

Assessing Elementary School Students' Conceptions of Engineering and Technology

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As our society becomes increasingly dependent on engineering and technology, it is more important than ever that our citizens are technologically literate. There are many possible ways to develop technological literacy—one of the most wide-reaching is through K-12 schools. The Museum of Science, Boston is working to create curricular materials and professional development for K-12 students and teachers. However, previous research in science has evinced that responsible curriculum development draws upon and is shaped by students' conceptions and misconceptions (Posner, Strike, Hewson, & Gertzog, 1982).

While the field of science education research has provided (and continues to develop) a strong base of research about students' conceptions for educators, developers, and scholars to reference, similar efforts in technology and engineering education research are nascent. A literature review surfaced only a handful of relevant studies. There have been a few studies that probes students understanding of design (Sadler, Coyle, & Schwartz, 2000), and students' conceptions of strength of materials and stability (Davis, Ginns, & McRobbie, 2002). The ITEA has conducted one study of adults' thinking about technology and engineering (Rose, Gallup, Dugger Jr, & Starkweather, 2004). Clearly, much more research is needed in this area to guide the field (Davis et al., 2002; Lewis, 1999; Rose et al., 2004).

One of stumbling blocks that has been identified, is that scholars have not yet come to consensus on the specific concepts and process understandings that comprise technological literacy (Boser, Palmer, & Daugherty, 1998). More clarification at the national, state, district, or project level could provide some guidelines. However, we have chosen to begin to investigate conceptions at a much more basic level; specifically what do students' think engineering and technology are? One could argue that for any person to be technologically literate, s/he must first have some idea of what engineering and technology are. Though we are surrounded by the products of engineering in our everyday lives, students, and the general public, generally don't understand what engineers do (Davis & Gibbons, 2002; Frehill, 1997; Wulf, 1998). A dearth of information currently exists that probe students' understandings of these fundamental concepts. This paper reports the creation of one instrument that we have developed to probe these concepts in students. It presents some statistical data from 500 students who have completed the survey and draws some conclusions about what the average child thinks engineering and technology are. It concludes with some further uses for the instrument and next steps for the research agenda.

METHODS

This study grew from a previous study that probed students' conceptions of what engineers do (Knight & Cunningham, 2004). We modified the "Draw A Scientist Test" (Chambers, 1983) to

focus on engineering as a “Draw an Engineer Test (DAET).” Respondents were asked what engineering is, were asked to draw a picture of an engineer at work, and then were asked describe in their picture in writing. Over 500 students Grades K-12 completed this instrument. In later survey instruments, we added a question that asked students to describe what technology was. The results of this survey supported our hypothesis that most students have a limited, and often incorrect view of what engineers and what technology is.

While an interesting first diagnostic, the DAET had multiple limitations—students drew only one image which did not allow researchers to fully understand the breadth of their understanding of what engineers do (and the range of fields of engineering), there is a possibility that students were evoking stereotyped images of what engineers do, and because it was an open-ended format, it was not conducive to quantitative analysis. Therefore, we drew upon the findings of the DAET to develop a second set of instruments to more systematically probe students’ conceptions about engineering and technology. We were interested in creating an instrument that could be scored easily and that could be used to assess students’ growth in understanding of these fields. To this end, we aimed to create an instrument that would be somewhat difficult and nuanced so only students with a deep understanding would select all the correct items.

Reviewing students’ conceptions and misconceptions about the work that engineers do, we created a table with 16 images and descriptions of people at work and asked students to circle the kinds of work that engineers do. Pictures were included to help early readers and English language learners. The final items included:

- Improve machines
- Supervise construction
- Set up factories
- Construct buildings
- Drive machines
- Arrange flowers
- Read about inventions
- Design ways to clean water
- Work as a team
- Make pizza
- Install wiring
- Sell food
- Repair cars
- Design things
- Clean teeth
- Teach children

The children were also asked to complete the phrase “An engineering is a person who”

Similarly we created an instrument to measure students’ conceptions of technology. The technology table also contained 16 images and descriptions and asked students to circle those items that were technology. The final items included:

- Shoes
- Subway

- Dandelions
- Cellular phone
- Oak tree
- Bridge
- Television
- Cup
- Parrot
- Factory
- Bandage
- House
- Power lines
- Bicycle
- Lightening
- Books

Students were asked to respond to the open-ended question “How do you know if something is technology” in writing.

We have administered these two instruments to over 6000 students in Grades 1-5. This paper reports findings from a random sample of 504 students in Grades 1-5 from 18 elementary schools in one Massachusetts district. The district has a total of 11,697 students in Grades K-12. In the 2003-04 school year, 23.3% of students in this district were of a racial or ethnic minority (African American, Asian, Hispanic, or Native American), and 53.8% were from low-income families. Additionally, 30.2 % of students in the district spoke a first language other than English, and 4.7% were identified as having limited English proficiency. Of the students in our sample, 23.7% were of a racial or ethnic minority, and 60.0% were from low-income families. The students in the sample spoke a total of 10 different first languages (including English), and 27.3% spoke a first language other than English, the most common being Portuguese (16.1% of students). A total of 2.9% of students in our sample were identified as having limited English proficiency.

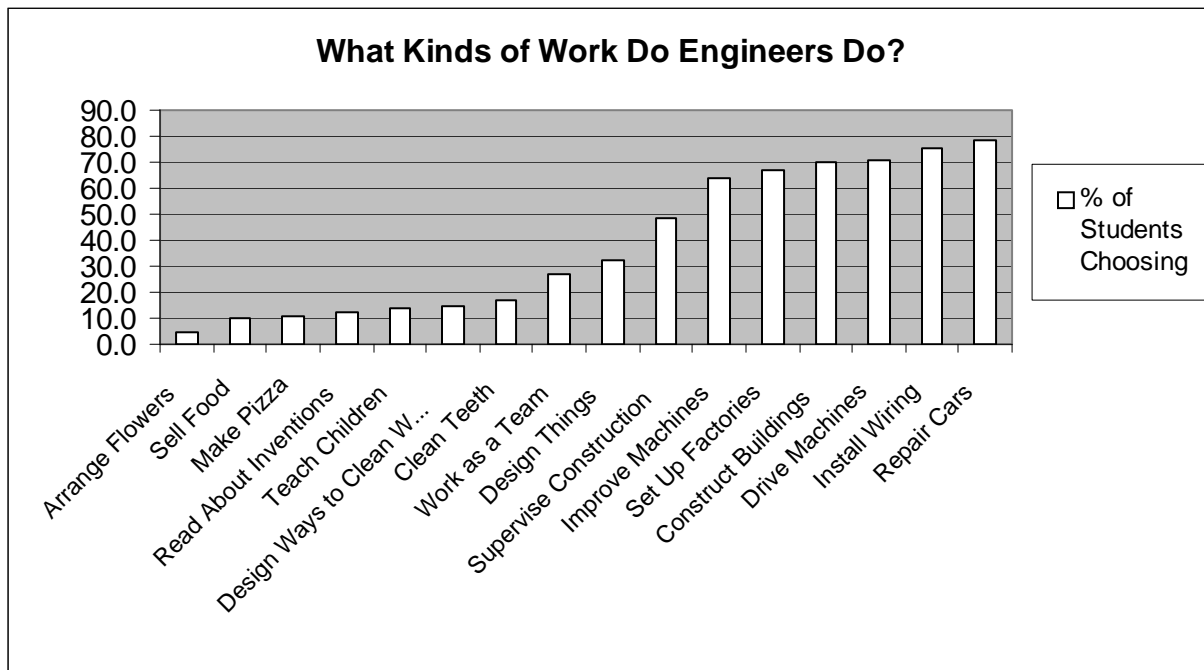
Prior to 2004, the district had not had any efforts to teach concepts related to technology and engineering in the K-5 classes. In 2004, the district science supervisor identified technology and engineering learning, consistent with the Massachusetts State Frameworks (Massachusetts Department of Education, 2001), as one of the improvement goals for the district. To help meet these goals, the district partnered with the Museum of Science, Boston, to implement the *Engineering is Elementary (EiE): Engineering and Technology Lessons for Children* curriculum. As part of this effort, district administrators agreed to administer baseline questionnaires about engineering and technology to all Grade 1-5 students (and their teachers). The questionnaires included both the “What is Technology” and “What is Engineering” instruments. The district administration has also agreed to provide basic demographic information for every student in the district so we can run statistical analyses with these variables.

Data analysis was conducted using basic statistic to generate frequencies of responses. To determine whether there were any differences in responses between the sexes or between students in different grades, chi-square analyses were run. Students’ open-ended comments were read and coded into categories.

FINDINGS

What is engineering?

When asked to choose what kinds of work engineers do, over half of the students indicated that they thought engineers repair cars (78.4%), install wiring (75.2%), drive machines (70.7%), construct buildings (69.7%), set up factories (67.1%), and improve machines (63.5%). These data support DAET data that students perceive that engineers are auto mechanics and construction workers. Few students thought that engineers supervised construction (48.7%), designed things (32.1%), and worked as a team (26.9%). Students were more likely to associate any of these tasks with engineering than the least cited responses: clean teeth (17.7%), design ways to clean water (14.4%), teach children (14.0%), read about inventions (12.2%), make pizza (10.6%), sell food (10.4%), or arrange flowers (4.6%). Graph * displays these results.



A crosstab to determine whether there were differences in responses between male and female students and students in different grades indicated that no significant differences exist.

A few major categories of codes emerged from students' open-ended responses to complete the sentence "An engineer is a person who...". The most commonly cited response was that engineers fix things. When students were more specific than "things" they indicated that the items that were fixed included buildings, cars, electricity/wiring, phones, motors/engines and technology.

"I think that sell food and repair cars are an engineer because they both work like it"

"works with special technology to fix things"

Second most commonly students indicated that engineers build things. Again, specificity about what was being built primarily included buildings and wiring.

"bills thing and wacks as a team. And most are boys."

“Makes stof and brakes stof.”

“An engineer is some one how does lectrisady.”

Reciting examples in the table or indicating they didn't know was the third most generated response. That engineers work things was also common. General attributes of engineers such as people who have a job, people who work with other engineers, people who work hard, and people need science and math were also recognized.

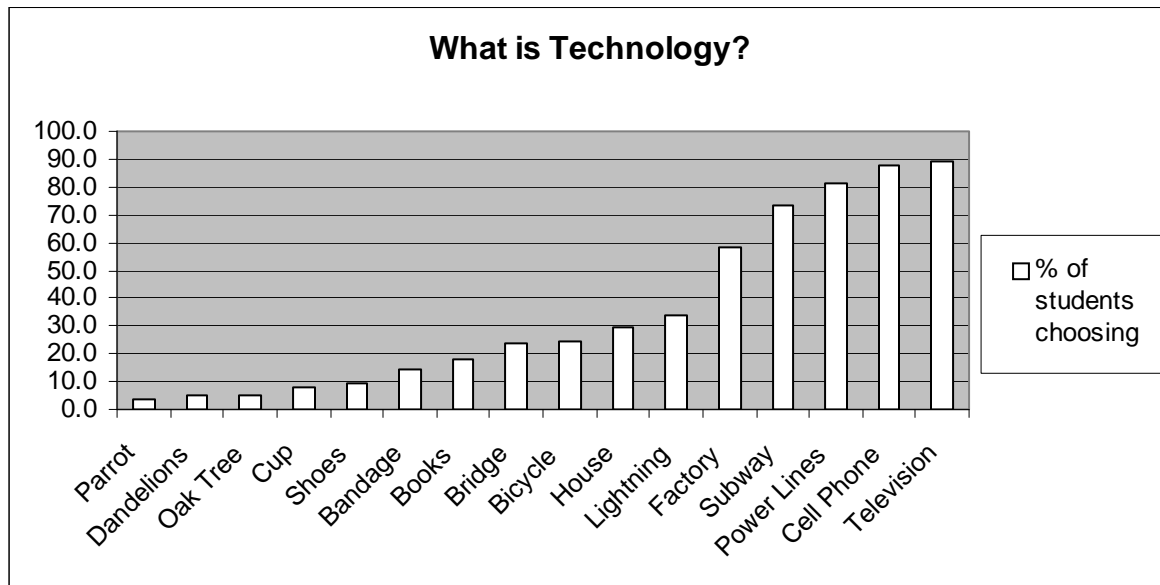
“Has a vevry in porting job.”

“is very, very very smart at math”

Some students also recognized that engineers design or improve things.

What is technology?

Students' selections of examples of technology indicate that there are items that they strongly associate with technology. As Graph # represents, students are most likely to indicate something is technology if it requires power. Television (89.2%), cell phone (87.4%), power lines (81.0%), subway (73.7%), and factory (58.1%) were chosen as technological items. One of the roots of these choices, that they require electricity, evinces itself as a misconception in 58.1% of students identification of lightening as technology. Less common responses include house (29.3%), bicycle (24.6%), bridge (23.8%), books (18.0%), bandage (14.2%), shoes (9.2%), and cup (8.0%). The items that are not examples of technology were also those least likely to be chosen by students: oak tree (5.4%), dandelion (4.8%), and parrot (3.8%).



Male and female student responses about technology differed only for one item—lightening. Female students were significantly more likely to chose this item (41.1%) than male students (28.7%). A crosstab analysis by grade indicated that there was also one item that first graders were significantly more likely to choose than second-fifth graders—12% of first graders indicated that a parrot was technology while 2.9% or fewer of students in higher grade chose this item.

Students' open-ended responses to how they knew something was technology most commonly cited the fact that it uses or has electricity. Responses such as:

"I think I know because I think that technology is something with power or electric"

"stuff that they did not have in the old days that runs on electric"

"I know technology because you need to plug it in that is why I know."

"it works by batteries or by a plug. A lot of the time you need a charger."

"I think I know because these things work on electricity. These things can electrify you."

were extremely common. The second most cited set of reasons had students referencing their knowledge—they recited specific examples, indicated that they were smart "I know cus I am smart", or admitted that they didn't know. Students' responses also referenced what the function of the technology was, for example, helping you, learning from it, or the ability to use it

"Technology is something that makes you learn like books and a computer."

"technology is something that makes it easier for people so they won't have to do all that stuff"

Other students explained that they knew it was technology because it was created by people.

"you can find out if something is technology if it is made by human minds"

"I know if something is technology because it takes lots of men to build something and because it takes a very long time."

DISCUSSION

The results of our survey further bolster the findings of our previous work about some of the conceptions and misconceptions that students hold about engineering and technology. Students strongly conflate construction workers and auto mechanics with engineers. While these are understandable (engineering has the word engine in it), they are also concerning, especially since these are fields that are not traditionally populated by women. Thus, these conceptions might be one reason for the lower number of girls that enter engineering than boys. Students' identification of engineering with civil engineering is also illustrated by this survey. While machines, factories, construction, and building all ranked high (regardless of whether people were supervising, improving, or designing or working as a tradesperson), the lack of understanding about the breadth of the fields of engineering is also captured by the survey. Children are more likely to think that engineers clean teeth than design ways to clean water! This suggests that much more education is needed to help children understand the range of the type of work engineers do. Fewer than third of the students recognized one of the central features of engineering, design.

To better assess the degree to which students understand the range of types of engineering, we plan to modify the survey and replace half of the six items that focus on machinery and construction with items that reflect other fields such as chemical and biomedical engineering. We hypothesize that students will not recognize these disciplines as engineering.

It is clear that for the majority of students, technology is closely linked with power and electricity. While this was also expected and is certainly understandable, it presents a narrow (and developed country) view of technology. Fewer than a third of the students identified any of the everyday human-made objects as technology. Clearly students need to be educated about the prevalence of technology not only in our society, but in societies across the world.

The statistical results of these surveys have helped us to identify some conceptions and misconceptions that students hold. We plan to modify the engineering survey (as mentioned above) to further explore some hypotheses and to conduct some interviews with students to get some more in-depth information about how and why they are thinking about engineering and technology. We are also using the two survey instruments in two additional ways. First, because the surveys are nuanced we can use it as a measure of students' growth in understanding. Thus, we will administer these instruments again at the end of the school year to the same students and annually to assess how their knowledge has changed and what the effect, if any, of our curricular program has been on their knowledge. Second, we have begun to use these assessments with our teachers to evaluate what they think engineering and technology are and how these understandings change. Based on these uses, we believe that these instruments provide one way to understand what students think and how their perceptions change. We hope that the findings from this first study can be used by educators and curriculum developers to help them design materials and pedagogical techniques that address students' misconceptions and help them to develop an understanding of technology and engineering that is more robust and accurate.

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