposed to do or engineers were thought to do those workers’ jobs.

R1: … there are some bridges and it’s kind of crazy looking. Do you have any ideas about who made the decisions of how that should be built?
SF04: Road constructers.
R1: Okay. The same people who, road constructers are they the same people who are pouring the concrete or are they different people?
SF04: Probably different because some people work on roads and the other people work on the concrete, while the other people like get the road done and then while they work on another section the other people work on pouring the concrete in. And building different roads.

Another major field that students confused with engineering was science. One student, for example, believed that engineers have attempted to understand the universe. Another one claimed that Thomas Edison was a scientist because he invented the light bulb.

SF18: … there are engineers that make things for people to have fun like roller coasters and things and there are some that want to figure out about our universe and everything. They have different ideas, but they pretty much do the same thing but not exactly in the same way.

Some students confused engineers’ work with mechanics and technicians’ work because they either involve fixing machines or electronic equipment.

R1: What do you mean by engineers? What type of people are they?
SF02: What, like? They’re mechanics and stuff. They help fix it or they help put it together and stuff.

As seen in Figure 4, another student also had a similar view that mechanical engineers work in an auto body shops to repair cars.

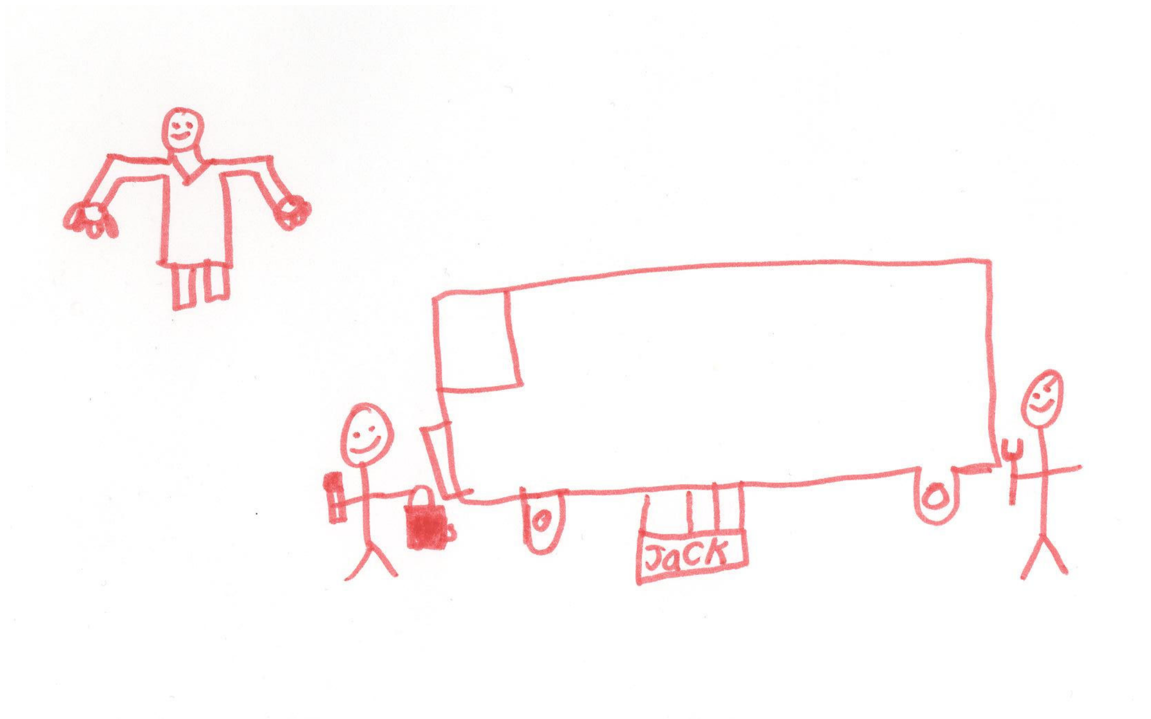

Figure 4. A student drawing that indicates engineers fix cars

SM05: Draw a little car, I draw the guy working on it…Put a little guy under it working… That's done.
R1: So, what is going on?
SM05: The guy is working on the tail of the car. That guy is painting it and working on the car in the body shop.
R2: So, those are engineers?
SM05: They're mechanical engineers.

Sources of experiences

Interview analysis revealed many sources by which students' views of engineering were influenced. The sources of students' engineering views and number of students who indicated their sources are seen in Table 3. Family, school/teacher, and TV (media) are the main sources of students' responses. An interesting response came from a female participant that noted the interviewers had a major impact on her view of engineering.

R1: Okay. So, where have you learned the most of your information about engineering or engineers?
SF14: Math.
R1: Math class?
SF14: And pretty much math and that's it.

R2: And?
SF14: And you guys!

Table 3.Main sources that affect students' views of engineering

Main Sources	Sub/sources and number of students
TV	Discovery channel, (4), building (car) shows (3), History channel (2), CNN News (1), not specified (3), internet (1)
School	Purdue guidance (6), science, reading class, (2) social studies (3), mathematics class (2), games (educational, online) (1), project (1), talks about engineering and need of engineers (1), general (1)
Teacher	Help students to differentiate engineering from other disciplines (2), math teacher (1)
Family	Father (6), mother (1), older brother (1), cousin (1), not specified (1)
Library	Books (5), articles-magazines (1), not specified (1)
Movie	about engineering (2)
Engineers	Purdue engineers' visits (5), neighbor (1), father (1), cousin (1)
Interviewers	"You guys!" (1)

Discussion and conclusions

The results of this study indicate that students' views of engineering are poor and sometimes ill-developed and overlap with the results of the other studies that were conducted in the field[14-16,18]. Making and/or building vehicles and structure was cited most by the participants in this study as well as the studies conducted by Oware and her colleagues[18] and Knight and Cunningham[16]. Fixing things was also mentioned by half of the students, which is a much higher ratio than other studies. However, many students also stated and/or pictured design element of engineering. Even though most of the students referred to design as sketching out or planning a vehicle or a machine, or a building, a few students also pointed out calculations and estimations that engineer have to do in order to do their jobs. Another finding that was revealed in this study was that many students mentioned engineers test a product, machine, building, or other artifacts for their functionality as well as their safety. Even though this finding may be associated with fixing things, it is also a main part of the engineering design process that students pointed out as engineering work.

Although students mentioned design and elements of engineering design in interviews and in their drawings, their views were not consistent and tended to change during the interviews. One student, for example, indicated engineers design theme parks then he changed his mind and stated that architects design it, but engineers build it. When we asked a similar question within a different context, he changed his mind again and claimed architects build highway overpasses. A similar trend happened with many students when the context of the question or the object (building, machine, or high-tech electronics) changed, students' thoughts of what engineers do changed as well. Additionally, students demonstrated a lack of self confidence in their responses. All students responded as "I do not know" or "I guess" and finished the conversation when we wanted to confirm their responses or further investigate their claims. This was clear evidence the students' views of engineering were poorly developed.

Furthermore, students' drawings and their responses did not demonstrate a great overlap. Even though students' drawings mentioned more design elements that involve engineers than in their interviews, their understanding was influenced by interviews. Moreover, as mentioned above, students did not show a strong ownership to their claims and readily departed from their claims and pursued any clue that was offered by the researchers. Without interviews, it may not have been possible to realize that students' views of engineering and engineering work were not stable and that students might hold many views about engineering. Thus, it may not be possible to grasp students' fragile conceptions of engineering. Even though drawings provided a different source to collect data, without a supporting data collection technique it might have been misguided because students did not hold one consistent view about engineering. Students at a young age may not represent their views orally very well, but this study also indicates that they are not very good at representing their views by drawing with regards to an abstract phenomenon akin to engineering. Students in this study, for example, expressed only one aspect of their views of engineering even though they held more.

Implications for teaching

Students' poorly developed concepts are not limited to engineering. They need to develop better understandings of other phenomena and occupations to better understand engineering. This study gave us more clues of what the other fields are and how to overcome this problem. The findings showed, for example, students mostly confused engineering with architecture, science, or art (a few references to painting and fashion design) and engineers with construction/factory workers, and blue collar labor. To improve students' views of engineering and the nature of engineering, it should be taught by comparing engineering with these fields. Without enriching students' conceptions of other fields, including science, art, and architecture, efforts to improve students' views of engineering may be relatively unsuccessful.

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