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ENGINEERS' SELF-PERCEPTIONS AND A STRATEGY FOR FOSTERING AUTHENTIC IMAGES OF ENGINEERS AND SCIENTISTS AMONG ELEMENTARY SCHOOL STUDENTS

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ENGINEERS' SELF-PERCEPTIONS AND A STRATEGY FOR FOSTERING AUTHENTIC IMAGES OF ENGINEERS AND SCIENTISTS AMONG ELEMENTARY SCHOOL STUDENTS

A DISSERTATION APPROVED FOR THE
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IN SCIENCE EDUCATION

BY

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DEDICATION

This dissertation is dedicated to three awesome men who give my life purpose and meaning: my husband, Patrick, and our sons, Kenneth and Robert. I don't tell them often enough how much I love and appreciate them. They inspired me to begin this journey and stood by me throughout. I thank Patrick for his steadfast love and confidence, combined with infinite forbearance. I thank Kenneth and Robert for keeping me laughing with their irrepressible wit, and for patiently rescuing me from many the information technology crisis.

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PROLOGUE

This dissertation is prepared in journal-ready format. The body of the dissertation consists of three journal articles, which have been prepared for submission in refereed journals. Manuscript I, "The Image of the Scientist: What We Know Today", is prepared for submission to *School Science and Mathematics*. Manuscript II, "Engineers' Self-Perceptions: A Phenomenological Study of Engineers in Academia", is prepared for submission to *Journal of Engineering Education*. Manuscript III, "How Does Participation in a STEM Club Affect Identified Gifted Fifth Grade Girls' Perceptions of Scientists and Engineers?", is prepared for submission to *Journal of Engineering Education*. The appendices include the Prospectus and Institutional Review Board approvals of the three studies on which these articles are based.

DISSERTATION ABSTRACT

Over a decade since Finson's 2002 review article, "Drawing a Scientist: What We Do and Do Not Know After Fifty Years of Drawings", images of scientists, sometimes stereotypes, continue to be created and promoted in popular media. The scholarly literature amply documents how education stakeholders ranging from elementary school age children to in-service teachers throughout the world perceive scientists. The impact of these images on students' coursework and career choices is likewise well established. Strikingly, there are few studies where scientists reveal their self-perceptions. The most recent of these were published in 1975. The less well developed literature on engineer images reflects how they are stereotyped as "geeks" and "nerds". No prior work on engineers' self-perceptions has been identified. The engineering profession has explicitly recognized the importance of improving the image of engineering (Engineers Dedicated to a Better Tomorrow, 2006).

Two research projects were initiated, a first to learn about the lived experiences of scientists, defined as faculty members in a natural science discipline at a research university holding a PhD and a second to learn about the lived experiences of engineers, defined as faculty members in a college of engineering at a research university, likewise holding a Ph.D. A naturalistic or constructivist research paradigm provided the theory base that guided the phenomenology research approach. No scientists agreed to join the scientist study. Engineer participants were asked to share their lived experiences as engineers in semi-structured in-person interviews. The interview data were analyzed according to a phenomenological reduction methodology (Moustakas, 1994). All identified protecting and serving society as an essential element of their experiences as

engineers. Other themes that played significant roles in their experiences included their perceptions of the public; the public's perception of engineers; stereotypes; gender; solitary work and team work; hard work/rigor; designing and building; solving problems; and creativity. While the engineers shared themes, they were not a monolithic group. Each had a unique underlying philosophy that governed how these themes were manifested. The engineers' self-perceptions are valuable for designing interventions to foster accurate images of engineers for K-12 students. Curricula can be prepared that allow students to experience these essential aspects of being an engineer. The engineers' Draw-An-Engineer Test (DAET) drawings can be used as benchmarks against which students' drawings can be compared to assess the extent to which students' perceptions of engineers and their work is aligned with that of these engineers' self-perceptions.

The themes described above guided the development of a curriculum for a STEM Club. The STEM Club was for identified gifted fifth grade girls. A female scientist/engineer led the club. The girls' perceptions were accessed using the Draw-A-Scientist-Checklist (DAST-C) (Finson, et al., 1995); Enhanced-Draw-A-Scientist-Test (E-DAST) (Farland-Smith & McComas, 2009); and Draw-An-Engineer-Test (DAET) (Thompson et al., 2008; Knight & Cunningham, 2004) instruments administered before and after participation in STEM Club. The girls held well-developed, stable perceptions of scientists and drew traditional, predominantly male scientist images. After participation in STEM Club, they drew traditional images of scientists; however, female images increased by 30%. By contrast, the girls' perceptions of engineers were far more plastic than their perceptions of scientists. By the last STEM Club meeting, they

drew realistic images of engineers involved in design, laboratory investigation and testing activities. Female engineer images increased by 42%. These results suggest that a female scientist/engineer mentor in an informal club setting can have a significant impact on gifted fifth grade girls' perceptions of scientist and engineer gender. STEM Club participation developed realistic perceptions of engineers among this group of fifth grade girls.

MANUSCRIPT I

The Image of the Scientist: What We Know Today

This manuscript is prepared for submission to the peer-reviewed journal, *School Science and Mathematics* and is the first of three manuscripts prepared for a journal-ready doctoral dissertation.

The Image of the Scientist: What We Know Today

Abstract

Over a decade since Finson's 2002 review article, "Drawing a Scientist: What We Do and Do Not Know After Fifty Years of Drawings", images of scientists continue to be created and promoted in popular media. The impact of these images on students from elementary school age to college age is well established. Drawing based instruments still play an important role in accessing perceptions of scientists. There are now two new versions of the Draw-A-Scientist-Test (Chambers, 1983), the E-DAST (Farland-Smith & McComas, 2009) and the M-DAST (Walls, 2012). Studies using drawing based instruments extend to children from under-represented minority groups in developed countries as well as to general populations in developing countries. There is progress over these 10 years as more realistic images of scientists are available in the popular media. Likewise, interventions that give children direct experience working with scientists replace stereotypical scientist images with accurate ones. Work is needed to overcome the reticence of scientists to communicate their self-perceptions so that these self-perceptions can be available as yet one more resource for science educators to foster accurate scientist images.

Images of scientists abound in popular print, film and television media. It is important that science educators be aware of these images because the stereotypes that they reveal have significant implications for science education not only in the United States and Europe, but in developing nations of the world as well. This paper includes recent trends in images of scientists presented in film and television media against a backdrop of scant and dated knowledge about how scientists perceive themselves. Images of scientists presented in trade books and textbooks are included because they, too, play a role in how K-20 science education stakeholders, students and teachers, promote and acquire perceptions of scientists. For over 50 years, the use of drawings became well established as a tool to access the perceptions of scientists held by these science education stakeholders. The resultant literature dating to 2002 was documented and published by Finson in *School Science and Mathematics*. In the spirit of Finson's survey, this paper reviews the use of drawings to study K-20 students' and in-service teachers' perceptions of scientists from Finson (2002) through 2012.

Scientist images relate to what Schibeci (1986, p. 139) referred to as "school science", i.e. "the natural sciences (physical and biological) sciences". Hence, "scientists" will be defined as practitioners of one of these natural sciences, "those who do '[natural] science' " (Hills & Shallis, 1975, p. 471). Images of those "who teach it [science]", i.e., science educators; those who "write about it [science]" (Hills & Shallis, 1975, p. 471); and those who apply science, i.e., medical practitioners and researchers, engineers, inventors and technologists (Aikenhead & Ogawa, 2007) will not be considered. Likewise, images of social scientists will be excluded, "not because they are unimportant, but because it is school science, as previously defined, that is the concern" (Schibeci, 1986, p. 139) and the context for this paper.

Overview: Why Stereotypes of Scientists Matter

A stereotype, whether of a scientist or any minority group within a society, is a convenient mechanism for an uninformed society to manage a complicated issue. The stereotypical image of the scientist, when viewed as such cultural shorthand, demonstrates limited understanding of scientists and of science. Such stereotypes are especially dangerous for children who may derive "a distorted view of what scientists do and who they are" (Bowtell, 1996, p. 10) resulting in negative attitudes toward science and science careers (Osborne, 2003). Stereotypes may play a role in the negative stereotyping of females' ability to achieve success in mathematics or the physical sciences. Such negative stereotypes, along with the stereotype threat they generate, contribute to shaping females' intellectual identity and can hinder their performance in mathematics and physical science (Robelen, 2012; Steele, 1997).

Another consequence of stereotyping is that the target group, whether it is a gender group, ethnic minority, racial minority, or scientists, internalizes the stereotypical images thrust upon them by society (Tatum, 2000). In the extreme, the stereotype becomes a self-fulfilling prophecy. The power of the scientist stereotype is readily apparent in *Materials Research Society Bulletin* (Saini, 2012), where a female materials chemist, Sujata Kumdu, at University College, London commented on the challenges she faced as a female scientist working in the predominantly male physical sciences. According to the article, "she used to feel under pressure to be 'less feminine'. In the end, she realized that she had no choice but to unmask her personality. ‘I feel now that, if I can enjoy music, dance, shoes and handbags, and still push the boundaries of science, then that is something to be proud of…to stand against the stereotype, without the fear of not being taken seriously’ (Saini, 2012, p. 548)”.

An understanding of current trends in how scientists are perceived is needed to inform efforts to engage scientists and the public in “mutual conversation” (Pandora & Rader, 2008, p. 363) that can overcome the prevailing “communication failure” (Haynes, 1994, p. 6). Once developed, communication can guide interventions to provide children with accurate, authentic scientist images. Interventions can counter pressures that might make scientists and prospective scientists feel compelled to conform to a stereotype. Such interventions can support individuals who might be inclined to avoid science altogether, rather than resist the stereotype.

Rather than embrace an unappealing image of science, youth in developed countries opt to avoid science (Osborne & Dillon, 2008). Studies by highly respected institutions in the United States and Europe reveal diminishing interest in science, technology, engineering, and mathematics (STEM) disciplines among young people in these developed areas of the world. Reports in the US from the National Academies (National Academy of Sciences, National Academy of Engineering, Institute of Medicine and the National Research Council) along with various government and business groups paint a gloomy picture for the future of the United States' competitiveness in STEM (“U.S. Missing Goal”, 2008). A recent report by a coalition including the U.S. Chamber of Commerce and the National Defense Industrial Association predicts a substantial shortfall from the 400,000 new STEM graduates needed by 2015 (U.S. Missing Goal, 2008). In Europe, the Nuffield Foundation of the

United Kingdom brought science educators together from nine European countries to address these same issues (Osborne & Dillon, 2008). They generated a report entitled, *Science Education in Europe: Critical Reflections* (Osborne & Dillon, 2008).

This report highlighted a startling fact. "The more advanced a country is [as measured according to the UN Index of Human Development], the less its young people are interested in the study of science (Osborne & Dillon, 2008, p.13)." Analysis of the 1999 Third International Mathematics and Science Study (TIMSS) data reveals that highly achieving students have fewer positive attitudes toward science than their lower achieving counterparts. *Science Education in Europe: Critical Reflections* attributes this lack of interest, in part to an unengaging, memory-based curriculum that presents science for scientists rather than for general scientific literacy (Osborne & Dillon, 2008).

Youth in developed (industrialized) countries place a premium on creativity and innovation and do not see STEM careers as a means for self-realization (Osborne & Dillon, 2008). These young people (ages 12-13) hold a stereotypical image of the scientist (Koren & Bar, 2009b). The stereotypical image is one of a solitary, be-spectacled, white male working at a laboratory bench surrounded by equipment associated with chemistry (Koren & Bar, 2009b). Sometimes that image is exaggerated to the point of caricature, the mad scientist (Koren & Bar, 2009b; Gregory & Miller, 1998). At best, high school students in an industrialized country are likely to hold ambivalent images of scientists (Koren & Bar, 2009b). These ambivalent images are consistent with Osborne and Dillon's (2008) finding that in economically advanced countries there is a mismatch between the values held by youth and the "perceived values associated with science and technology" (Osborne & Dillon, 2008, p. 17).

Gregory and Miller (1998, p. 131) raise the possibility that the images of scientists shown in drawings are not representations of what people "think scientists look like." Instead, they are deliberate choices of a representative, well-established icon for the purpose of communication with other people (Scantlebury et al., 2007; Gregory & Miller, 1998). Symington and Spurling (1990) suggest that stereotypical images of scientists drawn by children may not reflect what the children actually know about scientists. Rather, they base the images on the popular scientist stereotype so that the images are widely recognized as representing scientists. Such use of an iconic image seems plausible since prominent scholars in education also invoke the stereotype of the "white-coated demigod" (Lincoln & Guba, 1985, p. 92) to depict a scientist. According to Rahm (2007), "the images [stereotypical images of scientists] and notions themselves seem resistant to change and appear to have been taken as unquestionable realities" (p. 519). It can be difficult to resolve the complex "entanglement of fact and value" (Putnam, 2002, p. 34) that these stereotypes represent. As Roslynn Haynes observes, "Popular belief and behavior are influenced more by images than by demonstrable facts" (Haynes, 1994, p. 1). These stereotypical images and their implicit attitudinal and evaluative components are real. Hence, the stereotypes must be considered for the power of influence they wield. The very fact that people, including elementary school age children, use such caricatures knowing that they will be recognized by others and effectively communicate the meaning "scientist" has profound implications for scientists and science educators.

A link exists between portrayals of scientists in the media and student attitudes toward science (Jones & Bangert, 2006; Boylan et al., 1992). According to Bowtell (1996), children's exposure to stereotypical scientist characters appearing in television programming aimed at children and in television commercials contributes to children's perceptions of science and scientists. In a study of primary school children (Year 5) in the United Kingdom, stereotypical images of scientists and engineers, rather than an intrinsic dislike for science and engineering, are responsible for students' lack of interest in becoming scientists or engineers (Silver & Rushton, 2008). "[C]loudy career paths and low wages relative to other specialized careers such as medicine, law and finance" (Toppo & Vergano, 2009, p. 1) also contribute to avoidance of STEM careers.

Stereotypes: Indicators of the Relationship Between Scientists and the Public

The image of science and scientists held by the public has changed from a largely positive image in the World War II era to "ambivalent" (Gregory & Miller, 1998, p. 3) by the 1970's. Immediately after World War II, when scientists were "held in high regard" (Gregory & Miller, 1998, p. 3), a hierarchical relationship between scientists and the public prevailed. Scientists, the experts, validated new knowledge and the public, presumably non-experts, accepted their authority (Patton, 2002; Pepper, 1967). During the twentieth century, scientists became mythic figures simultaneously inspiring awe and fear. The popular view of "science" came to be construed as "physics and a few other fields with similar methodologies" (Diamond, 1999), such as chemistry.

The "intricate relationship" (Mitias, 1970, p. 135) between science and society is to some extent dysfunctional. Despite the recognition forty years ago "that realistic and favorable concepts of and attitudes toward science by non-scientists are essential for continued support of scientific research and exploration" (Mitias, 1970, p. 135), there nevertheless exists a significant "disconnect" between scientists and society (Haynes, 2006). Thirty-five years ago, Hills and Shallis (1975) found that scientists' self-perceptions diverged considerably from non-scientists perceptions of scientists. The seeds for the modern "disconnect" between science and society were first sowed in the late 16th century when the Royal Society was founded in England. With the professionalization of science in the 19th century, a dichotomy, albeit a false one, given their acknowledged interdependence, was firmly established between scientists and society (Gregory & Miller, 1998). Society came to terms with scientists and their work by creating a popular view of science and scientists. A persistent stereotype of scientists (McAdam, 1990) pervades the mass media (Frayling, 2005; Haynes, 1994; Goldman, 1989; Jacobi & Schiele, 1989), children's trade books (Ford, 2006; McAdam, 1990), and high school and college science textbooks (van Eijck & Roth, 2008).

More realistic portrayals of scientists, especially with respect to equal representation of both male and female scientists, are evident in television dramas such as *Crime Scene Investigation (CSI)* (Jones & Bangert, 2006). Neil deGrasse Tyson, an African-American astrophysicist and author appears as the outgoing, engaging host of PBS (Public Broadcasting Service) *NOVA* and *NOVA scienceNow* (Hayden Planetarium, 2010). A recent movie, *2012* (Emmerich, 2009), features a scientist, Adrian Helmsley, as one of the lead characters. As a youthful, African-American geologist, Helmsley defies the stereotypical scientist image. Through organizations like the Union of Concerned Scientists, scientists have taken collective action to prevent the misuse of science and to take scientific facts about such controversial environmental issues as climate change directly to the public. Yet another cause for optimism comes from President Obama's support of nationwide STEM initiatives. On November 23, 2009 (Prabhu, 2009), he remarked, "Scientists and engineers ought to stand side by side with athletes and entertainers as role models, and here at the White House we're going to lead by example. We're going to show young people how cool science can be."

Over fifty years ago, Eiduson and Holton addressed scientists' self-perceptions (Eiduson & Holton, 1960). They recognized that scientists' self-perceptions played an important role in establishing a schism between science and other intellectual disciplines, a "gulf of mutual incomprehension" (Snow, 1965, p. 4). Thirty-two years later, images of science and scientists, this time those promoted in the popular media, were again identified as playing an important role in creating a rift between science and students (Boylan, Hill, Wallace & Wheeler, 1992).

Starting in the 1970's, the public was no longer willing to accept scientists' authority without question. Scientists' credibility came to be in serious jeopardy when they were viewed as "bewigged judges in court-remote, out of touch, unconsultative, much given to pontificating and immune from criticism" (Frayling, 2005, p. 226). Carl Sagan (1995, p. 25-26) comments stridently on this state of affairs: "We've arranged a global civilization in which the most crucial elements … profoundly depend on science and technology. We have also arranged things so that no one understands science and technology. This is a prescription for disaster." Moreover, a 2009 survey by the Pew Research Center for the People and the Press and the American Association for the Advancement of Science (AAAS) of 2000 members of the public and 2500 "scientists", i.e. members of the AAAS, reveals a significant gap between the public's and the scientists' views on science issues including climate change, evolution and America's scientific leadership position (Dean, 2009). The survey also reveals that scientists hold a relatively low opinion of the public, with 85% citing public ignorance of science as a major problem. By contrast, the public generally holds the scientists in high regard (Dean, 2009).

Scientists' Self-Perceptions

The literature on scientists' self-perceptions is scant and outdated. What little research exists is limited to male scientists, exclusively. Only 5 references (Hills & Shallis, 1975; "The Scientist as Stereotype", 1975; Storer, 1963; Eiduson & Holton, 1960; Morris, 1957) report on scientists' self-perceptions. These studies are between 37 and 53 years old. The most recent of these references both date from 1975 and the oldest from 1960. Two references report the results from a survey of *New Scientist* and *New Society* readers that probed their images of scientists by asking what came to mind when they thought of a scientist (Hills & Shallis, 1975; "The Scientist as Stereotype", 1975). Scientists who responded characterized themselves as "approachable, sociable, open, unconventional, possessing many interest [sic] and being popular" (Science News, 1975, p. 167).

Eiduson and Holton (1960) report in *Science* on a study concerning the self-images of forty male academic natural scientists. These male scientists saw themselves as intellectuals, driven by a search for truth, rather than monetary reward or recognition. Their happiness and fulfillment came from their work where rigor and persistence were highly valued. The scientists advocated "sciencemanship" (Eiduson & Holton, 1960, p.

553) to communicate their findings effectively so that they would be put to use. Such sciencemanship also involved shunning the "eccentric" (Eiduson & Holton, 1960, p. 553) colleague or student. Holton, a professor of physics at Harvard University, recognized alienation of science from the larger culture as long ago as 1960 (Holton, 1960). His *Science* article (Holton, 1960) is significant as a reflexive piece. Eiduson, a physicist, belonging to one of the iconic disciplines typically represented in the popular view of the scientist, acknowledged the "public images" (p. 1188) of science.

In the early 1960's, one particular group of scientists, the American Chemical Society (ACS), attempted to gain a better understanding of their group identity using a mail survey of one-ninth of the ACS membership (Storer, 1963). When completed surveys were returned, "the small number of women and non-chemists were eliminated" (Storer, 1963, p. 410). This *a priori* elimination of women's responses implicitly embodied the notion that the chemists perceived themselves as an exclusive profession of males. Women were indiscriminately relegated to the category of the "non-chemist", without inquiry into their academic, or other, credentials. [It is encouraging to note that a brochure distributed by the ACS in late 2009 as part of a membership drive prominently displays a photograph of a female Ph.D. chemist (American Chemical Society, 2009).]

The Popular Image of Scientists

When the images held by non-scientists are compared to those held by scientists, the contrast is jarring. Are the non-scientists and scientists describing the same group of people? While scientist survey respondents described themselves in generally positive terms, non-scientist respondents characterize the scientists negatively as "remote, secretive, conventional, having few interests and unpopular" ("The Scientist as Stereotype", 1975, p. 167; Hills & Shallis, 1975). Other non-scientists' comments were critical of a presumably masculine personal appearance, bald, middle-aged, be-spectacled, poorly dressed and short. Representative non-scientists' comments include: "an uncultured illiterate"; "largely unjustified arrogance"; "often blind to the disastrous consequences of his work"; and as allowing "intellectual curiosity to triumph over moral responsibility" ("The Scientist as Stereotype", 1975, p. 167).

Roslynn Haynes' book, *From Faust to Strangelove* (1994), exhaustively surveys how the scientist has been portrayed in western literature from Chaucer's 14th century *Canterbury Tales* to 1980's science fiction novels. Her survey provides insight into how non-scientists perceive scientists as well as of the relationship between science and the public in western society. When scientists are portrayed in popular science magazines they are depicted according to three archetypal images: (1) the inhuman, dangerous mad scientist; (2) the authoritative teacher who transmits dogmatic knowledge with a dreary blackboard and chalk; and (3) an everyday human being (Jacobi & Schiele, 1989).

Non-scientists have produced a considerable body of work on scientist images over the past 55 years. However, it is striking that no new study of scientist self-perceptions has appeared in over 35 years since the “Scientist as Stereotype” (1975) and Hills & Shallis (1975) studies. An explanation for scientists’ inattention to image, whether how they perceive themselves or how others perceive them, may reside in the culture of science. Visual or verbal portraits of scientists are rarely found together with their work in peer-reviewed scientific journals. In that context, the face or the personality of the scientist is irrelevant. Perhaps even more than irrelevant, it is anathema to the “myth of a scientific community working anonymously to construct a common, universal knowledge” (Jacobi & Schiele, 1989, p. 759). Consistent with this mythology, “science is enunciated without reference to the enunciator”. Even scientific language “strives for absolute intellectualization, that denies all emotion and that it submits to an ideal from which all subjectivity would be excluded” (Jacobi & Schiele, 1989, p. 750).

Images of Scientists in Film and Television Media

While scientists remain reticent in communicating their self-perceptions, the popular media are prolific in creating scientist images. The negative characteristics of the scientist identified by the non-scientist *New Scientist* and *New Society* readers in 1975 persist in the popular, i.e. intended for a mass, rather than specialized or scholarly audience, film and television media. Most U.S. citizens derive their conceptions of science from “prime-time entertainment” (Gerbner, 1987, p. 110), television shows. These shows have the potential to shape scientist images held by the public. Commercial television shows also strongly impact how science education K-20 stakeholders, especially K-12 students, perceive science and scientists (Vilchez-Gonzales & Palacios, 2006).

Generally, the images of scientists portrayed in film and television media, especially children's Saturday morning television programming (Schibeci, 1986) are negative stereotypes. This media scientist is a brilliant, but evil male genius. He simultaneously evokes "respect and terror" and definitely does not evoke any desire to "emulate him" (Hassard, 1990, p. 10). Media stereotypes of female scientists, though rare, are hardly more appealing. Schibeci (1986) described a female scientist comic strip character, Dr. Payne. She was "young, and attractive, though spectacled" (Schibeci, 1986, p. 148). "As a scientist she is perfectly capable of committing one of the many anti-social or dangerous acts that typify her kind [the scientist] (Schibeci, 1986, p. 148), despite her superficial beauty."

Much of children's' and adolescents' informal science knowledge and their images of scientists come from the popular audiovisual medium of cartoons (Vilchez-Gonzales & Palacios, 2006). In 100 cartoon episodes on free access Spanish television, physics images dominate, representing 46% of the science images. Physics images are followed by general science (19%), chemistry (8%), biology (7%), earth sciences (7%), environmental sciences (4%), mathematics (5%) and others (4%). According to Vilchez-Gonzales & Palacios (2006), cartoons and popular comics provide a distorted, elitist image of science as isolated from its environment through the use of jargon and obscure mathematics.

This image of the evil genius, mad scientist or, at best, an "eccentric bespectacled man who wears a white coat and works in a laboratory containing a lot of glassware" (McAdam, 1990, p.102), persists in the public mind. Meanwhile, "counternarratives" of "intimate" scientists such as Luther Burbank or Frank Capra's television character from the 1950's, "Dr. Research", have faded (Pandora & Rader, 2008, p. 361). It is not surprising then that 44% of American adults "couldn't identify a single scientist, living or dead, whom they'd consider a role model for the nation's young people" ("Are We Science Savvy Enough to Make Informed Decisions?", 2008) according to a Harris Interactive survey of 1,304 American adults.

The *Curious George* series (PBS KIDS, 2010) introduces pre-schoolers to science, engineering and math concepts. Scientist cartoon characters on the series are portrayed as highly knowledgeable and intelligent, yet affable and approachable. The realistic scientist characters reflect gender and ethnic diversity despite the fact that all wear white lab coats. The lead scientist character is a woman of color, Professor Wiseman. *Bill Nye the Science Guy* (Bill Nye, 2009) with his light blue lab coat and bow tie clad character may be outgoing and funny. However, it does perpetuate several elements of the stereotypical scientist image including the lab coat, male gender and white, European-American ethnicity.

Given the power of television to deliver images of science to a large audience, it is encouraging that a recent series, *Crime Scene Investigation (CSI),* includes more realistic portrayals of scientists (Heyman, 2008; Jones & Bangert, 2006; Bort, 2005), especially, equal numbers of male and female laboratory scientists. There is evidence for a "*CSI* effect" (Jones & Bangert 2006, p. 39). Seventh grade girls who watched the show drew a greater percentage of female scientists on a Draw-A-Scientist (DAST) activity. When interviewed, the girls explained that seeing female scientists on the *CSI* television show was a factor that influenced them to draw female scientist images (Jones & Bangert, 2006).

Another television series, *The Big Bang Theory*, has not generated an impact similar to the *"CSI* effect", despite featuring scientists and engineers as the main characters (Blikenstaff, 2011). Characters include Sheldon and Leonard, two male physicists. They have two male friends, Rajeesh, an astrophysicist, and Howard, an engineer. All the male characters work at California Institute of Technology (Blickenstaff, 2011). Many scenes in the series revolve around accurately portrayed particle physics science content (Heyman, 2008). *The Big Bang Theory* has three female scientist characters: Leslie, a physicist; Amy, a neuroscientist; and Bernadette, a microbiologist (Blickenstaff, 2011). Both male and female scientists in *The Big Bang Theory* are shown in everyday situations, but much of their behavior reinforces "nerd" and "geek" stereotypes. According to Blickenstaff (2011), "They [the scientists] are very intelligent, they have a deep and abiding love of science fiction, and they have difficulty relating to non-scientists (Blickenstaff, 2011, p. 14)".

A welcome contrast to these past stereotypical portrayals of scientists is the balanced portrayal of the African-American geologist, Adrian Helmsley, in the movie *2012* (2009). In this movie Helmsley is acutely aware of moral and ethical issues. Hardly a pawn of the military and political establishment, he proactively interacts with these powers to influence policies concerning who would be admitted to the United States ark and thus saved from the catastrophic global flooding that had occurred in the wake of massive world-wide earthquakes. He is well-read and equally comfortable conversing with field geologists or art historians. Helmsley has a "normal" emotional life. He cares deeply about his friends and ultimately falls in love with Dr. Wilson, the art historian daughter of the U.S president.

Women scientists fare particularly badly at the hands of Hollywood filmmakers. They are often portrayed as white lab-coated, spectacled "research assistants or career scientists with boys' names who badly needed to rediscover their feminine mystique" (Frayling, 2005, p. 201). Even when they are shown as equal members of a team, they become "simpering victims" (Frayling, 2005, p. 201) at the first sign of threat.

A more balanced female scientist image is developed in the motion picture, *Avatar* (2009). Dr. Grace Augustine (Sigourney Weaver), exobiologist and the head of the Avatar program, is not intimidated by the military authorities on Pandora. Contrary to the stereotype, she is aware of the moral and ethical issues related to exploitation of the Na'vi, indigenous inhabitants of Pandora as a result of the RDA Corporation's unobtanium mining operations.

Images of Scientists in Trade Books and Textbooks

Science trade books can be an elementary school classroom resource for teaching that science is a human endeavor (Farland, 2006a; Farland, 2006b). According to Farland (2006a, 2006b), these trade books generally avoid the cartoon image of the scientist. Nevertheless, science trade books do perpetuate the image of scientists as overwhelmingly older white males. Scientists are portrayed as exceptionally hard working and highly intelligent (Ford, 2006). When biographical information is provided in an effort to "humanize" the scientists, this information is often isolated from the rest of the text in marginal boxes establishing a gulf between the person of the scientist and the scientific work.

Textbooks, likewise, exert a strong influence on the images of scientists held by elementary and middle school students (Turkmen, 2008). This influence is apparent in the striking similarities observed between children's drawings of scientists and figures from science textbooks. Curricula developed for grades K-12 since the early 1970's present "inclusive" images of scientists as "regular people" and develop connections between science and everyday life (Barman & Ostlund, 1996, p. 16). Textbooks also play a role in establishing high school and college students' images of scientists.

Accessing Scientist Images: Modifications of the DAST

In order to learn how these scientist images impact science education stakeholders, a probe is needed to access their images of scientists. As stated previously, drawings have proven to be a robust instrument for acquiring these data over the last 50 years. Finson (2002) traced the history of the Draw-a-Scientist-Test (DAST) from its origins in the work of Margaret Mead and Rhonda Metraux (Mead & Metraux, 1957) through its introduction as an instrument to access children's perceptions of scientists (Chambers, 1983). Finson (2002) also considered the extension of Chambers' (1983) seven stereotypical elements in the DAST-C introduced in 1995 by Finson, Beaver and Cramond (1995). The DAST has been further adapted to access images of engineers (Knight & Cunningham, 2004; Thompson & Lyons, 2008) and mathematicians (Pickle & Berry, 2000).

Work is ongoing to evaluate the methodological soundness of DAST-based research. DAST images should be used with caution as a psychological projective test related to science coursework and career choices, or as an indicator of science-self-efficacy or self-perception for elementary school age children (Losh, Wilke, & Pop, 2008). Recently revisited is the adequacy of a single drawing to represent a research participant's concept of a scientist (Farland-Smith & McComas, 2009). Sets of multiple scientist drawings more accurately represent students' knowledge about science and scientists. The Enhanced Draw-A-Scientist-Test (E-DAST) (Farland-Smith & McComas, 2009) allows students to construct multiple scientist drawings. The E-DAST scoring rubric characterizes drawings on the basis of three criteria: the scientist's "appearance", "location" and "activity" (Farland-Smith & McComas, 2009, p. 49-50). These criteria are characterized and scored as "Can't Be Categorized" (0), "Sensationalized" (1), "Traditional" (2) or "Broader Than Traditional" (3) (Farland-Smith and McComas, 2009, p. 50). According to this rubric, a low score is associated with a caricature or stereotypical scientist image. A high score indicates an authentic image of a scientist.

The M-DAST (Walls, 2012) adds three modifications to Chambers' (1983) instrument. The M-DAST requires a student to provide a name for a scientist image. The name helps in assigning gender to scientist images drawn as stick figures or without any clear indicators of gender. Students are also required to write and read aloud a story about the scientist image. Finally, students state explicitly the race of their scientist images, thereby avoiding possible incorrect racial assignment of drawings on the basis of the presence or absence of shaded skin.

Images of Scientists Held by Students in Grades K-12

New studies address how special populations of students perceive scientists. While most of this work involves groups of students with mixed abilities, one study used the DAST to assess the impact of a museum's after-school program on gifted fourth and fifth grade students (Melber, 2003). The DAST-C is valid for accessing the perceptions of culturally diverse students, specifically, Native American and African

American eighth graders (Finson, 2003). These diverse groups of children include ethnic groups, like the Native American and African American students of the Finson (2003) study, and girls who are traditionally under-represented in science in the United States.

Studies using the DAST with students also come from developed and developing countries around the globe. Generally, students from underrepresented ethnic groups in developed countries and students from developing countries tend to draw less stereotypical scientist images than their dominant ethnic group or developed country counterparts. Often, students in developing countries draw idealized portrayals of scientists and highlight their efforts to help people live better lives. Sometimes, students incorporate characteristic elements from their culture into their scientist drawings. Overall, these results challenge the notion that children worldwide hold a stable, monolithic scientist stereotype. Representative studies include Navajo children in the United States (Monhardt, 2003); elementary and middle school children in Israel (Koren & Bar, 2009a); Colombian and Bolivian 5^{th} – 11^{th} graders (Medina-Jerez et al., 2010); elementary and secondary school age Turkish children (Akcay, 2011; Buldu, 2007; Korkmaz, 2007; Turkmen, 2008); primary and secondary school students in Hong Kong (Fung, 2002); and elementary school age children in China (Farland-Smith & McComas, 2009).

Scientist Images in the United States and Israel

African-American third grade students draw images that include traditional stereotypical elements: "glasses, professional dress (suit and/or tie), lab coat, mature age, and male" (Walls, 2012, p. 15), but depict the scientists' ethnicity/race as "African-

American or, a non-White individual" (Walls, 2012, p. 17). Fifth-to-ninth-grade girls who work beside scientists in a week long summer camp create drawings that include personal characteristics, such as glasses, hairstyle and facial hair, in their drawings. The "scientists had become real people to them (Farland-Smith, 2012, p.15)."

Navajo elementary school students (grades 4-6) in the western United States typically draw European-American scientists. However, one male student drew a Navajo scientist, a medicine man (Monhardt, 2003). Despite the fact that most of the Navajo fourth-sixth graders draw scientists with European facial features, overall their DAST-C scores indicate that they hold less stereotypical views of scientists than typical United States elementary school students, as reflected in the Barman (1999) nationwide study. However, another explanation of the low DAST-C scores (Monhardt, 2003) is that these Navajo children are so completely unfamiliar with scientists that stereotypical DAST-C indicators are absent from their drawings. Significantly, Navajo elementary school students incorporate elements from their own cultural experience into their DAST-C drawings. These elements include outdoor settings, local geological formations, horses and even gang symbols (Monhardt, 2003). Only 47% of the Navajo students' DAST-C drawings show male gender. The predominant portrayal of female scientists may be attributed to the fact that the Anglo female researcher was introduced to the children as a scientist or to the matriarchal Navajo culture where women are "generally viewed in roles of power" (Monhardt, 2003, p. 31).

Like the United States, Israel includes minority populations, such as Arabic-speaking Bedouins, who are economically deprived and have little familiarity with western science. The scientist images held by the dominant population, Hebrew-speaking students ages 9-14, differ from those held by their Arabic-speaking Bedouin peers (Koren & Bar, 2009a). The Hebrew-speaking students' images resemble the stereotypical images held by students in developed countries. The Bedouin students' images include traditional Muslim dress. Drawings of male scientists predominate for both groups.

Scientist Images in Developing Countries

Colombian and Bolivian 5th to 11th grade students draw scientist images that mirror results obtained in the more developed nations, as in the United States and Israel, i.e., higher socioeconomic status students generally draw stereotypical white male scientist images (Medina-Jerez, Middleton, & Orihuela-Rabaza, 2011). A lack of traditional stereotypical elements in the images drawn by lower socioeconomic status students may be attributed to their incomplete knowledge of science resulting from inadequate school experiences. Specifically, Colombian students from rural and public schools draw stereotypical scientist images, while their less-advantaged Bolivian counterparts draw relatively fewer stereotypical images. However, wealthy Columbian students attending private schools depict scientists less stereotypically than both the Columbian rural and public school students and Bolivian students.

Turkish students ages 5-8 and in grades 5-11 (Akcay, 2011; Korkmaz, 2009; Turkmen, 2008; Buldu, 2006) generally draw stereotypical white, male scientist images. Scientist images become less stereotypical as students advance into secondary school (Akcay, 2011). For young children, 5-8 years of age, higher parental education level and socio-economic status are associated with less stereotypical scientist images (Baldu, 2006). Only female students draw images of female scientists (Akcay, 2011; Buldu, 2006).

Scientist Images in Asia

A study of 1350 elementary school students in the United States and China using the E-DAST shows that cultural influences determine how children perceive what science is and where and by whom it is done (Farland-Smith, 2009). Like the Navajo students (Monhardt, 2003) in the United States, Chinese students incorporate elements from Chinese culture into their scientist drawings (Farland-Smith, 2009). Consistent with the Chinese custom of nap taking at mid-day, Chinese students include beds in their drawings. Basement laboratory venues, while common to United States students' drawings, are absent from the Chinese students' drawings. Since most of the Chinese students live in high-rise apartments, they may be unfamiliar with basements (Farland-Smith, 2009). In the drawings by Chinese students, the scientists are surrounded by robots, rather than by beakers or other chemistry-related equipment (Farland-Smith, 2009). However, male gender and European ethnicity appear to be two elements of the stereotypical scientist image that persist significantly across cultures. Likewise, Hong Kong Chinese primary through secondary school students, ages 7-17, draw stereotypical predominantly male scientist images (Fung, 2002). As in Turkey, only female students draw female scientist images.

Images of Scientists Held by College Students

While the body of literature documenting college students' perceptions of scientists is smaller than that for K-12 students, several studies are reported in the literature since the Beardslee & O'Dowd study (1961) revisited by Finson (2002). Stereotypical scientist images persist in drawings by United States and Russian college students (Bovina & Dragul'skaia, 2008; Thomas, Henley, & Snell, 2006; Flannery, 2001).

United States college students in a science, technology and society course, as well as college students in a psychology or computer science course, produced stereotypical scientist drawings on the DAST that closely resembled those of elementary school children in the fourth grade and beyond (Thomas, et al., 2006; Flannery, 2001; Chambers, 1983). The white lab coat is the most "ubiquitous element" among all these drawings (Flannery, 2001, p. 947). The lab coat is a masculine status symbol that broadcasts power and control, a "different way of behaving", and a "better way of thinking" that distinguishes the scientist as a "breed apart" (Flannery, 2001, p. 947). However, not all scientists wear white lab coats, of course; typically, chemists and biologists may wear lab coats.

Like their United States counterparts, Russian college students acknowledge a scientist's high intellectual capacity, but "his personality and social position are viewed with disdain and pity" (Bovina & Dragul'skaia, 2008, p. 45). It can be inferred from the use of the masculine "his" that the predominant image was that of a male scientist. Poverty is also an attribute of the scientist. These results reflect the diminution of scientists' social status in post-Cold War Russia along with adoption of western values.

Images of Scientists Held by K-12 Teachers

Studies in the United States confirm that stereotypical images of scientists persist among pre-service and in-service teachers. In-service teachers' Draw-a-Scientist-Test (DAST) images show stereotypical images of white males, "serious, sometimes ominous, people who pursue science as solitary investigators working in an environment devoid of social interactions" (McDuffie, 2001, p. 18). A 2006 study of nineteen female pre-service elementary school teachers found perceptions of solitary male or genderless scientists clad in lab coats or drab attire. They were accompanied by traditional symbols of science, particularly chemistry, including flasks, Bunsen burners and microscopes (McCann, 2006). The scientists are portrayed as cold and dispassionate even with respect to the experimental work depicted along with the scientist image. These pre-service elementary school teachers had already taken a science methods course where they examined their own attitudes toward science and received explicit instruction on the nature of science, yet the stereotypical image persisted.

Nigerian pre-service science teachers also bring stereotypical images of scientists with them to science education courses (Mbajiorgu, & Iloputaife, 2001). Likewise, Israeli pre-service teachers hold traditional, predominantly male, physicist or chemist images (Rubin, Bar, & Cohen, 2003). However, the ethnicity of the male figures differs depending on the cultural background of the pre-service teacher. Hebrew-speaking pre-service teachers draw "a typical Western male" (Rubin et al., 2003, p. 821), while Arabic-speaking pre-service teachers draw an Arab male. This incorporation of cultural elements into pre-service teacher scientist drawings mirrors trends observed in Hebrew-speaking and Arabic-speaking children's scientist drawings (Koren & Bar, 2009a) as already summarized in the preceding section of this review.

Charting a Course for 2022 and Beyond

During the decade that has elapsed since Finson (2002) published his review paper, there are several "bright spots" that highlight progress in promoting realistic images of scientists in films and television programming. Particularly encouraging are images that reflect gender and ethnic diversity and that are inclusive of women, women of color and African-American men. Such positive images appear in PBS television shows like *Curious George* (PBS KIDS, 2010), commercial television shows like CSI (Heyman, 2008; Jones & Bangert, 2006; Bort, 2005), and movies like *2012* (2009). These images have the potential to replace the iconic stereotype of the traditional middle-aged European male. However, science educators must exercise continued vigilance, since popular television shows like *The Big Bang Theory* still perpetuate unattractive nerd and geek stereotypes.

Science education researchers continue to monitor the images of scientists held by students in grades K-20 and their teachers. The DAST instrument has been a significant research tool for this community for over 50 years. It is reassuring that neither this instrument, nor its usage has been stagnant during this time. Instead, researchers have been introspective and diligent in continually reevaluating the methodological soundness of the DAST. Modifications of the DAST, the E-DAST (Farland-Smith & McComas, 2009) and the M-DAST (Walls, 2012) are the results of this introspection. Especially significant is the awareness of global, multicultural perspectives and critical examination of the DAST to determine whether it can effectively access the perceptions of minority populations in developed countries as well as overall populations in developing countries. The DAST has withstood this scrutiny. It has revealed that children around the world do not have a single, monolithic image of a scientist. Rather, they incorporate elements unique to their culture in their scientist images (Farland-Smith & McComas, 2009; Koren & Bar, 2009a; Monhardt, 2003). Such insights gained from the DAST can enable science educators to develop inclusive instruction and curriculum that make science more accessible to groups traditionally underrepresented in science. However, more work exploring how special female populations including high ability, Latina and African-American girls perceive scientists is still needed.

However, based on the absence of any literature on scientist self-perceptions since 1975 (Hills & Shallis, 1975; "The Scientist as Stereotype", 1975), it appears that the scientific community is reluctant to address the issues of image and perception. Rather than engage in introspection, scientists have, instead, superficially considered the practices of science, without delving deeper into their self-perceptions. In a study of scientists' understanding of the Nature of Science (NOS), several scientists representing a variety of disciplines described their scientific practices (Wong & Hodson, 2009). While this understanding is a valuable resource for teaching about NOS, the essence of scientists' self-perceptions remains unexamined. There is a need to fill this gap in the scientist image and perception literature. Researchers who attempt to develop this knowledge face a challenge in overcoming the scientific community's reticence to be forthcoming about how they see themselves as scientists.

Within the last two years, the present authors attempted such a study. They invited 18 science faculty distributed among a diversity of disciplines at a large research university to participate in the study. Not a single scientist responded. Simultaneously, they contacted 12 engineering faculty at the same university inviting them to participate in a study of engineers' self-perceptions. Within 2-3 days of initial contact, 8 engineering faculty had joined the study. Preliminary results from this study indicate that engineering faculty at this university, like the broader engineering community (Clark & Illman, 2006; Engineers Dedicated to a Better Tomorrow, 2006), are acutely aware of the importance of image and perception in students' making coursework and career choices. This recognition along with engineers' proactive involvement with outreach to the STEM education community bodes well for creation of realistic, appealing engineer images over the next decade. Engineers offer an example for their colleagues in the other STEM disciplines who seek to provide accurate images of STEM practitioners for young people.

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MANUSCRIPT II

Engineers' Self-Perceptions: A Phenomenological Study of Engineers in Academia

This manuscript is prepared for submission to the peer-reviewed journal, *Journal of Engineering Education*, and is the second of three manuscripts prepared for a journal-ready doctoral dissertation.

Engineers' Self-Perceptions: A Phenomenological Study of Engineers in Academia

Background

Engineers are stereotyped as "geeks" and "nerds". The engineering profession has recognized the importance of improving the image of engineering (Engineers Dedicated to a Better Tomorrow, 2006). There is a need to document how engineers perceive themselves and engineering.

Purpose (Hypothesis)

The purpose of the study was to learn about the lived experiences of engineers, faculty members holding a PhD in a college of engineering at a research university. Specifically, the study was designed to understand how these engineers perceived themselves and the public as well as how they engaged with the larger community.

Design/Method

A naturalistic or constructivist research paradigm provided the theory base that guided the phenomenology research approach. Engineers were asked to share their lived experiences as engineers in semi-structured in-person interviews. The interview data were analyzed according to a phenomenological reduction methodology (Moustakas, 1994).

Results

All participants identified protecting and serving society as an essential element of their experience as engineers. Other themes that played significant roles in their experiences included their perceptions of the public; the public's perception of engineers; stereotypes; gender; solitary work and team work; hard work/rigor; designing and building; solving problems; and creativity.

Conclusions

The findings of this study are valuable to engineers as well as K-20 education stakeholders as a tool for challenging negative stereotypes of engineers. Negative stereotypes of engineers can be replaced with accurate images constructed from the lived experiences of the participants.

In his book, *To Engineer Is Human*, Henry Petroski wrote, “Though ours is an age of high technology, the essence of what engineering is and what engineers do is not common knowledge (Petroski, 1992, page vi)”. The scant literature relating to images of engineers corroborates Petroski’s conclusion. Given this absence of “common knowledge”, it is not surprising that an uninformed society has created stereotypes of engineers in an effort to make an ill-understood reality manageable.

Vaughan (1990) traced the popular image of the engineer as represented in “popular fiction and film” (Vaughan, 1990, p.301) over 100 years from 1880-1980. During this period, images evolved from the “god-like figure whose power is the power of applied technology” (Vaughan, 1990, page 302) of Jules Verne’s fiction to the heroic figure of the early 20th century. While engineers were still seen in a generally positive light at the end of World War I, they and their work came to be viewed with increasing skepticism. By the 1960’s a distinctly negative image of engineers prevailed, with engineers often associated with war and destructive activity. By 1990, the stereotypical image of the nerd was firmly established. Two movies of that era, *Revenge of the Nerds* and *Revenge of the Nerds, Part II* created the image of engineering students as “intellectual overachievers but as social outcasts” (Vaughan, 1990, page 302). A current television series, *The Big Bang Theory*, brings a group of scientists and an engineer who work at the California Institute of Technology to prime time audiences. While the scientists are portrayed in everyday situations, much of the behavior depicted reinforces “nerd” and “geek” stereotypes (Blickenstaff, 2011).

Misconceptions about engineering and engineers were already prevalent in elementary school age (Authors, submitted manuscript) and middle school age children

(Fralick, Kearn, Thompson & Lyons, 2009; Silver & Rushton, 2008a; Silver & Rushton, 2008b). These children typically did not know what an engineer was or saw them as manual laborers and repairmen. College freshmen assigned masculine gender and personality traits to engineers (Cory & Rezaie, 2008). Faulkner (2000) studied this relationship between technology and gender. The Faulkner study (2000) acknowledged the association between technology and masculinity and the concept that gender influences how men and women approach engineering. It relied on literature references to "argue that engineers' shared pleasures in and identification with technology both define what it means to be an engineer and provide appealing symbols of power that act to compensate for a perceived lack of power or competence in other areas (Faulkner, 2000, p.87)". Faulkner's conclusions represent her interpretation of the literature and are not derived directly from interviews or surveys of engineers.

Stereotypes of engineers are significant for K-20 education stakeholders because of their profound influence on children's choice of field of study and career. Silver & Rushton (2008b) concluded that it is "children's stereotypical images of scientists, rather than an actual dislike of science and design technology that dissuades them from becoming scientists and engineers" (Silver & Rushton, 2008b, p. 66). The engineering profession is likewise aware of the implications for the largely negative stereotype of the engineers. One organization, Engineers Dedicated to a Better Tomorrow, has worked to replace that negative view with a "new, more compelling image" (Engineers Dedicated to a Better Tomorrow, 2006). These efforts indicate a positive trend of introspection and reflexive practice developing within the engineering community; however, the authors are not aware of any studies where engineers "speak" and directly share their self-perceptions. It is interesting to note that even in the significantly more developed literature on scientist images, only five, dated studies address scientist self-perceptions (Hills & Shallis, 1975; Science News 1975; Storer, 1963; Eiduson & Holton, 1960; Morris, 1957).

This study of engineers' self-perceptions is valuable to the engineering community because this introspection can help engineers identify the essential aspects of engineering that they should highlight to create authentic images that can be promoted in outreach and recruitment efforts. Children are being exposed to STEM (Science, Technology, Engineering and Mathematics) education at ever earlier ages. Engineering themes have been introduced on *Sesame Street* where characters and children were confronted with design challenges including a boat, car and tower, (Bybee, 2011). The Next Generation Science Standards (NGSS) explicitly address "disciplinary core ideas" of engineering design as well as the role of engineering in society (NGSS Public Release II, 2013). Information about engineers' self-perceptions documented by this study can be a valuable resource for K-12 educators as they work to implement new science standards. Farland (2006a; 2006b) established that science trade books can play a role in elementary school classrooms for teaching students that science is a human endeavor. Likewise, this study can supplement actual interactions between students and engineers or substitute for them when engineers are unavailable.

Research Design

Research Questions

Three research questions guided the study. "Engineers" were defined as members of a faculty within the college of engineering at a research university and holding a Ph.D. Likewise "public" refers to anyone without formal university-level education in some discipline of engineering.

1. What are the lived experiences of engineers?
2. Within these lived experiences, how do the engineers perceive themselves and the public?
3. Within these lived experiences, how do the engineers engage with the larger community?

Design/Method

The research paradigm, "the basic belief systems" that "we use in guiding our actions" (Guba, 1990, p.18), selected for the present study is naturalistic or constructivist inquiry. This selection was based on the criteria described by Patton (2002). These criteria require that a research paradigm match the research questions, the purpose of the research and the intended audience. The ontological assumptions of naturalistic inquiry allow for multiple, socially constructed realities, such as each engineer participant's lived experience as an engineer. The goal of naturalistic inquiry or constructivist inquiry is to create transferable, rather than generalizable knowledge. According to social constructionism, "individuals seek understanding of the world in which they live and work" (Creswell, 2007, p. 20; Patton, 2002). From multiple individual understandings, a collective reality is generated resulting in the social constructivism paradigm.

Phenomenology was the specific research approach chosen within the broad framework of the naturalistic or constructivist research paradigm. It optimally matched the research question and the nature of the group being studied (Creswell, 2007). The participants in the present study were faculty in a college of engineering at a research university. These individuals all shared the experience of being engineers in a research university setting. The phenomenological approach has as its particular focus the "understanding the essence of the experience" (Creswell, 2007, p. 78). Hence, it was best aligned with the present study's goal of seeking "to describe the essence of a lived phenomenon" (Creswell, 2007, p. 78), i.e., being engineers at a research university. The phenomenological approach was used to elucidate how these engineers experienced their lives and understood their identities.

Phenomenology relies on "descriptions of experiences" (Moustakas, 1994, p. 59). Such descriptions included drawings, along with interviews and field notes that represented engineers' self-perceptions, to "accentuate … underlying meaning" (Moustakas, 1994, p. 58-59). Interviews were semi-structured in the sense that a set of questions was not prepared in advance and then asked of each participant. Prepared questions were avoided because they would constrain the participants' expression within the framework generated by the authors/researchers. Structured interviews with prepared questions would compromise the extent to which the descriptions authentically represented the participants' self- perceptions. The phenomenology approach also allowed for a researcher who was involved and "intimately connected" (Moustakas, 1994, p. 59) with the phenomenon under study.

For this study, the unit of analysis was a group of university engineers who have experienced the phenomenon of being engineers at a research university. Data collected included audio recordings of participant interviews supported by documents, observations and drawings (Creswell, 2007). For this study, the drawings were in the particular format of the Draw-An-Engineer-Test (DAET) (Thompson & Lyons 2008; Knight & Cunningham, 2004). From these data, "significant statements, meaning units, textural and structural description" that allow articulation of the "essence" of the lived experience (Creswell, 2007, p. 61) of being an engineer were obtained.

The phenomenological approach has been used to access the lived experiences of other groups including nurse educators (Grigsby & Megel, 1995); physicists (Ingerman & Booth, 2003); and science educators (Taylor, Jones, Broadwell, & Oppewal, 2008). The Ingerman and Booth study (2003) used a phenomenographic approach which shares with phenomenology "a common focus on exploring how human beings make sense of experience" (Patton, 2002, p. 104). Grigsby and Megel (1995) studied the dynamics of caring among nursing school faculty. Their study was guided by the research question, "How do nurse educators experience caring in their work situations?" (Grigsby & Megel, 1995, p. 411). They interviewed seven nurse educators among three separate nursing programs in one Midwestern state to identify themes that characterized caring in these academic settings. In their study, Ingerman and Booth (2003) interviewed six senior physics students and ten research physicists in the physics departments of two Swedish universities to examine the types of exposition used by each group. The study also considered the implications of these expository styles for the pedagogical interactions that are part of the everyday life of the physicist or physics student. Interviews were 45-120 minutes long. Interviews were recorded on both audio and videotape so that the body language of participants could be captured. The researchers used a semi-structured style designed to explore the physicists' and physics students' relationship with talking about physics. Distinct categories of exposition were identified and evaluated for efficacy in creating physics understanding. The Taylor et al. study (2008) addressed scientists' and science teachers' perceptions of K-12 science education. It applied the phenomenological approach to middle and high school science educators who had a lived science education experience.

Tucker-Raymond, Varelas, Pappas, Korzh, and Wentland (2007) used a multimodal approach that involved both drawings and interviews. In the study, interviews of primary school students in grades 1-3 took the form of multimodal narratives where the students drew pictures of two times that they were scientists and explained how they thought of themselves as scientists in each picture. Findings were presented as case studies of three students including pictures along with excerpts transcribed from the students' verbal descriptions.

According to the axiological assumptions of naturalistic or constructivist inquiry, the interaction between the researcher and the researched is an opportunity to be "capitalized" (Lincoln & Guba, 1985, p. 100) upon. Therefore, it is important to develop the concept of researcher positionality. Researcher positionality is the acknowledgement that the researcher's interpretation of others' meanings "flows from the researcher's own personal, cultural and historical experiences" (Creswell, 2007, p. 21). The epistemological assumptions inherent in naturalistic or constructivist inquiry emphasize close proximity between the researcher and the participants' environment (Moustakas, 1994). Hence, the researchers' perspectives and prior experiences relevant to the present study must be fully disclosed (Jones, Torres & Arminio, 2006; Patton, 2002).

The author-researcher who conducted the interviews had already done nearly thirty years of "fieldwork" with scientists and engineers as an academic research scientist and engineer, and later a patent agent. As a patent agent, she experienced how scientists and engineers were perceived in the legal and business worlds. It was jarring when she realized that scientists who were idolized within the small worlds of their own disciplines became just another mad scientist or eccentric in the "real" world of law and business. As a doctoral student in science education, she had the opportunity to undertake formal, scholarly consideration of the prevailing popular images of scientists and engineers.

Jones, et al. (2006) illustrated the concept of researcher positionality with an example of a Latina researcher who in her research simultaneously held "insider" and "outsider" status (Jones, et al., 2006, p. 104). Her insider status derived from her shared Latin ethnic and cultural background. Her interviewing approach and data interpretation were influenced by this insider status. However, her different educational, nationality and generational status made her an outsider.

Applying this analysis to the interviewing author-researcher likewise resulted in identification of simultaneous "insider" and "outsider" status. Her educational credentials in physics and materials science and engineering, and experience as a published researcher in these fields gave her strong empathy with the engineer participants in this study. The participants were acquaintances and professional colleagues of her husband, an engineering professor. Simultaneously, she was an outsider. As a female, even when she perceived herself as an insider, she was to an extent an outsider in these male dominated STEM fields. She is an outsider now according to how this study defined “engineer”, since she is a science educator and social science researcher. Her insider/outsider researcher positionality had important implications for the substance and style of the interviews and subsequent data interpretation. Her earlier insider status in engineering played a role in giving her access to academic engineers and credibility for generating their interest in participating in the study.

The co-author-researcher (CAR) is a professor of science education and brings a different positionality to the study. He has 43 years of teaching and research in science education; his teaching experiences are at all levels from elementary school through graduate school education. CAR’s teaching includes middle school and high school science, university science, and college science education. His research on the teaching and learning of science is published in over 100 articles, 3 college textbooks and numerous laboratory manuals. During his 32 years at the institution of this study, CAR participated in numerous collaborations with faculty in the College of Engineering. For example, he has been Co-PI with Engineering faculty on several grant projects in engineering education and presented seminars to engineering faculty about learning theory. He, too, has aspects of both the “outsider” and “insider”. He is an “outsider” according to the definition of engineer used for the study. However, due to his extensive collaborations with College of Engineering faculty at this university, he is an “insider” with respect to engineering education.

Participant Selection

The naturalistic or constructivist research paradigm dictated the “sampling logic” (Schwandt, 2007, p. 269) for study participants. Participants were selected by “purposeful sampling” (Patton, 2002, p. 230; Lincoln & Guba, 1985, p. 102), also known as a “theoretical or purposive strategy” (Schwandt, 2007, p. 269). Study participants were selected according to explicitly established and explained criteria. This acknowledged “bias”, i.e. non-random nature of these selection criteria, became the “intended focus” (Patton, 2002, p. 230) for the sampling. Likewise, according to the purposeful sampling strategy, there was no pre-determined sample size. Instead, the purposeful sampling emphasized sample quality. Participants who were likely to provide “*information-rich cases* for study in depth” (Patton, 2002, p. 230) were recruited.

The sample size for this study fell in the range between 5 and 25 which is typical for a phenomenological study (Creswell, 2007, p. 61). Initially, a sample of 11 engineers was invited to join the study. Keeping the sample size around 10 was expected to allow in-depth study of their experiences (Patton, 2002). The members of this homogeneous sample were people who shared the common experience (Patton, 2002) of being engineers in a research university academic setting. The sample was recruited from university faculty in college of engineering at a research university in the southwestern United States. Each faculty participant had a Ph.D. in his or her specific engineering discipline.

University engineering faculty were chosen to represent the lived experience of engineers because they were considered to be the thought leaders for the profession. They educate the next generation of engineers and possibly even K-20 STEM teachers, in addition to discovering new knowledge through research. They have the potential to shape the next generation of engineers and educators as well as chart the course of technical progress. Thus, their lived experiences as engineers are especially relevant for K-20 education stakeholders.

The pool of 11 engineers initially invited to join the study was chosen on the basis of the likelihood that they would recognize the authors'-researchers' names. It was thought that such name recognition would give credibility to the project and make engineers more likely to participate in the study. In fact, all participants were friends, acquaintances or colleagues of one or both author-researchers. It is worth noting that the authors-researchers had previously attempted a companion phenomenological study of academic natural scientists, likewise recruiting among candidate participants who would recognize their names and credibility as researchers. Of the 18 scientists invited to participate in that study, 0 joined. Using this constraint of name recognition, 11 engineers were sent email invitations to participate in this study. Five engineers accepted the invitation to participate in the study based on this initial email recruitment. Three additional participants were recruited during a university dinner and speaker function. The ninth participant was recruited when the interviewing author-researcher encountered him in the hallway outside the university office of another participant after she had concluded the interview with that participant. All engineers who were recruited through social contacts were then sent the same email recruitment materials as those participants who were recruited solely through email contact. An effort was made to represent a diversity of engineering disciplines, ages, faculty ranks, and gender among the participating engineers. The 9 participants who joined the study included faculty from electrical and computer engineering (5), computer science (1) (a discipline housed in the college of engineering at this university), aerospace and mechanical engineering

(1), and civil engineering and environmental science (2). Five participants were full professors and four were associate professors. Eight participants were male and one was female. All were tenured. Information regarding discipline, rank, and gender were separated to protect the anonymity of the participants.

The recruitment process was approved by the authors'-researchers' university Institutional Review Board (IRB). Each potential participant received an email invitation to participate in the study. Attached to the email was a packet that met Institutional Review Board (IRB) requirements for description of the study and the participant's role in the study. After they reviewed the packets, the 9 participants joined the study by documenting their informed consent. The packet also included a Draw-An-Engineer-Test (DAET) (Thompson & Lyons, 2008; Knight & Cunningham, 2004) as given in the Appendix. The instructions followed the spirit of E-DAST (Farland-Smith & McComas, 2009) administration by allowing participants to construct multiple drawings. The instructions directed participants to make as many drawings as needed for them to communicate their understanding of what it means to be an engineer.

Participants had the option of completing the DAET prior to or during an in-person interview. For the present phenomenological study, the drawings were not scored according to either the Knight and Cunningham (2004) or Thompson and Lyons (2008) rubrics. Rather, they served as conversation prompts during the in-person interviews and later as supporting data for the transcribed interviews.

Data Collection

In-person interviews of all participants were conducted by one of the authors-researchers in the participants' university offices over a six month period from January to June 2011. Interviews ranged from approximately 45 minutes to 2 hours, as is typically reported in the phenomenology literature (Ingerman & Booth, 2003; Grigsby & Megel, 1995). Participants were assigned alphanumeric code names to insure their anonymity. The interviews centered around the broad, open ended questions, "What have you experienced in terms of the phenomenon [being an engineer]?" and "What contexts or situations have typically influenced or affected your experiences of the phenomenon [being an engineer]?" (Moustakas, 1994, p. 61). The interviews were informal and interactive (Moustakas, 1994).

The DAET drawing(s) were used to initiate conversation about participants' experiences of being engineers. Many interviews began with participants elaborating on their drawings. Opening questions asked participants to describe what they drew and why. In some cases where the participant and author-researcher knew each other well or had recently attended a university social event together, the interview conversation began where a recent, prior conversation had left off. Participants were asked follow-up questions based on their responses or related to the particular images drawn, consistent with an emergent design strategy. When conversations related to the drawings were exhausted, the author-researcher prompted the participants to share their self-perceptions, their perceptions of the public and how their lived experience as engineers led them to engage with the larger community in keeping with the three research questions that guided the study. Each interview concluded with the author-researcher asking the participant whether there was anything else that he or she wanted to share related to his or her lived experience as an engineer. This open-ended questioning strategy, facilitated by the drawing(s), enabled participants to construct a multimodal narrative (Tucker-Raymond, et al., 2007) of their lived experiences as engineers. Such an adaptive approach was responsive to participants' behavior and was also used by Grigsby and Megel (1995) in their phenomenological study of caring experiences among nurse educators.

Eight of the nine participants permitted audio recording of their interviews. The same author-researcher who interviewed the participants transcribed the audio recordings. This melding of interviewer and transcriber roles protected participants' privacy and insured accuracy and fidelity, especially with respect to specific engineering terminology. This author-researcher then listened to the recordings again and proofread the transcripts for literal accuracy. Following the Grigsby and Megel (1995) approach, participants had an opportunity to evaluate descriptions and interpretations related to their interviews during the "member check" phase of the research (Lincoln & Guba, 1985, p. 236).

Immediate post-interview impressions of the engineers' work environments, overall demeanor, body language and any other non-verbal cues were recorded by the interviewing author-researcher in a research journal (Lincoln & Guba, 1985). The interviewing author-researcher reviewed these data prior to analyzing the interview transcripts to address any biases she might have held related to these observations. These field notes became part of a reflexive research journal that documented the entire research process, including decisions regarding research design, data collection and data analysis.

Data Analysis

Data analysis procedures were designed to develop "trustworthiness". Lincoln and Guba (1985, p. 290) framed the concept of "trustworthiness" in terms of a question, "How can an inquirer persuade his or her audiences (including self) that the findings of an inquiry are worth paying attention to, worth taking account of?". This study established that its findings had credibility or truth value by verifying that the findings were true for the participants. Each participant had an opportunity to review the authors'-researchers' interpretations of interview data during the "member check" phase of data analysis, "having them [the findings] approved by the constructors of the multiple realities being constructed" (Lincoln & Guba, 1985, p. 296).

Credibility was further addressed through data triangulation (Patton, 2002; Lincoln & Guba, 1985) and peer debriefing (Lincoln & Guba, 1985). Data triangulation involved use of a variety of data sources (Patton, 2002; Lincoln & Guba, 1985) and was accomplished when participants constructed multimodal narratives using two data sources, the DAET drawing(s) and verbal description along with other interview data. The author-researcher who had not conducted or transcribed the interviews, the science education professor, facilitated peer debriefing and served as a "disinterested peer" or the "devil's advocate" (Lincoln & Guba, 1985, p. 308). In this capacity, the debriefing author-researcher questioned the interviewing author's-researcher's methodology including execution of the purposeful sampling strategy, working hypotheses during analysis of transcript data and biases. Peer debriefing also helped maintain neutrality, insuring that the findings derived from the participants without distortion from the biases or perspective of the interviewer. The debriefing author-researcher did not know the identities of the participants. He knew them by alphanumeric codes that revealed only their departmental affiliations. Hence, he was able to critique the interviewing author's-researcher's interpretations with a high degree of objectivity. A written record of the debriefing sessions was kept by the interviewing author-researcher. The interviewing author-researcher also reflected on any "thoughts and feelings" (Moustakas, 1994, p. 89) related to each participant and the particular circumstances of each interview in an effort to approach the interview data with "unbiased looking and seeing" (Moustakas, 1994, p. 89).

Data analysis for this study followed Moustakas' (1994) phenomenological reduction methodology modified to accommodate a member check phase where participants reviewed provisional textural descriptions derived from their interviews, as will be described in more detail below. This modification was consistent with an emergent design that recognized that participants would be more comfortable reviewing provisional interpretations that included quotes from the interviews along with the key phrases that described their experience as engineers. If the Moustakas (1994) methodology were literally followed, this participant review step would occur as step 2 immediately following the "bracketing" process (Patton, 2001, p.485), step 1 as described below. However, in the present study it was step 5. Data analysis also included a step of "horizonalization" (Moustakas, 1994, p. 95). All steps are described in detail below.

1. In the bracketing process, each of the authors-researchers separately reviewed the interview transcripts and DAET drawings. Each separately identified key phrases that spoke directly to the lived experience of being an engineer and interpreted their meanings. For the interviewing author-researcher, this step was actually begun informally as she recorded key phrases that stood out as significant while she was transcribing the audio recordings. The interviewing author-researcher recorded the phrases in the chronological order in which they occurred in the interviews. This chronological order facilitated development of the structural description for each participant in a later stage of data analysis. The authors-researchers then met to discuss their findings with the intention of resolving areas of disagreement through dialogue and reference to the interview data. When they met, the authors-researchers found that they had no areas of disagreement. Instead, they had identified the same key phrases only differing in some instances with respect to taxonomy, organization or semantics. Both authors-researchers were satisfied that all key phrases relevant to the research questions had been extracted from the data while neither author-researcher had derived unsupported meanings from the data.
2. The authors-/researchers studied the meanings obtained in step 1 for "essential, recurring features" (Patton, 2002, p.89) related to the lived experience of being an engineer.
3. The authors-researchers generated a tentative statement regarding the essence of being an engineer based on the results of step 2.

4. The authors-researchers examined all of the features of the data identified in the bracketing step 1 and assigned them all an equal significance (Moustakas, 1994). Clusters of meaning were developed and redundant data were eliminated. The "textural meanings" (Moustakas, 1994, p. 97) and invariant themes that remained were clustered and organized to create a textural description of the phenomenon as experienced by each of the participants (Creswell, 2007; Moustakas, 1994). Direct quotes from the interview transcripts as well as DAET drawings or written descriptions supplied by a participant in lieu of a DAET drawing were included in the textural description. A provisional textural description of each participant's lived experience of being an engineer was produced at the end of this phenomenological reduction phase of data analysis.
5. Participants were asked to review and evaluate the provisional interpretations generated in step 4.
6. The authors-researchers revisited steps 2-4 making revisions, if needed, according to the comments that participants provided in step 5. Themes from the textural analysis that were shared among participants are reported in the "Collective Textural Description" in the "Findings" section that follows.

After completion of phenomenological reduction, the next phase of data analysis was "imaginative variation" (Creswell, 2007, p. 61; Moustakas, 1994, p. 97). During imaginative variation, the invariant themes were examined systematically from different perspectives. The goal of the imaginative variation phase was to generate a structural description of an experience, an understanding of the underlying factors that give rise to the experiences set forth in the textural description (Moustakas, 1994). The structural description was “the ‘bones’ of the experience” (Patton, 2002, p. 486), the skeletal structure of each participant’s experience.

In the synthesis phase, the textural and structural descriptions were integrated to produce a “synthesis of the meanings and essences of being” (Moustakas, 1994, p. 144) an engineer for each participant. A statement of the structural description for each participant was added behind the last page of the textural description for each participant. This arrangement facilitated a mental image of “dissecting” the textural description, the “flesh” of the experience, to expose the “bones” of the experience, the structural description as the authors/researchers conducted this phase of data analysis.

From this collection of synthesized structural and textural descriptions for each participant, a “Composite Description” (Moustakas, 1994, p. 121) was developed to represent the experience of the phenomenon of being an engineer across the entire group of participants.

Findings

The authors-researchers have deliberately headed this section as “Findings” rather than the more commonly used “Results and Discussion”. The “Findings” subheading is consistent with the naturalistic/constructivist paradigm that is the theory base for this research. The role of the authors-researchers has been one of organizing and transmitting the knowledge that the participants constructed, while preserving the participants’ intended meanings. By contrast, a “Results and Discussion” subheading would be consistent with a positivist research paradigm. A “Results and Discussion” subheading would imply an experimental or treatment based methodology including evaluation and interpretation of data.

First, a tentative statement of the lived experience of being engineers was generated from the key phrases identified in step 1 of the phenomenological reduction method (Moustakas, 1994).

> Engineers are creative, hard-working, ethical, self-effacing problem solvers/designers and builders who protect and serve society by improving the quality of aspects of people's lives related to their specific disciplines.

While this statement accurately described the participants' collective understanding of what an engineer does, in its present form it had the potential to create a misconception of a monolithic engineering experience. However, the synthesis of the textural and structural descriptions revealed that this statement needed to be qualified to reflect the individual motivations and visions that were foundational for the participants' experiences of being engineers.

Then the collective textural description and structural description was developed from the participants' interviews and DAET drawings. The topics considered in the collective textural description were identified by the participants as essential aspects of the lived engineering experience.

Collective Textural Description

The participants' individual textural descriptions demonstrated that they shared several themes in common as they experienced being engineers. These themes were: protecting and serving society; perceptions of the public; the public's perception of engineers; stereotypes; gender; solitary work and team work; hard work/rigor; designing and building; solving problems; creativity; and personal traits. These themes are presented in the order of how frequently they arose in interviews with participants. Only themes that appeared in two or more participants' individual textural descriptions are considered in this section since it represents a collective textural description.

Protecting and Serving Society

Each of the nine participants identified protecting and serving society and fulfilling a civic duty to be responsible to the public and improve people's lives as an essential aspect of the experience of being an engineer. For one civil and environmental engineer, an engineer has "…serving society as your guiding principle. You define your success from there." Another civil and environmental engineer maintained that the engineer's "role is extraordinarily important in society, because you are the only out there who's making sure the numbers are correctly collected, interpreted and paid attention to." An electrical engineer stated, "Engineers are focused on serving the society, serving the citizenry through improved products and services. They provide good value and performance and also are safe." Another electrical engineer articulated this concept slightly differently, "The key is the ability to make life easier for people. … improve the life of people in some quantitative way." A third electrical engineer linked public service to education, "There are those who we serve who are young people who need to learn."

In the context of protecting and serving the public, the topic of addressing ethics as part of three participants' experience as educators arose. Two of the participants who explicitly discussed ethics were electrical engineers. One described how in his teaching, he was "trying to work on ethics, larger picture side of things."

Engineers' Perceptions of the Public

The theme of engineers' perceptions of the public emerged as all nine participants considered their relationships with the public and the society they served. An electrical engineer articulated this connection, "Engineers see the public as someone to serve." How engineers perceived the public played a significant role in these nine participants' experience of being engineers and represented a diverse spectrum of opinions. According to another electrical engineer, "People are transparent. We look at the problem and don't see the people".

One participant stated, "most engineers think the public are idiots". At the other end of the spectrum was a civil and environmental engineer who saw in the public an opportunity. "So you can see people or the public as an obstacle to get to your goal and you're not going to be very effective or you can see the public or people as an opportunity to achieve the goal and there's a lot more opportunity for success." Between these two extreme opinions, there was a general consensus that the public was ignorant about what engineers do. There was also the perception that the public was unable or unwilling to make connections between everyday technology and the engineers who make it. According to a civil and environmental engineer, "I don't think they [the public] really understand what the engineers do." In doing outreach with children, a computer scientist's perception was that "they [the children] had no concept of what an engineer is." Two electrical engineers recognized that the media contribute to this ignorance by paying little attention to engineers. As a civil and environmental engineer said, "Television programs give a lot of visibility to a lot of disciplines. Engineering doesn't tend to be one of them." Engineers' poor public relations and communication skills were identified as playing a role in the public's ignorance about the engineering profession. These engineers saw a need to be proactive in developing a better informed public. A computer scientist's comment was representative, "I think having a better image of engineers would be very helpful. I think engineers are terrible communicators of what we do and the value to society."

The Public's Perception of Engineers

Despite the engineers' perception that the public was ignorant concerning the details of engineers' work, overall they indicated that the public attributes both positive and negative qualities to the engineering profession and to engineers. According to an aerospace and mechanical engineer, "Society appreciates engineers." This engineer expanded on this public perception of engineering and engineers as "an honorable profession with good pay", "respectable citizens, hardworking", "smart", "honest". An electrical engineer characterized the public's perception as, "They're nice. They're clean. They're well-kept, but nothing fancy." However, six of the participants also indicated awareness of negative public perceptions of engineers as "cold and calculating", and of engineering as not involving creativity as well as "too boring" and "too hard". An electrical engineer acknowledged the impact of public sentiment on his experience as an engineer. "We're told that we can't write, can't speak. That's because people want to measure us with their metrics." The concept of engineers and engineering being invisible to the public, except when there were major failures of the technological infrastructure, was raised by a civil and environmental engineer and an electrical engineer. The electrical engineer illustrated with a student's statement, "Where does electricity come from? I just plug it into the wall."

Gender

The issue of gender was raised by eight of the nine participants. The prevalence of this theme may be attributed to the fact that six of their DAET drawings included human figures. Five drawings included stick figures, similar to those in Figure 1, and one drawing, Figure 2, depicted a clearly identifiable male figure. As participants elaborated on these drawings during the interviews, a natural and organic discussion ensued regarding assignment of a gender to the stick figures. All responded that while they had not intended to assign a gender to the stick figures, if they were to have a gender it would in most cases be male, since most engineers are males. The electrical engineer who created the male-gendered drawing explained that he was “drawing and referring to myself. I’m projecting myself on engineering, not engineering on myself.”

Overall, eight participants experienced engineering as a historically male dominated profession. However, they expressed dissatisfaction with that aspect of engineering and were unanimous in striving to attract more women to engineering. One recognized a sense of male entitlement to technology. One electrical engineer commented on the lack of women engineers, “If the most valuable resource is a human being, we have 50% of our resources that we don’t even want to use.” According to another electrical engineer, “The engineering environment is handicapped by the fact that we are unable to attract more women. They make great leaders and program managers”. A civil and environmental engineer indicated that female students have an affinity for courses that have a societal context. He provided an example from his own experience as a professor, “… my course [related to a social justice issue] has a higher representation of underrepresented groups and females than typical classes.” An electrical engineer echoed this experience and observed that female students are interested in “social based projects that benefit humanity”. A civil and environmental engineer was optimistic about increasing the female presence in engineering saying, “Nowadays, it [the engineering profession] is becoming more acceptable for young girls”. However, an aerospace and mechanical engineer acknowledged , “The current generation doesn’t seem to be choosing based on conventional gender roles. They choose what they truly like to do.” However, he predicted, “There will never be a 50/50 male/female ratio in engineering.”

Stereotypes

When seven participants described their experiences with the public’s perception of engineers, the topic of stereotypes entered the conversation. For this study, a stereotype is a well-defined, iconic visual image or verbal description that is used by society to identify a group, here engineers. Participants’ experience of the public’s ignorance of what engineers do is consistent with what Petroski (1992) described in *To Engineer is Human.* Hence, it is not surprising that the public invokes stereotypes to manage this ill-understood reality.   Some stereotypes were based on physical characteristics or symbols, while others were based on behaviors or character traits.

An electrical engineer distinguished an academic engineer stereotype and an industry engineer stereotype. This engineer portrayed the academic stereotype of an electrical engineer as a male “with messy hair and whiskers”, of computer scientists as males who “have long hair in the back and of scientists as males with “some wavy hair and no beard”. By contrast, the industry engineer stereotype was presumably also of males, "clean cut, well shaven, nice hair, no razzle dazzle". The computer scientist further supported a male engineer stereotype, "Computer scientists are almost exclusively male. Certainly, the image of the computer scientist is the super geek, an exclusively male image." A civil and environmental engineer also described a male engineer stereotype with "white shirt, pocket protector, pencil behind the ear, slide rule on the belt, the white socks which were not in vogue, the pants rolled up." The symbol of the hard hat was used by two participants, one an aerospace and mechanical engineer and the other a civil and environmental engineer. An electrical engineer described a behavioral stereotype, "They're geekish and don't relate to people."

Solitary Work and Teamwork

Seven of the nine participants saw how an engineer's work is accomplished, typically an iterative process of solitary design work and group interaction with engineering team members and/or clients, as an important part of what it means to be an engineer. Three of the eight participants who provided DAET drawings used stick figures to depict this iterative process. A representative drawing is shown in Figure 1. In discussing how engineers work, one electrical engineer stated, "I think collective activity. There might be a breakdown of skill sets among individuals and then they're put together." This sentiment was supported by another electrical engineer who said, "You still have to have a team. Products these days are complicated." A civil and environmental engineer went further and recognized the importance of interdisciplinary teams in solving complex global problems, "So then you see the engineers bringing an important part, the technology, but recognize that we can't do it ourselves in a vacuum. To be really successful, we believe we need the anthropologists, sociologists and entrepreneurs so we built relationships on campus". An electrical engineer connected team work with undergraduate education in engineering, "They [the students] worked in teams-leadership opportunities."

Communication skills and gender arose naturally in the course of conversations about teamwork. Communication skills were explicitly addressed by two participants. A computer scientist recognized the connection between good communication skills and engineering success, "Most of the successful software engineers are people who are able to explain their message to a broader audience." One electrical engineer made several observations on the relationship among communication skills, gender and team efficacy in the engineering experience, "They [women] make great leaders and program managers. Engineers are typically boy types who can't talk their way out of a paper sack. … Boys don't listen. Engineer girls are able to change their minds. Teams managed by women almost always do better because they [the women] are better team managers."

Hard Work / Rigor

Five of the nine participants addressed hard work, often associated with rigorous mathematics, as a significant aspect of their experiences as engineers. Three participants, two electrical engineers and a computer scientist explicitly discussed mathematics. One electrical engineer linked mathematical understanding with engineering success.

> I think higher math is probably the most difficult thing. It's been my observation that science is not that difficult to understand and the physical processes of science and engineering are not that difficult to understand if you

> understand the underlying math. If you don't make an effort to learn the math that really allows you to rigorously describe things and design things, then it's hard to be successful as a scientist or engineer.

The other acknowledged the importance of mathematics, "You have to have it [mathematical aptitude]. If you don't have that ability, this is not where you want to be. It's hard to be an engineer." However, he distinguished engineers from mathematicians, "We're [engineers] appliers. We [engineers] do math. Math provides with a tool; we're not a tool for math." The computer scientist recognized how mathematics prerequisites set up barriers to achieving diversity in engineering. According to this participant, "When you say you have to know math first before we're going to let you play in computer science, you're cutting off a huge part of the group that would be very interested in computer science."

Designing and Building

Four of the nine participants saw designing and building activities as important elements of their experience as engineers and considered the relative importance of these two activities to engineering. The computer scientist said, " I actually build things that are used by people. But, you could just design and still be an engineer." A civil and environmental engineer stated, "You need to make tangible stuff." An electrical engineer indicated that both designing and building skills are "not very often" combined. For him, an engineer didn't need to do both designing and building. "Some do one and not the other. Some like to do both."

Solving Problems

Solving problems was either implicitly or explicitly discussed as an aspect of 4 of the 9 participants' experiences as engineers. Two participants characterized the engineer's mission as finding optimal solutions.   A civil and environmental engineer said, "We want to solve problems, make progress, see positive movement and see a better world." Another civil and environmental engineer raised the topic of the engineer as a problem solver in the context of discussing how the engineering method was distinguished from the scientific method.

> [T]the engineering method is a very straightforward process of solving a problem, identifying the issues, identifying the parameters, clarifying where you want to go what criteria determine success, looking at a design that might get you to that endpoint, doing something to evaluate it, build a bridge or create a computer model. You test it; identify the weak points. Go back iteratively and you adjust until you reach your endpoint. In doing so, you have to know your science. You have to know your math. Now you contrast that with science. Science is really cognitively a very different thing to get your head around. It's a philosophy of how do you approach reality and I set my graduate students in cognitive dissonance. I want to study this and I want to take these measurements with these instruments. So I sit them down and say now your model of this chemical system is this and you think this is occurring and you think your data are showing you this. What you're thinking is just a mental model. It's what you think it is. It's not reality. The only connection to reality is the data you're going to collect if your measuring device is truly valid, your calibrations, your standards it's really measuring what you think it's measuring.

If you don't have a clear concept of what that system is, you could be measuring something else. What you're measuring could perturb the system. So you have to approach it from multiple ways using multiple measuring devices and even so always some doubt are you really understand in your mind what's going on in that system that you can't directly see molecules. That's a very challenging thing for a lot of people and I think that's why, one reason why we have such a difficult time teaching science in schools."

An electrical engineer distinguished scientists and engineers according to their involvement with design; "what takes you from the scientist to the engineer is the engineer is much more focused on the design process."

Creativity

While a civil and environmental engineer characterized one aspect of the public's perception of engineering as not involving creativity, he, himself, identified creativity as an essential quality of engineers. An aerospace and mechanical engineer said, "The essence of engineering includes both creativity and the fact that it must work." An electrical engineer grouped art together with science as creative activities and considered it important "To let people know that engineering is an art form just as much as making music or designing Facebook sheets." Another civil and environmental engineer connected design with creativity, "designing something, creating new ideas." However, he also appreciated that engineering design is constrained by nature and the laws of physics. He explained, "You can be creative with the design of an airplane wing, but if it doesn't follow Bernoulli's principle, it isn't going to fly."

Personal Traits

All nine participants mentioned one or more personal traits or characteristics that they associated with being an engineer. This collective textural description includes only those traits identified by two or more participants. These traits were honesty; being multifaceted, i.e. having scope and breadth; ability to communicate effectively; educating the next generation of engineers; and being lifelong learners. All participants were implicitly self-effacing in their attitudes towards stereotypes and public perceptions. Three participants made explicit comments about engineers' ability to laugh at themselves. According to an aerospace and mechanical engineer, "We do like to laugh at ourselves. We have great jokes about ourselves. We have no problem laughing at jokes about engineers. *The Big Bang Theory*, although a little weird, shows engineers laughing at themselves, but also taking a back seat to everybody."

Structural Descriptions

While the steps of identifying key phrases and building the individual and collective textural descriptions pointed to common themes among the participants' experiences of being engineers, the structural descriptions were idiosyncratic and unique for each individual. Often, the chronological order in which the key phrases and quotes were identified in the textural analysis for an individual gave immediate insight into how the structural description should be constructed. The first or second key word or phrase identified for 5 of the 9 participants' individual textural analyses anchored their structural descriptions.

For one participant, this underlying structure was that of the committed educator firmly grounded in a philosophy of self-reliance and self-determination. Although another participant’s experience was also strongly identified with the role of educator, it differed in having a strong focus on academia-industry engineering partnerships. Another’s engineering experience was anchored in ethical use and management of technology. A social justice agenda pervaded the engineering experience of a fourth participant. Yet another participant’s experience was framed around personal experiences within a particular engineering discipline and gender. Being a “real engineer” grounded in both academic and industry engineering cultures characterized another participant’s experience. For two participants, artifacts or products of engineering, as shown in Figures 3 and 4, were foundational in their descriptions of their experiences. However, one placed those artifacts in the context of undergraduate and graduate education, while the other emphasized the interrelationship between technology/engineering and society. Finally, one participant’s experience was shaped by a holistic, big picture personal philosophy that emphasized life/work balance.

Composite Description

Comparison of the collective textural description with each of the nine participants’ individual textural descriptions showed that their experiences of being engineers were characterized in varying degrees by the same several themes. However, consideration of the structural descriptions that uniquely characterized the central motivation of each participant dispelled any notion of a monolithic, one-size-fits-all lived engineering experience. The underlying traits of the structural descriptions determined how those common themes were uniquely embraced and expressed by each participant.

A civil and environmental engineer wrote a verbal description of a DAET drawing in lieu of drawing a picture in an effort to convey the complexity of what it means to be an engineer. It simultaneously captured the commonality and individuality of the participants' lived experiences as engineers. Since a goal of this research was to give voice to engineers' self-perceptions and have them "speak" about their lived experiences as engineers, his "word picture" was selected as the composite description. He wrote:

> The DAET, well, I need to think in terms of a mural, with multiple panels and media. In short, I have no idea how I could convey such complex and multi-faceted ideas as to what it means to be an engineer in a hand drawn picture or two. There is so much that goes into this idea: the interactions with the physical and biological world; the use of science and mathematics; the applications and thinking; the ethical and professional responsibilities to the world, the environment and the human race; and the need to see the big, long-term picture, while taking care of a myriad of details. None of what I mentioned begins to address the multiple areas and ways engineering and engineers directly impact the things we do, the way we live, the way we perceive the world and communicate with others, and the way we live.

Summary and Implications

These findings are significant for K-20 education stakeholders and for the engineers themselves. Participation in the study gave the participants the opportunity to be introspective and to reflect on their life experiences as engineers. One participant remarked. "Just talking with you has opened my eyes. I just did my engineering. Now, I'm thinking about how engineers are perceived differently in different countries." The collective textural description highlights several themes that characterize the participants' aggregate lived experience as engineers. Engineers can refer to the collective textural description to select themes appropriate for highlighting in outreach activities. The finding that all participants in this study identified protecting and serving society as an essential aspect of their experiences as engineers can be especially useful in attracting females to the engineering profession.

K-12 educators can refer to the findings as a resource as they implement new STEM curricula. These educators can use the findings to help design learning experiences for their students that foster development of accurate perceptions of engineers and engineering. Such a resource is valuable to support actual interactions between K-12 students and engineers. It can also provide K-12 teachers with authentic information about what it means to be an engineer that they can share directly with their students when direct interaction between students and engineers is not possible.

Researchers who design interventions to develop accurate images of engineers among K-12 students can use the collective textural description, the structural descriptions, DAET drawings and other findings as benchmarks to assess the efficacy of their interventions. The researchers can compare the K-12 students' post-intervention perceptions of engineers with the themes and images found in this study to evaluate the degree to which the students' perceptions have become aligned with the engineers' self-perceptions. They can use the findings to structure developmentally appropriate curricula starting at the elementary school level that "grow" with students and introduce them to new aspects of engineering as they progress into middle and high school.

Suggestions for Further Work

The authors-researchers utilized a well-defined phenomenology methodology (Moustakas, 1994), including peer debriefing, data triangulation and member checks to insure that the findings of this study accurately present the nine participants' understandings of their lived experiences as engineers. However, these nine participants came from just four engineering disciplines: (1) aerospace and mechanical engineering; (2) civil and environmental engineering; (3) computer science; and (4) electrical and computer engineering. These participants described their experiences as engineers through the lenses of their engineering disciplines. Additional studies that include participants from other engineering disciplines such as chemical engineering, materials science and engineering, industrial engineering, and petroleum engineering, may generate a broader, more expansive representation of the lived experience of engineers. Since the present study had only one female participant, the findings are heavily skewed towards males' lived experiences as engineers. It would be valuable to design a study exclusively involving female engineers. Such a study would allow females' lived experiences as engineers to be expressed fully. It can provide insights on whether and to what extent gender affects the lived experience of being an engineer.

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Appendix

The Draw-An-Engineer Test (DAET)

Directions: Draw an engineer. (Construct a single drawing or as many drawings as necessary to communicate your understanding of what it means to be an engineer. You may use additional sheets of paper, if needed.)

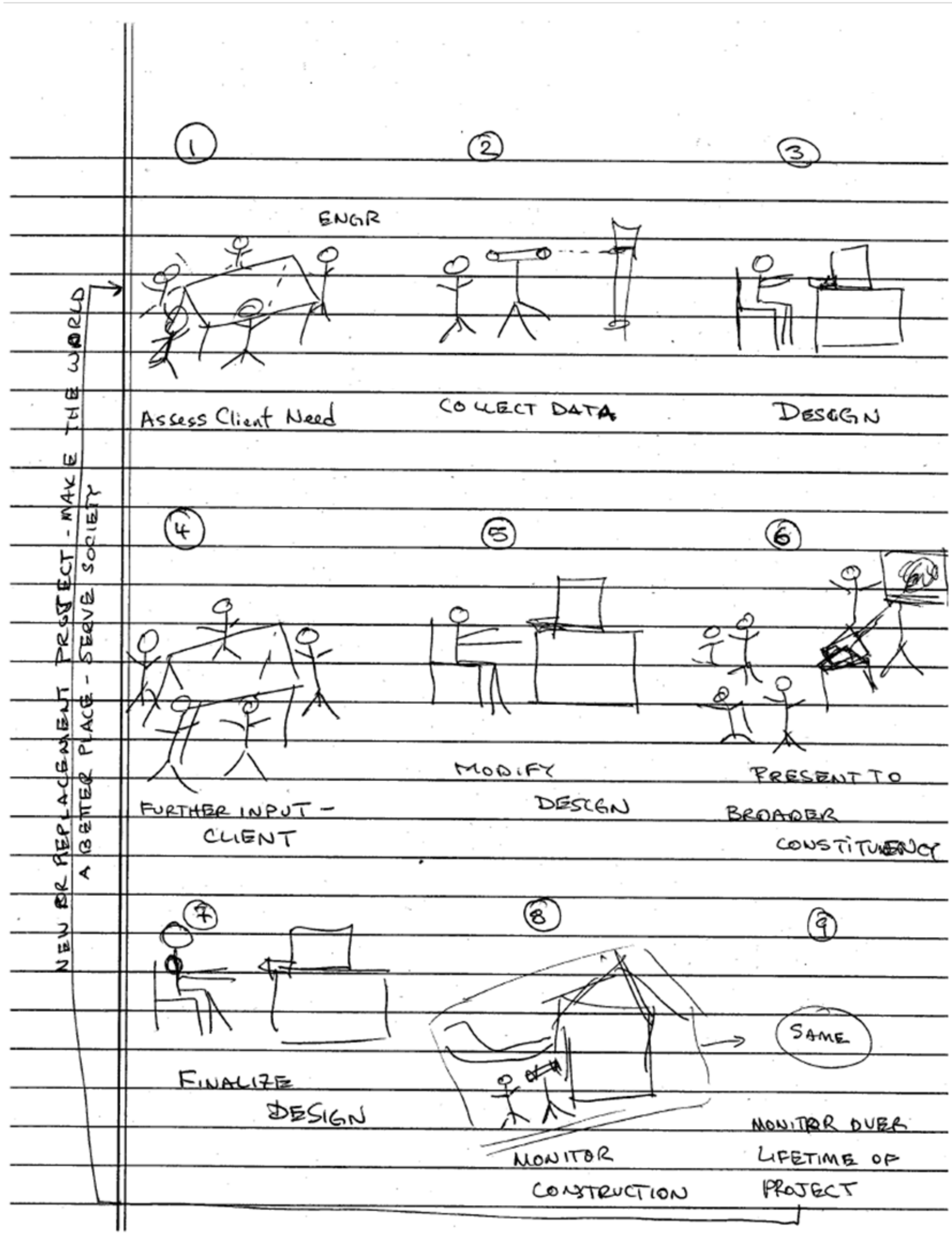

Figure 1. DAET drawing showing stick figures.

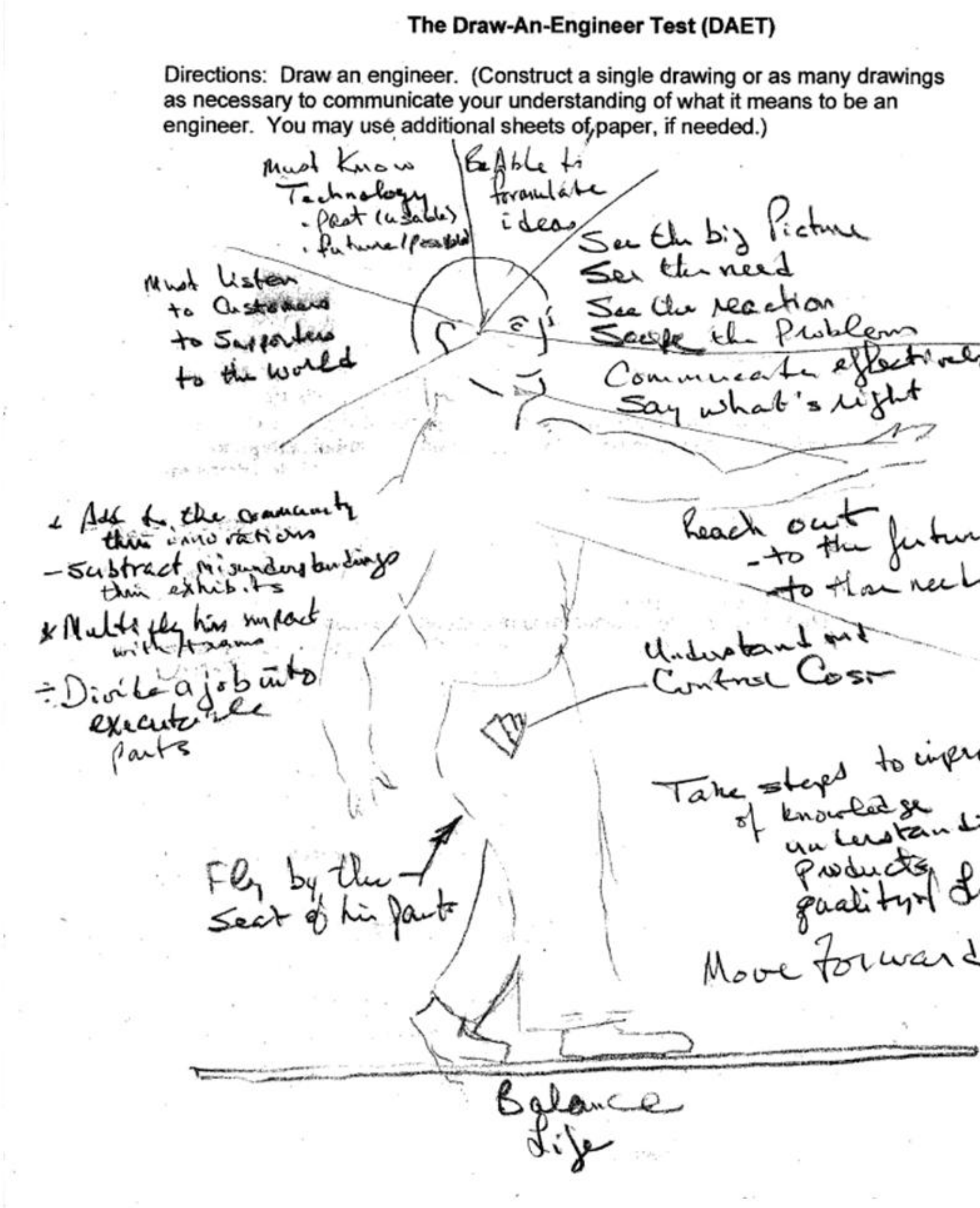

Figure 2. DAET drawing showing clearly identifiable male gender.

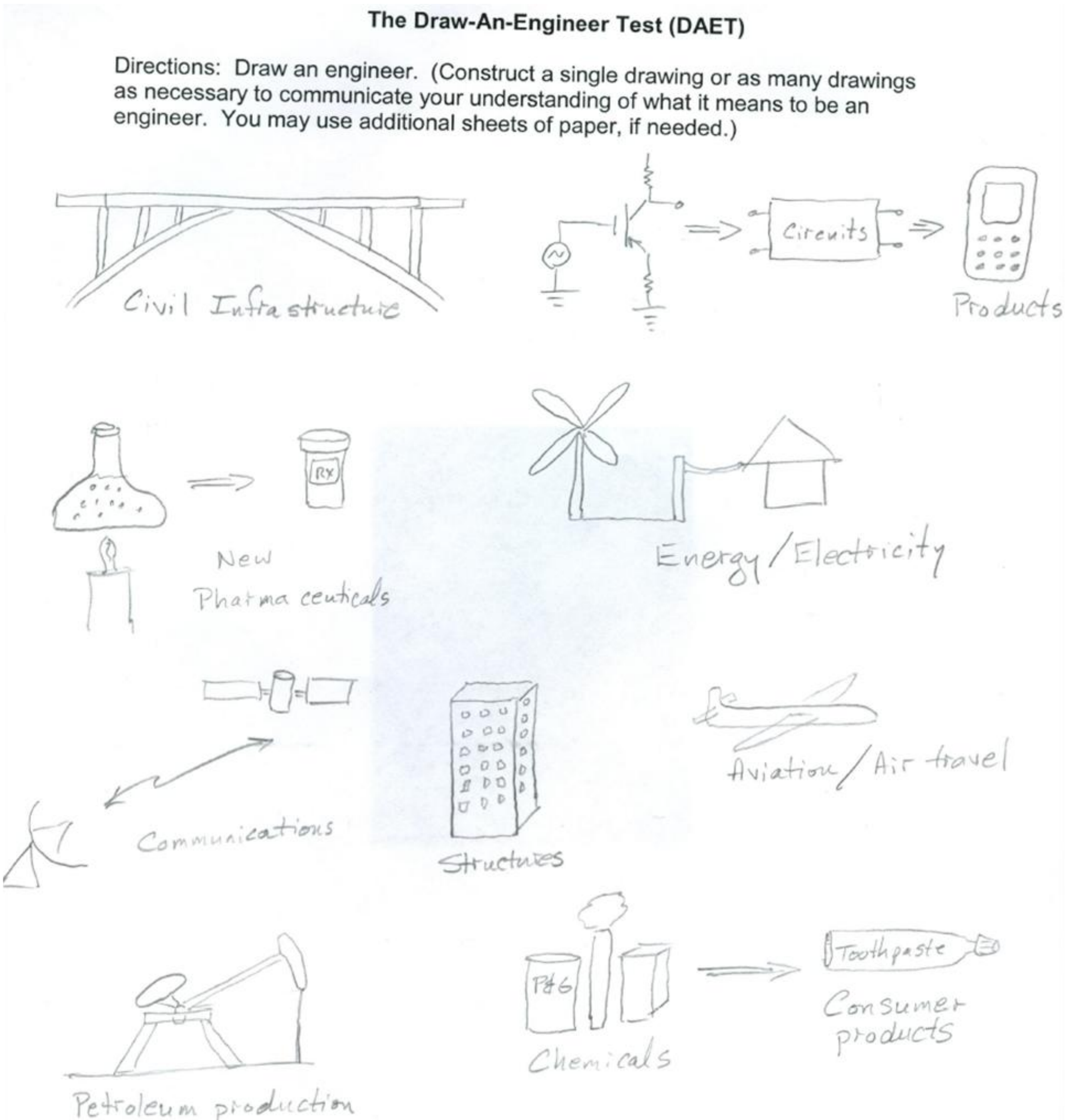

Figure 3. DAET drawing showing artifacts or products of engineering.

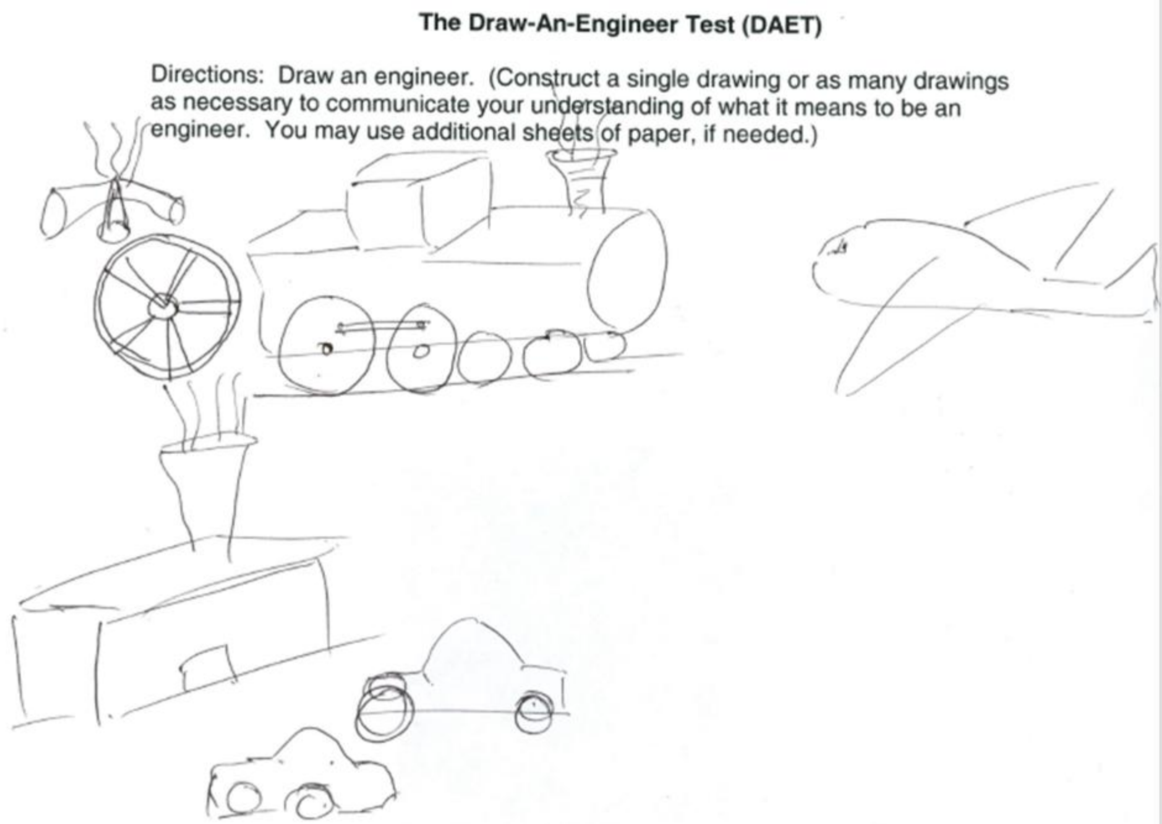

Figure 4. Another DAET drawing showing artifacts or products of engineering.

MANUSCRIPT III

How Does Participation in a STEM Club Affect Identified Gifted Fifth Grade Girls' Perceptions of Scientists and Engineers?

This manuscript is prepared for submission to the peer-reviewed journal, *Journal of Engineering Education,* and is the third of three manuscripts prepared for a journal-ready doctoral dissertation.

How Does Participation in a STEM Club Affect Identified Gifted Fifth Grade Girls' Perceptions of Scientists and Engineers?

Background

Research has shown that direct interactions between STEM (Science, Technology, Engineering and Mathematics) practitioners and elementary school students were only sometimes successful in developing realistic perceptions of STEM practitioners. Other times, informal STEM learning experiences actually resulted in elementary school students developing more stereotypical perceptions of scientists.

Purpose (Hypothesis)

Gifted fifth grade girls participated in a STEM Club led by a female scientist/engineer. The Club met approximately monthly during the school year. The research question addresses how participation in the Club affected their perceptions of scientists and engineers.

Design/Method

The girls' perceptions were accessed using the Draw-A-Scientist-Checklist (DAST-C) (Finson, et al., 1995); Enhanced-Draw-A-Scientist-Test (E-DAST) (Farland-Smith & McComas, 2009); and Draw-An-Engineer-Test (DAET) (Thompson et al., 2008; Knight & Cunningham, 2004) instruments administered before and after participation in STEM Club.

Results

The girls held well-developed, stable perceptions of scientists and drew traditional, predominantly male scientist images. After participation in STEM Club, they drew traditional images of scientists; however, female images increased by 30%. By contrast, the girls' perceptions of engineers were far more plastic than their perceptions of scientists. By the last STEM Club meeting, these same 5th grade girls drew realistic images of engineers involved in design, laboratory investigation and testing activities. Female engineer images increased by 42%.

Conclusions

These results suggest that a female scientist/engineer mentor in an informal club setting can have a significant impact on gifted fifth grade girls' perceptions of scientist and engineer gender. STEM Club participation developed realistic perceptions of engineers among this group of fifth grade girls.

Keywords: gender, gifted education, scientist stereotypes, engineer stereotypes, Draw-A-Scientist-Test (DAST), Draw-An-Engineer-Test (DAET)

STEM (Science, Technology, Engineering, Math) clubs have effectively engaged student interest in STEM at the high school and community college level (NSTA Reports, 2010). Girlstart (www.girlstart.org), an organization founded in 1997 in Austin, Texas, has provided a range of informal hands-on STEM educational events. These STEM events include a conference for girls in grades 4-8 (NSTA Reports, 2011). Other efforts to provide direct STEM experiences for elementary school age children have included the Horsham Greenpower Goblin Challenge (HGGC) in the UK (Silver & Rushton, 2008a; Silver & Rushton, 2008b). This project-based program involved 9-11 year olds from 18 schools in building a single-seat electric car. The different schools then raced the cars in 1-hour races. Entire classes built the cars during a 1-2 week period, typically during school hours, from kits that included parts and building instructions. Adults assisted and a female engineer provided technical expertise and final safety inspections. The study found that after participation in HGGC, students drew images of scientists that were more stereotypical than the scientist images they had drawn prior to participation. Likewise, their engineer images showed an increase in repairing activities and reflected the car mechanic stereotype. An after-school, museum sponsored informal education program was designed specifically for gifted fourth and fifth grade students (Melber, 2003). After participating in this program, students had enhanced understandings of scientists' work and increased interest in science careers.

Other interventions at the elementary school level have incorporated scientists and engineers as visitors to formal science classes during the school day. When a female chemical engineer visited a fourth grade class and involved them in a "student-centered activity to 'practice' engineering skills" (Bodzin & Gehringer, 2001, p. 38), 31% of female students, whose pretest images were of male scientists, instead drew female scientist images in their post-test drawings. However, when two fifth grade classes were visited by a male physicist, female students' perceptual changes with respect to gender were mixed. In one class, 16% of female students' drawings changed from male to female scientist images in pretests and posttests respectively. In the second class, two female students' scientist images instead changed from female to male images in pretests and posttests, respectively.

Another study (Buck, Leslie-Pelecky, & Kirby, 2002) demonstrated persistence of stereotypical scientist images when three young female scientists, a white American physicist, an African-American physicist, and a white American materials scientist worked with 4th and 5th graders in their elementary school classrooms on a daily basis over a four week period. While in the classrooms, the scientists led physical science inquiry activities and discussed their research careers with the children. Furthermore, the study found that the students actually "questioned the true identity of the scientists, categorizing them as teachers" (Buck et al., 2002, p.1).

Children's images of scientists are fully developed and stable between the 3rd and 5th grades (Chambers, 1983). A recent study by Walls (2012) of African-American 3rd graders continues to validate this 30 year old finding that children formulate their views of scientists by the lower elementary school grades. Hence, an elementary school STEM club is an ideal venue for authentic STEM learning experiences. Such experiences are essential during this critical period when life-long perceptions of STEM practitioners are formed. Maltese & Tai (2010) studied a group of scientists and found that these scientists developed their interest in science before middle school. These results are further evidence that it is important to provide high quality STEM learning experiences for elementary school age children. Such experiences keep students engaged with their early interests in STEM. Silver & Rushton (2008b) concluded that it is “children’s stereotypical images of scientists, rather than an actual dislike of science and design technology that dissuades them from becoming scientists and engineers” (Silver & Rushton, 2008b, p. 66). They identified a “need to provide more positive, inspiring images of the work of scientists and engineers if children are to be encouraged to consider these career options” (Silver & Rushton, 2008b, p. 66). All of the foregoing studies involved classes and groups presumably including male and female students having a range of intellectual abilities. None specifically described any efforts to examine the perceptions of female elementary school students, specifically identified gifted female students.

It is especially important to sustain girls’ early interest in STEM, since their attrition from science begins between the ages of 9 and 14 starting when they enter the upper elementary school grades (McCrea, 2010; Steinke & Long, 1996). McNeill (2011) has shown that elementary school age children can successfully engage in the scientific inquiry processes that a STEM club offers. For these children to have a realistic understanding of the work of scientists, it is important that they be able “to tie the word *scientist* to a particular person” (Ashbrook, 2010, p. 26). Teen girls need that “particular person” to be female, since female mentors encourage persistence in STEM (NSTA Reports, 2011; McCrea, 2010; Vanmali & Abell, 2009). Bohrmann & Akerson (2001) also identified interaction with female role models as a strategy that was “effective and important in improving self-efficacy” (Bohrmann & Akerson, 2001, p.

51). Hence, it is desirable for fifth grade girls to interact informally with a visiting female STEM practitioner role model.

Research Design

Research Question

The research question for the study was: How does participation in a STEM Club affect gifted fifth grade girls' perceptions of scientists and engineers?

Definitions

The purpose of this study was to examine how participation in a STEM Club affects identified fifth grade girls' perceptions of practitioners of two of the STEM disciplines, science and engineering. The girls were not asked to make drawings of practitioners of technology and mathematics, "technologists" and mathematicians, respectively. For the purposes of this paper, scientists are defined as practitioners of the natural sciences including "school science" (Schibeci 1986, p. 139), i.e., "the natural sciences (physical and biological) sciences with the addition of earth science". Engineers are defined to include practitioners of civil, environmental, aerospace, mechanical, structural, chemical, materials, electrical, computer or petroleum engineering as taught at a university level. Since the term "technologist" is not a commonly used word, it was unlikely that the girls would be able to make drawings that would provide useful data about practitioners of technology (Silver & Rushton, 2008b). It was similarly unlikely that they would be able to make meaningful drawings of mathematicians.

Participants

Initially, STEM Club membership consisted of 12 identified gifted, female fifth graders. While all identified gifted girls in the fifth grade were invited to join, participation in STEM Club was a voluntary, rather than required activity. Hence, the fact that a girl decided to join STEM Club presumably represented an interest in and desire to learn more about STEM topics. Eight of the 12 girls gave their assent and had parental consent to participate in the current study. The remaining 4 girls who were not part of the study attended all STEM Club meetings and took part in all Club activities. However, their scientist and engineer drawings were returned to them and were not collected as data for the present study. The female STEM practitioner did not know the identities of study participants.

Context

STEM Club is an enrichment activity offered at a large (over 600 students), suburban elementary (grades pre-K - 5) school in the Southwestern United States. Fewer than 40% of students at the school qualified for free or reduced-price lunch. The school's gifted resource coordinator and a doctoral student in science education, who had experience as a published researcher in physics and engineering, led the Club. Both Club leaders were European-American females. STEM Club met 7 times, approximately once monthly, for 40 minutes during the school day.

Hallmarks of the successful Girlstart program as well as high school and community college STEM clubs include (1) learning STEM by doing; (2) making STEM learning fun and (3) connecting STEM learning to real life experiences (NSTA Reports, 2011; NSTA Reports, 2010). These criteria guided selection and design of the elementary school STEM Club activities. Since STEM Club members were identified gifted 5th graders, meetings incorporated instructional strategies that addressed the particular needs of gifted STEM learners (Park & Oliver, 2009). Activities were appropriately paced. Challenging questions were welcomed. Risk taking was actively encouraged to counter the perfectionism and fear of failure often experienced by gifted students, especially gifted girls (Park & Oliver, 2009). Since all STEM Club members were gifted girls, the Club provided a psychologically safe environment where they could explore their STEM abilities and develop their identities in STEM (Carlone, et al., 2011; O'Neill, 2010). Within this safe environment, the Club leaders deliberately implemented strategies to improve the girls' STEM self-efficacy. One such strategy was the use of "specific praise" (Bohrmann & Ackerson, 2001, p. 51). Club leaders consistently praised the girls when they displayed scientific reasoning and practice skills in the context of independent decision-making. The leaders referred to each girl as a young scientist and/or engineer.

During each STEM Club meeting, the girls collaborated in teams of four (NSTA Reports, 2011; Vanmali & Abell, 2009) on an inquiry science investigation developed specifically for STEM Club. These investigations were designed using a two-pronged lesson model. Two-pronged lesson plans are a common instructional strategy as evidenced by their prevalence among online resources for teachers such as www.lessonplanet.com. Two-pronged STEM Club lessons were embedded within a 5-E (engage, explore, explain, extend and evaluate) instructional approach (Marek, 2009). The first "prong" of the lesson was the STEM content. The second "prong" was a "life lesson" that suggested ways to use their understanding of STEM to be responsible citizens (Hodson, 2004; 2003). Lessons encouraged the girls to be part of a solution to a STEM-related problem facing society. Specifically, the unifying theme of these life lessons was "living green" by using STEM knowledge to be a more efficient energy consumer. The lessons also prompted the girls to be the inventors of the next generation of green energy solutions. Providing a real world context that demonstrates the relevance of science for societal issues has been identified as one way of supporting girls' science learning (McCrea, 2010; Vanmali & Abell, 2009).

The STEM content "prong" included two of the three major dimensions put forth by the National Research Council in *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* released in July 2011, (1) "scientific and engineering practices" and (2) "crosscutting concepts that unify the study of science and engineering" (National Research Council, 2011). The girls gained experience with crosscutting concept #6 named, "Structure and Function" (Duschl, 2010, p. 10), as they explored the relationships between a material's structure and its properties. The life lesson second prong of the lesson supported "Core Idea 2B: Influence of Engineering, Technology and Science on Society and the Natural World" (Sneider, 2012, p. 9) as the girls gained experience understanding the impact of improved technology on their own daily lives.

The STEM content and life lesson were incorporated within the phases of the 5-E approach. The STEM-related life lesson was introduced by the Club leaders in the engage phase. During the explore phase, the girls collaborated in their groups to perform materials rich inquiry activities and collect data needed to develop the STEM concept. As the Club leaders circulated among the groups during the explore phase, they encouraged the girls to analyze and interpret their data. The girls made entries in their STEM Club notebooks. The scientist/engineer Club leader shared how she had used her laboratory notebooks to record data and as a "diary" to chronicle the development of her thinking and understanding throughout a research project (Leffler & Crauder, 2011). For some activities, the girls were assigned specific roles that modeled a STEM research group. These roles included principal investigator, research assistant, laboratory/equipment manager and intern. The girls explored the different responsibilities and perspectives of each of these research group members as they prepared to present their work to the rest of the Club. During the explain phase, all Club members together developed the STEM concept.

In the extend phase, the girls revisited the life lesson first introduced in the engage phase and made connections to the STEM concept. The extend phase offered strategies for how the girls could use their STEM knowledge to "make a difference" (Kaufman. 2010). It suggested how the girls could start by using the STEM content that they had learned within the context of their own homes and families to effect positive change. These life lessons were intended to go beyond a science-technology-society (STS) curriculum perspective. Rather, they were designed to help the girls become proactive in developing their own positions regarding responsible use of energy resources and then take action within a fifth grader's scope (Hodson, 2004; 2003).

The evaluate phase began at the end of each Club meeting when the girls classified that day's investigation as "S" for science, "E" for engineering, "T" for technology or "M" for mathematics. This was an opportunity for the girls to exercise their metacognitive skills as they reflected on their learning. Typically, there was lively discussion about how best to classify each investigation. The investigations deliberately integrated at least 3 and sometimes all 4 STEM disciplines. Debates indicated that the girls accurately perceived how the activities included content from more than one STEM discipline. Most often, the girls concluded that there was some content from each STEM discipline, but that one discipline predominated. This wrap-up activity supported "Core Idea 2A: Interdependence of Science, Engineering and Technology" (Sneider, 2012, p. 9) as the girls identified the links among STEM disciplines for themselves.

In order to maintain a relaxed, club-like atmosphere, informal evaluations were made during and after each Club meeting. These evaluations included formative assessments of the girls' understanding based on the Club leaders' observations of group discussions during Club meetings. The girls' notebook entries were reviewed after each Club meeting by the Club leaders to gain insight into the development of their STEM reasoning and grasp of STEM content (Carlisle, 2011).

Data Collection Procedures

The fifth grade girls' perceptions were accessed using three instruments: the Draw-A-Scientist-Checklist (DAST-C) (Finson, et al., 1995); Enhanced-Draw-A-Scientist-Test (E-DAST) (Farland-Smith & McComas, 2009) and Draw-An-Engineer-Test (DAET) (Thompson et al., 2008; Knight & Cunningham, 2004). The DAST and DAET were administered as pre-tests at the beginning of the first Club meeting on December 3, 2010 and as post-tests at the beginning of the last Club meeting on May 6, 2011. The students were given approximately 10 minutes to complete each test. During test administration, students were given instructions consistent with the E-

DAST instructions (Farland-Smith & McComas, 2009, p. 49) for both the DAST and DAET administration. The intention was to encourage the girls to make as many drawings as they needed to convey fully their understanding of a scientist and a scientist's work or of an engineer and an engineer's work.

Each girl was given a sheet of white unlined paper and a pencil. For the pre-test, the paper was folded into thirds to allow students to make more than one scientist or engineer drawing on a single sheet of paper. Pre-test drawing data showed that most students used 1 of the 3 sections to make a single scientist or engineer drawing. No students requested additional paper. For the post-test, instead of folding the first sheet of paper into thirds, we gave the students a single, unsectioned sheet of unlined paper. Piles of blank white paper were placed in the middles of the tables where students sat during the DAST and DAET administration. Club leaders again instructed the students to make as many drawings as they needed to communicate their understanding of what it meant to be a scientist or engineer. They were told to take any extra paper that they needed from the center of the table. For both pre- and post-testing, the DAET was administered after the DAST. During the DAET pre-test administration, some girls raised their hands asking what they should draw since they didn't know what an engineer was. They were instructed to write on their papers that they did not know what an engineer was.

Results and Discussion

In order to obtain as much information as possible from the students' drawings, each pre and post-test scientist drawing was separately scored according to the DAST-C (Finson et al., 1995) and E-DAST (Farland-Smith & McComas, 2009) evaluation criteria by 3 raters working independently. The raters were a science education doctoral student, an elementary school gifted resource coordinator and a professor of science education. The raters were each provided with identical scoring packets. Raters referred to the Finson et al., 1995 and Farland-Smith & McComas, 2009 articles for interpretation of the DAST-C and E-DAST scoring criteria, respectively, to insure consistency in scoring. Pre- and post-test DAST scores were determined by the 3 raters for each participant's drawing. Descriptive statistics, including the mean and range, were calculated from these 3 scores. The results of these analyses are summarized in Table 1.

Table 1

STEM Club aggregate DAST-C and E-DAST data

ID No.	***Age***	***Pre DAST-C Mean***	***Pre DAST-C Range***	***Post DAST-C Mean***	***Post DAST-C Range***	***Pre E-DAST Mean***	***Pre E-DAST Range***	***Post E-DAST Mean***	***Post E-DAST Range***
1	10-11	7	1	10	3	5	0	8	2
2	11	5	1	5	1	7	0	9	0
3	10	6	2	4	6	7	0	7	1
4	10	7	2	6	3	5	2	8	2
5	10	5	0	Absent	Absent	7	1	Absent	Absent
6	11	6	1	6	0	6	2	5	3
7	10	7	0	6	4	6	2	7	1
11	10	7	3	5	4	7	2	9	0

DAST-C Analysis

The Draw-A-Scientist-Checklist was used to obtain the DAST-C scores shown in Table 1. The Checklist inventories symbols considered representative of a stereotypical image of a scientist that appear in a particular drawing. (Only one symbol associated with each category was counted for scoring purposes if multiple symbols from the same category appeared in the drawing.) Unless there was a clear indication of an outdoor setting, the scientist images were classified as showing work indoors.

Likewise, images were classified as white unless there were any clear indications of shading to represent a darker skin color or facial features of a different race/ethnicity. A high DAST-C score is associated with a stereotypical scientist image. A low score is associated with a realistic scientist image.

Typically, DAST-C and DAST-E scores assigned by the three raters fell within narrow ranges (0-2) indicating overall consistent interpretation of the scoring criteria. However, scores for Participant #3's DAST-C post test had a wide range of 6. Examination of the drawing and the raters' scores revealed variation in their interpretations of the "lab coat", "knowledge symbols" and "technology" scoring criteria. The science education professor classified the outer garment the female scientist was wearing as a lab coat. However, both the gifted resource coordinator and scientist/engineer leader identified it as a cardigan or "street clothes" since it didn't have the stereotypical pocket filled with a pocket protector and pens. Neither the gifted resource coordinator nor scientist/engineer leader found "knowledge symbols" in the drawing, while the science education professor considered the paper in the female scientist's hand as a symbol of knowledge. The beaker, test tube and Bunsen burner were classified as "research symbols" by the gifted resource coordinator and scientist/engineer leader, but as "technology" by the science education professor.

Comparison of the DAST-C mean scores for each participant shows that scores either stayed the same or declined slightly after being a member of STEM Club for the school year. For Participant #1, the post-DAST-C score actually increased after being a member of STEM Club. These data indicate that most girls, including Participant #3, maintained the scientist images that they brought to the club or developed slightly more realistic scientist images. The number (n) of pre and post-test score pairs is small (n=7); however, a paired samples t-test analysis was carried out using SPSS software. The result of the paired samples t-test for the dast-c scores is shown in Table 2 below. The mean DAST-Cscore remained unchanged to significant figure after participation in the club. With p = 0.534, the change in means is not statistically significant.

Table 2 *Paired samples t-test results for pre and post DAST-C scores*

Pre-test mean	***Pre-test range mean***	***Post-test mean***	***Post-test range mean***	***Paired samples t-test sig.***
6	1	6	3	.534

Qualitative visual examination of the drawings supports this quantitative analysis. STEM Club participants drew traditional (Silver & Rushton, 2008b; Chambers, 1983), although not monstrous or cartoonish, scientist images both before and after their participation in STEM Club. Pre and post-DAST drawings made by one girl, Figures 1a and 1b, respectively, are representative of this trend.

Figure1a. A representative pre-test DAST drawing of a stereotypical male scientist working with chemistry apparatus.

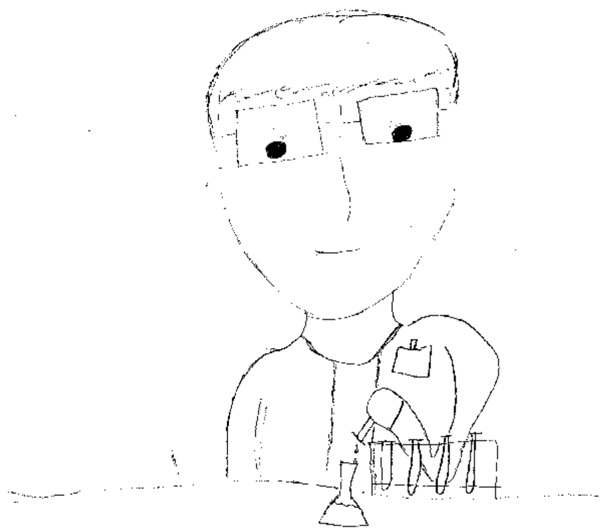

Figure 1b. DAST post-test stereotypical male scientist image drawn by the same girl who drew the image shown in Figure 1a.

Participant #3's pre- and post-DAST drawings as shown in Figures 2a and 2b are also consistent with this trend of maintaining static scientist images that are not affected by participation in STEM club. While this girl's pre- and post-test drawings include traditional chemistry laboratory equipment such as the iconic Erlenmeyer flask, both her drawings depart from stereotypical representations by depicting a female scientist.

Figure 2a. A pre-test DAST drawing of a female scientist working with traditional chemistry laboratory equipment.

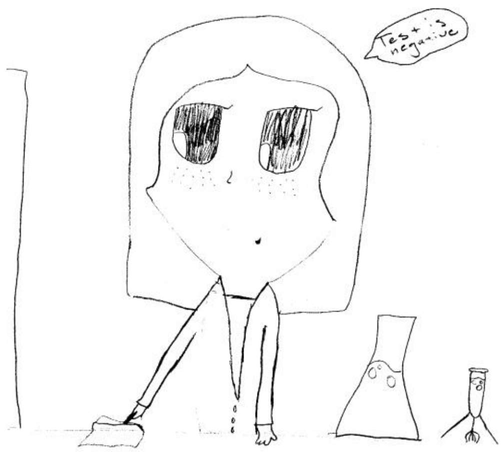

Figure 2b. A post-test DAST image drawn by the same girl who drew the image in Figure 2a and still including a female scientist with traditional chemistry laboratory equipment.

The DAST-C checklist does not include gender among the symbols used to analyze drawings of scientists. Hence, the DAST-C scores do not reflect scientist gender. This is one aspect of the scientist drawings that did change after the girls' participation in STEM Club. While only 1 (Participant #3's drawing shown in Figure 2a) of 8 pre-test DAST drawings showed an identifiably female scientist image, 3 of 7 post-test DAST drawings showed an identifiably female scientist image. This increase in female scientist images represents a change from 13% female scientist images prior to STEM Club participation to 43% female images after participation in Stem Club. This change in scientist image gender is particularly evident in the pre and post-test DAST images shown in Figures 3a and 3b, respectively. Furthermore, the female scientist image in Figure 3b and the female engineer image in Figure 11b show a hairstyle and glasses that resemble the female scientist/engineer club leader's hairstyle and glasses. Farland-Smith (2012) likewise found that 5^{th} - 9^{th} grade girls, presumably representing a range of intellectual abilities, who attended a summer science camp drew E-DAST scientist images that resembled the scientists from the camp, including their glasses and hair. She concluded "that the scientists were not just viewed as teachers the girls had spent the day with, but had become real people to them" (Farland-Smith, 2012, p. 15).

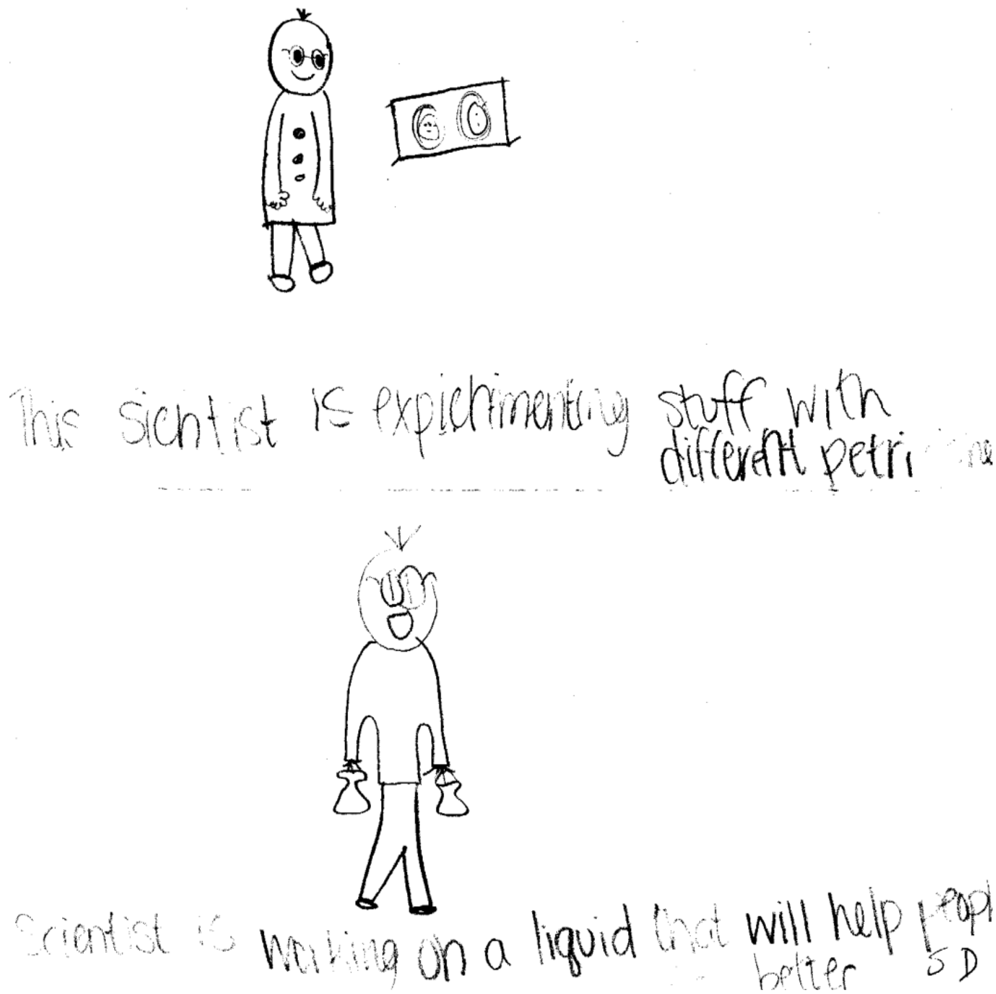

Figure 3a. Male scientist images drawn by a girl on the DAST pre-test. The scientist in the upper part of the figure is “experimenting stuff with different petri dishes”. The one in the lower part is “holding a liquid that will help people get better”.

Figure 3b. Female scientist DAST post-test image drawn by the same girl who drew the pre-test image shown in Figure 3a.

E-DAST Analysis

The E-DAST scoring rubric enables a more sophisticated interpretation of the DAST drawings than does the DAST-C checklist. Rather than merely generating an inventory of symbols associated with stereotypical scientist drawings like the DAST-C checklist, the E-DAST rubric characterizes the scientist image according to the criteria of "appearance", "location" and "activity". These criteria are scored as "can't be categorized", "sensationalized", "traditional" or "broader than traditional" (Farland-Smith & McComas, 2009, p. 50). Points are awarded on a scale of 0-3, with 0 points corresponding to "can't be categorized" and 3 points corresponding to "broader than traditional". Hence, the higher the E-DAST score, the more the drawing tends to represent a scientist image that transcends the traditional, stereotypical scientist image. According to this rating system, a score of "9" indicates a scientist image that goes beyond the traditional stereotypical appearance, location and activity. For the present study, teaching was considered as falling under the category of "broader than traditional" for the "activity" criterion.

Mean E-DAST scores were calculated from the scores generated by the 3 raters. Comparison of the E-DAST mean scores for each participant shows that for more than half of the participants, E-DAST mean scores increased after participation in stem club. For three of the participants, scores increased by 3 points. One participant's scores stayed the same and for another, her score decreased by 1. Furthermore, 86% of post-test scores were in the range of 7-9 with two scores of 9, placing them solidly in the category of "broader than traditional" image. 100% of pre-test scores were in the range of 5-7 indicating that students held "traditional" scientist images when they began

STEM Club. Use of this more sophisticated rubric indicates that some STEM Club participants' images of scientists evolved from traditional, stereotypical images to more realistic images that went beyond the standard, stereotypical image.

A paired samples t-test analysis (n=7) was carried out for the 7 pre and post-test score pairs using SPSS software as was done for the DAST-C analysis. The result of the paired samples t-test for the E-DAST scores is shown in table 3 below.

Table 3

Paired samples t-test results for pre and post -DAST scores

Pre-E-DAST mean	***Post-E-DAST range mean***	***Post-E-DAST mean***	***Post-E-DAST range mean***	***Paired samples t-test sig***
6	1	8	1	.047

The mean E-DAST score (to 1 significant figure) increased by 2 after participation in STEM Club. Given the small n (n=7), p=.047 may indicate that the difference between pre and posttest E-DAST score means may be approaching statistical significance.

As previously discussed in the context of the DAST-C analysis, quantitative analysis and qualitative visual examination of the drawings are consistent. The quantitative and qualitative analyses both indicate that after participation in STEM Club, some girls drew scientist images that extended beyond the traditional, mostly male stereotype, not only in terms of including more depiction of female scientists, but in other aspects as well. The E-DAST scoring rubric identified how their post-test drawings included broader than traditional elements. These elements included settings other than a laboratory such as a classroom setting where a scientist is shown teaching as in Figure 4.

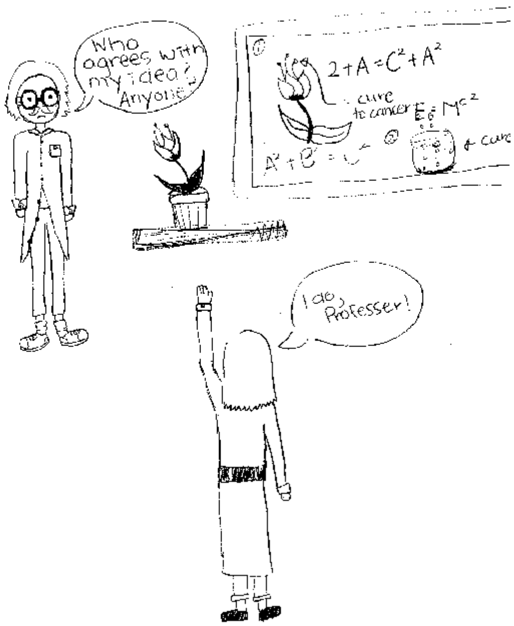

Figure 4. DAST post-test image showing a scientist teaching in a classroom.

DAET Analysis

Efforts were made to obtain as much information as possible from the girls' DAET drawings. Just as for the DAST drawings, each pre and post-test engineer drawing was separately scored according to two rubrics, the Knight & Cunningham (2004) image frequency analysis (Knight & Cunningham, 2004) and the "DAET Scoring Guide" (Thompson et al., 2008, p. 199-200). The DAET drawings were scored by the three previously described raters who scored the DAST drawings. Again, the raters scored the DAET drawings independently. They referred to the Knight & Cunningham (2004) and Thompson et al., (2008) articles for interpretation of the image frequency and DAET Scoring Guide scoring criteria to insure consistency. The pre and post-test DAET drawing scores assigned by the 3 raters were tabulated and descriptive statistics for each participant's scores, including the mean and range, were calculated.

Image Frequency Analysis

The image frequency analysis (Knight & Cunningham, 2004) identifies and tallies the occurrence of traditional, stereotypical images associated with engineering in DAET drawings. This rubric designates 6 thematic groupings: (1) images of building/fixing, (2) images of designing, (3) images of products of mechanical engineering, (4) images of products of civil engineering, (5) images of trains, and (6) images of laboratory work. Stereotypical building/fixing images relate to construction i.e. hard hats and heavy machinery or repair work i.e., safety glasses and tools. Traditional designing images include blueprints, pen/pencil and desks. Products of mechanical engineering include cars and engines. Products of civil engineering include bridges, roads and houses. Train images are defined as trains, tracks or train engineers. Laboratory images are represented by test tubes and beakers. For the present study, if more than one image associated with a particular thematic grouping was present, the thematic grouping was counted once. Pre-test drawings in Figures 5 and 6 link the activity of fixing to a product of mechanical engineering, the car. Figure 7 depicts building activity and incorporates traditional symbols associated with construction, a hard hat and a nail gun. However, the image goes beyond the stereotypical construction/building image by showing a female construction worker. No train-related images were drawn.

Figure 5. DAET pre-test drawing of a male figure holding a tool, presumably to repair a broken car light.

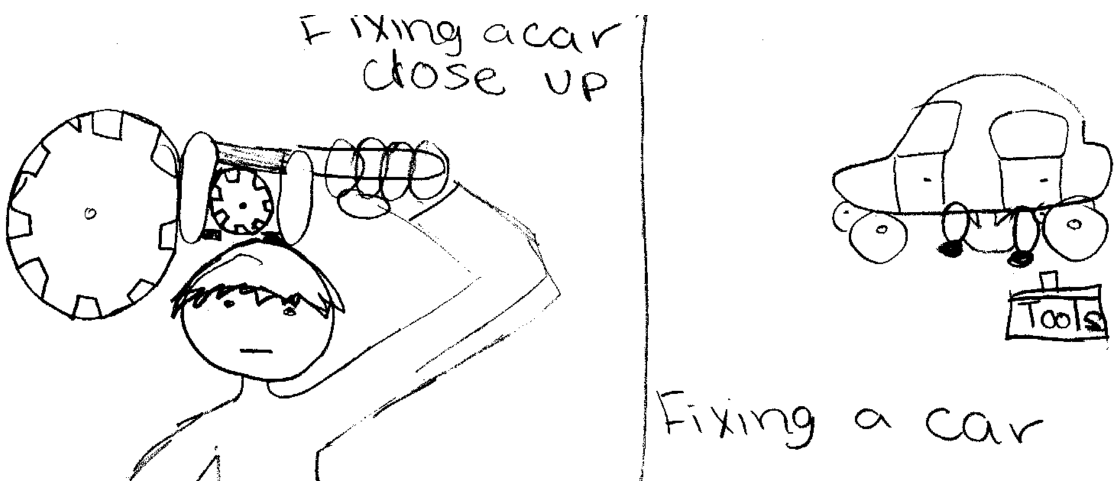

Figure 6. Tools, a car part, and a car are shown in the DAET pre-test image of engineers repairing a car.

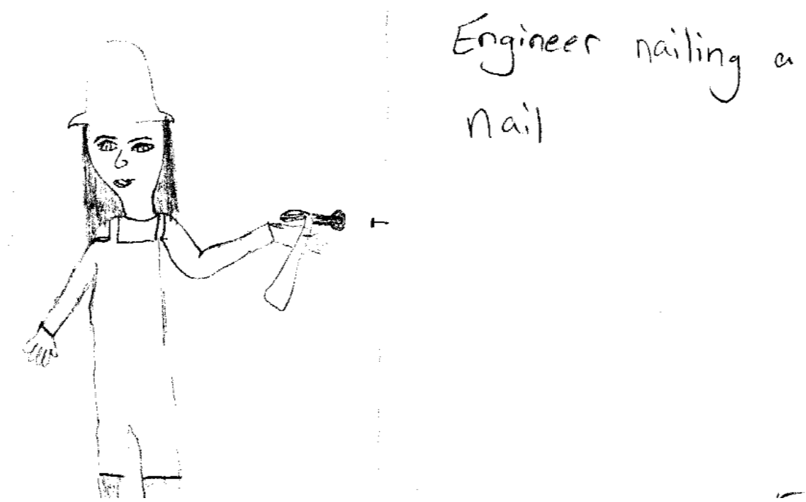

Figure 7. DAET pre-test drawing of a female construction worker includes stereotypical building/construction symbols like a hard hat and tool.

Table 4

STEM Club pre and post-test DAET image frequency data

Image *(Knight & Cunningham (2004)*	***Pre Mean (n=8)***	***Pre Range***	***Post Mean (n=7)***	***Post Range***
Designing	13%	0%	52%	14%
Products of Engineering – Mechanical	50%	0%	29%	0%
Trains	0%	0%	0%	0%
Race/Ethnicity	White 100%	0%	White 100%	0%

Table 4 summarizes mean pre- and post- DAET image frequency data for 3 of the 6 thematic groupings identified by Knight & Cunningham (Knight & Cunningham, 2004). For these three thematic groupings: (2) images of designing, (3) images of products of mechanical engineering and (5) images of trains, the three raters were consistent in their interpretations of the girls' drawings. Ranges for pre- and post-test image frequencies for these thematic groupings were 0% except for the post-test designing images range of 14%. This 14% post-test range was associated with a relatively large post-test mean frequency of designing images, 52% which was 400% larger than the pre-test mean frequency of designing images, 13%. Comparison of mean pre- and post-test DAET image frequencies shows a decline in the presence of stereotypical images of products of mechanical engineering. The decline from 50% to

29% in the images of products of mechanical engineering, i.e., engines and cars, is especially marked.

However, the three raters diverged significantly in interpreting and identifying the thematic groupings: (1) images of building/fixing; (4) products of engineering-civil and (6) images of laboratory work. This divergence was reflected in large pre- and post- test mean ranges which made direct quantitative comparison of pre- and post-test images impossible, hence the exclusion of these image categories from Table 4. For these 3 categories, image interpretation was highly sensitive to a particular rater's familiarity with various engineering disciplines and/or whether the rater had actually attended the STEM Club meetings. The scientist/engineer and gifted resource coordinator raters sometimes recognized images in the girls' drawings of materials and equipment that they had worked with during Club meetings. By contrast, the science education professor who had not attended the meetings did not. Other times, the scientist/engineer identified specific STEM content from the STEM Club as relating to materials/electrical engineering, while the gifted resource coordinator and science education professor raters classified it as related to civil engineering. The DAET pre- and post-test drawings made by participant #6, Figures 8a and 8b, demonstrate how the extent of a rater's familiarity with multiple engineering disciplines influenced drawing interpretation.

Figure 8a. DAET pre-test image of a male engineer drawn by participant #6.

Two of the 3 raters identified an image of building/fixing in the DAET pre-test drawing shown in Figure 8a. They interpreted this drawing as showing a traditionally attired male engineer fitting two pieces of material together. The drawing may represent an assembly of components into a larger part, i.e., building or putting fragments of a broken part back together, i.e., fixing.

Figure 8b. DAET post-test image also drawn by Participant #6.

Two of the 3 raters characterized the post-test drawing shown in Figure 8b as a depiction of designing. However, the raters diverged in identification of the particular field of engineering associated with the design process shown. The gifted resource coordinator and science education professor classified the design process as including products of civil engineering. However, the scientist/engineer interpreted these same drawing elements as depicting the process of cutting silicon wafers from larger blocks of crystalline silicon material. The girls had learned about silicon wafer processing during an investigation entitled “Taking Apart Technology”.

Variation in interpretation of images representative of laboratory work correlated with whether or not a rater had attended STEM Club meetings and was familiar with the investigations that the girls performed. The scientist/engineer and gifted resource coordinator who had both been present at STEM Club meetings identified symbols of research in the DAET drawings shown in Figures 9 and 10b, a beaker and balance, respectively. During two STEM Club meetings, the girls used balances to weigh metal samples as part of an activity that introduced the chemistry concept of a “mole”. The science education professor who had not witnessed these STEM Club investigations did not identify these images as laboratory work.

Engineer image gender and race/ethnicity were not included in the Knight & Cunningham image analysis rubric (Knight & Cunningham, 2004). Table 4 adds image race/ethnicity to the categories provided by Knight & Cunningham (Knight & Cunningham, 2004). Images were classified as “white” for race/ethnicity if there was no clearly identifiable skin shading or other facial features characteristic of a non-white race/ethnicity. Only 2 of the 3 raters provided data on race/ethnicity for the DAET images. These 2 raters classified 100% of both pre- and post- DAET images as “white”.

These image interpretation inconsistencies even among raters who are evaluating DAET drawings guided directly by the Knight & Cunningham image analysis rubric (Knight & Cunningham, 2004) indicate that caution must be exercised in making conclusions based solely on quantitative image frequency data. Rather, a holistic approach including a qualitative visual examination of the DAET drawings provides insight into the girls' evolving perceptions of engineers. The girls' developments are particularly evident in their portrayals of designing activity and laboratory work as aspects of engineering along with portrayals of female engineers. Girls' engineer images created after participating in STEM Club reflect a more realistic understanding of engineering. These post-test drawings include design and laboratory study that extend far beyond the fixing and building or creating products shown in the images drawn before participation in the Club. It should also be noted that for the pre-test, one girl was unable to draw an image of an engineer. Instead, she wrote, "Nothing in my mind … what does an engineer do?" Her post-test DAET image of a non-stereotypical, clearly female engineer doing laboratory work is shown in Figure 9.

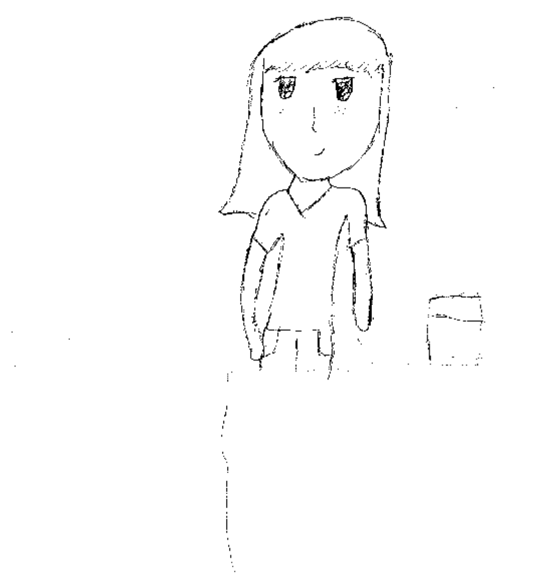

Figure 9. DAET post-test image of a female engineer doing laboratory work drawn by a participant who before attending STEM Club had no idea of what an engineer was or did.

DAET Scoring Guide Analysis

The "DAET Scoring Guide" developed by Thompson et al. (2008) goes beyond the tally of stereotypical engineering images generated by the previously considered Knight & Cunningham (2004) image frequency analysis. Like the E-DAST rubric (Farland-Smith & McComas, 2009), the DAET Scoring Guide is a tool for assessing the extent to which the image conveys an accurate and complex understanding of engineering. The Guide scores drawings on a scale from 0-2 based on 4 categories: (1) "Engineering Artifacts (Tools/Equipment/Models/Symbols); (2) "Diversity of Fields"; (3) "Engineering Processes"; and (4) "Portrayals of Engineering" (Thompson et al., 2008). A score of "0" is assigned for explicit statements of not knowing or the absence of any representation of that category in the drawing. A score of "1" is assigned for simplistic and/or traditional, stereotypical representations of a category. Lastly, a score of "2" is assigned for representations that go beyond the traditional/stereotypical and reflect a more complex, sophisticated understanding of engineering. For example, with respect to the Artifacts category, image elements such as standard building/fixing tools or equipment being used in a technician or repairman-like fashion would receive a score of "1". Under this same category, design, presentation or experimentation activities would receive a score of "2". Overall, scores obtained using the DAET Scoring Guide can range from 0-8 corresponding to levels of understanding of engineering from total ignorance about the field (0) to a highly nuanced understanding (8). The sophisticated understanding of engineering encompasses realistic design, experimentation and presentation of information. Such drawings can include multiple engineering fields. Table 5 summarizes DAET Scoring Guide pre and post-DAET scores.

Table 5

STEM Club "DAET Scoring Guide" (Thompson et al., 2008) data

Participant ID No.	***Age***	***Pre-Score Mean***	***Pre-Test Race/Gender Comments***	***Post-Score Mean***	***Post-Test Race/Gender Comments***	***Pre-Score Range***	***Post-Score Range***
1	10-11	5	White/Male	7	White/Female	1	3
2	11	7	White/Female Highly sophisticated dwg. & caption "Transportation Engineer"	4	White/Female	3	3
3	10	5	White/Male "Stereotypical" Auto Mechanic	6	Race/Gender cannot be determined	2	7
4	10	5	White/Female Construction Worker	7	White/Female Conducting an experiment	0	6
5	10	5	White/Male "Stereotypical" Auto Mechanic	Absent	Absent	1	Not available (absent)
6	10-11	6	White/Male Putting parts together - technician	10	Race/Gender cannot be determined Design activity	7	1
7	10	0	"What does an engineer do?"	5	White/Female Design activity	0	6
11	10	4	White/Male "Stereotypical" Auto Mechanic	7	White/Female Hairstyle & glasses similar to those worn by female scientist/engineer club leader	6	7

Comparison of pre and post-test DAET scoring guide scores shows that except for Participant # 2, DAET scores increased after being a member of STEM Club. As stated in Table 5, Participant #2 drew a pre-test image that showed a female transportation engineer looking over detailed road plans, Figure 10a. Her post-test drawing, Figure 10b, still shows a female engineer. However, the post-test image shows the engineer doing laboratory work, specifically using a balance to weigh a sample. This drawing may reflect the girl's recollection of one of the STEM Club materials science & engineering activities that involved weighing bar-shaped metal samples. While this girl retained the female engineer image, her perspective was broadened to reflect the engineering laboratory activities she had experienced in STEM Club. The lower post-test score may be an artifact of rater interpretation of the laboratory research activity as already considered in the discussion of image frequency analysis.

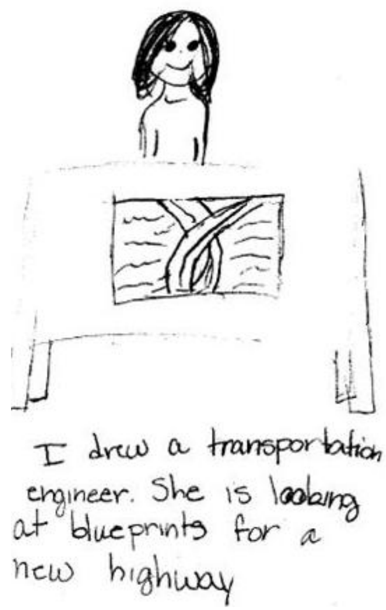

Figure 10a. DAET pre-test drawing of a female transportation engineer.

Figure 10b. DAET post-test image of a female engineer doing laboratory work drawn by the same girl who drew the image shown in Figure 10a.

Continuing the holistic approach of integrating scores with qualitative visual examination of the DAET drawings reveals more sophisticated, authentic engineer images in the post-test DAET drawings as compared to the pre-test DAET drawings. The dramatic change shown by one girl's development from having no idea of what an engineer was or did to drawing a normal looking female engineer (Figure 9) for the post-test has already been discussed in the image frequency analysis section. Another girl's engineer image developed from a traditional male auto mechanic standing near a car pre-test image (Figure 11a) to a female engineer performing laboratory testing on a model of a "green" car equipped with solar panels and led lights (Figure 11b). It is interesting to note that this girl's post-test engineer drawing is identical to her post-test scientist drawing, except for changing the word "scientist" to "engineer" in the caption of the engineer drawing. This similarity may reflect her understanding of the inter-connected nature of the science and engineering stem disciplines that was evident during club discussions. Both post-test drawings also reflect this girl's retention and synthesis of science content she learned from an inquiry investigation done during the STEM Club meetings. In this investigation, the girls compared the light and heat emission characteristics of led bulbs to those of conventional incandescent bulbs. They also learned about the element silicon and how it can be used to make solar panels that generate electrical energy from sunlight.

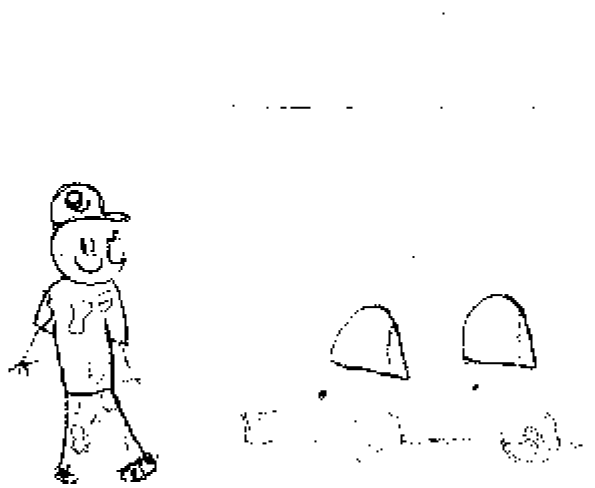

Figure 11a. DAET pre-test drawing of a stereotypical male mechanic wearing dirt-spattered clothing and standing beside a car.

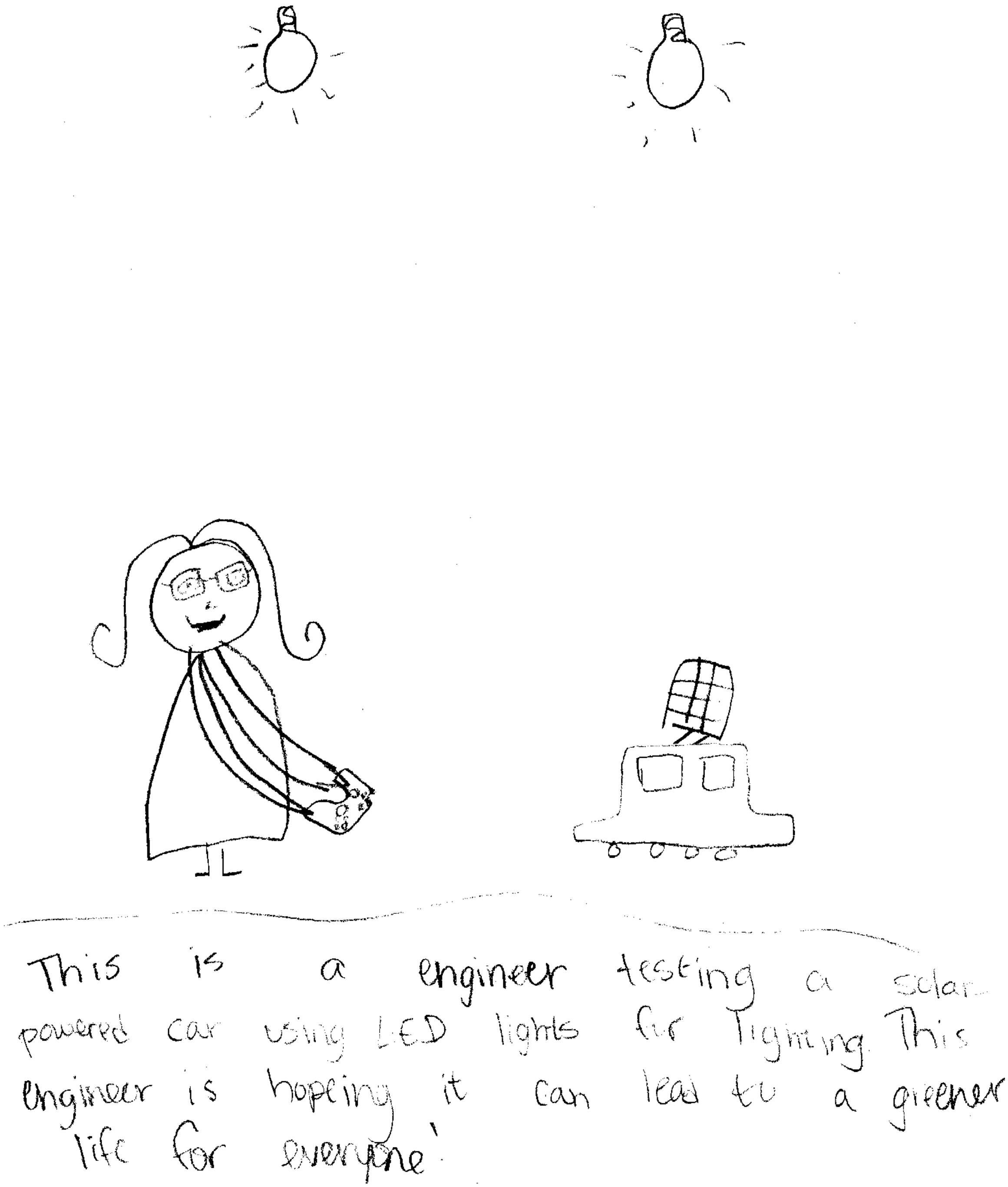

Figure 11b. DAET post-test image drawn by the same girl who drew the male engineer image in Figure 11a. According to the girl's caption this female engineer is "testing a model of a solar powered car using led lights for lighting. This engineer is hopeing [sic] it can lead to a greener life for everyone."

Likewise, Participant #1's engineer images show similar development from her DAET pre-test to DAET post-test drawings. Her DAET pre-test drawing showed a stereotypical male auto mechanic repairing a car, captioned, "someone who works with engines" as shown in Figure 5. After participation in STEM Club, she drew a fashionably dressed female engineer posing the research oriented question, "I wonder what kinda rocky metal this is!" As shown in Figure 12. STEM Club activities that involved visual examination of metal samples, including rough chunks of silicon, with a magnifying glass may have influenced this girl's drawing.

Figure 12. DAET post-test drawing of a female engineer drawn by the same girl who drew the male auto mechanic shown in Figure 5.

Conclusions

Gifted fifth grade girls' DAST and DAET drawings provided insight into how their understandings of scientists and engineers changed over the course of 7 STEM Club meetings. The most dramatic change was observed in their perceptions of engineers. Images drawn before participation in STEM Club were highly stereotypical representations that associated engineers with repairmen, mechanics or construction workers, albeit a female construction worker for one girl. These images are consistent with the findings of Silver & Rushton (2008b). Images drawn after STEM Club involvement were non-traditional images of females doing authentic design or laboratory work. One girl's perception moved from a completely naïve understanding of not knowing what an engineer was or did, to that of a non-stereotypical female engineer doing laboratory work as shown in Figure 9.

Changes in the girls' perceptions of scientists were more subtle. Their pre-STEM Club images of traditional, male scientists primarily doing bench chemistry work with beakers and flasks were broadened to less traditional images that included female scientists or scientists engaged in teaching. However, some traditional images did persist even after participation in STEM Club. These results are consistent with Melber's (2003) findings that gifted fourth and fifth graders drew DAST images with fewer stereotypical elements after participating in a museum after-school outreach program. The girls' perceptions of scientists as revealed in their DAST drawings are significant for the information they provide about their future coursework and career choices. Joyce and Farenga (1999) concluded that high ability children have decided whether they will study science by age 9.

From these pilot study data, it would appear that gifted fifth grade girls already have fairly well established perceptions of scientists as reflected in the images of scientists that they drew. These findings are consistent with those of Chambers (1983) who showed that children's scientist images had already stabilized between 4^{th} and 5^{th} grades. Participation in a STEM Club led by a female scientist/engineer was successful in "tweaking" these images to be somewhat less traditional, particularly with respect to scientist gender. Drawings made after STEM Club participation showed a 30% increase in the number of female scientist images. This increase in the number of female scientist images is consistent with the findings of Bodzin & Gehringer (2001). In their study, 4^{th} and 5^{th} grade students participated in activities led by two visiting stem practitioners, one a female chemical engineer and the other a male physicist. The study found that students drew more female scientist images in the classroom visited by the female chemical engineer (Bodzin & Gehringer (2001) than in those visited by the male physicist.

Gifted fifth grade girls' perceptions of engineers, on the other hand, were more plastic than their scientist perceptions. At the outset, the girls confused engineers with technicians and repairmen. They held stereotypical images of mechanics or construction workers. In these preconceptions, they substituted a mechanic for a mechanical engineer. One girl was a "blank slate" with no idea of what an engineer was or did. The girls abandoned these naïve or non-existent preconceptions for authentic images of engineers after participation in STEM Club. For engineer drawings, the change in the engineer image gender was also greater than the change observed for scientist images. The number of female engineer images showed a 42%

increase compared to the 30% increase in female scientist images. It appears that providing a female scientist/engineer role model may have influenced the girls to replace male scientist or engineer images with female images. By contrast with the findings of Buck et al. (2002), the visiting scientist/engineer retained her stem practitioner identity. Unlike the female scientists in the buck et al. (2002) study, she was not categorized as a teacher. It appears that having the STEM practitioner as a regular visitor, rather than part of the daily classroom routine avoided confusion of her identity with that of a classroom teacher.

Likewise, this study's results of (1) broadening perceptions of scientists beyond the traditional male stereotype to include more females; (2) developing realistic perceptions of engineers involved in design and laboratory research, rather than as mechanics or construction workers; and (3) dramatically broadening perceptions of engineers to include more females, differ from the results of the HGGC project (Silver & Rushton, 2008a; Silver & Rushton, 2008b). In the present study, gifted fifth grade girls' perceptions of scientists and engineers became more realistic while those of the fifth graders who participated in the HGGC project became more stereotypical. These divergent outcomes suggest that a short (1-2 weeks) intensive building project, the HGCC electric car, reinforces scientist and engineer stereotypes. By contrast, monthly club meetings including a variety of interdisciplinary stem inquiry investigations situated within a "real life" context and held regularly during the school year dispel scientist and engineer stereotypes.

In their study of middle school students in grades 6-8, Fralick et al. (2009), found that even these older students had limited understanding of engineers and their work. Middle school students either had “no perception of engineering” (Fralick et al., 2009, p. 60) or associated engineering with manual labor. Like the gifted fifth grade girls in this study, the middle school students had more developed images of scientists as experimenters and observers. The persistence of naïve engineer stereotypes into the middle school grades identified by Fralick et al. (2003) together with the indication from this study that gifted fifth grade girls who participated in a stem club developed realistic and sophisticated perceptions of engineers suggest that outreach efforts to introduce children to engineering should begin in elementary school.

Suggestions for Future Work

This pilot study involved a small number, eight, participants. Since one of the 8 participants was absent for administration of the post-tests, the complete pre- and post-test data set included only 7 pairs of pre- and post- tests. Efforts are under way to continue STEM Club and enroll additional gifted female 5th graders to participate in the study. A larger number of participants will elucidate the extent to which the results of the present study can be generalized for gifted female 5th graders. Future work can include studying the effect of participation in a STEM Club on the perceptions of scientists and engineers held by female 5th graders having a range of abilities.

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APPENDIX A: APPROVED PROSPECTUS

THE UNIVERSITY OF OKLAHOMA

JEANNINE RAINBOLT COLLEGE OF EDUCATION

SCIENTISTS' SELF-PERCEPTIONS: A PHENOMENOLOGICAL STUDY OF NATURAL SCIENTISTS IN ACADEMIA

A PROSPECTUS

SUBMITTED TO THE GRADUATE COMMITTEE

in partial fulfillment of the requirements for the

degree of

DOCTOR OF PHILOSOPHY

SUBMITTED BY

FLORENCE F. McCANN

Norman, Oklahoma

2009

SCIENTISTS' SELF-PERCEPTIONS: A PHENOMENOLOGICAL STUDY OF NATURAL SCIENTISTS IN ACADEMIA

A Prospectus APPROVED FOR THE DEPARTMENT OF INSTRUCTIONAL LEADERSHIP AND ACADEMIC CURRICULUM
in

Science Education

BY

Edmund A. Marek, Chair

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CHAPTER 1

Introduction

Reports from the National Academies (National Academy of Sciences, National Academy of Engineering, Institute of Medicine and the National Research Council) and various government and business groups paint a gloomy picture for the future of the United States' competitiveness in **S**cience, **T**echnology, **E**ngineering and **M**athematics, often referred to by the acronym STEM (eSchool News, 2008). A recent report by a coalition including the U.S. Chamber of Commerce and the National Defense Industrial Association predicted a substantial shortfall from the 400,000 new STEM graduates needed by 2015 (eSchool News, 2008). This problem is not restricted to the United States. It afflicts Europe as well. The Nuffield Foundation of the United Kingdom recently brought science educators together from nine European countries to address these issues (Osborne & Dillon, 2008). A report was generated, *Science Education in Europe: Critical Reflections* (Osborne & Dillon, 2008).

The report highlighted two startling facts. "The more advanced [as measured according to the UN Index of Human Development] a country is, the less its young people are interested in the study of science (Osborne & Dillon, 2008, p.13)." Analysis of the 1999 Third International Mathematics and Science Study (TIMSS) data revealed that highly achieving students have less positive attitudes toward science than their lower achieving counterparts. Why do high achieving youth from wealthy countries lack interest in STEM? The report identified unengaging, memory-based curriculum that presents science for scientists rather than for general scientific literacy as a contributor to the problem (Osborne & Dillon, 2008). Roth & Calabrese Barton (2004,

p. 74) have described such a “classical approach” as serving to expose children and older students to the “images of scientists’ science.” According to this classical approach, science is “taught in special physically separated rooms” (Roth & Calabrese Barton, 2004, p. 74) isolated from other disciplines. Such traditional curriculum is especially ineffective in engaging girls’ interest (Osborne & Dillon, 2008). Over a century since Dewey recognized the inherent futility of a curriculum based on memorization of disembodied facts, particularly for teaching science (Dewey, 1902), such practices persist. Another contributing factor is that for these young people, science has an unappealing image (Osborne & Dillon, 2008). The present study will consider aspects of this image problem.

Youth in developed (industrialized) countries place a premium on creativity and innovation and do not see STEM careers as a means for self-realization (Osborne & Dillon, 2008). These young people (ages 12-13) hold a stereotypical image of the scientist (Koren & Bar, 2009). The stereotypical image is one of a solitary, be-spectacled, white male working at a laboratory bench surrounded by equipment associated with chemistry (Koren & Bar, 2009). Sometimes that image is exaggerated to the point of caricature, the mad scientist (Koren & Bar, 2009; Gregory & Miller, 1998). At best, high school students in an industrialized country are likely to hold ambivalent images of scientists (Koren & Bar, 2009). These ambivalent images are consistent with Osborne and Dillon’s (2008) finding that in economically advanced countries there is a mismatch between the values held by youth and the “perceived values associated with science and technology” (Osborne & Dillon, 2008, p. 17).

Gregory and Miller (1998, p. 131) raised the possibility that the images of scientists shown in drawings are not representations of what people "think scientists look like." Instead, they proposed that caricature is a deliberate choice of a representative, well-established icon for the purpose of communication with other people (Scantlebury et al., 2006; Gregory & Miller, 1998). Symington and Spurling (1990) suggested that stereotypical images of scientists drawn by children may not reflect what the children actually know about scientists. Instead, the children construct images based on the popular scientist stereotype so that their images are widely recognized as representing scientists. Even prominent scholars in education invoke the stereotype of the "white-coated demigod" (Lincoln & Guba, 1985, p. 92). These stereotypes are efforts to make the positivist scientist reality with its implicit "premise of subject-object dualism" (Lincoln & Guba, 1985, p. 93) manageable. According to Rahm (2007), "the images [stereotypical images of scientists] and notions themselves seem resistant to change and appear to have been taken as unquestionable realities" (p. 519). It can be difficult to resolve the complex "entanglement of fact and value" (Putnam, 2002, p. 34) that these stereotypes represent. As Roslynn Haynes observed, "Popular belief and behavior are influenced more by images than by demonstrable facts" (Haynes, 1994, p. 1). These stereotypical images and their implicit attitudinal and evaluative components are real. Hence, the stereotypes must be considered for the power of influence they wield. The very fact that people, including elementary school age children, use such caricatures knowing that they will be recognized by others and effectively communicate the meaning "scientist" has profound implications for scientists and science educators.

A link exists between portrayals of scientists in the media and student attitudes toward science (Jones & Bangert, 2006; Boylan et al., 1992). Bowtell (1996) concluded that children's exposure to stereotypical scientist characters appearing in commercial television programming aimed at children and in television commercials contributes to children's perceptions of science and scientists. A study of primary school children (Year 5), in the United Kingdom concluded that stereotypical images of scientists and engineers, rather than an intrinsic dislike for science and engineering, are responsible for students' lack of interest in becoming scientists or engineers (Silver & Rushton, 2008). "[C]loudy career paths and low wages relative to other specialized careers such as medicine, law and finance" (Toppo & Vergano, 2009, p. 1) also contribute to avoidance of STEM careers. The implications of the stereotypical scientist image transcend the purely aesthetic in a world where science touches every aspect of life. According to Dr. John Holdren, Obama's Presidential Science Adviser, "More and more the challenges we face are going to require big infusions of science and technology to get solved" (Toppo & Vergano, 2009, p. 1). These stereotypical images will profoundly influence the relationship that society, including stakeholders in K-20 education, has with science and scientists, and ultimately society's ability to meet the "challenges" envisioned by Dr. Holdren.

The context of the present study is Kindergarten through college science education, what Schibeci (1986, p. 139) referred to as "school science", i.e. "the natural sciences (physical and biological) sciences" with the addition of the earth sciences. Hence, "scientists" will be defined as practitioners of one of these natural sciences, "those who do '[natural] science' " (Hills & Shallis, 1975, p. 471). For this study, Schibeci's description of the natural sciences (1986) is broadened to include earth sciences, since earth science concepts are included in K-12 curricula. Those "who teach it [science]", i.e., science educators, those who "write about it [science]" (Hills & Shallis, 1975, p. 471) and those who apply science, i.e., medical practitioners and researchers, engineers, inventors and technologists (Aikenhead & Ogawa, 2007), are excluded from the present study.

It is significant that elementary school children likewise differentiate among the disciplines of science, engineering and technology. They characterize science as "investigative", engineering as involving "repairing" and technology as "creative" (Silver & Rushton, 2008, p. 51). Those who, like C.P. Snow, a molecular physicist-turned public servant and author (Haynes, 1994), were once natural scientists, but have since joined other professions likewise are not considered "scientists" for the present study. "Social science and social scientists" will not be "included-not because they are unimportant, but because it is school science [as previously defined] that is the concern" (Schibeci, 1986, p. 139) here.

Another aspect of the definition of scientist derives from the relationship between science and society. This aspect involves a continuum that ranges from a natural science practitioner "devoted mainly or almost exclusively to the discovery of new knowledge" (Hills & Shallis, 1975, p. 471) to the public. For the present study, the public is "those outside the scientific elite" (Gregory & Miller, 1998, p. 1). The British public-understanding-of-science movement further expands on this definition of the public to refer to adults, families and community groups outside the schools who obtain the bulk of their information about science through the media (Gregory & Miller, 1998).

This definition of the public is applied inclusively in the present study to embrace a spectrum of people living in the United States of America who are culturally and demographically diverse with respect to ethnicity, gender, sexual orientation, socio-economic status and immigration status. This continuum includes the "man and woman in the street" (Gregory & Miller, 1998, p. 52) along with well-educated intellectuals in disciplines outside the natural sciences as already defined.

Scientists and the Public

A significant aspect of the nature of science (NOS) is that science is part of the greater body of human endeavor and is embedded within society (McComas, 2004; McComas, 1996). Science is itself a social institution (Pepper, 1967). The relationship between science and the public is plastic and shaped by world events. The public's view of science and scientists has changed from largely positive after World War II to "ambivalent" (Gregory & Miller, 1998, p. 3) by the 1970's. Immediately after World War II when scientists were "held in high regard" (Gregory & Miller, 1998, p. 3), a hierarchical relationship between scientists and the public prevailed. Scientists, the experts, validated new knowledge and the public, presumably non-experts, accepted their authority (Patton, 2002; Pepper, 1967).

During the twentieth century, the relationships among science, war and the public became firmly cemented. These inter-relationships have narrowed the perception of "science" in popular culture from its broadest interpretation as the Latin "scientia", knowledge, to two specialized disciplines, chemistry and physics. World War I was the chemist's war with its widespread use of poison gas and World War II was the physicist's war with its introduction of the ultimate weapon, the atomic bomb

(Bowler & Morus, 2005). Hence, if a country prevailed in one of these conflicts, some credit was due its chemists and physicists. They became mythic figures simultaneously inspiring awe and fear. Hence, the popular view of “science” came to be construed as “physics and a few other fields with similar methodologies” (Diamond, 1999). Diamond (1999) characterized these methodologies as laboratory experiments wherein a single parameter (independent variable) is manipulated while other parameters are held constant, enabling the determination of a precise mathematical relationship between a selected independent variable and the parameter of interest (dependent variable). When this definition is applied, it is understandable that chemistry stands beside physics in this popular (mis)construction of science.

The “intricate relationship” (Mitias, 1970, p. 135) between science and society is to some extent dysfunctional. Despite the recognition forty years ago “that realistic and favorable concepts of and attitudes toward science by non-scientists are essential for continued support of scientific research and exploration” (Mitias, 1970, p. 135) there nevertheless exists a significant “disconnect” between scientists and society (Haynes, 2006). Thirty-five years ago, Hills and Shallis (1975) found that scientists’ self-perceptions diverged considerably from non-scientists perceptions of scientists. The seeds for the modern “disconnect” between science and society were first sowed in the late 16th century when the Royal Society was founded in England. With the professionalization of science in the 19th century, a dichotomy, albeit a false one, given their acknowledged interdependence, was firmly established between scientists and society (Gregory & Miller, 1998). Society came to terms with scientists and their work by creating a popular view of science and scientists. A persistent stereotype of scientists (McAdam, 1990) pervades the mass media (Frayling, 2005; Haynes, 1994; Goldman, 1989; Jacobi & Schiele, 1989), children's trade books (Ford, 2004; McAdam, 1990), and high school and college science textbooks (van Eijck & Roth, 2008).

More realistic portrayals of scientists, especially with respect to equal representation of both male and female scientists, are becoming evident in television dramas such as *Crime Scene Investigation (CSI)* (Jones & Bangert, 2006). Neil deGrasse Tyson, an African-American astrophysicist and author appears as the outgoing, engaging host of PBS (Public Broadcasting Service) *NOVA* and *NOVA scienceNow* (Hayden Planetarium, 2010). A recent movie, *2012* (2009), features a scientist, Adrian Helmsley as one of the lead characters. As a youthful, African-American geologist, Helmsley defies the stereotypical scientist image. Through organizations like the Union of Concerned Scientists (Union of Concerned Scientists, 2009) scientists are taking collective action to prevent the misuse of science and to take scientific facts about such controversial environmental issues as climate change directly to the public. Yet another cause for optimism comes from President Obama's support of nationwide STEM initiatives. On November 23, 2009 (eSchoolnews, 2009), he remarked, "Scientists and engineers ought to stand side by side with athletes and entertainers as role models, and here at the White House we're going to lead by example. We're going to show young people how cool science can be."

Studies of elementary school students' perceptions of scientists ranging from the elementary and middle school levels (Huber & Burton, 1995; Flick, 1989; Schibeci & Sorensen, 1983) to the college level (Bovina & Dragul'skaia, 2006; Rosenthal, 1993; Beardslee & O'Dowd, 1961) are extensively reported in the literature. The influence of gender on these perceptions (Finson, 2002; She, 1998; Sumrall, 1995) is likewise documented. Misconceptions generated by stereotypical portrayals of scientists disproportionately discourage women from entering science careers (She, 1998; Newton & Newton, 1992; Mason et al., 1991; Pendleton, 1975). However, little work has been done to elucidate how scientists perceive themselves.

Almost fifty years ago, Eiduson and Holton addressed scientists' self-perceptions (Eiduson & Holton, 1960). They recognized that scientists' self-perceptions played an important role in establishing a schism between science and other intellectual disciplines, a "gulf of mutual incomprehension" (Snow, 1965, p. 4). More than thirty years later, images of science and scientists, this time those promoted in the popular media, were again identified as playing an important role in creating a rift between science and students (Boylan et al., 1992).

Starting in the 1970's, the public was no longer willing to accept scientists' authority without question. Scientists' credibility is now in serious jeopardy if they continue to be viewed as "bewigged judges in court-remote, out of touch, unconsultative, much given to pontificating and immune from criticism" (Frayling, 2005, p. 226). Carl Sagan (1995, p. 25-26) commented stridently on this state of affairs: "We've arranged a global civilization in which the most crucial elements … profoundly depend on science and technology. We have also arranged things so that no one understands science and technology. This is a prescription for disaster." Moreover, a 2009 survey by the Pew Research Center for the People and the Press and the American Association for the Advancement of Science (AAAS) of 2000 members of the public and 2500 "scientists", i.e. members of the AAAS, revealed a significant gap between the public's and the scientists' views on science issues including climate change, evolution and America's scientific leadership position (Dean, 2009). The survey also revealed that scientists held a relatively low opinion of the public, with 85% citing public ignorance of science as a major problem, while the public generally held the scientists in high regard (Dean, 2009).

This complex relationship is further strained when the purportedly objective factual claims of science encounter the value claims of society (Campbell, 2003). As long as science and scientists cling to an artificial fact/value dichotomy (Putnam, 2002) and maintain that "science is value-free" (Toulmin, 1985, p. 29), meaningful dialog with the public is impossible (Dickson, 2000). Instead, "communication failure" (Haynes, 1994, p. 6) fueled by the "mutual suspicion" associated with this artificial dichotomy persists.

A stereotype, whether that of the scientist or of any minority group within a society, is a convenient mechanism for an uninformed society to manage a complicated issue. The stereotypical image of the scientist when viewed as such cultural shorthand demonstrates the very lack of understanding referred to by Sagan (1995). Such stereotypes are especially dangerous for children who may derive from them "a distorted view of what scientists do and who they are" (Bowtell, 1996, p. 10). Another consequence of stereotyping is that the target group, here scientists, internalizes the stereotypical images thrust upon them by society (Adams, et al., 2000). In the extreme, the image of the mad scientist becomes a self-fulfilling prophecy.

A better understanding of scientists' self-perceptions is needed to inform efforts to engage scientists and the public in "mutual conversation" (Pandora & Rader, 2008,

p. 363) that can overcome the prevailing “communication failure” (Haynes, 1994, p. 6). Improved communication is party of any prescription for averting the “disaster” foreseen by Sagan (1995, p. 25-26). This study is designed to open channels of communication as it examines the lived experience of scientists. Inherent in this lived experience are scientists’ own understanding of the nature of science and their views on the public’s understanding of science.

Problem Statement and Research Questions

The purpose of this study is to explore the self-perceptions of twenty-first century scientists as previously defined. Efforts will be made whenever possible to access the self-perceptions of female and traditionally under-represented ethnic minority scientists. An in-depth understanding of scientists’ self-identities will be developed that reflects the association between identity and agency in their practice of science (Roth & Calabrese Barton, 2004) by examining the lived experiences of scientists.

The following research questions guide this study.

4. What are the lived experiences of scientists as defined for this study?
5. Within these lived experiences, how do the scientists as defined for this study perceive themselves and the public as likewise defined for this study?
6. Within these lived experiences, how do the scientists as defined for this study engage with education, research and commercialization activities in the university and the larger community?

This is an exploratory study designed literally to allow scientists to “speak” in their own words about science, themselves as scientists, and their relationships with the public.

Significance of the Study

The present study has significance for filling a gap in the published literature about scientists' self-perceptions. In their books, *The Demon Haunted World* (Sagan, 1995) and *Wrinkles in Time* (Smoot, 1993), Carl Sagan and George Smoot wrote about the enterprise of science framed within the context of their discipline, astronomy. In recent online and magazine interviews, other scientists have discussed their fascination with science in the context of their scientific work (2010; http://Elements of Humanity.com; Kruglinski, 2009). While these books and interviews do provide some insights into the human side of science, they do not go to the essence of what it means to be a scientist. Neither do these scientists voice their self-perceptions.

In only five of the over 125 cited references (Hills & Shallis, 1975; Science News, 1975; Storer, 1963; Eiduson & Holton, 1960; Morris, 1957), do scientists "speak" and directly share their self-perceptions. Only male scientists are represented in these five references. It is important that all legitimate voices, including those of male, female and minority scientists be heard in the public space of a democratic society, especially one desperately in need of a scientifically literate citizenry. Development of a scientifically literate citizenry, a mission of science educators, requires accurate, authentic scientist images. Existing stereotypes have made science unappealing to students (Silver & Rushton, 2008).

The present study will enhance the participants' and researcher's understanding of scientists' self-perceptions and includes an agenda for allowing scientists to engage with the public concerning how they perceive themselves. I, the researcher, will be the first member of the public, as defined earlier, engaging with the scientists. When this work is disseminated through publications and conference presentations, the scientists will engage indirectly with a scholarly community outside the natural science community including, science educators, historians of science and other STEM disciplines. Engaging scientists with the public is strongly aligned with promoting widespread scientific literacy. The definition of scientific literacy is complex and context dependent (Laugksch, 2000). When applied to adult Americans, this study distinguishes three categories of scientific literacy: (1) professional scientific literacy; (2) consumer or practical scientific literacy; and (3) civic scientific literacy (Laugksch, 2000). Professional scientific literacy refers to the scientific knowledge needed to be considered "learned" (Laugksch, 2000, p. 83). The latter two categories of scientific literacy describe how science knowledge is used when an individual fulfills a particular role in society, respectively, that of the consumer or citizen in a democracy. When applied to children and adolescents in grades K-12, "scientific literacy" is used in a manner consistent with the 2006 Program for International Student Assessment (PISA) Science. The PISA Science definition emphasizes use of science content knowledge and science process skills in everyday science-related situations (Bybee, et al., 2009). These definitions are compatible with those provided in the *Science for All Americans* (SFAA) monograph as described by Eisenhart, et al. (1996).

When scientists are stereotypically portrayed as middle-aged, white men, women and other under-represented minority scientists are made invisible. Women and under-represented minority scientists are, thus, twice-marginalized groups. They are minorities within the scientific community and they are invisible to the public. A more accurate portrayal of scientists' gender and ethnic identities can create a more gender and ethnically diverse scientist image in the "eyes" of other disciplines and the public.

Within STEM disciplines, an organization dedicated to advancing the engineering profession, Engineers Dedicated to a Better Tomorrow, has explored the popular, largely negative, view of engineers with the intention of replacing it with a "new, more compelling image" (Engineers Dedicated to a Better Tomorrow, 2006). These efforts indicate a positive trend of introspection and reflexive practice developing within the STEM community as a whole. However, it must be acknowledged that engineers "benchmark" their professional image against the image of the scientist (Clark & Illman, 2006). If engineers frame their image as applied scientists, it is important that a more holistic understanding of the underlying scientist image be available. A better understanding of scientists' self-perceptions can help scientists to create an alternative popular image, and support similar efforts in the larger, interrelated STEM community, especially in K-12 science education.

CHAPTER 2

Theoretical Underpinnings: Review of Related Literature

The goal of this chapter is to set the stage for the proposed phenomenological study. It reviews the substantial literature that documents the images and stereotypes of scientists. These images will provide the background for the scientists' self-perceptions that will emerge from the present study. This chapter documents the images and stereotypes of scientists prevalent in the popular media, particularly film and television, since these media are especially relevant for students in grades K-12. It provides insight into how K-12 students; college students, especially non-science majors; and pre-service teachers portray scientists. It is important to consider how college students and pre-service teachers perceive scientists because of their potential to shape children's perceptions of science and scientists. This review also addresses how gender can influence portrayals of scientists. Interventions to replace stereotypical images of scientists held by these groups with authentic images of scientists are also summarized.

Theoretical foundations are provided for the Draw-a-Scientist Test (DAST), a well-established instrument used to access perceptions of scientists. The chapter introduces two worldviews, a transactional worldview and transformational worldview. The transactional worldview is useful for interpreting the backdrop of existing images and stereotypes of scientists. The transformational worldview frames the present study in its aspiration to empower both scientists and the public by examining the essence of the lived experience of being a scientist. Research paradigms, including positivism, post-positivism, naturalism and constructivism are introduced. The qualitative approach, phenomenology, which will be used to conduct the present study is reviewed in detail. Several phenomenological studies are provided as practical models for how phenomenology can be implemented as a research tool in science education research.

Scientists' Self-Perceptions

Five reports were found in the literature that addressed scientists' self-perceptions (Hills & Shallis, 1975; Science News, 1975; Storer, 1963; Eiduson & Holton, 1960; Morris, 1957). The most recent two of these references date from 1975. These two references report the results from a survey of *New Scientist* and *New Society* readers that probed their images of scientists by asking what came to mind when they thought of a scientist.   Scientists who responded characterized themselves as "approachable, sociable, open, unconventional, possessing many interest [sic] and being popular" (Science News, 1975, p. 167).

Eiduson and Holton (1960) wrote in the "Letters" section of *Science* about a study conducted by Eiduson concerning the self-images of forty male academic natural scientists. They reported that these exclusively male scientists saw themselves as intellectuals, driven by a search for truth, rather than monetary reward or recognition. Their happiness and fulfillment came from their work where rigor and persistence were highly valued. The column also noted that the scientists advocated "sciencemanship" (Eiduson & Holton, 1960, p. 553) to communicate their findings effectively so that they would be put to use.   Such sciencemanship also involved shunning the "eccentric" (Eiduson & Holton, 1960, p. 553) colleague or student. Holton, a professor of physics at Harvard University, recognized alienation of science from the larger culture as long ago as 1960 (Holton, 1960). His *Science* article (Holton, 1960) is significant as a reflexive piece where a physicist, a member of one of the disciplines typically represented by the popular view of the scientist, acknowledged the “public images” (p. 1188) of science and proceeded to analyze their philosophical foundations.

In the early 1960’s, one particular group of scientists, the American Chemical Society (ACS), attempted to gain a better understanding of their group identity using a mail survey of one-ninth of the ACS membership (Storer, 1963). When completed surveys were returned, “the small number of women and non-chemists were eliminated” (Storer, 1963, p. 410). This a priori elimination of women’s responses implicitly embodied the notion that the chemists perceived themselves as an exclusively male profession. Women were indiscriminately relegated to the category of the “non-chemist”, without any inquiry into their academic or other credentials. It is encouraging to note that a brochure distributed by the ACS in late 2009 as part of a membership drive prominently displayed a photograph of a female Ph.D. chemist (American Chemical Society, 2009).

The Popular Image of Scientists

While scientist survey respondents described themselves in generally positive terms, non-scientist respondents characterized the scientists negatively as “remote, secretive, conventional, having few interests and unpopular” (Science News, 1975, p. 167; Hills & Shallis, 1975). Other non-scientists’ comments were critical of a presumably masculine personal appearance that was bald, middle-aged, be-spectacled, poorly dressed and short. Respondents were even critical of scientists’ intellectual nature. Representative non-scientists’ comments included: “an uncultured illiterate”; “largely unjustified arrogance”; “often blind to the disastrous consequences of his work”; and as allowing “intellectual curiosity to triumph over moral responsibility”

(Science News, 1975, p. 167). An education professor wrote in 1957 that action was needed to address the perceived shortage of scientific and technological personnel in the United States (Morris, 1957). He described the "low estate" of the scientist, an "odd kind of person" whose work was incomprehensible to the average person (p. 127), as a factor contributing to the personnel shortage. The negative, stereotypical image of the scientist would still be identified over fifty years later (Silver & Rushton, 2008) as a factor leading to avoidance of science careers. Head (1979) attempted to identify particular personality traits associated with scientists in industrialized English-speaking countries. He drew upon a variety of sources including surveys, psychometric studies and clinical reports to profile characteristics including gender, person orientation, political attitudes, creativity and socio-economic background. The somewhat dated model that emerged was consistent overall with the popular image of scientists and strongly influenced by British societal norms.

Images of Scientists in Print, Film and Television Media

It would be unlikely to find visual or verbal portraits of scientists together with their work in the peer-reviewed scientific journals. In that context, the face or the personality of the scientist is irrelevant. Perhaps even more than irrelevant, it is anathema to the "myth of a scientific community working anonymously to construct a common, universal knowledge" (Jacobi & Schiele, 1989, p. 759). Consistent with this mythology, "science is enunciated without reference to the enunciator" and even scientific language "strives for absolute intellectualization, that denies all emotion and that it submits to an ideal from which all subjectivity would be excluded" (Jacobi & Schiele, 1989, p. 750).

Hence, it is necessary to examine the popular print media to find visual or literary portrayals of scientists. For the purpose of this literature review, "popular media" are print, film or television works intended for mass distribution as distinguished from scholarly, especially peer-reviewed, media intended for an elite, highly specialized professional audience. When scientists are portrayed in popular science magazines they are depicted according to three archetypal images: (1) the inhuman, dangerous mad scientist; (2) the authoritative teacher who transmits dogmatic knowledge with a dreary blackboard and chalk; and (3) an everyday human being (Jacobi & Schiele, 1989). The negative characteristics of the scientist identified by the non-scientist *New Scientist* and *New Society* readers in 1975 persist in the popular print, film and television media.

Roslynn Haynes' book, *From Faust to Strangelove* (1994), exhaustively surveys how the scientist has been portrayed in western literature from Chaucer's 14th century *Canterbury Tales* to 1980's science fiction novels. Her survey provides insight into how non-scientists have perceived scientists as well as of the relationship between science and the public in western society. This literature review will focus, instead on film and television media. According to a 1987 study (Gerbner, 1987), most U.S. citizens derive their conceptions of science from "prime-time entertainment" (Gerbner, 1987, p. 110) television shows. Commercial television shows still strongly impact how science education K-20 stakeholders, especially K-12 students, perceive science and scientists (Vilchez-Gonzales & Palacios, 2006).

Generally, the images of scientists portrayed in film and television media, especially children's Saturday morning television programming (Schibeci, 1986) are negative stereotypes. This media scientist is a brilliant, but evil male genius, simultaneously evoking “respect and terror” and definitely not evoking any desire to “emulate him” (Hassard, 1990, p. 10). Media stereotypes of female scientists, though rare, are hardly more appealing. Schibeci (1986) described a female scientist comic strip character, Dr. Payne. She was “young, and attractive, though spectacled” (Schibeci, 1986, p. 148). “As a scientist she is perfectly capable of committing one of the many anti-social or dangerous acts that typify her kind [the scientist]” (Schibeci, 1986, p. 148), despite her superficial beauty. Spanish researchers acknowledged that much of children’s and adolescents’ informal science knowledge and their images of scientists come from the popular audiovisual medium of cartoons (Vilchez-Gonzales & Palacios, 2006). Their study analyzed 100 cartoon episodes broadcast on free access Spanish television and compared them with popular comics. They found that physics images dominated, representing 46% of the science images observed. Physics images were followed by general science (19%), chemistry (8%), biology (7%), earth sciences (7%), environmental sciences (4%), mathematics (5%) and others (4%). Vilchez-Gonzales & Palacios (2006) concluded that cartoons and comics provide a distorted, elitist image of science as isolated from its environment through the use of jargon and obscure mathematics. This image of the evil genius, mad scientist or, at best an “eccentric bespectacled man who wears a white coat and works in a laboratory containing a lot of glassware” (McAdam, 1990, p.102) has persisted in the public mind. Meanwhile, “counternarratives” of “intimate” scientists such as Luther Burbank or Frank Capra’s television character from the 1950’s, “Dr. Research”, have faded (Pandora & Rader, 2008, p. 361). It is not surprising then that 44% of American adults “couldn’t identify a single scientist, living or dead, whom they’d consider a role model for the nation’s young people” (NSTA Express, 2008) according to a Harris Interactive survey of 1,304 American adults.

There is some cause for optimism based on children’s programming provided by PBS (Public Broadcasting Service). The *Curious George* series (PBS KIDS, 2010) introduces pre-schoolers to science, engineering and math concepts. Scientist cartoon characters on the series are portrayed as highly knowledgeable and intelligent, yet affable and approachable. The realistic scientist characters reflect gender and ethnic diversity despite the fact that all wear white lab coats. The lead scientist character is a woman of color, Professor Wiseman. *Bill Nye the Science Guy* (Bill Nye, 2009) was a PBS program from 1993-1997 that aimed to engage a pre-teen audience in learning science concepts. While his light blue lab coat and bow tie clad character was outgoing and funny, it did perpetuate several elements of the stereotypical scientist image including the lab coat, male gender and white, European ethnicity.

Scientist portrayals on commercial television series designed to appeal to adult and young adult audiences have historically tended to rely on aspects of stereotypical scientist images. The *Star Trek* television series from the 1960’s depicted a somewhat positive image of the scientist in the persona of the science officer, Mr. Spock. Part Vulcan, he was partially, but not totally “alien”. His social skills were awkward and robotic, but he still remained somewhat tenuously connected to the human race. Despite his cold, dispassionate and unfailingly logical Vulcan façade complete with pointed ears, a moral sense, at times seemingly almost tinged with human kindness, pervaded his scientific counsel. Spock was an icon for the socially isolated, “alien” scientist trying to connect with other beings and their respective disciplines as represented by, Scotty, the engineer and McCoy, the physician.

Gerbner (1987) analyzed the images of science and technology that appeared in "network prime-time dramatic programs telecast between 1973 and 1983" (Gerbner, 1987, p. 111). The study found that although scientists were generally portrayed positively, scientist portrayals were overall less positive than portrayals of other professionals such as doctors. There were more "ambivalent and troublesome portrayals" (Gerbner, 1987, p. 111) of scientists than of other professionals. Overall, scientists were the least sociable among the professionals. Furthermore, the scientist image "was somewhat foreboding, touched with a sense of evil, trouble and peril" (Gerbner, 1987, p. 112). Increased television viewing resulted in less favorable views about science and "more willingness to place restrictions on science" (Gerbner, 1987, p. 114). According to Gerbner (1987, p. 114), "television drama tends to reflect and exacerbate public ambivalence and anxiety about science" and "inhibit the inclination for science as an occupation or an area of public participation".

Given the power of television to deliver images of science to a large audience, it is encouraging that recent series like *Crime Scene Investigation (CSI)* and *The Big Bang Theory* include more realistic portrayals of scientists (Heyman, 2008; Jones & Bangert, 2006; Bort, 2005). *CSI* has been praised by science educators for portraying equal numbers of male and female laboratory scientists. Moreover, Jones & Bangert (2006, p. 39) have identified evidence for a "*CSI* effect". Seventh grade girls who had watched the show drew a greater percentage of female scientists on a Draw-A-Scientist (DAST) activity. When interviewed, the girls explained that seeing female scientists on the *CSI* television show was a factor that influenced them to draw female scientist images (Jones & Bangert, 2006). The popularity of the *CSI* television show and its positive science associations has led science teachers to structure activities around a forensics context to engage student interest (Bort, 2005).

While a similar impact has not been found for *The Big Bang Theory*, it is significant as a successful prime time comedy series where many scenes revolve around highly accurate particle physics science content (Heyman, 2008). By contrast with *CSI*, only one scientist on *The Big Bang Theory* is female. However, she by contrast with her male counterparts demonstrates an ability to use scientific theory to formulate practical, "common-sense" solutions to the male characters' problems. The male scientist characters on *The Big Bang Theory* do not fare as well as the female scientist. They are shown in everyday situations, but much of their behavior supports "nerd" and "geek" stereotypes.

Cinematic images of the scientist, like their literary and television counterparts, are often caricatures. According to Frayling (2005, p. 166), "the mad scientist and the saintly one are in some ways two sides of the same Hollywood coin." Overall, the mad scientist stereotype predominates. Starting in the mid-1920's, popular films and, after the 1930's, horror movies presented particularly harsh portrayals of science and scientists (Goldman, 1989; Tudor, 1989). Goldman argued that, paradoxically, the same public that funds government science projects and enthusiastically embraces the latest high-technology gadgets marketed by corporations revels in seeing science and technology parodied and reviled on the silver screen. Hence, a popular theme was the scientist as the dupe of a corporate, political or military power. The scientist functioned essentially like the robot science officer on the freighter, Nostromo, from the 1986 movie, *Aliens* (Goldman, 1989). The archetypal 1964 movie, *Dr. Strangelove, or How I Learned to Stop Worrying and Love the Bomb*, branded an image on the public consciousness of the scientist as an amoral egotist seeking to gratify his intellectual curiosity at the expense of humanity (Goldman, 1989). In the 1952 British film, *The Man in the White Suit*, a chemist, Sidney Strafford, developed a new textile fiber impervious to wear and dirt. At the movie's end, he remained himself impervious to the impact that his fiber might have for society and was content with the intellectual satisfaction he gained from his science (Goldman, 1989).

A welcome contrast to these stereotypical portrayals of scientists is the balanced portrayal of the African-American geologist, Adrian Helmsley, in *2012* (2009). Helmsley was acutely aware of moral and ethical issues. Hardly a pawn of the military and political establishment, he proactively interacted with these powers to influence policies concerning who would be admitted to the United States ark and thus saved from catastrophic global flooding in the wake of massive world-wide earthquakes. He was well-read and equally comfortable conversing with field geologists or art historians. Helmsley had a "normal" emotional life. He cared deeply about his friends and ultimately fell in love with Dr. Wilson, the art historian daughter of the U.S president.

Women scientists fare particularly badly at the hands of Hollywood filmmakers. They are often portrayed as white lab-coated, spectacled "research assistants or career scientists with boys' names who badly needed to rediscover their feminine mystique" (Frayling, 2005, p. 201). Even when they are shown as equal members of a team, they become "simpering victims" (Frayling, 2005, p. 201) at the first sign of threat. An exception to this trend was the portrayal of Marie Curie as a saintly heroine in the 1943 *Madame Curie*. The film's producers were so concerned with authenticity that a Cal Tech physicist was hired to create accurate re-enactments of experiments (Frayling, 2005).

A more balanced female scientist image appears in the motion picture, *Avatar* (2009). Dr. Grace Augustine (Sigourney Weaver) was an exobiologist and the head of the Avatar program. She was not intimidated by the military authorities on Pandora. Contrary to the stereotype, she was aware of the moral and ethical issues related to exploitation of the Na'vi indigenous inhabitants of Pandora as a result of the RDA Corporation's mining operations for unobtanium.

Images of Scientists in Trade Books and Textbooks

Farland considered science trade books as an elementary school classroom resource for teaching that science is a human endeavor (Farland, 2006a; Farland, 2006b). According to Farland, these trade books generally avoided the cartoon image of the scientist (Farland, 2005). Nevertheless, science trade books were found to perpetuate the image of scientists as overwhelmingly older white males. Scientists were portrayed as exceptionally hard working and highly intelligent (Ford, 2005). When biographical information was provided in an effort to "humanize" the scientists, this information was often isolated from the rest of the text in marginal boxes establishing a gulf between the person of the scientist and the scientific work.

Textbooks, likewise, exert a strong influence on the images of scientists held by elementary and middle school students (She, 1995). This influence is apparent in the striking similarities observed between children's drawings of scientists and figures from science textbooks. Curricula developed for grades K-12 since the early 1970's have presented "inclusive" images of scientists as "regular people" and developed connections between science and everyday life (Barman & Ostlund, 1996, p. 16). Textbooks also play a role in establishing high school and college students' images of scientists. Canadian high school and first year college biology textbooks were examined for their portrayals of scientists associated with key breakthroughs in biology (van Eijck & Roth, 2007). The study concluded that the biology textbooks represent the practice of science as culturally isolated. These textbooks convey the idea that scientists do science just for their peers, other scientists.

Images of Scientists Held by Students in Grades K-12

A substantial body of literature has emerged over the past fifty years that documents elementary and secondary school students' perceptions of scientists starting with the 1957 study by Margaret Mead and Rhoda Metraux (Mead & Metraux, 1957). In the Mead and Metraux study (1957), 35,000 high school students wrote essays that described their images of scientists. The typical high school student's perception according to this study was consistent with images promoted in the popular media, an "elderly or middle-aged man in a white coat and glasses who worked in a laboratory where he performed dangerous experiments" (Finson, 2002, p. 335). While these students did recognize that science was valuable to society, they rejected science careers (Mead & Metraux, 1957). Studies over the next half-century established the stability of this stereotypical image across gender, cultural and socioeconomic status lines (Silver & Rushton, 2008; Finson, 2002; Barman, 1999; Barman, 1997; Barman 1996; McAdam, 1990).

The development of the Draw-a-Scientist-Test (DAST) in the 1980's and its validation as an instrument for studying the perceptions of children in grades K-5 (Chambers, 1983; Schibeci & Sorensen, 1983) opened a window into the thinking of elementary school students. DAST data enable comparisons of perceptions of scientists held by kindergarten age students through university faculty. The power of the DAST lies in its apparent simplicity. This instrument requires that a research participant literally draw an image of a scientist. Hence, it is accessible to children with emerging literacy skills as well as to adults with highly developed literacy skills (Schibeci & Sorensen, 1983).

Taken in aggregate, DAST data from K-12 students support an image (male scientist, likely a chemist) that has been durable since 1957 and stable among K-12 students of different gender, cultural background and socio-economic status (Finson, 2002; Barman, 1999; Barman, 1997; Barman & Ostlund, 1996). Such stability of the lab coat clad white, male scientist image extends worldwide as demonstrated by studies of secondary school students in Korea and the United Kingdom (Song & Kim, 1999; Matthews, 1996) and elementary and middle school students in Taiwan (She, 1998). Starting in the late 1990's, cartoon-like images, that Finson described as "Frankenstein-type", appeared less frequently (Finson, 2002, p. 341). Generally, images showed male scientists. Typically, only female students drew female scientists as illustrated by a study of nine to twelve year olds' images of scientists (Huber & Burton, 1995; Maoldomhnaigh & Hunt, 1988). African-American students, likewise, didn't project their self-image into their scientist drawings. Instead, they drew about as many European-American as African-American scientists (Sumrall, 1995). Among Navajo elementary school students (grades 4-6) in the western United States, most (66%) drew European-Americans scientists. Only one male student drew a Navajo scientist, a medicine man (Monhardt, 2003). Six year olds had already developed a stereotypical scientist image in a United Kingdom study of students ranging in age from approximately four to eleven (Newton & Newton, 1992). However, three studies provide some challenges to this notion that children worldwide hold a stable, monolithic scientist stereotype (Farland-Smith, 2009; Monhardt, 2003; Petkova & Boyadjieva, 1994).

In the emerging eastern European nation of Bulgaria, high school students (120 males, 170 females) held an "idealized" image of the scientist (Petkova & Boyadjieva, 1994). Petkova & Boyadjieva analyzed these images as social representations and social stereotypes to assess the shared beliefs of the students about the characteristics of a scientist. These representations of scientists were almost entirely positive. Stable, core characteristics identified by a majority of the students included "wise, noble, intelligent, disinterested, open-minded, hard-working, honest, independent in judgment, devoted to science, selfless" (Petkova & Boyadjieva, 1994). Perhaps these students see the promise of improved economic prosperity and western European high living standards associated with scientific progress.

Despite the fact that most of the Navajo fourth-sixth graders in the Monhardt (2003) study drew scientists with European facial features, overall their DAST-C scores indicated that they held less stereotypical views of scientists than typical United States elementary school students as reflected in the Barman (1999) nationwide study. However, another explanation of the low DAST-C scores advanced by Monhardt (2003) was that these Navajo children were so completely unfamiliar with scientists, that stereotypical DAST-C indicators were absent from their drawings. Of particular interest is how Navajo elementary school students incorporated elements from their own cultural experience into their DAST-C drawings. These elements included outdoor settings, local geological formations, horses and even gang symbols (Monhardt, 2003). Only 47% of the Navajo students' DAST-C drawings showed male gender. The predominant portrayal of female scientists may be attributed to the fact that the Anglo female researcher had been introduced to the children as a scientist or to the matriarchal Navajo culture where women are "generally viewed in roles of power" (Monhardt, 2003, p. 31).

Recently, a new version of the DAST, the Enhanced Draw-A-Scientist-Test (E-DAST) (Farland-Smith & McComas, 2009) has been developed. The E-DAST allows students to construct multiple scientist drawings rather than the single drawing associated with the DAST and DAST-C. According to Farland-Smith and McComas (2009), such drawing sets more accurately represent what students know about science than does a single drawing. Using the E-DAST, Farland-Smith (2009) studied how a total of 1350 elementary school students in the United States and China perceived scientists. The study concluded that cultural influences determine how children perceive what science is and where and by whom it is done.

Like the Navajo students (Monhardt, 2003), Chinese students incorporated elements from their culture into the scientist drawings (Farland-Smith, 2009). Consistent with the Chinese custom of nap taking at mid-day, Chinese students included beds in their drawings. Basement laboratory venues while common to United States students' drawings were absent from the Chinese students' drawings. Since most of the Chinese students lived in high rise apartments, they may have been unfamiliar with basements (Farland-Smith, 2009). In the drawings by Chinese students, the scientists were surrounded by robots, rather than by beakers or other chemistry-related equipment (Farland-Smith, 2009). However, three of the four Chinese student drawings reproduced in the Farland-Smith article (2009) showed scientists with European rather than Asian features. Furthermore, two of these three Europeans were male. Male gender and European ethnicity appear to be two elements of the stereotypical scientist image that persist significantly across cultures.

Images of Scientists Held by College Students

The body of literature that documents studies of college students' overall perceptions of scientists is small when compared to that on K-12 students' perceptions. A 1961 study of college students revealed a relatively negative image of the scientist consistent with the image depicted in movies of that era (Beardslee & O'Dowd, 1961). For 1960's college undergraduates, the scientist was highly intelligent, objective, diligent, oblivious to society and family, and socially unpopular. This ambivalent image of the scientist persisted in later studies (Bovina & Dragul'skaia, 2008; Flannery, 2001; Rosenthal, 1993; Mitias, 1970).

Rosenthal compared the images of scientists held by liberal studies majors, many of whom planned to be elementary school teachers, with those of biology teachers using the Draw-A-Scientist-Test (DAST) instrument. The study found that both groups pictured the scientist as a benign and bespectacled white male working in a chemistry laboratory. It is important to note that only female students from the two groups drew female scientists.

College students in a science, technology and society course at a university in the eastern United States produced stereotypical scientist drawings on the DAST that closely resembled those of elementary school children in the fourth grade and beyond (Flannery, 2001; Chambers, 1983). Flannery identified the white lab coat as the most "ubiquitous element" among all these drawings (Flannery, 2001, p. 947). Additionally, she described the white lab coat as a masculine symbol since most are made according to design criteria of male tailoring including button placement and straightness through the hips. According to Flannery, this masculine status symbol broadcasts power and control, a "different way of behaving", and a "better way of thinking" that distinguishes the scientist as a "breed apart" (Flannery, 2001, p. 947). However, all scientists do not wear white lab coats. Typically, practitioners in three natural science disciplines, chemistry, biology and medicine wear lab coats.

Bovina and Dragul'skaia (2008) examined the attitudes of Russian college students toward scientists. Like their United States counterparts, Russian college students recognize the scientist's high intellectual capacity, but "his personality and social position are viewed with disdain and pity" (Bovina & Dragul'skaia, p. 45). It can be inferred from the use of the masculine "his" that the predominate image is that of a male scientist. Poverty was also an attribute of the scientist. These results reflect the diminution of scientists' social status in post-Cold War Russia along with adoption of western values.

Images of Scientists Held by K-12 Teachers

Pre-service teachers, especially pre-service elementary school teachers, are a significant group among college students because of their ultimate potential to influence their own students' attitudes and perceptions about science (Finson, et al., 2002; Finson, et al., 1995; Mason et al., 1991). In his review of the fifty years of research on perceptions of scientists, Finson (2002) described a 1994 study by Reap, Cavallo and McWhirter that examined pre-service elementary school teachers' perceptions of scientists. The study found that the pre-service elementary school teachers came to their science education methods classes with a stereotypical image of solitary chemists working indoors in danger-laden laboratories (Finson, 2002). Another study of nineteen female pre-service elementary school teachers found perceptions of solitary male or genderless scientists clad in lab coats or drab attire and accompanied by traditional symbols of science, particularly chemistry, including flasks, Bunsen burners and microscopes (McCann, 2006). The scientists were portrayed as cold and dispassionate even with respect to the experimental work depicted along with the scientist image. These pre-service elementary school teachers had already taken a science methods course where they examined their own attitudes toward science and received explicit instruction on the nature of science, yet the stereotypical image persisted. A study including early childhood education majors, secondary education majors and graduate students along with elementary education majors (Moseley & Norris, 1999) likewise found that these students entered science education courses with stereotypical perceptions of scientists.

Even in developing countries like Nigeria and India, pre-service teachers hold stereotypical scientist images. A study of Nigerian pre-service science teachers revealed that they brought stereotypical images of scientists with them to science education courses (Mbajiorgu, & Iloputaife, 2001). Eighty-five percent of Indian pre-service teachers participating in a science teaching program held a stereotypical image of a scientist as a brilliant, preoccupied individual with a "distinct 'lost' look" (Rampal, 1992, p. 432).

While pre-service elementary school teachers represent the "future of science education", their in-service counterparts are the "present of science education". They, too, have a significant impact on their students' perceptions of science and scientists (Finson et al., 1995). Overall, in-service teachers' Draw-a-Scientist-Test (DAST) images showed stereotypical images of white males, "serious, sometimes ominous, people who pursue science as solitary investigators working in an environment devoid of social interactions" (McDuffie, 2001, p. 18).

Effect of Gender on Perceptions of Scientists

Several studies have examined how gender impacts perceptions of science and scientists. Pendleton (1975) found that "social stereotyping" was a factor that contributed to female attrition from science. However, the conflict that the women perceived between the demands of a science career and family obligations was found to be an even more significant factor in leading women to pursue non-science careers. A study by Lips (1984) examined the relationship between women's self-schemas regarding math and science ability and their course choices. This study concluded that women avoided math and science courses, not because they thought they were unable to succeed, but simply because they were not interested (Lips, 1984). Lips attributed this lack of interest to women's math and science experiences. Meyer's narrative account of her experience in school science provides additional insights into why science is unattractive to women (Meyer, 1998). While not explicitly addressing stereotypical perceptions of scientists, the narrative clearly embodied a theme of women as outsiders in science, "the deficient female who cannot do math and science" (Meyer, 1998, p. 465).

The Draw-A-Scientist Test (DAST)

The Draw-a-Scientist-Test (DAST) instrument has been used widely to access the perceptions of scientists since its introduction in 1983 (Chambers, 1983). The DAST requires that the test subject literally "draw a scientist" and has been administered to kindergartners, to pre-service teachers, and to in-service teachers among others (Finson, 2002). The DAST has strong historical grounding. Drawings made by children in response to the prompt, "Draw a scientist." were part of a collection of visual images of scientists, including images from periodicals, considered by Margaret Mead and Rhoda Metraux (Mead & Metraux, 1957). The use of drawing in the area of intelligence testing was pioneered by Florence Goodenough with her Draw-a-Man test (Goodenough, 1926). Engineers have recognized the value of a DAST-type instrument for studying perceptions of engineering and engineers. A Draw-an-Engineer- Test (DAET) is in the early stages of development (Knight & Cunningham, 2004).

Chambers' 1983 study represented the culmination of eleven years of research intended to determine the age at which "children first develop distinctive images of the scientist" (Chambers, 1983, p. 257). In this study, students in grades K-5 were asked simply to “draw a scientist” as had been suggested by Mead & Metraux (1957). Chambers found that the stereotypical image began appearing in the second grade and that by the fifth grade, the students’ drawings included the same number of indicators as those drawn by adults (Chambers, 1983). Hence, the study concluded that by fifth grade the image of the scientist was fully formed and might persist largely unaltered through adulthood. The Draw-a-Scientist-Checklist (DAST-C) was developed to facilitate DAST scoring (Finson, et al., 1995). The DAST-C adds eight additional indicators to the original seven indicators used by Chambers (1983). Researchers, concerned that instructions requiring a single scientist drawing might represent a forced choice, found that when students drew more than one scientist, the multiple drawings were sufficiently similar that the extra time needed for additional drawing was not justifiable (Barman, 1996).

However, the question of whether a single drawing adequately represents a test subject’s concept of a scientist has recently been revisited (Farland-Smith & McComas, 2009). Farland-Smith and McComas (2009) concluded that sets of multiple scientist drawings more accurately represent students’ knowledge about science and scientists. They modified the DAST (Finson, 2002) to create the Enhanced Draw-A-Scientist-Test (E-DAST) (Farland-Smith & McComas, 2009). The E-DAST allows students to construct multiple scientist drawings. A scoring rubric was also developed to evaluate the E-DAST drawings on the basis of three criteria: the scientist’s “appearance”, “location” and “activity” (Farland-Smith & McComas, 2009, p. 49-50). These criteria are characterized and scored as “Can’t Be Categorized” (0), “Sensationalized” (1), “Traditional” (2) or “Broader Than Traditional” (3) (Farland-Smith and McComas, 2009, p. 50). According to this rubric, a low score is associated with a caricature or stereotypical scientist image.

Interventions to Develop Accurate Images of Scientists

Several studies by science educators have recognized that children form fixed images of scientists by the fifth grade (Barman, 1997; Chambers, 1983; Schibeci & Sorensen, 1983). The images are strongly influenced by the stereotypical images of the scientist promulgated by popular media as well as by attitudes and pedagogical practices of their teachers. These stereotypical images may be a factor that contributes to women's under-representation in science (She, 1998; Newton & Newton, 1992; Mason et al., 1991). Hence, direct interventions have been implemented with children through (1) K-12 curriculum design (Newton & Newton, 1998; Barman, 1997; Barman, 1996; Newton & Newton, 1992); (2) trade books (Farland, 2006); (3) scientists' classroom visits (Bodzin & Gehringer, 2001); and (4) "Scientist in Residence" programs (Flick, 1990; Flick, 1989).

Other interventions involved pre-service teachers (McCann, 2009; McCann, & Pedersen, 2006) and still others in-service teachers (Mason et al., 1991). While scientists did participate in classroom visits (Bodzin & Gehringer, 2001), "Scientist in Residence" programs (Flick, 1990; Flick, 1989) and as mentors for pre-service early childhood teachers (Katz, Sadler, & Craig, 2005), there is no evidence that the scientists engaged in any reflection on how they perceived themselves as scientists, nor did they have any proactive role in design of the studies.

Interventions in grades K-12.

The stereotypical image of the white male at work indoors in a laboratory steadfastly persists among K-12 students. In the United States, this image endures despite implementation of curricula that actively involve students in "doing science" and provide inclusive images of scientists as ordinary people (Barman, 1997; Barman, 1996; Barman & Ostlund, 1996). In the United Kingdom, stereotypical images of scientists, especially with respect to gender, persist despite similar curriculum reform (Newton & Newton, 1998; Newton & Newton, 1992). However, a 2002 study showed that use of age-appropriate, non-fiction trade books strikingly broadened third-graders' perceptions regarding who may be a scientist and the nature of a scientist's work (Farland, 2002). The trade books accurately depicted non-stereotypical scientists' work, struggles and perseverance.

Outcomes of efforts to challenge scientist stereotypes by bringing scientists into elementary school classrooms are mixed. In one study (Buck, Leslie-Pelecky, & Kirby, 2002), three young female scientists, a white American physicist, a black African physicist and a white American materials scientist, worked with fourth and fifth graders in their elementary school classrooms over a four week period. The scientists led physical science inquiry activities and discussed their research and careers with the children. Despite these regular interactions, the stereotypical scientist image persisted. In fact, the students actually "questioned the true identity of the scientists, categorizing them as teachers" (Buck et al., 2002, p. 1).

However, other intervention programs have succeeded in displacing stereotypical scientist images. Scientists' visits to elementary school classrooms gave opportunities for “face to face social interactions” between students and scientists as “ordinary people” with a passion for science (Bodzin & Gehringer, 2001, p. 40). These visits led to more realistic scientist images, especially with respect to “indications of danger” as measured using the DAST-C. A “Scientist in Residence Program” (SiR) gave fifth graders multiple contacts totaling seven hours of interaction with three female scientists and one male scientist. The program included field trips to the scientists’ laboratories (Flick, 1989; Flick, 1990). These students developed more realistic images of scientists as measured by the DAST. Among drawings with a discernible scientist gender, there was an equal representation of males and females. Qualitative results included comments from the children on their newfound knowledge that scientists “could have families or a sense of humor-or that they or their classmates could understand what the scientist was saying” (Flick, 1989, p. 7). It should be noted that none of the four scientists who participated in the program were chemists or physicists, the two disciplines most commonly identified in popular views /stereotypes of scientists. Instead, the SiR scientists were two biologists, a forest ecologist and a psychologist. There was no explicit consideration of these scientists’ self-perceptions nor did the scientists actively design specific intervention strategies for replacing stereotypical images of scientists. Scientist participation was limited solely to doing science activities with the children.

Preparation of in-service teachers with strategies that included career information and teaching materials promoting gender equality, resulted in significant increases in female scientist images and reduction in sinister, mad scientist images among their high school students (Flick 2002; Mason, Kahle, & Gardner, 1991). A similar reduction in stereotypical views of scientists was observed when an in-service teacher education intervention modeled after the Mason et al. work (1991) was implemented with nine-twelve year olds (Huber & Burton, 1995). However, a study designed to investigate what, if any, links existed between fifth to eighth grade teachers' didactic or constructivist science teaching approaches and their students' perceptions of scientists found no relationship between teaching approach and the students' images of scientists (Finson, Thomas & Pedersen, 2006).

Interventions at the college level.

Programs in colleges and universities where undergraduate students work side-by-side with scientists on research projects provide those students with direct experiences with science and scientists. The Undergraduate Research Opportunities Program (UROP) was first pioneered at the Massachusetts Institute of Technology (MIT) in 1969 (MIT, 2009). It has served as model for undergraduate-faculty research partnerships at the university level. The UROP at the University of Michigan (University of Michigan, 2009) targets freshman and sophomores to provide them with a first time research experience. Programs such as Women in Science and Engineering (WISE) specifically address the under-representation of women in these fields (University of Michigan, 2009). The WISE program combines academic and personal support in a residential program for first and second year women. Strong connections have been found between WISE programs and retention in science disciplines (Hathaway, Sharp, & Davis, 2001). While these programs do not explicitly aim to identify stereotypical images of scientists and replace them with accurate images, their very design intrinsically addresses the same issues.

Interventions in teacher education programs.

Pre-service elementary school teachers were mentored by a scientist-turned science educator, the present author, in developing inquiry science lessons (McCann & Pedersen, 2006) using the learning cycle approach (Marek, 2009; Marek, 2008; Marek & Cavallo, 1997) in a science "methods" course. At the beginning of the course, the pre-service elementary school teachers' DAST drawings showed drably attired, dispassionate, male scientists along with stereotypical science symbols such as flasks, test tubes, Bunsen burners, microscopes, eye glasses and pocket protectors. Two of the drawings showed scientists removed from their workbenches and experiments as if they were mere observers of what was supposed to be their own work. DAST drawings from the end of the semester demonstrated a sophisticated, authentic understanding of science and the scientist, which was in sharp contrast with the beginning drawings. End of semester drawings showed scientists as "real people", mostly females, engaged in everyday activities associated with science, including reading journal articles. Stereotypical symbols of science were absent.

My work involved regular interaction between the pre-service elementary school teachers and me, a female scientist-turned science educator. I had a deliberate strategy to challenge the stereotypical popular culture image of the scientist by modeling an accurate one that embraced the diversity of scientists. As a result of this interaction, the pre-service teachers attained accurate scientist images. I shared anecdotes of my lived experiences in science. By the end of the semester, I felt that I had allowed the students to participate vicariously in "being a scientist". Learning cycles experienced by the pre-service teachers authentically modeled the reality of how scientists do science (Marek,

2009) and played a key role in their attaining a realistic perception of science and scientists.

Relevant Worldviews

A transactional worldview (Altman & Rogoff, 1987) and a transformational leadership model (Kezar, Carducci, & Contreras-McGavin, 2006) are relevant for this study. The transactional worldview helps make sense of the current breakdown in communication between scientists and the public. It will also support interpretations of the knowledge about scientist self-perceptions that will be generated by this study. The transformational leadership perspective provides inspiration and motivation for conducting the present study.

The transactional worldview is embraced by Dewey and Pepper (Dewey & Bentley, 1949; Pepper, 1967). The transactional worldview posits a "whole" that is a co-mingling of distinct, yet coupled factors. According to a transactional worldview, a "holistic person-environment" is the relevant unit of analysis (Altman & Rogoff, 1987). For the present study, the relevant unit of analysis is the scientists and the public as previously defined. As far back as the 1970's, scientists acknowledged this understanding with the realization that they and the public were interdependent (Gregory & Miller, 1998).

Implicitly, scientists and the public participate in what Kezar et al. (2006) would characterize as a transactional leadership model. In return for public trust and financial support, scientists reward the public with breakthroughs that improve quality of life while ensuring military superiority and economic prosperity. With such a transactional relationship comes the acknowledgment that "realistic and favorable concepts of and attitudes towards science by non-scientists are essential for continued support of scientific research and exploration" (Mitias, 1970, p. 135). Yet, statements that some branches of the physical sciences, particle physics and physical chemistry, need not consider human implications were still being made fifteen years later (Toulmin, 1985). In light of at least some scientists' explicit denial of their transactional relationship with the public, the existing communication breakdown epitomized by stereotypical scientist images is understandable.

However, Alan I. Leshner, chief executive of the American Association for the Advancement of Science (AAAS) provides hope that leaders of the scientific establishment are accepting the interdependence of science and the public implicit in the transactional worldview. Furthermore, his remarks urge that scientists adopt a transformational leadership perspective. He stated, "One cannot just exhort, 'we all agree you should agree with us'. It's a much more interactive process that's involved. It's time consuming and can be tedious. But it's very important" (Dean, 2000, p. 1-2). Leshner's challenge echoes the conclusion of the United Kingdom House of Lords report on *Science and Society* that beyond mere dialog, "empowerment" of the public is required (Dickson, 2000, abstract).

Implementation of Leshner's and the House of Lords' visions is best accomplished within a transformational leadership model where the scientist takes the role of leader and "acts in mutual ways with the followers [the public], appeals to their higher needs, and inspires and motivates followers [the public] to move toward a particular [socially desirable] purpose" (Kezar et al., 2006, p. 34). It is incumbent upon scientists and science educators to heed Thomas Jefferson's prescient advice, "…if we think they [the public] are not enlightened enough to exercise their control with a wholesome discretion, the remedy is not to take it from them but to inform their discretion by education" (Association for Science Teacher Education, 2009). A naturalistic inquiry research paradigm, specifically a phenomenology approach, will be used to elucidate the essential lived experience of scientists as defined for this study. Scientists will be empowered by the opportunity to communicate the essence of their lived experiences as scientists and provide "counter images" (Bowtell, 1996, p. 10) to the well-established stereotypes. Likewise, the public will be empowered by gaining access to scientists' self-perceptions, rather than images that may have been distorted by the media or other cultural filters.

Research Paradigms

Multiple paradigms, interpretive communities and research methods are available to examine scientists' self-perceptions. This section provides the theoretical background necessary to justify selection of a research paradigm and method that optimally matches the research questions, the purpose and the intended audience for the present study (Patton, 2002). According to Guba (1990), paradigms are "basic belief systems" that "we use in guiding our actions" whether everyday activities or "disciplined inquiry" (p.18).

Research paradigms include positivism or postpositivism and naturalistic or constructivist inquiry. This literature review follows Guba's usage "positivism or postpositivism" (Guba, 1990, p. 78) and "naturalistic or constructivist inquiry" (Guba, 1990, p. 77). It proceeds to examine these paradigms on the basis of their underlying assumptions. Specifically, these are ontological, epistemological, axiological, rhetorical, and methodological assumptions (Creswell, 2007). This analysis will identify those paradigms that are best aligned with the needs and objectives of the present study.

Ontological assumptions refer to how a paradigm addresses issues of reality or being (Creswell, 2007; Webster's Unabridged Dictionary, 1983). Epistemological assumptions relate to how a paradigm defines the means whereby "genuine, legitimate knowledge (Schwandt, 2007, p.87)" is obtained and justified. Epistemological considerations also dictate the proximity relationship of the researcher to the researched (Creswell, 2007). Axiological assumptions reflect how a paradigm deals with the nature and types of value (Creswell, 2007; Webster's Unabridged Dictionary, 1983). Rhetorical assumptions guide the form and style of the language used by the researcher (Creswell, 2007). Methodological assumptions define the "process of research" (Creswell, 2007, p. 17) including research design, type of data collected i.e., quantitative or qualitative, and manner of data collection.

Positivist or postpositivist ontology has a realist orientation. Positivism or postpositivism has a goal of developing generalizable knowledge that can be applied dependably in terms of a law to predict and control the natural world. Typically, positivism or post-positivism undergirds the research done by most natural scientists, such as the ones who will participate in the present study (Guba, 1990). By contrast, naturalistic inquiry ontological assumptions allow for multiple, socially constructed realities. The goal of naturalistic inquiry or constructivist inquiry is to create transferable, rather than generalizable knowledge. According to social constructionism, "individuals seek understanding of the world in which they live and work" (Creswell, 2007, p. 20; Patton, 2002). From multiple individual understandings, a collective reality is generated resulting in the social constructivism paradigm. The knowledge generated by naturalistic or constructivist inquiry is "idiographic knowledge, usually expressed in the form of pattern theories, or webs of mutual and plausible influence expressed as working hypotheses, or temporary, time-and place-bound knowledge" (Guba, 1990, p. 77). The naturalistic or constructivist paradigm is highly compatible with the multi-paradigmatic research of social scientists.

Positivism/postpositivism can also be differentiated from naturalism/constructivism on the basis of underlying epistemological assumptions. According to positivist epistemology, there exists a subject-object dualism (Guba, 1990) characterized by no interaction between the observer and the observed. Instead, naturalistic or constructivist epistemology recognizes "interactivity between researcher and researched" (Guba, 1990, p. 78) and encourages its use as part of the research process.

Positivism or postpositivism and naturalistic or constructivist inquiry also diverge axiologically. Positivism or postpositivism assumes an objective researcher, while naturalistic or constructivist inquiry recognizes a subjective researcher (Guba, 1990). Naturalistic or constructivist inquiry goes beyond mere acknowledgement of researcher subjectivity. Instead, it embraces that subjectivity and urges "that the values that inhere in the research process-in the choice of a problem, the choice of an overall design strategy, the choice of the setting, and the decision to honor and present the values that inhere in the site(s)-be explicated and explored" (Guba, 1990, p. 78).

Rhetorical assumptions inherent in naturalistic or constructivist inquiry allow the researcher to write “in a literary, informal style using personal voice and qualitative terms” (Creswell, 2007, p. 17). Such a style, which can take the form of a case study, aims for “reconstruction of the *respondents’ constructions*” (Lincoln & Guba, 1985, p. 359). The term “emic” is applied to describe such fidelity to the “language, concepts, or ways of expression used by members in a particular group or setting to name their experience” (Schwandt, 2007, p. 81). Methodological assumptions of naturalistic or constructivist inquiry support use of inductive logic and an emergent research design strategy.

By contrast, the rhetorical assumptions of positivism or postpositivism dictate that the researcher generate a structured report including sections addressing “problem, questions, data collection, results, conclusions” (Creswell, 2007, p. 20). The language of the structured report is “etic”, specialized jargon belonging to the researcher and used by the researcher to describe the researched (Schwandt, 2007). The methodological assumptions of positivism or postpositivism encompass use of deductive logic along with the collection and reporting of quantitative data.

Another paradigm relevant for consideration is the advocacy/participatory paradigm. This paradigm requires that there be “an action agenda for reform that may change the lives of participants, the institutions in which they live and work, or even the researchers’ lives” (Creswell, 2007, p. 21). According to the advocacy/participatory paradigm, the researcher plays a role in giving a voice to marginalized groups. Scientists would not at first blush appear to be among groups traditionally considered “marginalized”. However, scientists, like groups traditionally considered marginalized, are little understood and, therefore, set apart from the majority. Iconic or archetypal images are a convenient means for the majority to manage what is poorly understood. Since ignorance breeds fear, it is not surprising that these iconic images degenerate into negative stereotypes. This study recognizes that scientists, like groups traditionally deemed "marginalized", are the subjects of negative stereotyping. Likewise, both groups' indigenous voices that might provide alternative or counter images have been largely, possibly deliberately, ignored or even suppressed.

Applying the caveat proposed by Patton (2002) that a research paradigm match the research questions, the purpose and the intended audience, leads to selection of a naturalistic or constructivist inquiry paradigm for the present study. Also highly relevant for achieving the goal of the study is the advocacy/participatory paradigm. The naturalistic or constructivist inquiry and advocacy/participatory paradigms are compatible with the overarching transformational leadership model (Kezar et al., 2006) that inspires this study.

Interpretive Communities

Within the broader paradigms that encompass qualitative research, there exist interpretive communities organized around a particular research orientation. These interpretive communities are defined by a "distinct body of literature and unique issues of discussion" (Creswell, 2007, p. 23). Interpretive communities relevant for this study are critical and feminist theory.

Critical theory addresses issues of power and justice (Creswell, 2007). Critical theory also "seeks to uncover-that is make transparent-the causes of distorted communication and understanding" (Guba, 1990, p. 181). As discussed in Chapter 1, a breakdown in communication between scientists and the public is partly responsible for the stereotypical popular image of the scientist. Feminist theory (Creswell, 2007; hooks, 2000) centers on the role of gender as it relates to a particular issue.

Both critical theory and feminist theory are highly relevant interpretive communities for this work because the stereotypes of white male scientists send the message “women and non-whites need not apply”. Furthermore, these stereotypes make women and non-whites within the scientific community invisible. In its negative stereotyping of scientists, a patriarchal mass media has willingly sacrificed a threatening sub-group, white-male scientists, who have neither the inclination nor the aptitude for crafting an accurate popular media image. Immediate parallels may be drawn to the negative stereotyping and marginalization of feminism itself by the mass media (hooks, 2000).

Qualitative Research Approaches

The broad framework of the naturalistic or constructivist inquiry paradigm encompasses several qualitative research approaches. These approaches include narrative research, phenomenology, grounded theory, ethnography and the case study. Optimization of the match between the approach and the research questions relies heavily on consideration of the nature of the group being studied and the problem addressed by the study (Creswell, 2007). The participants in the present study will be research university science faculty in the natural science disciplines of physical science, life science and earth science. These individuals all share the experience of being natural scientists in a research university setting.

Among the naturalistic research approaches listed above, the phenomenological approach has as its particular focus the "understanding the essence of the experience" (Creswell, 2007, p. 78). Hence, it is best aligned with the present study's goal of seeking "to describe the essence of a lived phenomenon" (Creswell, 2007, p. 78), i.e., being natural scientists at a research university. The phenomenological approach will be used to elucidate how these scientists experience their lives and understand their identities.

Moustakas (1994) described nine characteristics of phenomenology (p. 58-59). At least five of these nine characteristics are strongly aligned with the goals of the present study. Among these characteristics are the ideas that phenomenology focuses on "the appearance of things" and uses "intuition and reflection" (Moustakas, 1994, p. 58) to derive essential meaning from these appearances. Phenomenology relies on "descriptions of experiences" (Moustakas, 1994, p. 59), including art, for this study, DAST-E / DAST drawings, along with interviews and field notes that represent scientists' self-perceptions, to "accentuate … underlying meaning" (Moustakas, 1994, p. 58-59). This approach allows for a researcher who is involved and "intimately connected" (Moustakas, 1994, p. 59) with the phenomenon under study. The researcher and the researched are "integrated" (Moustakas, 1994, p. 59).

For this study, the unit of analysis is the group of university natural scientists who have experienced the phenomenon of being natural scientists at a research university. Data collected will include audiotaped participant interviews supported by documents, observations and art, including the DAST-E /DAST drawings (Creswell, 2007). These data will be analyzed for "significant statements, meaning units, textural and structural description" that allow articulation of the "essence" of the lived experience (Creswell, 2007, p. 61).

Model Phenomenological Studies

The phenomenological approach has been used to access the lived experiences of groups including nurse educators (Grigsby & Megel, 1995); physicists (Ingerman & Booth, 2003); and science educators (Taylor, Jones, Broadwell, & Oppewal, 2008). The Ingerman & Booth study (2003) used a phenomenographic approach. However, since phenomenological and phenomenographic approaches share "a common focus on exploring how human beings make sense of experience" (Patton, 2002, p. 104), it is a relevant model for the present study.

Grigsby and Megel (1995) studied the dynamics of caring among nursing school faculty. Their study was guided by the research question, "How do nurse educators experience caring in their work situations?" (Grigsby & Megel, 1995, p. 411). They interviewed seven nurse educators among three separate nursing programs in one midwestern state to identify themes that characterized caring in these academic settings.

In their study, Ingerman and Booth (2003) interviewed six senior physics students and ten research physicists in the physics departments of two Swedish universities to examine the types of exposition used by each group and the implications of these expository styles for the pedagogical interactions that are part of the everyday life of the physicist or physics student. For the students, the experience was the discussion of a textbook problem in quantum mechanics, the barrier problem. For the physicists, the experience was their own physics research. The interview process itself was discussed extensively and supported with excerpts from interview transcripts.

Interviews were 45-120 minutes long. Interviews were recorded on both audio and videotape so that the body language of participants could be captured. The researchers used a semi-structured style designed to explore the physicists' and physics students' relationship with talking about physics. Interview transcripts were analyzed separately for the physics students and physicists. Distinct categories of exposition were identified and evaluated for efficacy in creating physics understanding.

The Taylor et al. study (2008) addressed scientists' and science teachers' perceptions of K-12 science education. The authors claimed, "Phenomenology was the lens through which this study was framed" (Taylor, et al., p. 1062). However, they admitted that for the most part none of the scientists interviewed had any experience with K-12 science education and only some, those employed by universities, had any teaching experience at all. Any teaching experience possessed by those scientists was limited to college teaching at the undergraduate and graduate levels. Since the scientists, unlike the K-12 science teachers, largely had not shared in the lived experience of being K-12 science educators, the researchers' lens was not phenomenological in the strictest sense with respect to the scientists. Also problematic was the fact that the Taylor et al. study (2008) didn't distinguish between scientists and engineers. It called both, collectively, "scientists". It did, however, appropriately apply the phenomenological approach to the study of the middle and high school science educators who had a daily-lived science education experience. The overall discussion of data analysis and representation of the "voices" (Taylor, et al., 2008, p. 1064, 1068) of scientists and science teachers is instructive for the present study.

A Model Multi-Modal Study

Tucker-Raymond, Varelas, Pappas, Korzh, & Wentland (2007) used a multimodal approach to explore the relationship between primary (grades 1-3) school students' actual identities and the designated identities that they attributed to scientists. In the study, interviews took the form of multimodal narratives where students drew pictures of two times that they were scientists and explained how they thought of themselves as scientists in each picture. Findings were presented as case studies of three students including pictures along with excerpts transcribed from the students' verbal descriptions. The multi-modal narratives also provided insights into the students' understandings of the nature of science and of the epistemological stances relevant for science.

Summary

This review of the literature demonstrates how scientists, with the rare exceptions of celebrity scientists like Sagan (1995) and Smoot (1993), have largely abrogated the defining of science and scientists to others, i.e., non-scientists (Pandora & Rader, 2008). A phenomenological research approach has been identified as appropriate to understand how twenty-first century scientists perceive themselves as practicing scientists. Model phenomenological studies and a multimodal study offer examples of design strategies for implementing a phenomenological approach that includes construction of a multimodal narrative.

CHAPTER 3

Research Methodology

This study will use the phenomenology approach to explore the lived experiences of scientists as already defined. This chapter sets forth the overall design strategy for the research. It considers issues of researcher positionality, sampling, data collection and data analysis associated with implementation of the study. Since the phenomenology approach is grounded in naturalistic inquiry, this research design is an emergent design (Lincoln & Guba, 1985). The strategy developed in this chapter will serve as a flexible framework within which succeeding steps are based on the results of prior steps as the research progresses.

Researcher Positionality

According to the axiological assumptions of naturalistic or constructivist inquiry, the interaction between the researcher and researched is an opportunity to be "capitalized" (Lincoln & Guba, 1985, p. 100) upon. Therefore, it is important to develop the concept of researcher positionality. Researcher positionality is the acknowledgement that the researcher's interpretation of others' meanings "flows from the researcher's own personal, cultural and historical experiences" (Creswell, 2007, p. 21).

The epistemological assumptions inherent in naturalistic or constructivist inquiry, as defined in Chapter 2, emphasize close proximity between the researcher and the participants' environment (Moustakas, 1994). Hence, the researcher's perspective and prior experiences relevant to the present study must be fully disclosed (Jones, Torres & Arminio, 2006; Patton, 2002). I, as the researcher, have already done nearly thirty years of "fieldwork" in the various environments where scientists practice. First, I was an academic research scientist as documented by my authorship of articles in peer-reviewed journals and an invited book chapter while at Bryn Mawr College and the Massachusetts Institute of Technology (MIT). Likewise, I worked in the unique, "visionary" industrial research environment of 1980's AT&T Bell Laboratories' flagship Murray Hill, NJ research facility, again publishing my work in a peer-reviewed journal. At Bryn Mawr, my research was in the area of chemical physics. At Bell Laboratories, my work was in physics as well as materials science. I pursued research in materials science at MIT. Since there is more than a semantic difference between "science" and "engineering", further explanation of my work in materials science is justified. The full title of my academic department at MIT was "Course 3-Materials Science & Engineering". Courses and research in that department ran the gamut from fundamental science related to the structure of materials including metals, ceramics, electronic materials and polymers to "nuts and bolts" engineering such as fracture analysis and corrosion studies. My work was on the fundamental science end of this research continuum. I studied the structure and ionic transport properties of lithium halo-borate glasses. However, my fundamental science research was motivated by engineering considerations. These glasses were candidate materials for a highly practical application as solid electrolytes in high energy density batteries. My self-assessment is that I have a strong affinity to "science", chemical physics, motivated by an appreciation of engineering issues and constraints.

While I did not at that time engage in the reflexivity encouraged by Creswell (2007), I have since looked back on those experiences with my recently acquired "reflexive eye". I first began observing how scientists were perceived outside the elite academic and quasi-academic environments, respectively, of Bryn Mawr, MIT and Bell Laboratories during my work in university technology transfer. As a registered patent agent, I obtained patent protection for inventions developed at MIT and Harvard University. These experiences were "eye-opening", even then. Now, when I view them from the perspective of a researcher in the social sciences, they take on even deeper significance. I found that the legal and business worlds derived their perceptions of scientists from the popular media images of scientists. It was jarring when I realized that scientists who were idolized within the small worlds of their own disciplines became just another mad scientist or eccentric in the "real" world of law and business. In my current role as a doctoral student in science education, I have had the opportunity to undertake formal, scholarly consideration of the prevailing popular images of scientists as documented in Chapter 2.

Consistent with the axiological assumptions of the naturalistic or constructivist inquiry paradigm, this study is "value-laden". It arises from my experiences in science education over the past five years (Creswell, 2007). During this time, my self-perception has gone full circle from physical scientist, to science educator, to physical scientist/educator and back to scientist, defined broadly to include social science in addition to physical science. This broad definition of scientist embraces a strong educator component. My life experience has allowed me to explore both the "physical scientist" and "educator" identities first hand at different times. My narrative study (McCann, 2009) further describes this aspect of my researcher positionality.

Jones, et al. (2006) illustrated the concept of researcher positionality with an example of a Latina researcher who in her research simultaneously held "insider" and "outsider" status (Jones, et al., 2006, p. 104). Her insider status derived from her shared Latin ethnic and cultural background. Her interviewing approach and data interpretation were influenced by this insider status. However, her different educational, nationality and generational status made her an outsider. When I apply this analysis to myself as a researcher, I realize that I am an insider by virtue of my past life experience. My STEM education, a bachelor's degree in physics and master's degree in materials science & engineering, experience as a published researcher in these fields and some undergraduate teaching at MIT give me strong empathy with the scientist participants in this study. Simultaneously, I am an outsider. As a female, even when I perceived myself as an insider, I was to an extent an outsider in these male dominated STEM fields. I first became conscious of having outsider status when I was a patent agent and consultant in the legal and business worlds. I remain an outsider now according to how this study defines "scientist" since I am a science educator and social science researcher. My insider/outsider researcher positionality will have important implications for the substance and style of the interviews with scientists and subsequent data interpretation. My earlier insider status in science and university technology transfer has already played a role in giving me access to influential academic scientists and credibility for generating their interest in participating in the study.

Selection of Participants for the Present Study

The positivist or post-positivist research paradigm and the naturalistic or constructivist research paradigm were introduced in Chapter 2. As discussed there, these paradigms embody different goals for the knowledge they generate. Positivist or post-positivist research results in generalizable knowledge that can be used to predict and control the phenomenon studied. By contrast, naturalistic or constructivist research creates transferable knowledge. The nature of the knowledge that results from use of a particular research paradigm determines the “sampling logic” (Schwandt, 2007, p. 269) that is appropriate for selection of study participants.

Research guided by a positivist or post-positivist paradigm applies an “empirical or statistical strategy” (Schwandt, 2007, p. 269) that requires a randomly selected sample of a pre-determined size to generate statistically significant results generalizable from the sample to a population. By contrast, research guided by the naturalistic or constructivist paradigm utilizes “purposeful sampling” (Patton, 2002, p. 230; Lincoln & Guba, 1985, p. 102), also known as a “theoretical or purposive strategy” (Schwandt, 2007, p. 269). Effective use of purposeful sampling requires deliberate selection of study participants according to explicitly established and explained criteria. The “bias”, i.e. non-random nature of these selection criteria, while a weakness in an empirical or statistical sampling strategy, becomes the “intended focus” (Patton, 2002, p. 230) of a purposeful sampling strategy. Likewise, according to a purposeful sampling strategy, there is no pre-determined sample size. Instead, purposeful sampling emphasizes sample quality. Rather than dictating a pre-determined number of cases, it requires selection of “*information-rich cases* for study in depth” (Patton, 2002, p. 230). Sample sizes ranging between 5 and 25 are typical (Creswell, 2007, p. 61). The researcher must insure that participant selection is not done merely to support a particular research outcome (Schwandt, 2007). While both empirical/statistical and purposeful sampling strategies may be used in qualitative research, most qualitative research relies on purposeful sampling.

The present study will further refine the purposeful sampling strategy to one of picking a small, homogeneous sample so that their experience can be studied in depth (Patton, 2002). The members of this homogeneous sample will be people who share the common experience (Patton, 2002) of being natural scientists, as defined in Chapter 1, in a research university academic setting. The sample will be recruited from university faculty in the natural science disciplines of physical science, life science and earth science to mirror the science disciplines that are part of the K-12 science curriculum. For the purposes of this study, faculty in astronomy, physics or chemistry departments will represent the physical science discipline. Faculty from departments of botany, biology, microbiology or zoology will represent the life science discipline and faculty from geosciences or atmospheric sciences will represent the earth science discipline. All faculty participants will have a Ph.D. in their specific natural science discipline. This study recognizes that it is possible to fulfill the scientist's mission as described in Chapter 1 of discovering new knowledge without having a Ph.D. degree. However, this academic credential is the accepted indicator that individuals have added meaningfully to the existing body of knowledge in their specific disciplines. For this study, sampling will be restricted to Ph.D. scientists in the physical, life and earth science disciplines and will not be extended to Ph.D. scientists in the same disciplines who are employed by research institutes or corporate research and development laboratories. Since university natural science faculty educate the next generation of professional scientists and K-12 teachers, in addition to discovering new knowledge through research, their lived experiences as scientists are especially relevant for science educators.

The purposeful sampling strategy of the present study will also accommodate passive "snowball or chain sampling" (Patton, 2002, p. 237). Participants will not be asked to identify other candidate study participants. However, if in the course of their participation in the study, they spontaneously suggest candidate participants who meet the selection criteria for the study, those suggested candidates will be invited to participate. Such an interactive and iterative approach is consistent with the overarching emergent design of the study.

Initially, study participants will be recruited from a pool of approximately 16 scientists at a research university in the southwestern United States in the natural science disciplines of physical, life, and earth science. An effort will be made to represent each discipline equally by inviting four scientists from each of the four disciplines to participate in the study. Special emphasis will be given to recruiting female scientists and scientists from under-represented minority groups whenever possible. The recruitment process will begin by giving each candidate participant a packet that meets Institutional Review Board (IRB) requirements for description of the study and the participant's role in the study. After they review their packets, candidate participants will join the study by documenting their informed consent.

The packet will include a Draw-A-Scientist-Test (DAST) form as given in the Appendix. The instructions will follow the spirit of E-DAST (Farland-Smith & McComas, 2009) administration by allowing participants to construct multiple scientist drawings. The instructions will direct participants to make as many drawings as needed for them to communicate their understanding of what it means to be a scientist. Participants will have the option of completing the DAST prior to or during an in-person interview. For the present phenomenological study, the drawings will not be scored according to any of the DAST (Chambers, 1983), DAST-C (Finson, et al., 1995), or E-DAST (Farland-Smith & McComas, 2009) indicators described in Chapter 2. Rather, they will be used as discussion prompts during in-person interviews.

Data Collection: Participant Interviews

In-person interviews will be conducted with all participants. Interviews lasting from approximately 45 minutes to 2 hours are anticipated. Such interview lengths are typically reported in the phenomenology literature (Ingerman & Booth, 2003; Grigsby & Megel, 1995). Additionally, guidance concerning the details of interviewing participants and collecting field notes is provided by Patton (2002), Moustakas (1994) and Lincoln & Guba (1985).

For the present study, the interview will center around the broad, open ended questions, “What have you experienced in terms of the phenomenon [being a scientist]? and What contexts or situations have typically influenced or affected your experiences of the phenomenon?” (Moustakas, 1994, p. 61). The style of the interview will be informal and interactive (Moustakas, 1994). Participants’ demographic data including where and when their Ph.D. degrees were obtained, professorial rank, tenure status, honors and awards and the number of years spent teaching at the university level, as well as any other information that they deem relevant will be collected during the interview.

I successfully used a similar open-ended interview style during my fifteen years as a patent agent. Patent application interviews centered on the question, "What is your understanding of your invention?". My goal then was to elicit the broadest possible, and hence most economically valuable, articulation of an invention. However, my experience was that many scientist inventors were uncomfortable responding to such an open-ended question. Here, I will use the DAST drawing(s) to initiate conversation about participants' experiences of being scientists. I will begin by having participants simply elaborate on their drawings. Opening questions will ask participants to describe what they drew and why. Follow-up questions will explore the locations shown in the drawings. Additional questions will be developed related to the particular images drawn, consistent with an emergent design strategy as earlier described.

This open-ended questioning strategy related to the drawing(s) will enable participants to construct a multimodal narrative (Tucker-Raymond, et al., 2007) of their lived experiences as scientists. Such an adaptive approach is responsive to participants' behavior and was used by Grigsby and Megel (1995) in their phenomenological study of caring experiences among nurse educators. In quantitative DAST- based studies, follow-up interviews have been used routinely to clarify and elaborate on drawing elements (Mason, et al., 1991).

All interviews will be audiotaped with the permission of the participants. Use of audiotaping will allow me to focus my attention on my conversation with each scientist and take brief notes as needed. I will transcribe the audio recordings. This melding of interviewer and transcriber roles will protect participants' privacy and insure accurate transcription of scientific terminology. I will then proofread the transcripts for literal accuracy. Following the Grigsby and Megel (1995) approach, participants will have an opportunity to evaluate descriptions and interpretations related to their interviews during the data analysis phase of the research. This phase where participants scrutinize "provisional" reports based on the data they provided is known as the "member check" phase of the research (Lincoln & Guba, 1985, p. 236).

Immediate post-interview impressions in the form of detailed field notes that document my observations of the scientists' work environments, overall demeanor, body language and other non-verbal cues during the interview will also be recorded in a research journal (Sader, in press; Lincoln & Guba, 1985). Efforts will be made to create richly descriptive notes. Vague, interpretive remarks will be avoided. The goal will be to generate field notes that enable the reader to visualize the setting and the participants. The field notes will be part of a reflexive research journal that will document the entire research process. This journal will also record decisions that I make throughout the research design, data collection and analysis phases of the project.

Data Management and Analysis

This section describes data management and analysis. It first develops the concept of trustworthiness as applied to naturalistic or constructivist inquiry. Naturalistic or constructivist inquiry trustworthiness criteria are compared with the corresponding criteria used in positivist or post-positivist research. It outlines the research strategies that will be implemented to address these trustworthiness criteria in the present study. It then describes relevant phenomenological data analysis procedures (Patton, 2002; Moustakas, 1994).

Trustworthiness.

Lincoln and Guba (1985, p. 290) frame the issue of "trustworthiness" in terms of a question, “How can an inquirer persuade his or her audiences (including self) that the findings of an inquiry are worth paying attention to, worth taking account of?”. This question is addressed by four criteria: (1) ‘truth value’ or credibility; (2) applicability; (3) consistency; and (4) neutrality. Their counterparts in the positivist or post-positivist paradigm, which Lincoln & Guba refer to as the “conventional paradigm” (1985, p. 290), are internal validity, external validity, reliability and objectivity, respectively.

Truth value or credibility requires the establishment of confidence that findings are true for the participants. Truth value or credibility is the naturalistic or constructivist inquiry counterpart to the positivist or post-positivist assumption of internal validity. Internal validity is designed to insure that the variation observed in a dependent variable is the direct consequence of changes in the independent variable, and is not attributable to one or more other factors. According to the naturalist or constructivist paradigm, the researcher must carry out the research in a manner that will enhance credibility and then establish the credibility of the findings by “having them approved by the constructors of the multiple realities being constructed” (Lincoln & Guba, 1985, p. 296), i.e. member checks mentioned in the preceding section.

Applicability concerns the extent to which findings apply to different groups in different contexts. According to the positivist or post-positivist paradigm, its counterpart is external validity. External validity measures generalizability of sample data to a population, while applicability is concerned, instead, with the extent of transferability. Applicability accounts for the role of context in obtaining and subsequently applying the research findings.

Consistency, which corresponds to reliability in the positivist or post-positivist paradigm, refers to the repeatability of results under similar conditions. The naturalistic or constructivist criterion of consistency extends beyond mere repeatability by taking into account a dynamic relationship between the researcher and the researched. The researcher is an intrinsically unreliable human instrument and the nature of the researched is changing. This broadened understanding leads to an operational notion of "dependability" (Lincoln & Guba, 1985, p. 299).

Neutrality establishes the extent to which findings derive from the participants rather than from the "biases, motivations, interests or perspectives of the inquirer" (Lincoln & Guba, 1985, p. 290) in a naturalistic or constructivist paradigm. The objectivity of the positivist or post-positivist paradigm is, instead, defined by the agreement of multiple observers on a result. This positivist or post-positivist objectivity criterion diverges axiologically from the naturalistic or constructivist criterion. The positivist or post-positivist paradigm assumes value-free, rather than value-laden research. Objectivity assumes that the observer does not interact with the observed so that "there is an isomorphism between the data of the study and reality" (Lincoln & Guba, 1985, p. 299).

Credibility will be addressed in the present study through data triangulation (Patton, 2002; Lincoln & Guba, 1985) and peer debriefing (Lincoln & Guba, 1985). Data triangulation involves using a variety of data sources (Patton, 2002; Lincoln & Guba, 1985). Data triangulation will be accomplished when participants construct multimodal narratives using two data sources, the DAST drawing(s) along with verbal description, as part of interviews with the researcher. According to peer debriefing, a "disinterested peer" serves as the "devil's advocate" (Lincoln & Guba, 1985, p. 308).

In this capacity, the debriefer questions the researcher's methodology, working hypotheses and biases. Written records of debriefing sessions are kept by the researcher and debriefer. For the present study, they will be incorporated into the reflexive research journal.

The criterion of transferability will be addressed by providing "thick description" (Lincoln & Guba, 1985, p. 316) including working hypotheses along with the context and time where they were found to hold. Instead of the numerical confidence limits provided in positivist or post-positivist research, the present naturalistic or constructivist study will provide relevant descriptive information to enable someone to evaluate transferability. Sufficient description will be provided to allow comparison of the context and time associated with the research findings to that of the new situation.

Criteria of dependability (consistency), confirmability and neutrality will be addressed using an "inquiry audit" (Lincoln & Guba, 1985, p. 317). Dependability refers to the process of the research and confirmability to its product. Halpern has developed procedures for creating an "audit trail" (Lincoln & Guba, 1985, p. 319). The reflexive journal for the present study will include audit trail entries related to raw data, data management and analysis, methodology and trustworthiness, along with personal notes relating to reflection, intention and motivation (Lincoln & Guba, 1985).

Phenomenological data analysis.

This section describes the procedural steps for analyzing data according to a phenomenological approach. The objective of phenomenological research is to "describe how participants view the phenomenon" (Creswell, 2007, p. 61). To satisfy this requirement, researchers must be aware of their own experiences with the phenomenon so that they can take steps to insure that they are describing the participants' experience of the phenomenon, unadulterated by their own experiences. In the preceding section on researcher positionality, I have documented how I have experienced being a scientist, in the physical science disciplines of physics and materials science. This reflection on my researcher positionality is consistent with the reflection on the researcher's own experience with the phenomenon described by Creswell (2007).

Data analysis for this study will follow Husserl's transcendental phenomenology approach. I will prepare for analyzing the data with the "Epoche" (Moustakas, 1994, p. 85). Moustakas (1994, p. 85) defines Epoche as "a preparation for deriving new knowledge but also as an experience in itself, a process of setting aside predilections, prejudices, predispositions, and allowing things, events and people to enter anew into consciousness and to look and see them again, as if for the first time". Before I read the interview transcripts for the purpose of identifying any categories, patterns or themes within each scientist's first person account of his or her experience of being a scientist, I will reflect on my "thoughts and feelings" (Moustakas, 1994, p. 89) related to the scientist and the particular circumstances of the interview until I can approach the interview data with "unbiased looking and seeing" (Moustakas, 1994, p. 89). I will record the "biases and prejudgments" (Moustakas, 1994, p. 89) that I identify during Epoche in the reflective research journal. Later, I will review my data analysis for traces of these prejudices.

After the Epoche, the next phase of data analysis is "phenomenological reduction" which includes processes of "bracketing" (Patton, 2002, p. 485; Moustakas, 1994) and "horizonalization" (Moustakas, 1994, p. 95). In the bracketing process, the researcher

" 'brackets out' " the world and presuppositions in order to identify the data in pure form" (Patton, 2002, p. 485). Specifically, I will conduct this bracketing process according to the following five steps for each participant. Given the relatively small number of participants, approximately 16, all data analysis will be done manually. The results obtained in each step will be documented in the reflexive research journal.

(1) I will identify key phrases that speak directly to the lived experience of being a scientist.

(2) I will interpret the "meanings of these phrases" (Patton, 2002, p. 485).

(3) I will ask participants to evaluate the provisional interpretations generated from step 2.

(4) I will study the meanings obtained in steps 2 and 3 for "essential, recurring features" (Patton, 2002, p. 89) related to the lived experience of being a scientist.

(5) I will generate a tentative statement regarding the essence of being a scientist based on the results of step 4.

The process of horizonalization examines all of the features of the data identified in the bracketing process and assigns them all an equal significance (Moustakas, 1994). Clusters of meaning are developed and redundant data are eliminated. The "textural meanings" (Moustakas, 1994, p. 97) and invariant themes that remain are clustered and organized to create a textural description of the phenomenon as experienced by each of the participants (Creswell, 2007; Moustakas, 1994). Direct quotes from the interview transcripts may be included in the textural description. For the present study, a textural description of each participant's lived experience of being a scientist will be produced at the end of this phenomenological reduction phase of data analysis.

After completion of phenomenological reduction, the next phase of data analysis is "imaginative variation" (Creswell, 2007, p. 61; Moustakas, 1994, p. 97). During imaginative variation, the invariant themes are examined systematically from different perspectives. The goal of the imaginative variation phase is to generate a structural description of an experience, an understanding of the underlying factors that give rise to the experiences set forth in the textural description (Moustakas, 1994). For the present study, the structural description will be "the 'bones' of the experience" (Patton, 2002, p. 486), the skeletal structure of each participant's experience. In the synthesis phase, the textural and structural descriptions are integrated to produce a "synthesis of the meanings and essences of being a scientist" (Moustakas, 1994, p. 144) for each participant. Finally, a "Composite Description" (Moustakas, 1994, p. 121) is developed that represents the experience of the phenomenon of being a scientist across the entire group of participants.

Summary

Chapter 3 described how naturalistic or constructivist inquiry, specifically a phenomenology approach, will be used in the present study to give scientists, as defined in Chapter 1, a voice to describe their understanding of themselves as scientists. The phenomenology approach will guide data collection and analysis to answer the research questions concerning the lived experience of being a scientist. Data will be collected from in-person interviews with participants. During the interviews, participants will construct multimodal narratives (Tucker-Raymond, et al., 2007) of their lived experience of being scientists. Phenomenological reduction will be used to develop and synthesize textural and structural descriptions of each participant's lived experience of being a scientist. From the composite textural and structural descriptions of the individual participants, a Composite Description will developed that captures the essence of the lived experience of being a scientist for the entire group.

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Appendix:

The Draw-a-Scientist Test (DAST)

Directions: Draw a scientist. (Construct a single drawing or as many drawings as necessary to communicate your understanding of what it means to be a scientist.)

APPENDIX B: INTERNAL REVIEW BOARD (IRB) MATERIALS

The University of Oklahoma

OFFICE FOR HUMAN RESEARCH PARTICIPANT PROTECTION

IRB Number: **13100**
Approval Date: **August 16, 2010**

August 17, 2010

Florence McCann
Instructional Leadership and Academic Curriculum
820 Van Fleet Oval, ECH 114
Norman, OK 73019

RE: Scientists' Self-Perceptions: A Phenomenological Study of Natural Scientists in Academia

Dear Ms. McCann:

On behalf of the Institutional Review Board (IRB), I have reviewed and granted expedited approval of the above-referenced research study. This study meets the criteria for expedited approval category 6 & 7. It is my judgment as Chairperson of the IRB that the rights and welfare of individuals who may be asked to participate in this study will be respected; that the proposed research, including the process of obtaining informed consent, will be conducted in a manner consistent with the requirements of 45 CFR 46 as amended; and that the research involves no more than minimal risk to participants.

This letter documents approval to conduct the research as described:

Consent form - Subject Dated: July 28, 2010
Survey Instrument Dated: July 28, 2010 E-DAST
Other Dated: July 28, 2010 Consent Cover Letter
Other Dated: July 28, 2010 In-Person Recruitment Script
Other Dated: July 28, 2010 Telephone Recrutiment Script
Other Dated: July 28, 2010 Recruitment Email
Recruitment flyer Dated: July 28, 2010
Protocol Dated: July 28, 2010
IRB Application Dated: July 28, 2010

As principal investigator of this protocol, it is your responsibility to make sure that this study is conducted as approved. Any modifications to the protocol or consent form, initiated by you or by the sponsor, will require prior approval, which you may request by completing a protocol modification form. All study records, including copies of signed consent forms, must be retained for three (3) years after termination of the study.

The approval granted expires on August 15, 2011. Should you wish to maintain this protocol in an active status beyond that date, you will need to provide the IRB with an IRB Application for Continuing Review (Progress Report) summarizing study results to date. The IRB will request an IRB Application for Continuing Review from you approximately two months before the anniversary date of your current approval.

If you have questions about these procedures, or need any additional assistance from the IRB, please call the IRB office at (405) 325-8110 or send an email to irb@ou.edu.

Cordially,

Donald Baker, Ph.D.
Vice Chair, Institutional Review Board

660 Parrington Oval, Suite 316, Norman, Oklahoma 73019-3085 PHONE: (405) 325-8110 FAX:(405) 325-2373

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Consent Documents: Participant Consent Form
University of Oklahoma
Institutional Review Board
Informed Consent to Participate in a Research Study

Project Title: Scientists' Self-Perceptions: A Phenomenological Study of Natural Scientists in Academia
Principal Investigator: Florence F. McCann
Department: Instructional Leadership & Academic Curriculum (ILAC)

You are being asked to volunteer for this research study. This study is being conducted at the University of Oklahoma, Norman Campus. You were selected as a possible participant because you are a scientist holding a Ph.D. degree in a natural science discipline including the physical, life or earth sciences and hold a faculty position at a research university.

Please read this form and ask any questions that you may have before agreeing to take part in this study.

Purpose of the Research Study

The broad research question that guides this study concerns understanding the lived experience of being a PhD scientist and research university faculty member in a physical, life or earth science discipline. More specific questions probe how, as part of this lived experience, these scientists perceive themselves and the public as well as how they engage with education, research and commercialization activities in the university community and beyond. The research will use qualitative methods, specifically a phenomenological approach (Moustakas, 1994), to address these questions.

The purpose of this study is to explore the self-perceptions of natural scientists as defined above and fill a 35 year gap in the literature since scientists last "spoke" and shared their self-perceptions (Hills & Shallis, 1975). The authentic scientist images that are developed as a result of the study can be used to counter the largely negative stereotypes of scientists (Koren & Bar, 2009) that persist in popular culture. Such negative stereotypes discourage children from studying science and pursuing science careers (Silver & Rushton, 2008; Jones & Bangert, 2006; Bowtell, 1996; & Boylan et al, 1992). The availability of accurate scientist images from the study can have profound implications for scientists, and science educators, alike. Such images can be used to recruit students, especially females and under-represented minorities for science coursework and careers.

(Bowtell, E. (1996). Educational stereotyping: Children's perceptions of scientists: 1990's style. *Investigating: Australian Primary & Junior Science Journal 12(1),* 10-13; Boylan, C.R. Hill, D.H., Wallace, A.R., & Wheeler, A.E. (1992). Beyond stereotypes. *Science Education, 76(5),* 456-476; Hills, P., & Shallis, M. (1975). Scientists and their images. *New Scientist, 67(964),* 471-475; Jones, R., & Bangert, A. (2006). The CSI effect changing the face of science. *Science Scope, 30(3),* 38-42; Koren, P. & Bar, V. (2009). Science and its images-promise and threat: From classic literature to contemporary students' images of science and "the scientist". *Interchange, 40(2),* 141-163; Moustakas, C. (1994). *Phenomenological Research Methods.* Thousand Oaks: Sage; Silver, A. & Rushton, B.S. (2008). Primary school children's attitudes towards science, engineering and technology and their images of scientists and engineers. *Education 3-13, 36(1),* 51-67)

Number of Participants

About 15-25 people will take part in this study.

Procedures

If you agree to be in this study, you will be asked to do the following two tasks: (1) complete the Enhanced-Draw-A-Scientist-Test (E-DAST) (Farland-Smith & McComas, 2009); and (2) participate in a face-to-face interview with Ms. McCann. Each of these two tasks will be performed once.

A copy of the E-DAST with instructions is attached to this document. This task requires that you make one or as many drawings as you need to communicate your understanding of what it means to be a scientist. The E-DAST task may be completed prior to or during the face-to-face interview task. Completion of the E-DAST may take from 10-30 minutes depending upon the number of drawings you make and the level of detail you choose to include in each drawing. You will be asked to elaborate on your E-DAST drawing(s) during the interview with Ms. McCann.

Interviews for this type of research study typically take between 45 minutes and 2 hours (Ingerman & Booth, 2003; Grigsby & Megel, 1995), assuming that the E-DAST has been completed prior to the interview. You will determine how much time you want to spend on the interview task when you schedule your interview with Ms. McCann. (A minimum of 30 minutes will be needed for the interview.) You should add 10-30 minutes to the interview time, if you plan to complete the E-DAST during the interview. The interview will have a conversational tone and informal, interactive style. During the interview, you will be asked about your experience "being a scientist" and about the contexts and situations that have influenced this experience.

During the data analysis phase of the study, you will be contacted by Ms. McCann and given the option to review a provisional interpretation of the data you provided earlier when you completed the E-DAST and interview tasks.

(Farland-Smith, D., & McComas W. (2009). Teaching the human dimension of science. *Science & Children, 46(9)*, 48-51; Grigsby, K., A., & Megel, M.D. (1995). Caring experiences of nurse educators. *Journal of Nursing Education, 34(9)*, 411-418; Ingerman, A., & Booth, S. (2003). Expounding on physics: A phenomenographic study of physicists talking about their physics. *International Journal of Science Education, 25(12)*, 1489-1508.)

Length of Participation

The total length of time for participation should be about 1.5 hours including the time it takes to complete the E-DAST and for a single in-person interview. Completion of both the E-DAST and interview tasks is necessary for this study. You may spend additional time, if you choose to, in performing an optional review of a provisional interpretation of your E-DAST and interview data during the data analysis phase of the study.

The only anticipated circumstances under which a participant's involvement in the study might be terminated by the investigator without the participant's consent is if the participant was unable to complete both the E-DAST and interview tasks within a semester of first consenting to participate in the study.

This study has the following risks:

No risks associated with participation in this study are foreseen.

APPROVED AUG 16 2010 OU NC IRB

APPROVAL AUG 15 2011 EXPIRES

Benefits of being in the study include benefits to individual participants, to scientists generally and to society as a whole.

It is anticipated that as participants respond to interview questions about their life experiences as scientists, they will reflect on their self-perceptions and professional identities. This reflection and awareness has potential to positively impact participants' university teaching, as well as science outreach, popularization and commercialization activities.

This research can benefit scientists generally and society as a whole by providing authentic images of natural scientists that can serve as counter-images to the largely negative stereotypes that persist in popular culture. Since several studies have identified links between stereotypical images of scientists (Koren & Bar, 2009) and students' lack of interest in science and science careers (Silver & Rushton, 2008; Jones & Bangert, 2006; Bowtell, 1996; & Boylan et al, 1992), the availability of accurate scientist images can have profound implications for science and science education. Such accurate images can be used to recruit students, especially females and under-represented minorities.

(Bowtell, E. (1996). Educational stereotyping: Children's perceptions of scientists: 1990's style. *Investigating: Australian Primary & Junior Science Journal 12(1),* 10-13; Boylan, C.R.. Hill, D.H., Wallace, A.R., & Wheeler, A.E. (1992). Beyond stereotypes. *Science Education, 76(5),* 456-476; Jones, R., & Bangert, A. (2006). The CSI effect changing the face of science. *Science Scope, 30(3),* 38-42; Koren, P. & Bar, V. (2009). Science and its images-promise and threat: From classic literature to contemporary students' images of science and "the scientist". *Interchange, 40(2),* 141-163; Silver, A. & Rushton, B.S. (2008). Primary-school children's attitudes towards science, engineering and technology and their images of scientists and engineers. *Education 3-13, 36(1),* 51-67.)

Confidentiality

In published reports, there will be no information included that will make it possible to identify you. Your E-DAST and interview data will be tracked with an alphanumeric code. Ms. McCann will transcribe all interviews. Research records will be stored securely and only approved researchers, Ms. McCann and Dr. Marek, will have access to the records. All records linking your identity to the alphanumeric code will be destroyed once the data analysis phase of this study is complete. All data including E-DAST and interview audiotapes and transcripts will be destroyed once the study is complete.

There are organizations that may inspect and/or copy your research records for quality assurance and data analysis. These organizations include the OU Institutional Review Board.

Compensation

You will not be reimbursed for your time and participation in this study.

Voluntary Nature of the Study

Participation in this study is voluntary. If you withdraw or decline participation, you will not be penalized or lose benefits or services unrelated to the study. If you decide to participate, you may decline to answer any question and may choose to withdraw at any time.

APPROVED
AUG 16 2010
OU NC IRB

APPROVAL
AUG 15 2011
EXPIRES

Waivers of Elements of Confidentiality

Your name will not be linked with your responses. Please select one of the following options by writing your initials on the appropriate line.

_____ I consent to being quoted directly.

_____ I do not consent to being quoted directly.

Audio Recording of Study Activities

To assist with accurate recording of participant responses, interviews may be recorded on an audio recording device. You have the right to refuse to allow such recording without penalty. Please select one of the following options by writing your initials on the appropriate line.

I consent to audio recording. ___ Yes ___ No.

Contacts and Questions

If you have concerns or complaints about the research, the researcher conducting this study, Ms. Florence F. McCann, can be contacted at 405-325-1498 and at fmccann@sbcglobal.net or Florence.F.Mc.Cann-1@ou.edu. Her advisor and faculty sponsor, Dr. Edmund A. Marek, can be contacted at 405-325-1498 and at eamarek@ou.edu. Contact the researcher(s) if you have questions or if you have experienced a research-related injury.

If you have any questions about your rights as a research participant, concerns, or complaints about the research and wish to talk to someone other than individuals on the research team or if you cannot reach the research team, you may contact the University of Oklahoma – Norman Campus Institutional Review Board (OU-NC IRB) at 405-325-8110 or irb@ou.edu.

You will be given a copy of this information to keep for your records. If you are not given a copy of this consent form, please request one.

Statement of Consent

I have read the above information. I have asked questions and have received satisfactory answers. I consent to participate in the study.

____

Signature Date

APPROVED
AUG 16 2010
OU NC IRB

APPROVAL
AUG 15 2011
EXPIRES

The UNIVERSITY of OKLAHOMA

Institutional Review Board for the Protection of Human Subjects

Approval of Continuing Review – Expedited Review – AP0

Date:	July 31, 2013	**IRB#:**	0763
Principal Investigator:	Florence F McCann, MS	**Approval Date:**	07/30/2013
		Expiration Date:	**06/30/2014**

Expedited Category: 6 & 7

Study Title: Engineers' Self-Perceptions: A Phenomenological Study of Engineers in Academia

Based on the information submitted, your study is currently: Active, open to enrollment. On behalf the Institutional Review Board (IRB), I have reviewed and approved your continuing review application. To view the documents approved for this submission, open this study from the *My Studies* option, go to *Submission History*, go to *Completed Submissions* tab and then click the *Details* icon.

As principal investigator of this research study, you are responsible to:

- Conduct the research study in a manner consistent with the requirements of the IRB and federal regulations 45 CFR 46.
- Obtain informed consent and research privacy authorization using the currently approved, stamped forms and retain all original, signed forms, if applicable.
- Request approval from the IRB prior to implementing any/all modifications.
- Promptly report to the IRB any harm experienced by a participant that is both unanticipated and related per IRB policy.
- Maintain accurate and complete study records for evaluation by the HRPP Quality Improvement Program and, if applicable, inspection by regulatory agencies and/or the study sponsor.
- Promptly submit continuing review documents to the IRB upon notification approximately 60 days prior to the expiration date indicated above.
- Submit a final closure report at the completion of the project.

You will receive notification approximately 60 days prior to the expiration date noted above. You are responsible for submitting continuing review documents in a timely fashion in order to maintain continued IRB approval.

If you have questions about this notification or using iRIS, contact the IRB @ 405-325-8110 or irb@ou.edu.

Cordially,

Lara Mayeux

Lara Mayeux, Ph.D.
Chair, Institutional Review Board

The University of Oklahoma

OFFICE FOR HUMAN RESEARCH PARTICIPANT PROTECTION

IRB Number: **13101**
Approval Date: **August 16, 2010**

August 17, 2010

Florence McCann
Instructional Leadership and Academic Curriculum
820 Van Fleet Oval, ECH 114
Norman, OK 73019

RE: Engineers' Self-Perceptions: A phenomenological Study Of Engineers In Academia

Dear Ms. McCann:

On behalf of the Institutional Review Board (IRB), I have reviewed and granted expedited approval of the above-referenced research study. This study meets the criteria for expedited approval category 6 & 7. It is my judgment as Chairperson of the IRB that the rights and welfare of individuals who may be asked to participate in this study will be respected; that the proposed research, including the process of obtaining informed consent, will be conducted in a manner consistent with the requirements of 45 CFR 46 as amended; and that the research involves no more than minimal risk to participants.

This letter documents approval to conduct the research as described:

Consent form - Subject Dated: July 28, 2010
Survey Instrument Dated: July 28, 2010 Interview Questions
Survey Instrument Dated: July 28, 2010 DAET
Other Dated: July 28, 2010 Consent Packet Cover Letter
Other Dated: July 28, 2010 In-Person Recruitment Script
Other Dated: July 28, 2010 Telephone Recruitment Script
Other Dated: July 28, 2010 Recruitment Email
Recruitment flyer Dated: July 28, 2010
Protocol Dated: July 28, 2010
IRB Application Dated: July 28, 2010

As principal investigator of this protocol, it is your responsibility to make sure that this study is conducted as approved. Any modifications to the protocol or consent form, initiated by you or by the sponsor, will require prior approval, which you may request by completing a protocol modification form. All study records, including copies of signed consent forms, must be retained for three (3) years after termination of the study.

The approval granted expires on August 15, 2011. Should you wish to maintain this protocol in an active status beyond that date, you will need to provide the IRB with an IRB Application for Continuing Review (Progress Report) summarizing study results to date. The IRB will request an IRB Application for Continuing Review from you approximately two months before the anniversary date of your current approval.

If you have questions about these procedures, or need any additional assistance from the IRB, please call the IRB office at (405) 325-8110 or send an email to irb@ou.edu.

Cordially,

Donald Baker, Ph.D.
Vice Chair, Institutional Review Board

660 Parrington Oval, Suite 316, Norman, Oklahoma 73019-3085 PHONE: (405) 325-8110 FAX:(405) 325-2373

Ltr_Prot_Fappv_Exp

Consent Documents: Participant Consent Form
University of Oklahoma
Institutional Review Board
Informed Consent to Participate in a Research Study

Project Title: Engineers' Self-Perceptions: A Phenomenological Study of Engineers in Academia
Principal Investigator: Florence F. McCann
Department: Instructional Leadership & Academic Curriculum (ILAC)

You are being asked to volunteer for this research study. This study is being conducted at the University of Oklahoma, Norman Campus. You were selected as a possible participant because you are an engineer holding a Ph.D. or equivalent degree in an engineering discipline such as aerospace, chemical, civil, computer, electrical, environmental, industrial, materials, mechanical or petroleum engineering and hold a faculty position at a research university.

Please read this form and ask any questions that you may have before agreeing to take part in this study.

Purpose of the Research Study

The broad research question that guides this study concerns understanding the lived experience of being a PhD engineer and research university faculty member. More specific questions probe how, as part of this lived experience, these engineers perceive themselves and the public as well as how they engage with education, research and commercialization activities in the university community and beyond. The research will use qualitative methods, specifically a phenomenological approach (Moustakas, 1994), to address these questions.

The purpose of this study is to explore the self-perceptions of engineers in academia. For the purpose of the study, engineers are defined as individuals holding a Ph.D. degree or the equivalent and serving as faculty members of a research university in engineering disciplines such as aerospace, chemical, civil, computer, electrical, environmental, industrial, materials, mechanical or petroleum engineering. The authentic engineer images that are developed as a result of the study can be used to counter the largely negative stereotypes of engineers either as self-serving tools oblivious to the consequences of their work or as social outcasts (Clark & Illman, 2006; Goldman, 1990; Vaughan, 1990). Such exaggerated images of engineers in popular culture are significant for engineering career recruitment (Engineers Dedicated to a Better Tomorrow, 2006; Vaughan, 1990).

(Clark, F., & Illman, D.L. (2006). Portrayals of engineers in "Science Times". *IEEE Technology and Society Magazine, 25(1)*, 12-21; Engineers Dedicated to a Better Tomorrow. (2006). Improving engineering's public image-ten guiding principles. www.DedicatedEngineers.org. downloaded 1/25/09; Goldman, S.L. (1989). Images of technology in popular films: Discussion and filmography. *Science, Technology, & Human Values, 14(3)*, 275-301; Moustakas, C. (1994). *Phenomenological Research Methods.* Thousand Oaks: Sage; Vaughan, D.K. (1990). The image of the engineer in the popular imagination, 1880-1980. *Bulletin of Science, Technology and Society, 10*, 301-304.)

Number of Participants

About 15-25 people will take part in this study.

APPROVED
AUG 16 2010
OU NC IRB

APPROVAL
AUG 15 2011
EXPIRES

Procedures

If you agree to be in this study, you will be asked to do the following two tasks: (1) complete the Draw-An-Engineer-Test (DAET) (Farland-Smith & McComas, 2009; Knight & Cunningham, 2004); and (2) participate in a face-to-face interview with Ms. McCann. Each of these two tasks will be performed once.

A copy of the DAET with instructions is attached to this document. This task requires that you make one or as many drawings as you need to communicate your understanding of what it means to be an engineer. The DAET task may be completed prior to or during the face-to-face interview task. Completion of the DAET may take from 10-30 minutes depending upon the number of drawings you make and the level of detail you choose to include in each drawing. You will be asked to elaborate on your DAET drawing(s) during the interview with Ms. McCann.

Interviews for this type of research study typically take between 45 minutes and 2 hours (Ingerman & Booth, 2003; Grigsby & Megel, 1995), assuming that the DAET has been completed prior to the interview. You will determine how much time you want to spend on the interview task when you schedule your interview with Ms. McCann. (A minimum of 30 minutes will be needed for the interview.) You should add 10-30 minutes to the interview time, if you plan to complete the DAET during the interview. The interview will have a conversational tone and informal, interactive style. During the interview, you will be asked about your experience "being an engineer" and about the contexts and situations that have influenced this experience.

During the data analysis phase of the study, you will be contacted by Ms. McCann and given the option to review a provisional interpretation of the data you provided earlier when you completed the DAET and interview tasks.

(Farland-Smith, D., & McComas W. (2009). Teaching the human dimension of science. *Science & Children, 46(9)*, 48-51; Grigsby, K., A., & Megel, M.D. (1995). Caring experiences of nurse educators. *Journal of Nursing Education, 34(9)*, 411-418; Ingerman, A., & Booth, S. (2003). Expounding on physics: A phenomenographic study of physicists talking about their physics. *International Journal of Science Education, 25(12)*, 1489-1508; Knight, M., & Cunningham, C. (2004). Draw an engineer test (DAET): Development of a tool to investigate students' ideas about engineers and engineering. Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition.)

Length of Participation

The total length of time for participation should be about 1.5 hours including the time it takes to complete the DAET and for a single in-person interview. Completion of both the DAET and interview tasks is necessary for this study. You may spend additional time, if you choose to, in performing an optional review of a provisional interpretation of your DAET and interview data during the data analysis phase of the study.

The only anticipated circumstances under which a participant's involvement in the study might be terminated by the investigator without the participant's consent is if the participant was unable to complete both the DAET and interview tasks within a semester of first consenting to participate in the study.

This study has the following risks:

No risks associated with participation in this study are foreseen.

Benefits of being in the study include benefits to individual participants, to engineers generally and to society as a whole.

It is anticipated that as participants respond to interview questions about their life experiences as engineers, they will reflect on their self-perceptions and professional identities. This reflection and awareness has potential for positive impact on participants' university teaching, as well as their involvement with ongoing College of Engineering student recruitment and retention and outreach activities.

The authentic engineer images that are developed as a result of the study can be used to counter the largely negative stereotypes of engineers either as self-serving tools oblivious to the consequences of their work or as social outcasts (Clark & Illman, 2006; Goldman, 1990; Vaughan, 1990). Such exaggerated images of engineers in popular culture are significant for engineering career recruitment (Engineers Dedicated to a Better Tomorrow, 2006; Vaughan, 1990). Hence, the accurate engineer images developed by the study can have profound implications for engineering as well as engineering and STEM education. These images can be used in recruitment of female and under-represented minority students.

(Clark, F., & Illman, D.L. (2006). Portrayals of engineers in "Science Times". *IEEE Technology and Society Magazine, 25(1)*, 12-21; Engineers Dedicated to a Better Tomorrow. (2006). Improving engineering's public image-ten guiding principles. www.DedicatedEngineers.org. downloaded 1/25/09; Goldman, S.L. (1989). Images of technology in popular films: Discussion and filmography. *Science, Technology, & Human Values, 14(3)*, 275-301; Moustakas, C. (1994). *Phenomenological Research Methods.* Thousand Oaks: Sage; Vaughan, D.K. (1990). The image of the engineer in the popular imagination, 1880-1980. *Bulletin of Science, Technology and Society, 10*, 301-304.)

Confidentiality

In published reports, there will be no information included that will make it possible to identify you. Your DAET and interview data will be tracked with an alphanumeric code. Ms. McCann will transcribe all interviews. Research records will be stored securely and only approved researchers, Ms. McCann and Dr. Marek, will have access to the records. All records linking your identity to the alphanumeric code will be destroyed once the data analysis phase of this study is complete. All data including DAET and interview audiotapes and transcripts will be destroyed once the study is complete.

There are organizations that may inspect and/or copy your research records for quality assurance and data analysis. These organizations include the OU Institutional Review Board.

Compensation

You will not be reimbursed for your time and participation in this study.

Voluntary Nature of the Study

Participation in this study is voluntary. If you withdraw or decline participation, you will not be penalized or lose benefits or services unrelated to the study. If you decide to participate, you may decline to answer any question and may choose to withdraw at any time.

APPROVED
AUG 16 2010
OU NC IRB

APPROVAL
AUG 15 2011
EXPIRES

Waivers of Elements of Confidentiality

Your name will not be linked with your responses. Please select one of the following options by writing your initials on the appropriate line.

_____ I consent to being quoted directly.

_____ I do not consent to being quoted directly.

Audio Recording of Study Activities

To assist with accurate recording of participant responses, interviews may be recorded on an audio recording device. You have the right to refuse to allow such recording without penalty. Please select one of the following options by writing your initials on the appropriate line.

I consent to audio recording. ___ Yes ___ No.

Contacts and Questions

If you have concerns or complaints about the research, the researcher conducting this study, Ms. Florence F. McCann, can be contacted at 405-325-1498 and at fmccann@sbcglobal.net or Florence.F.Mc.Cann-1@ou.edu. Her advisor and faculty sponsor, Dr. Edmund A. Marek, can be contacted at 405-325-1498 and at eamarek@ou.edu. Contact the researcher(s) if you have questions or if you have experienced a research-related injury.

If you have any questions about your rights as a research participant, concerns, or complaints about the research and wish to talk to someone other than individuals on the research team or if you cannot reach the research team, you may contact the University of Oklahoma – Norman Campus Institutional Review Board (OU-NC IRB) at 405-325-8110 or irb@ou.edu.

You will be given a copy of this information to keep for your records. If you are not given a copy of this consent form, please request one.

Statement of Consent

I have read the above information. I have asked questions and have received satisfactory answers. I consent to participate in the study.

____

Signature Date

APPROVED
AUG 16 2010
OU NC IRB

APPROVAL
AUG 15 2011
EXPIRES

The University of Oklahoma®

OFFICE OF HUMAN RESEARCH PARTICIPANT PROTECTION - IRB

IRB Number: 13101
Approval Date: July 19, 2011

July 19, 2011

Florence McCann
Dept. ILAC
6002 Flaming Oaks Circle
Norman, OK 73026

RE: Engineers' Self-Perceptions: A phenomenological Study Of Engineers In Academia

Dear Ms. McCann:

Thank you for completing and returning the IRB Application for Continuing Review (Progress Report) for the above-referenced study. You have indicated that the study is still active. I have reviewed and approved the Progress Report and determined that this study was appropriate for continuation.

This letter documents approval to conduct the research as described in:
Cont Review Form Dated: May 20, 2011
Protocol Dated: May 20, 2011
Other Dated: May 20, 2011 Summary of results
Consent form - Subject Dated: May 20, 2011

Please remember that any change in the protocol, consent document or other recruitment materials (adverstisements, etc.) must be approved by the IRB prior to its incorporation into the study procedures. Submit a completed Protocol Modification form to the IRB office.

Approximately two months prior to the expiration date of this approval, you will be contacted by the IRB staff about procedures necessary to maintain this approval in an active status. Although every attempt will be made to notify you when a study is due for review, it is the responsibility of the investigator to assure that their studies receive review prior to expiration.

The approval of this study expires on July 18, 2012 and must be reviewed by the convened IRB prior to this time if you wish to remain in an active status. Federal regulations do not allow for extensions to be given on the expiration date.

If we can be of further assistance, please call the IRB office at (405) 325-8110 or send an email to irb@ou.edu.

Cordially,

E. Laurette Taylor, Ph.D.
Chair, Institutional Review Board

Ltr_Prog_Appv_Active

1816 West Lindsey, Suite 150 Norman, Oklahoma 73069 PHONE: (405) 325-8110

Consent Documents: Participant Consent Form
University of Oklahoma
Institutional Review Board
Informed Consent to Participate in a Research Study

Project Title: Engineers' Self-Perceptions: A Phenomenological Study of Engineers in Academia

Principal Investigator: Florence F. McCann

Department: Instructional Leadership & Academic Curriculum (ILAC)

You are being asked to volunteer for this research study. This study is being conducted at the University of Oklahoma, Norman Campus. You were selected as a possible participant because you are an engineer holding a Ph.D. or equivalent degree in an engineering discipline such as aerospace, chemical, civil, computer, electrical, environmental, industrial, materials, mechanical or petroleum engineering and hold a faculty position at a research university.

Please read this form and ask any questions that you may have before agreeing to take part in this study.

Purpose of the Research Study

The broad research question that guides this study concerns understanding the lived experience of being a PhD engineer and research university faculty member. More specific questions probe how, as part of this lived experience, these engineers perceive themselves and the public as well as how they engage with education, research and commercialization activities in the university community and beyond. The research will use qualitative methods, specifically a phenomenological approach (Moustakas, 1994), to address these questions.

The purpose of this study is to explore the self-perceptions of engineers in academia. For the purpose of the study, engineers are defined as individuals holding a Ph.D. degree or the equivalent and serving as faculty members of a research university in engineering disciplines such as aerospace, chemical, civil, computer, electrical, environmental, industrial, materials, mechanical or petroleum engineering. The authentic engineer images that are developed as a result of the study can be used to counter the largely negative stereotypes of engineers either as self-serving tools oblivious to the consequences of their work or as social outcasts (Clark & Illman, 2006; Goldman, 1990; Vaughan, 1990). Such exaggerated images of engineers in popular culture are significant for engineering career recruitment (Engineers Dedicated to a Better Tomorrow, 2006; Vaughan, 1990).

(Clark, F., & Illman, D.L. (2006). Portrayals of engineers in "Science Times". *IEEE Technology and Society Magazine, 25(1)*, 12-21; Engineers Dedicated to a Better Tomorrow. (2006). Improving engineering's public image-ten guiding principles. www.DedicatedEngineers.org. downloaded 1/25/09; Goldman, S.L. (1989). Images of technology in popular films: Discussion and filmography. *Science, Technology, & Human Values, 14(3)*, 275-301; Moustakas, C. (1994).

Phenomenological Research Methods. Thousand Oaks: Sage; Vaughan, D.K. (1990). The image of the engineer in the popular imagination, 1880-1980. *Bulletin of Science, Technology and Society, 10,* 301-304.)

Number of Participants

About 15-25 people will take part in this study.

Procedures

If you agree to be in this study, you will be asked to do the following two tasks: (1) complete the Draw-An-Engineer-Test (DAET) (Farland-Smith & McComas, 2009; Knight & Cunningham, 2004); and (2) participate in a face-to-face interview with Ms. McCann. Each of these two tasks will be performed once.

A copy of the DAET with instructions is attached to this document. This task requires that you make one or as many drawings as you need to communicate your understanding of what it means to be an engineer. The DAET task may be completed prior to or during the face-to-face interview task. Completion of the DAET may take from 10-30 minutes depending upon the number of drawings you make and the level of detail you choose to include in each drawing. You will be asked to elaborate on your DAET drawing(s) during the interview with Ms. McCann.

Interviews for this type of research study typically take between 45 minutes and 2 hours (Ingerman & Booth, 2003; Grigsby & Megel, 1995), assuming that the DAET has been completed prior to the interview. You will determine how much time you want to spend on the interview task when you schedule your interview with Ms. McCann. (A minimum of 30 minutes will be needed for the interview.) You should add 10-30 minutes to the interview time, if you plan to complete the DAET during the interview. The interview will have a conversational tone and informal, interactive style. During the interview, you will be asked about your experience "being an engineer" and about the contexts and situations that have influenced this experience.

During the data analysis phase of the study, you will be contacted by Ms. McCann and given the option to review a provisional interpretation of the data you provided earlier when you completed the DAET and interview tasks.

(Farland-Smith, D., & McComas W. (2009). Teaching the human dimension of science. *Science & Children, 46(9),* 48-51; Grigsby, K., A., & Megel, M.D. (1995). Caring experiences of nurse educators. *Journal of Nursing Education, 34(9),* 411-418; Ingerman, A., & Booth, S. (2003). Expounding on physics: A phenomenographic study of physicists talking about their physics. *International Journal of Science Education, 25(12),* 1489-1508; Knight, M., & Cunningham, C. (2004). Draw an engineer test (DAET): Development of a tool to investigate students' ideas about engineers and engineering. Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition.)

Length of Participation

The total length of time for participation should be about 1.5 hours including the time it takes to complete the DAET and for a single in-person interview.

Completion of both the DAET and interview tasks is necessary for this study. You may spend additional time, if you choose to, in performing an optional review of a provisional interpretation of your DAET and interview data during the data analysis phase of the study.

The only anticipated circumstances under which a participant's involvement in the study might be terminated by the investigator without the participant's consent is if the participant was unable to complete both the DAET and interview tasks within a semester of first consenting to participate in the study.

This study has the following risks:

No risks associated with participation in this study are foreseen.

Benefits of being in the study include benefits to individual participants, to engineers generally and to society as a whole.

It is anticipated that as participants respond to interview questions about their life experiences as engineers, they will reflect on their self-perceptions and professional identities. This reflection and awareness has potential for positive impact on participants' university teaching, as well as their involvement with ongoing College of Engineering student recruitment and retention and outreach activities.

The authentic engineer images that are developed as a result of the study can be used to counter the largely negative stereotypes of engineers either as self-serving tools oblivious to the consequences of their work or as social outcasts (Clark & Illman, 2006; Goldman, 1990; Vaughan, 1990). Such exaggerated images of engineers in popular culture are significant for engineering career recruitment (Engineers Dedicated to a Better Tomorrow, 2006; Vaughan, 1990). Hence, the accurate engineer images developed by the study can have profound implications for engineering as well as engineering and STEM education. These images can be used in recruitment of female and under-represented minority students.

(Clark, F., & Illman, D.L. (2006). Portrayals of engineers in "Science Times". *IEEE Technology and Society Magazine, 25(1)*, 12-21; Engineers Dedicated to a Better Tomorrow. (2006). Improving engineering's public image-ten guiding principles. www.DedicatedEngineers.org. downloaded 1/25/09; Goldman, S.L. (1989). Images of technology in popular films: Discussion and filmography. *Science, Technology, & Human Values, 14(3)*, 275-301; Moustakas, C. (1994). *Phenomenological Research Methods*. Thousand Oaks: Sage; Vaughan, D.K. (1990). The image of the engineer in the popular imagination, 1880-1980. *Bulletin of Science, Technology and Society, 10*, 301-304.)

Confidentiality

In published reports, there will be no information included that will make it possible to identify you. Your DAET and interview data will be tracked with an alphanumeric code. Ms. McCann will transcribe all interviews. Research records will be stored securely and only approved researchers, Ms. McCann and Dr. Marek, will have access to the records. All records linking your identity to the alphanumeric code will be destroyed once the data analysis phase of this study is complete. All data including DAET and interview audiotapes and transcripts will be destroyed once the study is complete.

There are organizations that may inspect and/or copy your research records for quality assurance and data analysis. These organizations include the OU Institutional Review Board.

Compensation

You will not be reimbursed for your time and participation in this study.

Voluntary Nature of the Study

Participation in this study is voluntary. If you withdraw or decline participation, you will not be penalized or lose benefits or services unrelated to the study. If you decide to participate, you may decline to answer any question and may choose to withdraw at any time.

Waivers of Elements of Confidentiality

Your name will not be linked with your responses. Please select one of the following options by writing your initials on the appropriate line.

_____ I consent to being quoted directly.

_____ I do not consent to being quoted directly.

Audio Recording of Study Activities

To assist with accurate recording of participant responses, interviews may be recorded on an audio recording device. You have the right to refuse to allow such recording without penalty. Please select one of the following options by writing your initials on the appropriate line.

I consent to audio recording. ___ Yes ___ No.

Contacts and Questions

If you have concerns or complaints about the research, the researcher conducting this study, Ms. Florence F. McCann, can be contacted at 405-325-1498 and at fmccann@sbcglobal.net or Florence.F.Mc.Cann-1@ou.edu. Her advisor and faculty sponsor, Dr. Edmund A. Marek, can be contacted at 405-325-1498 and at eamarek@ou.edu. Contact the researcher(s) if you have questions or if you have experienced a research-related injury.
If you have any questions about your rights as a research participant, concerns, or complaints about the research and wish to talk to someone other than individuals on the research team or if you cannot reach the research team, you may contact the University of Oklahoma – Norman Campus Institutional Review Board (OU-NC IRB) at 405-325-8110 or irb@ou.edu.

APPROVED JUL 19 2011 OU NC IRB

APPROVAL JUL 18 2012 EXPIRES

You will be given a copy of this information to keep for your records. If you are not given a copy of this consent form, please request one.

Statement of Consent

I have read the above information. I have asked questions and have received satisfactory answers. I consent to participate in the study.

____

Signature Date

APPROVED
JUL 19 2011
OU NC IRB

APPROVAL
JUL 18 2012
EXPIRES

The University of Oklahoma®

OFFICE OF HUMAN RESEARCH PARTICIPANT PROTECTION - IRB

IRB Number: **13177**
Approval Date: **November 03, 2010**

November 03, 2010

Florence McCann
Dept. ILAC
6002 Flaming Oaks Circle
Norman, OK 73026

RE: The Impact of A STEM (Science, Technology, Engineering and Mathematics) Club On Fifth Grader's Perceptions of Scientists and Engineers

Dear Ms. McCann:

On behalf of the Institutional Review Board (IRB), I have reviewed and granted expedited approval of the above-referenced research study. This study meets the criteria for expedited approval category 7. It is my judgment as Chairperson of the IRB that the rights and welfare of individuals who may be asked to participate in this study will be respected; that the proposed research, including the process of obtaining informed consent, will be conducted in a manner consistent with the requirements of 45 CFR 46 as amended; and that the research involves no more than minimal risk to participants.

This letter documents approval to conduct the research as described:

Consent form - Parental Dated: October 29, 2010 Revised
Other Dated: October 19, 2010 Student Recruitment Flyer - Revised
Protocol Dated: October 19, 2010 Revised
Other Dated: October 19, 2010 Parent Recruitment Letter
Assent Form Dated: October 19, 2010 Revised
IRB Application Dated: October 19, 2010 Revised
Survey Instrument Dated: October 04, 2010 DAET
Survey Instrument Dated: October 04, 2010 E-DAST
Other Dated: October 04, 2010 Norman Public Schools IRB Approval Letter

As principal investigator of this protocol, it is your responsibility to make sure that this study is conducted as approved. Any modifications to the protocol or consent form, initiated by you or by the sponsor, will require prior approval, which you may request by completing a protocol modification form. All study records, including copies of signed consent forms, must be retained for three (3) years after termination of the study.

The approval granted expires on November 02, 2011. Should you wish to maintain this protocol in an active status beyond that date, you will need to provide the IRB with an IRB Application for Continuing Review (Progress Report) summarizing study results to date. The IRB will request an IRB Application for Continuing Review from you approximately two months before the anniversary date of your current approval.

If you have questions about these procedures, or need any additional assistance from the IRB, please call the IRB office at (405) 325-8110 or send an email to irb@ou.edu.

Cordially,

Donald Baker, Ph.D.
Vice Chair, Institutional Review Board

1816 West Lindsey, Suite 150 Norman, Oklahoma 73069 PHONE: (405) 325-8110

Ltr_Prot_Fappv_Exp

Appendix 1a: Child Assent Form

University of Oklahoma
Institutional Review Board
Assent to Participate in a Research Study

Project Title: The Impact of a STEM (Science, Technology, Engineering and Mathematics) Club on Fifth Graders' Perceptions of Scientists and Engineers
Principal Investigator: Florence F. McCann
Department: Department of Instructional Leadership and Academic Curriculum, Jeannine Rainbolt College of Education

For children 7-12 years old

Why are we meeting with you?

We want to tell you about something we are doing called a research study. In a research study researchers collect a lot of information to learn more about something. Sometimes, researchers will ask you a lot of questions. However, in this study we will only ask that your teacher let us keep 4 drawings that you will make during your regular Gifted/Talent pull-out class time. After we tell you more about our study, we will ask if you'd like to be in this study or not.

Why are we doing this study?

This study is being done to learn what fifth graders like you think about scientists and engineers.

For the whole study, we will ask about 60 children to be part of the study.

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What will happen to you if you are in this study?

1. STEM Club will meet as a gifted/talented pull-out class during the regular school day. All STEM Club members will be asked to draw pictures of scientists and pictures of engineers during the first and last STEM Club meetings. We will talk about the drawings during these Club meetings. If you agree to be in this study, the Gifted Resource Coordinator at your school will give us your drawings so that we can look at them carefully to learn how fifth graders think about scientists and engineers. No names will be on the drawings, so no one will ever know who made any of the drawings. You will only write your age and whether you are a boy or a girl on your drawings.

How long will you be in the study?

Your being in the study won't take any more of your time than the time that you will be part of the STEM Club during your regular school day.

What bad things might happen to you if you are in the study?

No bad things will happen to you. You will be drawing the scientist and engineer pictures as part of being in STEM Club during a regular gifted/talented pull-out class. Only your Gifted Resource Coordinator will know who is part of the study and who isn't, so you don't have to worry that the OU researchers who are running the STEM Club will treat you differently than any other fifth grader.

What good things might happen to you if you are in the study?

You may have fun drawing and talking about your scientist and engineer pictures during STEM Club. If you are in the study, you might feel good that you are helping teachers learn about how fifth graders think about scientists and engineers.

Do you have any questions?

You can ask questions any time. You can ask now. You can ask later. You can talk to your Gifted Resource Coordinator, Mrs. McCann, Dr. Marek or someone else.

Do you have to be in this study?

No, you don't. No one will be mad at you if you don't want to do this. If you don't want to be in this study, just tell us. Or if you do want to be in the study, tell us that. And, remember, you can say yes now and change your mind later. It's up to you.

Your parent or guardian will also have to give permission for you to be in this study.

If you don't want to be in this study, just tell us.

If you want to be in this study, just tell us.
The person who talks to you will give you a copy of this form to keep.

SIGNATURE OF PERSON CONDUCTING ASSENT DISCUSSION
I have explained the study to ____________________ *(print name of child here)* in language he/she can understand, and the child has agreed to be in the study.

______________________________ ____________
Signature of Child Date

______________________________ ____________
Signature of Person Conducting Assent Discussion Date

____
Name of Person Conducting Assent Discussion *(print)*
I

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Consent Documents: Parent / Guardian Consent Form
University of Oklahoma
Institutional Review Board
Informed Consent to Participate in a Research Study

Project Title: The Impact of a STEM (Science, Technology, Engineering and Mathematics) Club on Fifth Graders' Perceptions of Scientists and Engineers
Principal Investigator: Florence F. McCann
Department: Instructional Leadership & Academic Curriculum (ILAC)

Your child is being asked to volunteer for this research study because your child is a fifth grader. This study will be conducted at your child's school, Washington Elementary School during the regular school day.

Please read this form and ask any questions that you may have before agreeing to take part in this study.

Purpose of the Research Study

We would like to learn more about how participating in a monthly STEM Club affects the way children perceive scientists and engineers. Fifth graders, like your child, can help us answer this question by drawing pictures of scientists and engineers before they begin participating in the Club and after they have participated in the Club for one school year. We will compare these two sets of drawings according to established criteria to see whether and, if so, how, they represent changes in the children's perceptions of scientists and engineers.

Number of Participants

We would like to have about 10-15 fifth graders take part in this study each academic year.

Procedures and Length of Participation

If you agree for your child to take part this study, he or she you will be asked to do the following two tasks: (1) draw a picture of a scientist; and (2) draw a picture of an engineer. These two tasks will be performed twice during the school year, once during the first STEM Club meeting and once during the final STEM Club meeting. The children will be reminded that they are NOT required to do the drawings. The children will be told that they can still take part in the STEM Club activities regardless of whether or not they do a drawing. Also, the children will be told that they can stop drawing at any time, if they decide that they would no longer like to participate in the study. All drawings will be anonymous. The children will be asked only to write their ages and whether they are boys or girls. No one will ever know who made any particular drawing. The names of children who have permission to participate in the study will be kept confidential.

If you allow your child to take part in the drawing activities, they will require a total of 40 minutes to complete – 20 minutes the first time and 20 minutes the second time. The drawings will be completed during a STEM Club meeting that takes place during a "pull-out" Gifted/Talented class time during the regular school day.

Risks and Benefits

We do not foresee any risks to your child from participating in this study. The drawing tasks are a lot like other activities typically done during the regular elementary school day. Since the drawings are anonymous, your child need not be concerned about drawing quality or content.

We do foresee several possible benefits both directly to your child as well as to other children from participating in the study. As a result of doing the drawings, your child may think about more about what it means to be a scientist or engineer. This may help expand the range of potential careers he or she considers. We can use what we learn from this study when we set up STEM Clubs for other children, thereby benefiting the community as a whole.

Confidentiality

In published reports, there will be no information included that will make it possible to identify your child. When we present the results of this research project, we will only describe groups and never refer to individuals. The anonymous scientist and engineer drawings will be stored securely and only the researchers, Mrs. McCann and Dr. Marek, will ever access them. All information will be kept confidential and will not become part of your child's school record. The OU Institutional Review Board may inspect this project to be sure that we are following approved procedures and that your child's privacy is being protected.

Compensation

Neither you nor your child will not be compensated in any way for participation in this study.

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Voluntary Nature of the Study

Your child's participation in this study is completely voluntary. In addition to your permission (consent), your child will also be asked if he or she would like to participate in this study on the "Assent Form" attached to this form. Your child may decide to stop participating at any time during the study. A decision to stop participating in the study will not affect your child's status in the STEM Club and at the school or his/her future relationship with the school. If you would like a copy of the forms that will be used for your child's scientist or engineer drawings, please contact the researchers. Their contact information is given below.

Contacts and Questions

We are looking forward to working with your child. Contact the researcher(s) if you have questions or if you have experienced a research-related injury. The researcher conducting this study, Mrs. Florence F. McCann, can be contacted at 405-325-1498 and at fmccann@sbcglobal.net or Florence.F.Mc.Cann-1@ou.edu. Her advisor and faculty sponsor, Dr. Edmund A. Marek, can be contacted at 405-325-1498 and at eamarek@ou.edu.

If you have any questions about your rights as a research participant, concerns, or complaints about the research and wish to talk to someone other than individuals on the research team or if you cannot reach the research team, you may contact the University of Oklahoma – Norman Campus Institutional Review Board (OU-NC IRB) at 405-325-8110 or irb@ou.edu. ***You will be given a copy of this information to keep for your records. If you are not given a copy of this consent form, please request one.***

Statement of Consent

I have read the above information. I have asked questions and have received satisfactory answers. I consent for my child to participate in the study.

Child's Name:

Parent's/Guardian's Name:

Parent's/Guardian's Signature Date

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EXPIRES

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OFFICE OF HUMAN RESEARCH PARTICIPANT PROTECTION - IRB

IRB Number: 13177
Approval Date: October 25, 2011

October 31, 2011

Florence McCann
Dept. ILAC
6002 Flaming Oaks Circle
Norman, OK 73026

RE: The Impact of A STEM (Science, Technology, Engineering and Mathematics) Club On Fifth Grader's Perceptions of Scientists and Engineers

Dear Ms. McCann:

Thank you for completing and returning the IRB Application for Continuing Review (Progress Report) for the above-referenced study. You have indicated that the study is still active. I have reviewed and approved the Progress Report and determined that this study was appropriate for continuation.

This letter documents approval to conduct the research as described in:
Cont Review Form Dated: August 22, 2011
Protocol Dated: August 22, 2011
Other Dated: August 22, 2011 Summary of results
Assent Form Dated: August 22, 2011
Consent form - Parental Dated: August 22, 2011
Other Dated: August 22, 2011 NPS IRB approval letter

Please remember that any change in the protocol, consent document or other recruitment materials (adverstisements, etc.) must be approved by the IRB prior to its incorporation into the study procedures. Submit a completed Protocol Modification form to the IRB office.

Approximately two months prior to the expiration date of this approval, you will be contacted by the IRB staff about procedures necessary to maintain this approval in an active status. Although every attempt will be made to notify you when a study is due for review, it is the responsibility of the investigator to assure that their studies receive review prior to expiration.

The approval of this study expires on October 24, 2012 and must be reviewed by the convened IRB prior to this time if you wish to remain in an active status. Federal regulations do not allow for extensions to be given on the expiration date.

If we can be of further assistance, please call the IRB office at (405) 325-8110 or send an email to irb@ou.edu.

Cordially

Aimee Franklin, Ph. D
Vice Chair, Institutional Review Board

Ltr_Prog_Appv_Active

1816 West Lindsey, Suite 150 Norman, Oklahoma 73069 PHONE: (405) 325-8110

Consent Documents: Parent / Guardian Consent Form
University of Oklahoma
Institutional Review Board
Informed Consent to Participate in a Research Study

Project Title: The Impact of a STEM (Science, Technology, Engineering and Mathematics) Club on Fifth Graders' Perceptions of Scientists and Engineers
Principal Investigator: Florence F. McCann
Department: Instructional Leadership & Academic Curriculum (ILAC)

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We would like to learn more about how participating in a monthly STEM Club affects the way children perceive scientists and engineers. Fifth graders, like your child, can help us answer this question by drawing pictures of scientists and engineers before they begin participating in the Club and after they have participated in the Club for one school year. We will compare these two sets of drawings according to established criteria to see whether and, if so, how, they represent changes in the children's perceptions of scientists and engineers.

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If you allow your child to take part in the drawing activities, they will require a total of 40 minutes to complete – 20 minutes the first time and 20 minutes the second time. The drawings will be completed during a STEM Club meeting that takes place during a "pull-out" Gifted/Talented class time during the regular school day.

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OCT 2 4 2012
EXPIRES

Risks and Benefits

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We do foresee several possible benefits both directly to your child as well as to other children from participating in the study. As a result of doing the drawings, your child may think about more about what it means to be a scientist or engineer. This may help expand the range of potential careers he or she considers. We can use what we learn from this study when we set up STEM Clubs for other children, thereby benefiting the community as a whole.

Confidentiality

In published reports, there will be no information included that will make it possible to identify your child. When we present the results of this research project, we will only describe groups and never refer to individuals. The anonymous scientist and engineer drawings will be stored securely and only the researchers, Mrs. McCann and Dr. Marek, will ever access them. All information will be kept confidential and will not become part of your child's school record. The OU Institutional Review Board may inspect this project to be sure that we are following approved procedures and that your child's privacy is being protected.

Compensation

Neither you nor your child will not be compensated in any way for participation in this study.

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OCT 2 4 2012
EXPIRES

Voluntary Nature of the Study

Your child's participation in this study is completely voluntary. In addition to your permission (consent), your child will also be asked if he or she would like to participate in this study on the "Assent Form" attached to this form. Your child may decide to stop participating at any time during the study. A decision to stop participating in the study will not affect your child's status in the STEM Club and at the school or his/her future relationship with the school. If you would like a copy of the forms that will be used for your child's scientist or engineer drawings, please contact the researchers. Their contact information is given below.

Contacts and Questions

We are looking forward to working with your child. Contact the researcher(s) if you have questions or if you have experienced a research-related injury. The researcher conducting this study, Mrs. Florence F. McCann, can be contacted at 405-325-1498 and at fmccann@sbcglobal.net or Florence.F.Mc.Cann-1@ou.edu. Her advisor and faculty sponsor, Dr. Edmund A. Marek, can be contacted at 405-325-1498 and at eamarek@ou.edu.

If you have any questions about your rights as a research participant, concerns, or complaints about the research and wish to talk to someone other than individuals on the research team or if you cannot reach the research team, you may contact the University of Oklahoma – Norman Campus Institutional Review Board (OU-NC IRB) at 405-325-8110 or irb@ou.edu. ***You will be given a copy of this information to keep for your records. If you are not given a copy of this consent form, please request one.***

Statement of Consent

I have read the above information. I have asked questions and have received satisfactory answers. I consent for my child to participate in the study.

Child's Name:

Parent's/Guardian's Name:

Parent's/Guardian's Signature Date

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OU NC IRB

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OCT 2 4 2012
EXPIRES

Appendix 1a: Child Assent Form

University of Oklahoma
Institutional Review Board
Assent to Participate in a Research Study

Project Title: The Impact of a STEM (Science, Technology, Engineering and Mathematics) Club on Fifth Graders' Perceptions of Scientists and Engineers
Principal Investigator: Florence F. McCann
Department: Department of Instructional Leadership and Academic Curriculum, Jeannine Rainbolt College of Education

For children 7-12 years old

Why are we meeting with you?

We want to tell you about something we are doing called a research study. In a research study researchers collect a lot of information to learn more about something. Sometimes, researchers will ask you a lot of questions. However, in this study we will only ask that your teacher let us keep 4 drawings that you will make during your regular Gifted/Talent pull-out class time. After we tell you more about our study, we will ask if you'd like to be in this study or not.

Why are we doing this study?

This study is being done to learn what fifth graders like you think about scientists and engineers.

For the whole study, we will ask about 60 children to be part of the study.

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OCT 24 2012
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What will happen to you if you are in this study?

1. STEM Club will meet as a gifted/talented pull-out class during the regular school day. All STEM Club members will be asked to draw pictures of scientists and pictures of engineers during the first and last STEM Club meetings. We will talk about the drawings during these Club meetings. If you agree to be in this study, the Gifted Resource Coordinator at your school will give us your drawings so that we can look at them carefully to learn how fifth graders think about scientists and engineers. No names will be on the drawings, so no one will ever know who made any of the drawings. You will only write your age and whether you are a boy or a girl on your drawings.

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What good things might happen to you if you are in the study?

You may have fun drawing and talking about your scientist and engineer pictures during STEM Club. If you are in the study, you might feel good that you are helping teachers learn about how fifth graders think about scientists and engineers.

Do you have any questions?

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If you don't want to be in this study, just tell us.

If you want to be in this study, just tell us.
The person who talks to you will give you a copy of this form to keep.

SIGNATURE OF PERSON CONDUCTING ASSENT DISCUSSION
I have explained the study to ____________________ (*print name of child here*) in language he/she can understand, and the child has agreed to be in the study.

______________________________ ______________
Signature of Child Date

______________________________ ______________
Signature of Person Conducting Assent Discussion Date

____
Name of Person Conducting Assent Discussion (*print*)
I

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