

Children-Produced Drawings: An Interpretive and Analytic Tool for Researchers

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A BRIEF HISTORY OF THE USE OF SUBJECT-PRODUCED DRAWINGS OF THE HUMAN FIGURE

Charles Darwin's 1877 publication 'A biographical sketch of an infant' represented growing interest in child study. In his report, Darwin described long-term observations of his own son from birth, examining the child's expression in response to actions. Interest began with systematic observations of children's behaviors and eventually included the collection and examination of drawings produced by children. The notion that young children's unprompted drawings could shed light on the psychology of child development evolved over time, from interest in what was then termed children's artwork (Cooke, 1885; Ricci, 1887) to scientific studies of children's drawings prompted by standard directions (Partridge, 1902; Schuyten, 1904; Lamprecht, 1906; Claparede, 1907; Ivanoff, 1909; Rouma, 1913). The scientific interest manifested itself as exploring and understanding relationships

between children's intellectual ability, as measured by school work through teacher ratings for example, and children's ability to draw, as measured by a scoring system on a scale, or rating system.

John French (1956) included examples of children's drawings from Ricci's *L'Arte dei Bambini* (1887) (as translated by Maitland, 1894). Ricci had collected over 1250 drawings from elementary school children and observed:

... children at first do not artistically represent an object, but describe it according as the memory of it is more or less complete, and suggests to them while drawing the different parts of the object. Art, as art, is to them unknown (306).

Ricci compared children's art to adult art and concluded that children represent the figure of man 'in his literal completeness and not according to the visual impression' (304).

In the USA, Barnes (1892) and Burgess (1895) collected and analyzed children's drawings. Barnes (1892) collected 6393 drawings from children aged 6–16, in California and the

eastern USA. He asked children to illustrate a poem with the idea that it would allow for comparison of the collected drawings and some large generalizations (455–456). Barnes concluded from his analysis of these drawings that:

Pictures are for a young child simply a language. He makes pictures not to exactly imitate something, nor to produce an aesthetic feeling, but to convey an idea. Picture making is picture writing (460).

Barnes (1892), like Ricci (1887), concluded that children needed to be taught to make art and that this teaching should keep pace with the child's development.

A review of these early studies indicates the challenges with the idea of subject-produced drawings: What should the child be asked to draw? Could the child draw anything of her or his choice? How then might one score drawings that did not have any standards? At that point in time scientific interest was focused on developing objective measurement scales. Attention was given to assessing cognitive development through the characteristics and subject (content) of the drawings.

Partridge (1902) collected drawings of the human figure from children aged 4 through 10, and then associated age and development with the details of the drawings. Schuyten (1904) attempted to devise an objective system for rating children's drawings and established a standard of excellence for each age. Rouma (1913) used children's drawings of the human figure to suggest that there was a sequence of stages in children's human figure drawings.

Standardizing the prompt from a drawing 'in general' to that of 'a human figure' made it possible to hypothesize, study, and propose a general pattern of child development that is visible in children's drawings. Concerns that women's and children's clothing offered greater variety than men's clothing, using 'a man' for the human figure drawing test was settled upon. The uniformity of men's clothing was a factor considered important in providing a standardized prompt to elicit

subject-produced human figure drawings. Prompts that could potentially offer too many varieties from a child's perspective would be counterproductive when it came to developing a standardized scoring process.

Thus, in Florence Goodenough's (1926) *Draw-a-Man Test*, she developed standardized procedures and used a large sample in her study. The *Draw-a-Man Test* comprised the following: a child was asked to draw a picture of a man. The ensuing drawing was then examined for a relationship between concept development and general intelligence as visible in the quality of the drawing. The test had 51 scoring items. The fundamental assumption of the analysis was that the accuracy and the number of details in the drawing was an indicator of the child's intellectual maturity. This became the foundation for subsequent techniques that attempted to quantify qualities in the drawing by counting the number of details.

Children's human figure drawings as a measure of intelligence

The Goodenough *Draw-a-Man Test* was later modified by Dale Harris (1963) to be known as the Goodenough–Harris *Draw-a-Person Test*. This test included three drawings: 'draw a man', 'draw a woman', and 'draw yourself'. The scoring system included 73 items for the drawing of a man, 71 items for the drawing of a woman, and a 12-point quality scale. A scoring system for the drawing of the self was never fully developed.

Nevertheless, this revision represented an interesting change from 'draw a man' to 'draw a person', by attempting to extend the original test to include the figure of a woman and the child's self-portrait. An important distinction here was the provision of alternatives to drawing 'a man', since the drawing of 'the self' personalized the test. This personalization fundamentally altered the original test by offering the potential to extend the test as a perhaps more valid projective technique which could be used to study the

respondent's affect and interests. The idea of a projective test is that, through the process of projection, subjects reveal their private worlds and personality processes by reacting to stimuli presented. The subject-produced drawings were then used as a medium for interpreting symbols and observing expressions in the drawings. This personalization, via the inclusion of a projective prompt, opened up the possibility of studying emotional indicators, such as that offered by Koppitz (1968, 1983), who designed a scoring system for the *Draw-a-Person Test*.

Naglieri (1988) modified the test further to develop the *Draw-a-Person: A Quantitative Scoring System (DAP)*. Here the scoring system was designed with the idea that human figure drawings – of the woman, the man, and the self – could be scored with criteria where the subjects' language, verbal skills, and cultural differences would not become confounding factors (Naglieri and Bardos, 1987).

The idea that the technique of eliciting subject-produced human figure drawings was relatively culture-free was fundamental to its employment as a means to collect information about human cognitive abilities. A common use for this technique was to assess intelligence and academic readiness of young children, especially children who were non-readers, hyperactive, developmentally delayed, etc. This assumption about relative freedom from subjects' cultural difference would prove to be problematic when subject-produced drawings as a form of assessment were extended to other contexts and purposes (Chapman and Chapman, 1971; Koppitz, 1983; Golomb, 1992; Smith and Dumont, 1995; Dumont and Smith, 1996).

With increased interest in the *Draw-a-Person (DAP) Test* as a measure of intelligence, Neisworth and Butler (1990) began to carefully study the theoretical underpinnings of the test, its validity, reliability, and use across cultures. Construct validity and concurrent validity were specifically circumspect as researchers began to examine the usage of the *DAP Test* as an intelligence test.

The Naglieri *DAP Test*'s validity was based on evidence of *concurrent validity*: how strongly does the *DAP Test* correlate with its earlier predecessor such as the Goodenough–Harris *Draw-a-Person Test*? With the availability of other forms of comprehensive intelligence tests, such as versions of the *Wechsler Intelligence Scale for Children (WISC)*, concurrent validity of the *DAP* with the *WISC* was found to be weak (Motta et al., 1993; Smith and Dumont, 1995; Abell et al., 2001). There is considerable controversy about the use of children's human figure drawing as a measure of ability or intelligence; thus, authentic decisions about intellectual functioning based solely on subject-produced drawings is considered entirely unwarranted. The early challenges, related to the development of the prompts used to elicit subject-produced drawings, the subsequent development of methods such as scoring systems to make sense of the drawings, and the quality of interpretations drawn from such data continue to persist today, albeit to varying degrees, especially as we situate research with subject-produced drawings in socio-cultural contexts.

Psychological tests and Brown vs Board of Education (1954)

Kenneth and Mamie Clark (1950) conducted studies that challenged the notion that there were differences in the mental abilities of Black and White children and the results of their studies played a significant role in the desegregation of American public schools. They were the first African-American man and woman to earn psychology doctorates from Columbia University, NY. By 1950, they and other scholars had already conducted studies (Horowitz, 1939; Clark and Clark, 1939a; Clark and Clark, 1939b) showing that Black children of ages 3–7 years:

had a well developed knowledge of the concept of racial difference between 'White' and 'Colored' as indicated by the characteristic of skin color – and that this knowledge develops more definitely from

year to year to the point of absolute stability at the age of seven (Clark and Clark, 1950: 341)

The colored doll test involved showing groups of Black and White children two black and two white dolls and asked them to choose the doll that was 'nice', 'pretty' or 'bad'. The test results showed that both groups of children associated the white dolls with commendable characteristics. They then devised a technique to further investigate the development of racial identification and preference in Black children using the *Coloring Test* and spontaneous remarks of the children

as they responded to other techniques, including the colored doll test.

The *Coloring Test* (Clark and Clark, 1950: 342) in Figure 12.1 was used to establish the use of color and its relationship to specific objects, specifically skin color of the respondent to self-image and preference for skin color, thereby linking skin color to racial preference. The test comprised a sheet of paper with outline drawings of a leaf, an apple, an orange, a mouse, a boy, and a girl. A set of crayons that included the customary colors and brown, black, white, and tan was given to each subject. The study had 160 children aged

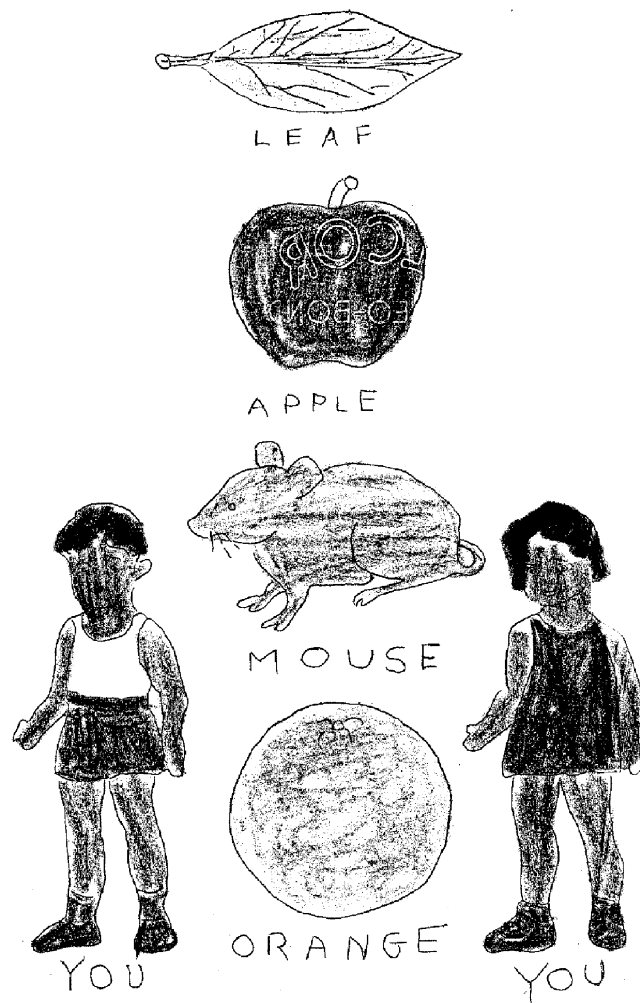


Figure 12.1 *Coloring Test*, developed by Clark and Clark (1950)

5–7 years old, whose responses on the coloring test were stable enough to analyze.

The first portion of the test was to determine whether subjects had a ‘stable concept of the relationship of color to object’ by coloring the objects and the mouse. Each child who passed this screening portion of the test was then given the prompt to color a human (child’s) figure that represented the subject: ‘Color this little boy (or girl) the color that you are. This is _____ (child’s name), color him (or her) the color you are’ (342). Once this portion of the test was completed, the child was given a human figure outline of the opposite sex to that of the subject, along with the second prompt: ‘Now this is a little girl, (or boy). Color her (or him) the color you like little boys (or girls) to be’ (342).

The data from the *Coloring Test* were categorized, based on their age; the region in which they lived (Southern or Northern USA); and skin color (Light, Medium, and Dark), as ‘Reality’, ‘Phantasy’ [sic] and ‘Irrelevant’ or ‘Escape’ responses. These categories and their definitions were based on the colors used as well as qualitative observations of the responses as the subjects worked on their drawings. For instance, a response was categorized as a ‘Reality’ response when the coloring of the outline drawing of the child was reasonably close to the subject’s own skin color. The Clarks reported that the qualitative observations indicated that subjects colored figure drawings that represented themselves with ‘painstaking care’ (343) when compared to the ‘matter-of-fact’ manner in which they colored the objects and the mouse. Through qualitative observations, they noted a difference in cases where the responses were classified as ‘Escape’ responses. In these cases, the subjects had been observed to make random scribbles when asked to color the outline drawing that represented the subject. And finally, the Clarks noted that, in addition to the color used in coloring an outline drawing of themselves, and this color’s relationship to the subject’s own skin color, they observed how

much ‘pressure’ the subjects applied when coloring.

In order to further develop the results of the coloring test, the Clarks recorded the subject’s spontaneous remarks and explanations of their responses to the *Colored Doll Test, Preference Series*. This served as a form of concurrent validity. They then categorized subjects’ responses for preference as *color*: ‘Black–White’; as *beauty*: ‘Ugly–Pretty’; as *purity*: ‘Dirty–Clean’; and identified some explanations as ‘Evasive’ as well as the use of the epithet ‘Nigger’, and tallied according to where the children lived: ‘North’ or ‘South’ (347). In their analysis, they found that Southern children had three times as many spontaneous explanations as the Northern children. In explaining this result they noted, ‘This might be considered as being indicative of the greater preoccupation of these Southern children with racial matters, or a greater spontaneity on their part in reference to this subject, or an attempt...’ (347). This kind of analysis required deep knowledge of the social context in which the subjects lived and the relation of the subject’s skin color to the subject’s perceived place in the social hierarchy where the subject lived. Location assumed significance with the traditions of the South vs North as they related to segregation and the Civil Rights movement. This was further enhanced by the fact that the Clarks were cultural insiders – they themselves were Black and had seen and experienced at first hand the effects of segregation. Ultimately the Clarks found that Black children, by age 7, had internalized racism caused by the discrimination and stigmatization resulting from racial segregation (349–350).

On 17 May 1954, the Supreme Court issued a decision in *Brown v. Board of Education* declaring that, ‘separate educational facilities are inherently unequal’. This decision specifically cited Kenneth B. Clark’s work titled, *The Effects of Prejudice and Discrimination on Personality Development* (K. B. Clark, 1950). I have highlighted the Clarks’ use of qualitative observations of children’s responses to the *Coloring Test* and

Colored Doll Test, their collection of verbal responses as explanations from participants, their identification of emergent categories of those responses, and the interpretation of the responses as a whole. In my view, the meaning-making process was firmly situated within the socio-cultural context of the research study, at a time when American society was legally segregated based on racial differences. The Clarks' roles, as African-American psychologists and researchers who were active in the American Civil Rights Movement, influenced their motivations for engaging with the type of research that had the potential to influence social policies. This is a powerful example of ways that results from visual research on child development, which involved subject-produced coloring of outline drawings of children, have had a lasting impact on public education policy.

Subject-produced drawings as contemporaneous responses to society and culture

Margaret Mead used subject-produced drawings as contemporary responses by the public to events that represented rapid technological change after the World War II. 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 the Sputnik satellite 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 and 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 (386–387)

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 4800 drawings-of-a-scientist made by elementary school children. He patterned the *Draw-a-Scientist Test* after the Goodenough *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: 258).

Fort and Varney (1989) similarly analyzed drawings of scientists made by 1600 students in grades 2–12. They also asked students to write about their drawing. They found that, of the 1600 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; studies were conducted in China (Chambers, 1983); India (Rampal, 1992), and Australia (Schibeci and 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.

Validity and reliability of subject-produced drawings

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 et al., 1991; Finson et al., 1995; Huber and Burton, 1995; Bodzin and Gehringer, 2001; Bohrmann and Akerson, 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 but also 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 et al. (2006) examined age and gender differences in the drawings of computer and technology users.

Other examples of subject-produced drawings: Education studies

Weber and 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 led 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 and 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 et al. (2000) used drawings from students in Massachusetts in a study of student's feelings about high-stakes testing. Haney et al. (2004)

described the use of subject-produced drawings to show how they could be used as a tool to examine teacher behavior and the impact of education reform.

THE DRAW-AN-ENGINEER TEST TO ASSESS MIDDLE SCHOOL STUDENTS PERCEPTIONS OF ENGINEERS

Just as subject-produced drawings have been used to study children's attitudes towards professions in science, researchers have used the *Draw-an-Engineer Test*, an adaptation of the *Draw-a-Scientist Test*, as a tool to examine children's attitudes and knowledge of engineers and engineering (Cunningham and Knight, 2004; Cunningham et al., 2005). Similarly, I used the *Draw-an-Engineer Test* in a longitudinal study of middle school children engaged in an after-school engineering education program over 2 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.

Context for the study

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 USA that the globalization of knowledge and increased use of low-cost labor had led to the erosion of the USA 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 2006–07, 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.

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 12.1 and 12.2. 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 2-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. Assessment

Table 12.1 Percent project participants by gender and year

	Number of students		Combined sample	Percent by gender
	2007–08	2008–09		
Female	32	35	67	58
Male	16	33	49	42
Total	48	68	116	

Table 12.2 Percent project participants by race/ethnicity and year

	Number of students		Combined sample	Percent by race/ethnicity
	2007–08	2008–09		
American Indian	4	1	5	4
Asian	2	0	2	2
Black	5	0	5	4
Hispanic	25	46	71	61
White	12	21	33	28
Total	48	68	116	

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 coordinators 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, project coordinators 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.

Pre-program drawings

With the pre-program *Draw-an-Engineer* assessments, 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. With the assistance of a graduate research assistant in education with a bachelor's degree in engineering and experience teaching high school mathematics, and an undergraduate engineering student who worked as a student data-analyst, we reviewed the drawings to identify elements that we felt were helpful in developing a description of what seventh-grade students depicted about engineers. It is important to note that I have also earned bachelor's and master's degrees in

engineering, and bring my own background and experience to this project.

To make sense of the drawings, we engaged in what Strauss and Corbin (1998) termed *open coding* and *axial coding*. We began *open coding* (101–121) with three broad theoretical categories:

- *Gender of the engineer.* Participants were 58% female and 42% male. We were 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, we were interested in observing whether male students made drawings of female engineers and if those changed.
- *Engineers in action.* The drawing prompt asked students to draw an engineer at work. Therefore, we 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 are related to understanding what the engineer could potentially do with those objects. Therefore we felt it was important to attend to the types of objects the engineer held or were around the engineer in the drawing.

We labeled the drawings with likely concepts suggested by the context in which the drawing was located, including the accompanying written responses describing the drawing. We prepared memos describing our thoughts about key elements we identified in the drawings. We reviewed the entire data corpus in this manner.

Once this process was completed, we compared the drawings, our labels, and memos to search for cross-cutting concepts. This process is what Strauss and Corbin termed *axial coding* (123–142). Our 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*. These concepts represented our interpretation of students' representations of engineers at work. We also used *image elicitation interviews* to confirm our interpretations of the students' drawings. The image elicitation

helped us access the ‘why’ and/or ‘how’ students thought about engineers at work. Many of them 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 our process of conceptualization with examples. Codes are in bold print. Not all instances of a concept are coded and others may use different labels or identify altogether different concepts.

Engineers work with engines

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.

We identified specific elements in the drawings that represented our theoretical categories. The specific elements we noted in Figure 12.2 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 our theoretical category *engineers use tools*.

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

Memo. It will be useful to explore the relationship between engineers and cars, trucks, and trains.



Figure 12.2 ‘My engineer has just finished fixing the train.’ Author: 12-year-old, seventh-grade, White, female

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. We should probe this idea when we interview the students.

In the drawing in Figure 12.2, 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). We examined what operations the engineer was described as doing with the car, truck, or train with our 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.

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 we noted in Figure 12.3 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*.

We labeled the drawing, 'engineers work with car engines.'

As we engaged in axial coding, we reviewed the key elements and memos and searched for categories that linked with each other (Strauss

and Corbin, 1998: 123–142). For instance, we wanted to explore why students believed that engineers work with cars, trucks, and trains. We began to group the notions that engineers fixing or driving a car, truck, or train were all related to each other. 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 12.2 and 12.3, and other drawings with similar concepts, were now conceptualized as *engineers work with engines*. This concept emerged from our data analysis. By constantly comparing drawings that had similar elements, we attempted to validate our interpretation that some participants believed that *engineers work with engines*. I found that member checking was also important; we talked with participants about their drawings to make sure that our interpretation was recognized by them. 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 author who made the drawing in Figure 12.3:

Interviewer: 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'**]

Interviewer: Do you know of anyone who fixes cars?

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

Interviewer: Are these people engineers?

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

Interviewer: Hmm...

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

Our concept *engineers work with engines* represents the phenomenon that some middle school students believe that engineers work with engines. We made memos that allowed



Figure 12.3 'My engineer is fixing a broken car.' Author: 13-year-old, seventh-grade, Hispanic, female

us 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? We should explore this idea further when we interview the students. Students will need to feel comfortable with us, 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. We re-conceptualized the drawings based on coding key elements

and categories as sharing common properties and dimensions. We iteratively reviewed all of 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. We confirmed our interpretations of the drawings we 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 12.4 lived in a neighborhood with largely Spanish-speaking people, 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*.

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 12.5 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 *engineers build buildings*. This conceptualization encompasses the dimension of physical labor involved in constructing a house.

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**

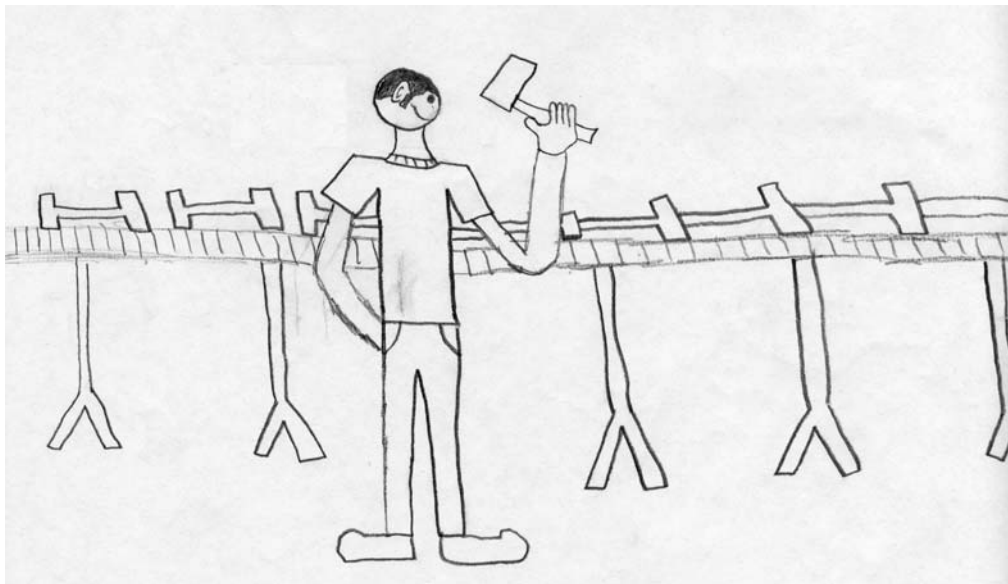


Figure 12.4 'My engineer assembles things in a factory.' Author: 12-year-old, seventh-grade, Hispanic, male



Figure 12.5 'My engineer is building a house.' Author: 13-year-old, seventh- grade, Hispanic, male

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 (Figure 12.6).

Engineers repair technical devices

Engineers repair technical devices is a phenomenon that encompasses participants ideas such as *engineers fix computers* (Figure 12.7), *engineers fix clocks and watches*, and *engineers fix televisions, microwaves*.

Written response:

The engineer is working to fix a broken computer hard drive. He also knows how to fix televisions, microwaves, etc., 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 we did not assign the drawings a specific label. There were a few drawings that we felt did not clearly indicate any specific conception of engineers. Interview data were used to access students' reasons for their drawing of an engineer.

Figure 12.8 is an illustration of such a drawing. 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



Figure 12.6 'My engineer is digging. He is working to build a bridge.'
Author: 13-year-old, seventh-grade, White, female

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 2-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:

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

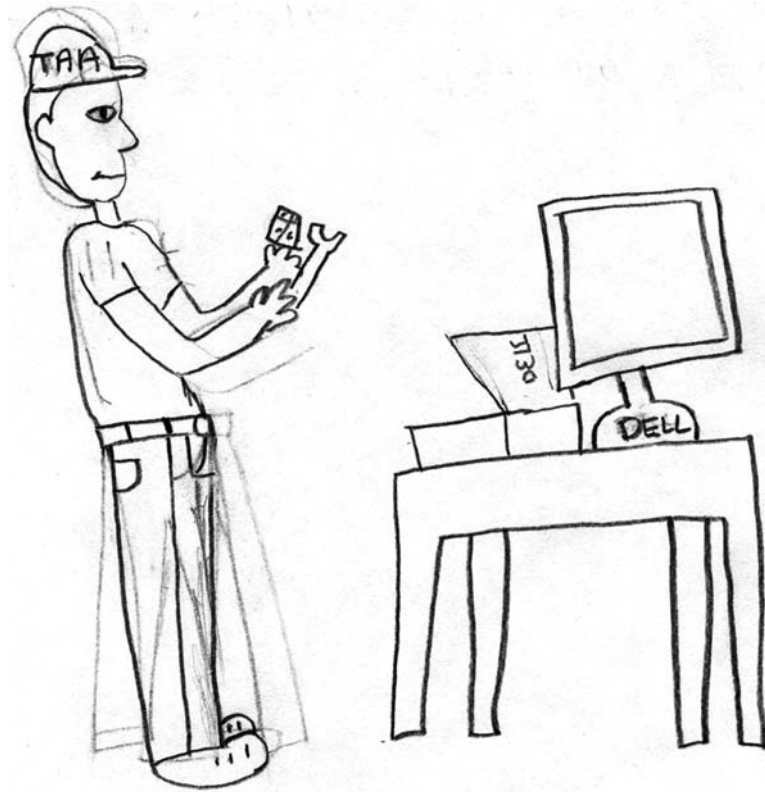


Figure 12.7 'My engineer is working to fix a broken computer hard drive.'
12-year-old, seventh-grade, White, female

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. screwdriver)

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) 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' (12) These abstract ideas about what engineers do were not in evidence in students' pre-program conceptions.

Our *Learning through Engineering Design* 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

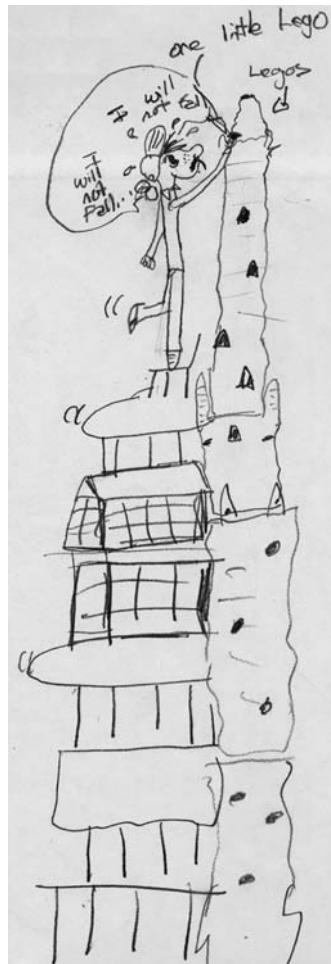


Figure 12.8 'The engineer guy built a tower of Legos.' Author: 12-year-old, seventh-grade, Hispanic, female

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 2-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.

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 and Corbin, 1998) until saturation occurred when the data analysis team felt that we had exhausted identification of all categories, elements, properties, and dimensions. Open coding and axial coding occurred simultaneously at times, and were not necessarily sequential in nature. As we reviewed the data, we not only assigned labels representing categories but also began to link data elements to others in the data corpus that we had encountered earlier. Our memos helped us articulate our 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. Through image-elicitation interviews we 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 the drawing (Figure 12.9) 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

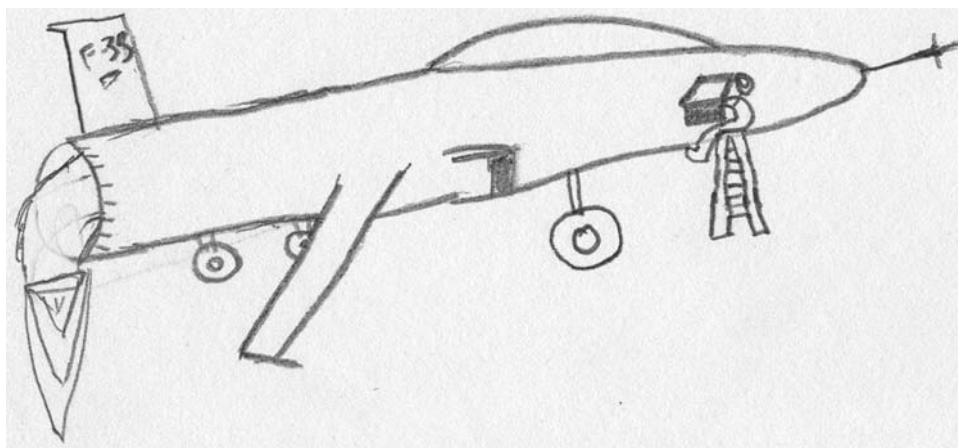


Figure 12.9 'He is working on a damaged F-35.' 14-year-old, eighth grade, Hispanic, male

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.

Written response:

The engineer is checking the steel. He is a man [**'engineers are male'**]. He is smart. He inspects stuff. He is checking what material this structure is made with.

In Figure 12.10, 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

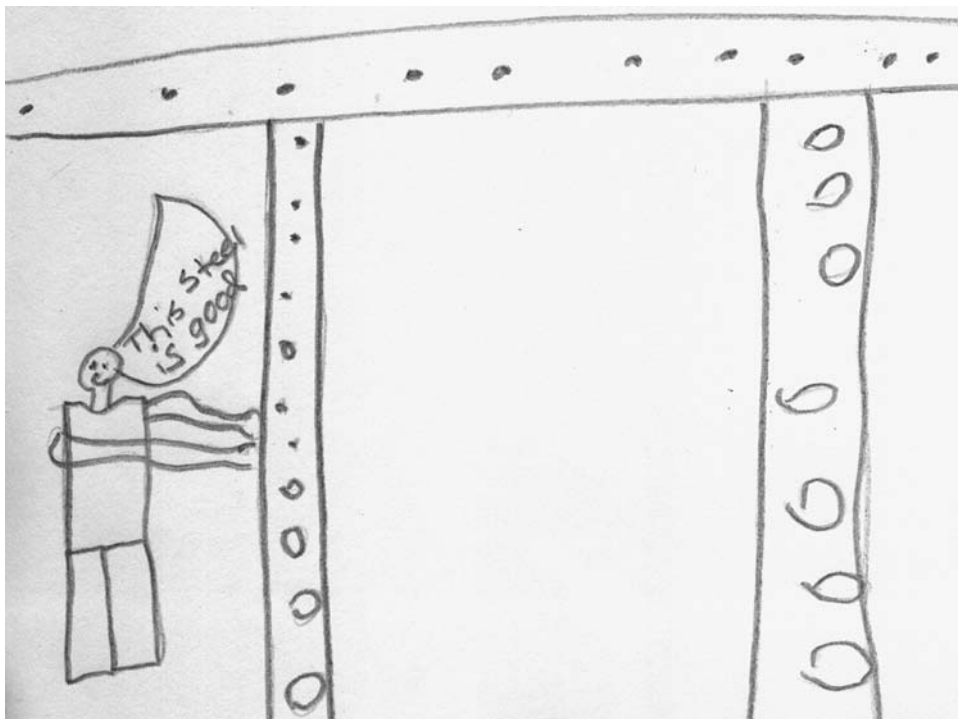


Figure 12.10 'The engineer is checking the steel.' Author: 14-year-old, eighth-grade, panic, male

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 we 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 2-year

period I was able to trace the participant's developing understanding of what an engineer did. 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 2-year program, some students identified themselves as the engineer in their drawing. (See Figure 12.8 for Nancy's pre-program conception of an engineer.) At the end of Year 1, Nancy represented a female engineer (see Figure 12.11) who worked at Microchip, a semiconductor company in Phoenix, Arizona, and had graduated from an engineering degree program.

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**].



Figure 12.11 'A 21-year-old female engineer who graduated from Arizona State University is working on a microchip'. Author: 12-year-old, seventh-grade, Hispanic female

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 12.12) 5 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.

Written response:

The female engineer tries to figure out a cure for cancer [**'engineers help people'**]. She works with chemicals and designs new medicines [**'engineers design things'**] [**'engineers make new products'**]. She is always thinking. She makes notes based on what she finds from her experiments.



Figure 12.12 'The female engineer is attempting to figure out a cure for cancer.' Author: 13-year-old, eighth-grade, Hispanic, female

She then uses it to redesign the drug [**'engineers follow a process'**] and make changes to the medicine she is designing to cure cancer.

Participants were introduced to engineering design as a process that engineers follow to generate the best possible solution(s) to any given problem (Ertas and 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 2-year program, extended her belief that *engineers go to college* to include the idea that *engineers work in a team*.

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 12.13 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 2-year period Nancy moved from an early conception of the 'engineer as a

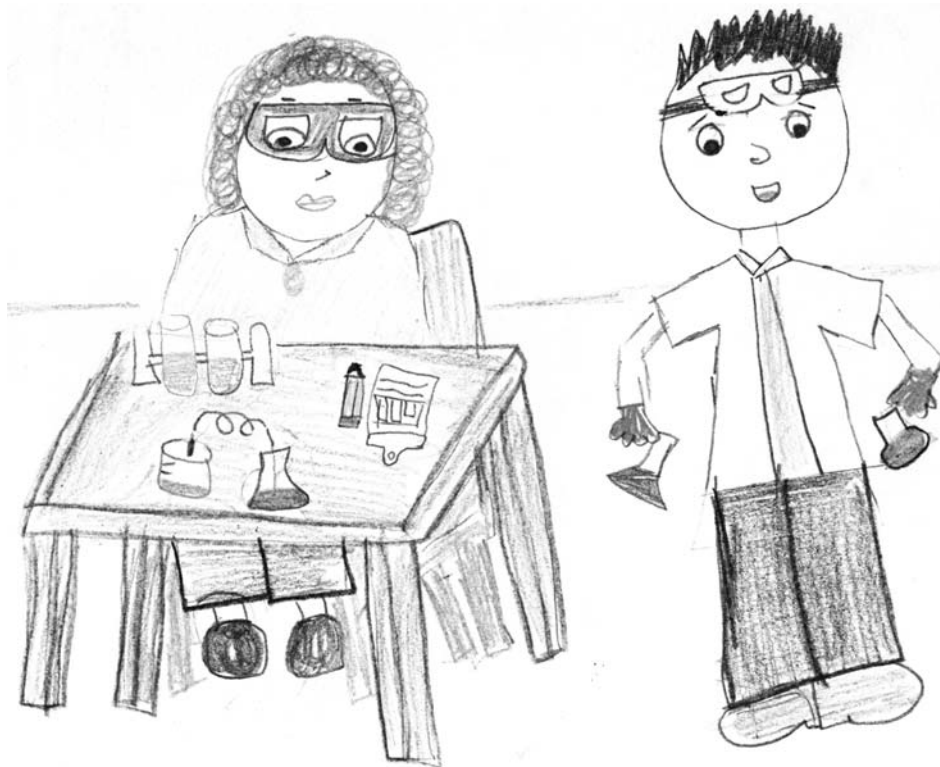


Figure 12.13 'I am a chemical engineer working with a medical research team to design a cure for cancer. I am working on an experiment.' Author: 13-year-old, eighth-grade, Hispanic female

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 every day*, and *engineers can be female and engineers can be male*. My intent with this chapter was to provide a glimpse into the process we followed for data analysis. 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.

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.

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