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Analyzing Subject-Produced Drawings: The use of the Draw-an-Engineer Assessment in Context

Introduction

In this paper, an example of children-produced drawings of the “engineer at work” and their analysis is provided as a means to explore how children-produced drawings can serve as an interpretive and analytic tool. The paper demonstrates how children-produced drawings can be used in research as empirical data that can be analyzed to make sense of our world in context.

Just as subject-produced drawings have been used to study children’s attitudes towards professions in science (Chambers, 1983; Fort & Varney, 1989), researchers have used the Draw-an-Engineer assessment, an adaptation of the Draw-a-Scientist test, as a tool to examine children’s attitudes and knowledge of engineers and engineering (Cunningham & Knight, 2004; Cunningham, Lachapelle & Lindgren-Streicher, 2005). Similarly, I used the Draw-an-Engineer assessment in a longitudinal study of middle school children engaged in an after-school engineering-education program over two years. The drawings collected pre-program were initially used as a type of formative assessment of the engineering-education program. These assessments were used to help design and implement specific learning experiences by addressing students’ conceptions and misconceptions about engineering. The use of drawings collected from participants over time — before, during, and after their program experience — allowed me to investigate, using a formative-summative evaluation strategy (Scriven, 1972), whether the engineering-education intervention helped influence students’ identities as engineers, and in what ways.

The publication of the report Rising Above the Gathering Storm by the National Academy of Sciences (NAS) (Augustine, 2005), highlighted political and popular concerns in the United States that the globalization of knowledge and increased use of low-cost labor had led to the erosion of the US as a leader in science, technology, and engineering. The report also argued that the federal government needed to act to ensure the country’s continued success in this area. As with the Sputnik ‘crisis’ nearly a half century earlier, these concerns were manifest as a call to increase the number of American-born students entering science, technology, and engineering careers. In 2006-7, I responded to a call for proposals from the National Science Foundation’s (NSF) Division for Research on Learning in Formal and Informal Settings for a program known as the Innovative Technology Experiences for Students and Teachers. My proposal, Learning through Engineering Design and Practice, intended to provide middle school students with in-depth experiences with engineering-related and project-based challenges.

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Review of the Literature

The use of children-produced drawings in research is not new. Margaret Mead used subject-produced drawings as contemporary responses by the public to events that represented rapid technological change after the Second World War. She had been deeply affected by the 1945 bombing of Hiroshima, and was concerned with the idea that everyone on earth was interconnected. The launch of Sputnik by Soviet Russia in 1957 produced fear and perceptions of loss of prestige in American science and engineering. In the 1950s, Mead and her colleague Rhoda Métraux, who had been studying contemporary culture after World War II, began a study of American students’ ‘Image of the Scientist’, in which they collected essays and drawings from children and college students about their perceptions of a scientist (Mead & Métraux, 1957). After Sputnik, Mead and Métraux collected essays and drawings from children about the satellite. They presented an analysis of 35,000 high school students’ essays in which the subjects described their image of a scientist. They found that the typical American high school student had a stereotypical notion of what a scientist looks like and does at work. They described this shared image from the national sample as:

The scientist is a man who wears a white coat and works in a laboratory. He is elderly or middle aged and wears glasses. He is small, sometimes small and stout, or tall and thin. He may be bald. He may wear a beard, may be unshaven and unkempt....He is surrounded by equipment: test tubes, Bunsen burners, flasks, and bottles...He spends his days doing experiments...He experiments with plants and animals, cutting them apart, injecting serum into animals. He writes neatly in black notebooks (p. 386-7).

Thanks to Mead’s use of subject-produced drawings, the study has a place in the study of human culture, specifically in traditions that have their origins in cultural anthropology.

Chambers (1983) developed the Draw-a-Scientist test, where subjects were simply asked to ‘draw a scientist’ as a means to identify when elementary school children develop the stereotypic image of the scientist described by Mead and Métraux (1957). Between 1966 and 1977, Chambers (1983) collected and studied over 4,800 drawings-of-a-scientist made by elementary school children. He patterned the Draw-a-Scientist test after the Goodenough (1926) Draw-a-Man test. He selected the following characteristics to analyze the drawings: lab coat, eyeglasses, facial hair (e.g. beard, mustache, long sideburns), symbols of research (e.g. scientific instruments, laboratory equipment), symbols of knowledge (e.g. books and filing cabinets), technology (as products of science), and relevant captions (e.g. formulae, taxonomic classifications, ‘Eureka!’). He found that this standard image of a scientist begins to emerge around second grade (Chambers, 1983, p. 258).

Fort & Varney (1989) similarly analyzed drawings of scientists made by 1,600 students in grades 2 to 12. They also asked students to write about their drawing. They found that, of the 1,600 drawings, only 20 depicted minority (non-white) scientists, and only 165 depicted females as scientists. In their analysis of the subject-produced drawings, they and other researchers began to note and count the presence of features such as the size of a scientific instrument in relation to the scientist; evidence of danger; the presence of light bulbs; the sex, race, or ethnicity of the scientist; and figures that represented eccentricity (‘mad scientists’ like Frankenstein). This quantification of indicators allowed researchers to record and provide evidence of the existence and prevalence of the stereotypical image of a scientist. Researchers next began to conduct cross-cultural studies in various countries to understand students’ perceptions of the scientist, and studies were conducted in China (Chambers, 1983); India (Rampal, 1992); and Australia (Schibeci & Sorensen, 1993). Researchers also paid
attention to gender, race, and ethnicity of the scientists depicted in the drawing (Sumrall, 1995; Finson, 2002). Sumrall (1995), for example, interviewed students to access their reasons for drawing a scientist of a particular race and gender. Thus, instruments that used subject-produced drawings were supplemented with verbal data collected via interviews or descriptive written responses about the drawing in mixed-method research approaches.

As researchers began to use subject-produced drawings, attempts to demonstrate validity and reliability of the instrument began to emerge. Techniques to ensure validity focused on ensuring that the instrument was designed to measure what it was supposed to measure: did the students’ drawings of a scientist depict specific characteristics that are stereotypical of a scientist’s image? To increase the validity of the subject produced drawings, researchers developed coding schemes that attempted to standardize the identification of stereotypical characteristics in the drawings. Codification schemes allow for human ‘raters’ or ‘coders’ to be trained, and the use of inter-rater reliability measures among raters allowed researchers to either modify the coding scheme or retrain the raters. Humans as ‘raters’ are fallible; therefore, the use of a score or statistical measure of homogeneity among raters was important.

Finson (2001) conducted a study to validate the Draw-a-Scientist test for populations other than the population of White middle class students for which the original instrument was validated. He used quantitative analysis and statistical techniques to describe relationships between variables such as the subject’s gender and race/ethnicity with each of the observed characteristics of the scientist depicted in their drawings.

Another attempt to improve the validity of subject-produced drawings as a measurement tool was to extend its use from that of a merely descriptive tool to that of an analytical tool. The studies described thus far in this chapter largely used subject-produced drawings to ‘describe’ what specific populations knew about some culturally relevant idea. These could be generally classified as descriptive studies that either used qualitative, quantitative, or mixed methods. Researchers began to use subject-produced drawings as pre- and post-assessments to measure the impact of an intervention. The post-drawings could then be compared with the pre-drawings allowing for a form of analysis using each individual respondent’s own initial response as a benchmark.

Flick (1990) reported using the Draw-a-Scientist test before and after an intervention that included scientists (three female and one male), who visited two fifth grade classrooms for an hour each week for three weeks to share their enthusiasm for science. The 47 fifth grade students also visited the scientists’ laboratories. Flick found that more males were depicted before the female scientists visited the classes, but more females were drawn after the intervention. A number of additional studies have focused on attempts to change students’ perceptions of scientists (Mason, Kahle & Gardner, 1991; Huber & Burton, 1995; Finson, Beaver & Cramond, 1995; Bohrmann & Akerson, 2001; Bodzin & Gehringer, 2001). Impacts of the interventions were studied using quantitative surveys that measured perceptions of science and attitudes towards science and science careers, as well as using qualitative measures such as the Draw-a-Scientist test. In these cases the subject-produced drawings were not used by themselves; they were typically combined with other measures such as questionnaires, open-ended written responses and interviews. Over time, the sole use of drawings became less common, especially with the assessment of students’ perceptions of a scientist.
Margaret Mead’s work using subject-produced drawings as a means of accessing contemporary cultural knowledge not only influenced the study of students’ perceptions of scientists, it has extended to other professions (teaching, engineering, statistics) and addressed other areas, such as the impact of media (TV, computer, Internet) on participants’ perceptions. For instance, Barba and Mason (1994) and Mercier, Barron, and O’Conner (2006) examined age and gender differences in the drawings of computer and technology users.

Weber & Mitchell (1995) reported on the enduring image of schooling among students via student-produced drawings of teachers. They used a variety of prompts to elicit students’ conceptions of teachers that lead to an examination of the dialectical relationship between schooling and the popular culture of everyday life. Fischman (2000) examined teacher education and the role of gender in education using drawings made by teachers-in-training. Kolb & Fishman (2006) elicited preservice teachers’ beliefs about technology integration using drawings and a survey. All of these studies however, used drawings as a part of a larger data collection strategy that included interviews and embedded the data analysis in qualitative research traditions. Wheelock, Bebell, & Haney (2000) used drawings from students in Massachusetts in a study of student’s feelings about high stakes testing. Haney, Russell & Bebell (2004) described the use of subject-produced drawings to show how it could be used as a tool to examine teacher behavior and the impact of education reform. Ganesh (2002, 2007a, 2007b) used drawings made by teachers to examine educators’ feelings about administering high stakes tests in a highly politically charged school accountability setting in the state of Arizona.

Specifically, Cunningham and Knight (2004) adapted the Draw-a-Scientist test and developed the use of the Draw-an-Engineer test. They noted that the limitation of such assessments is that they may produce stereotypical results. Cunningham, Lachapelle, and Lindgren-Streicher (2005) used the results of their study with the draw-an-engineer test to create a survey called “What is an Engineer?” where students are asked to identify the pictures that represented engineering and then answer complete the statement, “An engineer is a person who ______.” In the second part of this survey called, “What is Technology?” students were asked to identify the pictures where technology is represented and then answer the question, “How do you know if something is technology?” Oware (2008) used the draw-an-engineer with accompanying interviews in a dissertation study to access students’ perceptions of engineers.

These studies that used the draw-an-engineer assessment indicate that students may have a more complex understanding of a scientist or an engineer at work than may be reproduced in a single drawing. Furthermore, drawing as a form of expressing knowledge of a profession may not be familiar to students and students may not have the skills to draw. Having written descriptions accompany the drawing may be more beneficial than simply using the drawings alone. In this study, I extend the idea that the draw-an-engineer assessment when used over time with the same group of participants to show how their thinking about the “engineer at work” has changed over the course of a longitudinal intervention may provide a better sense for students’ evolving conceptions about the role of the engineer. The use of image-elicitation interviews were incorporated into the study as a means of ensuring that the researchers’ interpretations of the students’ drawings of an engineer at work were appropriate. The intent for the proposed study was not quantify and rate students’ drawings as a representation of what students knew about the profession of engineering, but to qualitatively examine students knowledge of engineers.
Research Question

The goal for the long-term engagement of middle school students traditionally not represented in the STEM fields through the Learning through Engineering Design and Practice project was a) to help middle school students confront their own misconceptions about engineers and engineering and b) to examine changes in students’ development of their own identity of engineers. The primary research question explored in this study is to determine whether student participants’ conceptions of engineers at work changed over the course of their participation in the two-year, year-round, after school program. The evidence needed to examine this research question was marshaled through the use of the draw-an-engineer assessment (i.e., the drawing and the related written descriptions) and the image-elicitation interviews.

Methods

Context for the Study

The Learning through Engineering Design & Practice program introduced participants to engineers who worked in the information technology and engineering industries and also to undergraduate engineering students. There were two female and three male undergraduate engineering students who worked side-by-side with the participants on program activities throughout the year-round engineering education program. There were three female and four male professional engineers who volunteered their time to work with the participants 8-10 times a year during the after-school program. In addition, two female middle school educators in participant schools who helped facilitate the after-school program were former engineers with industry experience. One was an aeronautics design engineer who worked as a middle school math teacher and another was a chemical engineer who worked as a middle school science teacher.

Print resources (ASEE, 2007) that had visual images and descriptions of engineers and undergraduate students in engineering degree programs, and images and descriptions of engineering products were introduced to participants. In addition, the program introduced participants to video resources (PBS Design Squad: http://pbskids.org/designsquad/profiles; Engineer Girl: http://www.engineergirl.org/) that profiled engineers and their work.

I wanted to access program participants’ developing understandings of what engineers do throughout the program. I used the draw-an-engineer assessment and accompanying image-elicitation interviews to access participants’ conceptions of engineers during the program and at the end of the two-year after-school program. Image-elicitation interviews along with analysis of written responses that accompanied the draw-an-engineer assessment were used to confirm our interpretations of students’ representations.

Table 1. Percent Project Participants by Gender and Year

<table>
<thead>
<tr>
<th>Number of Students</th>
<th>2007-08</th>
<th>2008-09</th>
<th>Combined Sample</th>
<th>Percent by Gender</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>32</td>
<td>35</td>
<td>67</td>
<td>58%</td>
</tr>
<tr>
<td>Male</td>
<td>16</td>
<td>33</td>
<td>49</td>
<td>42%</td>
</tr>
<tr>
<td>Total</td>
<td>48</td>
<td>68</td>
<td>116</td>
<td></td>
</tr>
</tbody>
</table>
A total of 116 seventh and eighth grade students from four different middle schools took part in the project during the 2007-10 school years. Each student participated in the after-school program from the start of seventh grade through the end of eighth grade. Participants’ gender and race/ethnicity are noted in Tables 1 and 2. Female participants and populations, traditionally under-represented in the engineering fields, were over-sampled at high rates per NSF program guidelines.

One of the project’s goals was to help middle school students to confront their own misconceptions about engineers and engineering (NAE, 2008). I wanted to examine changes in students’ development of their own identity of engineers. I used the Draw-An-Engineer assessment along, with written descriptions and interviews, to assess what middle school students know about engineers. I collected students’ drawings of an engineer from participants at different points during their two-year involvement in the project, and they offered an interesting and useful glimpse of how students depicted their understanding of engineers.

**Assessment Protocol**

Students were given 20-30 minutes to draw-an-engineer and answer three questions related to what they had drawn. Directions and question prompts were as follows:

Close your eyes and imagine an engineer at work... Open your eyes. On the attached sheet of paper, draw what you imagined. Once you have completed your drawing, please respond to the following prompts:

1. Describe what the engineer is doing in the picture. Write at least two sentences.
2. List at least three words/phrases that come to mind when you think of this engineer.
3. What kinds of things do you think this engineer does on a typical day? List at least three things.

Project facilitators were instructed to be careful not to talk about engineers or engineering during the first day of the project or during the administration of the Draw-An-Engineer assessment. During assessment administration, facilitators offered help to clarify directions and question prompts, but were again careful not to offer any ideas or assistance that would influence the students’ own conceptions of engineers or engineering. Semi-formal interviews were conducted — one-on-one discussions with students to understand their drawings and responses and to also elicit their thinking behind the drawings. This form of image-elicitation was an integral part of our data analysis process.
Data Analysis and Discussion of Results

Pre-Program Drawings

With the pre-program Draw-An-Engineer assessment, the intent was to examine the ‘drawings’ (by which I mean students’ drawings and accompanying written responses to the questions) to see what participants knew about engineers. I formed a research team with the assistance of a graduate research assistant in education who had a bachelor’s degree in engineering and had experience teaching high school mathematics, and an undergraduate engineering student who worked as a student data-analyst. The drawings were reviewed to identify elements the researcher team members felt were helpful in developing a description of what seventh grade students depicted about engineers. It is important to note that I have a bachelor’s and master’s degree in engineering, and bring my own background and experience to this project.

To make sense of the drawings, the research team engaged in what Strauss and Corbin (1998) termed open coding and axial coding. Open coding (p. 101-21) began with three broad theoretical categories:

- **Gender of the engineer.** Participants were 58% female and 42% male. The research team was interested in observing whether female participants depicted engineers as male in their drawings and whether those representations would change to a female engineer over time. Similarly, the research team was also interested in observing whether male students made drawings of female engineers and if those changed.

- **Engineers in action.** The drawing prompt asked students to make a drawing of an “engineer at work.” Therefore, the research team felt strongly that this category was important to focus on understanding what students perceived engineers did at work.

- **Engineers use tools.** The objects that students believe engineers use when at work is related to understanding what the engineer could potentially do with those objects. Therefore the research team felt it was important to attend to the types of objects the engineer held or was around the engineer in the drawing.

Drawings were labeled with likely concepts suggested by the context in which the drawing was located, including the accompanying written responses describing the drawing. Memos were prepared describing the researcher’s thoughts about key elements identified in the drawings. Memos were recorded as new themes emerged from the review of the drawings as a whole. The entire data corpus was reviewed in this manner.

Once this process was completed the research team compared the drawings, the labels, and memos to search for crosscutting concepts. This process is what Strauss and Corbin termed axial coding (p. 123-42). The analysis of the pre-program drawings yielded three conceptual categories that represent our interpretations of students’ initial conceptions of what engineers do at work: engineers work with engines, engineers build, and engineers repair technical devices. Image-elicitation interviews were used to confirm the research team’s interpretations of the students’ drawings. The image-elicitation helped researchers access the ‘why’ and/or ‘how’ students thought about engineers at work. Many students made the quite logical English language connection between ‘engines’ and ‘engineers’; similarly, probably influenced by television and movies, they recognized that ‘engineer’ is also the name of one who drives a train — even though many of them have probably never ridden a train themselves.
In the following sections, I have illustrated the research team’s process of conceptualization with examples. Codes are in bold print.

**Engineers work with engines**

![Image of a train with an engineer fixing it]

Figure 1. “My engineer has just finished fixing the train.”

Author: 12 year old, 7th grade, White, female

Written response:

The engineer has just finished fixing the train [‘engineers fix trains’]. He [‘engineers are male’] is also smiling. He really likes his job [‘engineers are male’]. He is very happy that he fixed the train [‘engineers fix trains’]. I think he drives the train [‘engineers drive trains’], he fixes the train [‘engineers fix trains’], and he puts coal into the train’s engine [‘engineers work with train engines’] so it can go.

Specific elements in the drawings that represented theoretical categories were identified. The specific elements noted in figure 1, included:

1. the engineer is described as male represented *gender of the engineer*;  
2. the engineer is standing by a train represented *engineers in action*; and  
3. the engineer in the drawing has an object that looks like a wrench represented the theoretical category *engineers use tools*.

The drawings were labeled ‘engineers work with train engines’. As the research team encountered more drawings that included an engineer as fixing a car, truck, or a train or driving a car, truck, or a train, a short memo describing possible concepts and general thoughts about those drawings was recorded:

**Memo.** It will be useful to explore the relationship between engineers and cars, trucks, and trains. What is common among these objects? They are all vehicles. They have engines. Maybe students think that because the word engineer has the word ‘engine’ in it, they believe that *engineers work with engines*. This is a much broader interpretation, a concept that encompasses the specific labels of engineers fix trains, engineers fix cars, and engineers fix trucks. This idea should be probed with students via image-elicitation interviews.

In the drawing in figure 1, the student described that the engineer ‘puts coal into the train’s engine so it can go’ indicating the student’s belief that the engineer has to do something to-
or with the engine (e.g. drive the train, fix the train, put coal in the train’s engine). The research team then examined what operations the engineer was described as doing with the car, truck, or train with the theoretical category *engineers in action*. The engineer was described as either fixing the vehicle or driving it — these operations or dimensions represented the sub-categories *engineers fixing* or *engineers driving* vehicles.

Figure 2. “My engineer is fixing a broken car.”
Author: 13 year old, 7th grade, Hispanic, female.

Written response:
The engineer is fixing a broken car [*engineers fix cars*]. The man [*engineers are male*] is laying on a board to fix the car. He installs things on the car. An engineer fixes broken engines [*engineers fix engines*]. He fixes leaks in the car [*engineers fix cars*].

Similar to this student, a number students depicted engineers as mechanics: people who worked on cars and fixed cars. This was by far the most popular initial conception of engineers at work. The specific elements noted in figure 2, included:

1. the engineer is described as male represented *gender of the engineer*;
2. the engineer is under a car represented *engineers in action*; and
3. the engineer in the drawing has an object that looks like a wrench and that the car was raised from the floor with a car jack represented our theoretical category *engineers use tools*.

The drawing was labeled, ‘engineers work with car engines.’

As the research team engaged in axial coding, the key elements and memos were reviewed and categories that linked with each other were searched for in the data corpus (Strauss & Corbin, 1998, p. 123-42). For instance, the research team explored why students believed that engineers work with cars, trucks, and trains. The common property among these vehicles was that the car, truck, and train, each had an engine and the common dimension was that the engineer drove or fixed the car, truck, or train engine. Figures 1 and 2, and other drawings with like concepts were now conceptualized as *engineers work with engines*. By constantly comparing drawings that had similar elements, the research team attempted to validate the interpretation that some participants believed that *engineers work with engines*. I found that member-checking was also important; when I talked with participants about their drawings to
make sure that they recognized the research team’s interpretation of their drawings. In this process of image-elicitation, participants provided insights about their drawings and thinking about engineers that were not always found in the accompanying written responses. For instance, to understand why middle school students made drawings of people working on cars or driving a train as representative of engineers, I provide this brief excerpt of an interview with the student who made the drawing in Figure 2:

**Interview:** I see that you made this drawing where a person is working on a car. Can you tell me why you made this drawing?

**Student:** The car has an engine and it breaks down. He is fixing it. *[‘engineers fix cars’]*

**Interview:** Do you know of anyone who fixes cars?

**Student:** Yes, my older brother does. And… there are people like mechanics who work on cars.

**Interview:** Are these people engineers?

**Student:** They work on engines. *[‘engineers work with engines’]*

**Interview:** Hmm…

**Student:** I guess ‘engineer’ has ‘engine’ in it. *[‘the word ‘engineer’ has the word ‘engine’ in it’]*

The concept *engineers work with engines* represents the phenomenon that some middle school students believe that engineers work with engines. The research team created memos that allowed the team to further conceptualize and probe students’ thinking about engineers.

**Memo.** This student said that the word ‘engineer’ has the word ‘engine’ in it. Perhaps students don’t know for sure what an engineer does. Some students are making sense of what the word could mean by examining the word itself. For instance ‘teacher’ has the word ‘teach’ in it, and ‘teachers teach,’ this is something familiar. The students who don’t know anything about engineers may think that they could find meaning in the word itself. Because the word ‘engineer’ has the word ‘engine’ in it, students believe that engineers have to be people who work on engines. Do they know anything that has engines? Do they know anyone that works on those objects that have engines? This idea needs further exploration when students are interviewed. Students will need to feel comfortable with the interviewer, before they are likely to share how and why they made sense of the word engineer by examining the word.

The process of conceptualization was essentially also a process of abstraction. The research team re-conceptualized the drawings based on coding key elements and categories as sharing common properties and dimensions. The research team iteratively reviewed all the drawings in the pre-program data corpus and arrived at the following additional conceptualizations about what some seventh grade students thought engineers do at work.

**Engineers Build**

*Engineers build* is a phenomenon that encompasses participant’s ideas such as *engineers assemble things in a factory*, *engineers build buildings*, and *engineers build bridges*. I have provided examples of students’ drawings to illustrate each sub-category. It is important to note that this concept primarily includes the dimension of assembly-line labor involved in working in a factory and the physical labor of constructing buildings and bridges. I confirmed the research team’s interpretations of the drawings categorized as *engineers build* with students by member-checking during image-elicitation interviews.
Written response:

The engineer is putting things together with a hammer ['engineers assemble things'] ['engineers use tools like a hammer']. His ['engineers are male'] job is to put things together properly and not let things go without putting them together ['engineers do assembly line work']. He works 8-10 hours a day, but not on weekends. He takes two 15-minute breaks and a lunch break during his workday ['engineers work in a factory']. He does not mess around and does a good job. His favorite tool is the hammer.

The participant who made the drawing in Figure 3 lived in a neighborhood with largely Spanish speaking neighborhoods, sometimes referred to as the ‘barrio’. When interviewed about his drawing, he said that he thought, ‘Engineers assemble things and work in a factory. They build things that are made in factories’. This is an example of the sub-category *engineers assemble things in a factory*. 

Figure 3. “My engineer assembles things in a factory.”
Author: 12 year old, 7th grade, Hispanic, male.

Figure 4. “My engineer is building a house.”
Author: 13 year old, 7th grade, Hispanic, male.
Written response:

The engineer is building a house ['engineers build houses']. He wears a hard hat. He ['engineers are male'] uses a crane, hammer, nail gun, drill, and tools like that ['engineers use tools']. He puts the house together and there are other workers also. They all build the house. He works hard. Today, he is lifting beams using the crane onto the house ['engineers do construction work'].

The participant who made the drawing in Figure 4 also lived in a barrio. When interviewed about his drawing, he said:

I made this drawing to show that engineers work to build houses, offices, and schools ['engineers build buildings']. They do the work to actually construct the house itself like hammering nails into beams, stuffing insulation, wiring a house, and things like that ['engineers do construction work'].

This is an example of the sub-category engines builds buildings. This conceptualization encompasses the dimension of physical labor involved in constructing a house.

Figure 5. “My engineer is digging. He is working to build a bridge.”
Author: 13 year old, 7th grade, White, female.

Written response:

This engineer is digging to build a bridge ['engineers build bridges']. He ['engineers are male'] is holding a shovel ['engineers use tools'] to dig the hole.
in the ground where the bridge is going to be built [‘engineers do manual labor at the construction site’]. There are others workers also who build the bridge. This is an example of the sub-category engineers build bridges. This conceptualization encompasses the dimension of physical labor involved in constructing a bridge.

**Engineers repair technical devices**

*Engineers repair technical devices* is a phenomenon that encompasses participants ideas such as engineers fix computers, engineers fix clocks and watches, and engineers fix televisions, microwaves.

![Image of an engineer fixing a computer](image-url)

Figure 6. “My engineer is working to fix a broken computer hard drive.” 12 year old, 7th grade, White, female.

Written response:

The engineer is working to fix a broken computer hard drive [‘engineers fix computers’]. He also knows how to fix televisions, microwaves, etc. [‘engineers fix televisions and microwaves’], but this particular engineer is a computer repair specialist. He works for Dell, Macintosh, or any other technology business. On a typical day, this engineer goes to work at the Macintosh headquarters. His job is to fix any computers that have defects. He loves his job. His motto is, ‘Choose a job you like and you’ll never have to work a day in your life.’

Other drawings in this category included representations of engineers as repairing microwaves, televisions, refrigerators, and watches.

**Drawings not categorized**

In some cases the research team did not assign the drawings a specific label. There were a few drawings that the research team felt did not clearly indicate any specific conceptions of engineers. Interview data were used to access students’ reasons for their drawing of an engineer.
Figure 7 is an example of such drawings. This drawing was made by Nancy, a Hispanic female who started the program as a 12-year old, seventh grade student. The school she attended in 2007-08 was 66% Hispanic, 10% American Indian, 7% African American, 2% Asian, and 16% White; 80% of these students were enrolled in the free and reduced price lunch program, a measure of poverty established by government standards. Her school was near a barrio, in an older neighborhood, where Spanish-speaking families had lived since World War II. One of the program goals was to provide students traditionally under-represented in the science, technology, engineering, and mathematics (STEM) fields with in-depth experiences to explore those subjects. Nancy explained that her motivation for volunteering to attend the after-school program (which met twice a week for 90 minutes during the school year from September to May, and included summer programming in June and July) was, ‘I wanted to join this program because I could be with others and have fun, go on field trips’.

Nancy illustrates how the use of subject-produced drawings and image-elicitation during the two-year after-school program helped me follow Nancy’s development of a self-identity as a potential engineer. In an interview, Nancy revealed that she did not know what engineers did, but she wanted to make a drawing.

Figure 7. “The engineer guy built a tower of Legos.”
Author: 12 year old, 7th grade, Hispanic, female.
Written response:
The engineer guy builds a tower of Legos. He is trying to put the last Lego piece on the top of the tower. He looks very stressed out. He does not want to fall.

In summary, our analyses of the pre-program data as represented within our theoretical frames indicated the following early conceptions:

- **Gender of the engineer.** A majority of the participants depicted engineers as male. Only two showed engineers as female. One drawing by a female student depicted the engineer as a female who fixed cars. Another drawing by a male student depicted the engineer as one of the female project coordinators and he labeled her by name.

- **Engineers in action.** Students depicted engineers as mechanics who repaired and drove cars, trucks, or trains; as people who assemble products in factories; as people who build buildings, roads, and bridges; and as people who repaired technical or electronic devices such as computers, microwaves, televisions, and watches.

- **Engineers use tools.** Students believed that engineers use tools. Tools depicted were largely used in construction (e.g. shovel, crane, hammer, wrench, nail gun, drill) or repair work (e.g. screw driver).

Participants’ pre-program conceptions of what engineers do at work encompassed engineers work with engines, engineers build, and engineers repair technical devices. The National Academy of Engineering (2008, p 12) in a report titled, ‘Changing the conversation: Messages for improving public understanding of engineering’ recommended that four specific messages be adopted by the engineering and engineering-education community: ‘Engineers make a world of difference,’ ‘Engineers are creative problem solvers,’ ‘Engineers help shape the future,’ and ‘Engineering is essential to our health, happiness, and safety.’ These abstract ideas about what engineers do were not in evidence in students’ pre-program conceptions.

**Post-Program Drawings**

Data analysis followed the same iterative pattern described in the pre-program data analysis section with open coding and axial coding (Strauss & Corbin, 1998) until saturation occurred when the research team felt that identification of all categories, elements, properties, and dimensions had been exhausted. Open coding and axial coding occurred simultaneously at times, and was not necessarily sequential in nature. As the data corpus was reviewed, the research team not only assigned labels representing categories but also began to link data elements to others in the data corpus that the research team had encountered earlier. The memos helped the research team articulate thoughts about categories, speculate about concepts, and specifically explore the why and how of students’ thinking through image-elicitation.

**Emerging conceptions of engineers at work**

I concluded that participants’ emerging conceptions of engineers were literal understandings of adult descriptions of engineers at work. Image-elicitation interviews confirmed this interpretation of the draw-an-engineer assessments. As before, I have provided a few examples of students’ representations of engineers at work that were collected post-program.
Written response:

The engineer is working on a damaged F-35. He does his work of repairing it and the F-35 turns on. I think he makes designs for building F-35s. He makes things he was trained to do. He makes things he studied in college ['engineers go to college'].

The student who made this drawing attended the engineering education after-school program where one of the after-school program teachers was a former aeronautical engineer. This teacher, Ms S, had said that she had an engineering degree and had worked for the US military as a design engineer working on a team that developed designs for a Stealth bomber. In this drawing the participant made a literal representation of his understanding of what Ms S did as a design engineer. Interestingly, the student described the engineer in his drawing as a male. I wanted to understand why the student made this drawing. The image-elicitation interview with the student illustrates how the student thought about engineers and the influence he attributed to his understanding of engineers:

Interviewer: What was your reason for making this drawing of an engineer at work?
Student: I thought it was cool that Ms S had worked on a Stealth bomber.
Interviewer: Hmm...
Student: I think engineers like her ['engineers are female'] work on F-35s, fixing them. That is what I think!
Interviewer: I don’t remember what Ms S said about what she used to do as an engineer… Do you?
Student: I think she said that she made designs for a bomber ['engineers design things']
Interviewer: What does ‘making designs for a bomber…’ mean?
Student: Hmm… I don’t know. She also said that she worked on a Stealth bomber…
Interviewer: OK. Let us get back to your drawing. What did you draw?
Student: I made a drawing of a man ['engineers are male'], an engineer who does things like Ms S did. He learned how to design an F-35 or parts for an F-35 in college. ['engineers attend college']

Although the student said he made his drawing of an engineer to represent the type of work Ms S said she had done as an aeronautical design engineer, the engineer in his drawing was male. As he did not know exactly what ‘designing a bomber’ meant, he drew the engineer literally fixing the F-35 which he equated to a bomber aircraft.
In Figure 9, a male participant represented his understanding of what a materials science engineer does at work. The participant had depicted his understanding of what Mr D, then a graduating senior from the Materials Science and Engineering bachelors program, had said he is studying. The participant depicted this engineer as a person who literally examines the quality of construction materials. The emerging understanding of what materials science engineers do was a representation that these types of engineers are concerned about materials and their uses. Mr D had interacted with participants at this after-school program for a year. In the image-elicitation interview the student traced his representation of an engineer to his interactions with Mr D during the after-school program.

Student: I made a drawing of Mr D. ['engineers are like the undergraduate engineer student interns in the program']. He is a materials engineer who looks at the quality of materials like steel ['materials engineers are interested in studying materials'].

Interviewer: What kinds of things does this engineer do at work?

Student: I think that engineers are interested in making new materials that are strong and powerful than what we have now. ['materials engineers invent new materials']

Interviewer: OK…Hmm…and?

Student: Engineers like Mr D make sure that the materials in a nuclear power plant like we have here in Phoenix are safe ['engineers ensure our safety'] and that the nuclear waste doesn’t harm us and the environment.

In this particular case, although the participant’s drawing doesn’t fully represent what he shared with the interviewer, it shows his emerging understanding of a specific aspect of what materials science engineers do. In his interview the participant literally described what Mr D had shared with the group about the type of job he intended to do when he graduated at the end of the year. Mr D had talked about his future job working for the United States Nuclear
Regulatory Commission and the type of work he hopes to do in his new job. It is clear that the role models the Learning through Engineering Design & Practice project introduced to the after-school program were represented in participants’ understandings of engineers, and they incorporated emerging ideas that approached conceptions of what engineers do at work that were prevalent in the engineering education community.

**Engineers go to College**

When I examined individual participants’ draw-an-engineer responses over a two-year period I was able to trace the participant’s developing understanding of what an engineer does at work. While not all participants’ drawings indicated a change in their thinking about engineers in action, some middle school participants demonstrated significant changes -- developing an identity as future engineers. The draw-an-engineer also began to include a projective element. By the fourth observation point, approximately 22 months into a two-year program, some students identified themselves as the engineer in their drawing. See Figure 7 for Nancy’s pre-program conception of an engineer. At the end of Year 1, Nancy represented a female engineer (see Figure 10) who worked at Microchip, a semiconductor company in Phoenix, AZ, and had graduated from an engineering degree program.

![Figure 10](image-url)
Written response:
A 21-year old female engineer ['engineers are female'] who graduated from Arizona State University ['engineers go to college'] is working on a microchip. She ['engineers are female'] needs to be very careful, so she doesn’t damage the whole microchip. She works on computers and uses technology and software ['engineers use tools'] to design microchips.

And interview responses:
Nancy: I made my engineer look a little like Ms M, because she is an engineer ['engineers are female']! And she works at Microchip.
Interviewer: Yes…
Nancy: She ['engineers are female'] went to college at Arizona State University and got a degree in electrical, electronics engineering? ['engineers go to college'] I want to go to college like her. ['participant projected personal education-career pathway goal']
Interviewer: OK.
Nancy: Like we went on a field trip to ASU and saw that lab where they made microchips. ['participant linked attending college to preparation for work as an engineer'] I want to work in a place like that.
Interviewer: Ok... [Pauses]...What is the engineer in your drawing doing?
Nancy: Like Ms M she is making, she is designing a microchip ['engineers design things']. She showed us the kinds of things she designs. They are like the electronic circuits that go in our cell phones. ['participant identified real life use for products made by engineers']

Ms M’s influence on Nancy was represented in the drawing and Nancy’s verbal description of her drawing of an engineer at work. In addition, Nancy had connected her own visit to Arizona State University, where she observed a micro-fabrication clean room facility in the Center for Solid State Electronics Research, with what she had learned from Ms M about Ms M’s degree program and job at Microchip.

At Nancy’s school, at the end of the first year during a family engineering night, a female Hispanic undergraduate chemical engineering student named Ms G discussed her engineering program and the type of work she wanted to do when she graduated. Ms G said:
I want to work in a pharmaceutical company, that is a company where medicines are made. I want to help make new medicines that will help people who have a medical illness.

Ms G had visited the program site only once. Nancy made the drawing (Figure 11) five-months after Ms G had visited the after-school program, at the start of the second year. The influence of these program experiences appeared in the drawings that Nancy made. At the start of the second year, Nancy had begun to develop a self-identity as an engineer, although she did not directly label her drawing of an engineer as depicting herself.
Participants were introduced to the engineering design as a process that engineers follow to generate the best possible solution(s) to any given problem (Ertas & Jones, 1996). They were encouraged to use the engineering design process in all of the project-based challenges they experienced throughout the program. Students were aware that the engineering design process is iterative and included identifying the challenge, gathering information, imagining or brainstorming solutions, planning, designing, building, testing, and redesigning a product.
based on information gathered from the previous iteration. In the related image-elicitation interview, Nancy also referred to the engineering design process that she would follow in designing new medicines to cure cancer.

Interviewer: Tell us about your drawing.
Nancy: I have an aunt who has cancer. I want to do something that will help people who have cancer. ['engineers help people']
Interviewer: Hmm...
Nancy: I want to help find a cure for cancer. ['engineers help people']... I want to be like Ms G. I want to make a cure and make it better for people.
Interviewer: OK.
Nancy: I can help people then. I can design medicines that will help people. I want to go to college ['engineers go to college'] so I can learn about this ['college prepares engineers for their job'].
Interviewer: OK
Nancy: When I grow up, I will be that engineer, who works with others who study people with illness like cancer and find a cure for people like that. ['engineers help people']
Interviewer: Hmm...
Nancy: We will use the process to understand the challenge. What cancer is like and what we need to cure it. What they do now. Then we will come up with new ideas. Find ways to make new medicines. Design new medicines to cure cancer. Test it. Collect data to see if it worked. Then redesign it. ['engineers follow a process.' ] It will be hard work. But I want to do it so I can help people like my aunt.

Nancy’s fourth drawing of an engineer, at the end of the two-year program, extended her belief that engineers go to college to include the idea that engineers work in a team.

Figure 12. “I am a chemical engineer working with a medical research team to design a cure for cancer. I am working on an experiment.”
Author: 13 year old, 8th grade, Hispanic female.

Written response:
In my drawing, it shows two people. I am the chemical engineer [‘self as engineer’]. I am designing a cure for cancer. I work with a research team on an experiment. We use chemicals and equipment like beakers, test tubes in our experiments. We also use computers, record different data from our experiments and study them. We discover new medicines to help people [‘engineers help people’].

In Figure 12 Nancy specifically indicated herself as the female chemical engineer. She was sure that she would go to college and become an engineer: ‘I will go to college. I want to help people and make medicine that can cure people who have, like cancer.’

The longitudinal analysis of students’ drawings of engineers at work is a useful example of how subject-produced drawings may be used in understanding the impact of educational interventions. Nancy’s case illustrates how the Draw-An-Engineer process, along with image-elicitation interviews, were used trace her development of her self-identification as an engineer. Over the two-year period Nancy moved from an early conception of the ‘engineer as a guy who builds a tower of Legos’ to ‘I am a chemical engineer who designs medicine for illnesses like cancer.’

Analysis of post-program drawings indicated a shift from students’ early understandings that included representations of concepts such as engineers work with engines, engineers build, and engineers repair technical devices to emerging understandings that included representations of concepts such as engineers go to college, engineers use the engineering design process, engineers design products we need, engineers invent new devices to help people, engineers find ways to improve things we use everyday, and engineers can be female and engineers can be male. My intent with this paper was to provide a glimpse into the data analysis process. I also demonstrated how broad conceptualizations were arrived at by analyzing subject-produced drawings, and illustrated ways that related data collected from image-elicitation interviews were broken down into key elements, properties and dimensions, and conceptualized the image as a whole.

Can the draw-an-engineer be used on its own without the accompanying interview to determine what students know about engineers? Researchers (Fralick, Kearn, Thompson, & Lyons, 2008; Oware, 2008; Weber, Duncan, Deyhouse, Strobel, Diefes-Dux, 2010) have developed and continue to develop elaborate coding systems to determine whether the draw-an-engineer will serve as an affordable valid instrument that will not require the expensive interview component to ensure that inferences drawn from the subject-produced drawing is reliable.

Studies have focused on analyzing popular literature and news media to understand how engineers are portrayed as a means of understanding their influence on people’s preconceptions of engineers (e.g., Clark & Illman, 2006; Vaughn, 1990). The draw-an-engineer assessment can also be used with image-elicitation to study influences from popular media on students’ pre-conceptions of engineers at work.

Conclusion

Subject-produced drawings have the potential, when used with care and rigor, to serve as useful descriptive and analytical tools. As a descriptive tool, subject-produced drawings can be used to elicit individuals’ understandings of a specific idea or construct. As an analytical
tool, subject-produced drawings can be used to compare an individual’s changes over time. While the subject-produced drawings offer rich descriptive data, the related issues with construct validity will persist, as data collected using drawings will be interpreted through the human perceptions of the researcher. It is not fully possible to discern the author’s intent without speaking with the author of the drawing. When drawings are considered as visual data and are analyzed in context, along with other sources of data such as author descriptions of the drawing or image-elicitation interviews, the validity of the inferences that one can make from such data is enhanced, as the inferences will not rely solely on the researchers’ interpretations. Ultimately, what matters is whether one has the evidence to warrant claims made. Subject-produced drawings offer an important tool for visual researchers as they have the following qualities: they can be projective, they permit expression of feeling and imagery, they allow for defining and redefining shared attitudes held by society, and they can be analyzed using psychological, sociological and cultural lenses with attention to the phenomena or concepts under study.

References

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