Drawing a Scientist: What We Do and Do Not Know After Fifty Years of Drawings

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Since 1957, there has been a growing body of research dealing with the perceptions students have of scientists. Typically, the research studies in this area have utilized students' drawings in efforts to discern what those perceptions are. Emergent from this research has been what one would call a stereotypical perception of scientists, and strong evidence exists that such a stereotypical perception is persistent and pervasive across grade levels, gender, racial groups, and national borders. This manuscript provides a review of the more salient studies done on students' drawings of scientists and the perceptions therein revealed since Mead and Metraux's seminal study in 1957. In addition, the manuscript summarizes what this body of research has and has not revealed thus far, and what seems to lie ahead, including implications for science education.

Over the past 50 years, a growing body of research has been conducted on people's perceptions of science and scientists. Much of this research has focused on children's perceptions, although not exclusively so. This article attempts to provide an overview of this research. This review is not exhaustive but provides the more salient aspects of the research findings on the topic. A review of the literature published in various journals or presented at conferences served as the basis for this overview. During the search, those works specifically dealing with subjects' perceptions of scientists were identified and included.

The implications of this body of research may be significant. Some have indicated that the perceptions of scientists held by students (or others) are related in some way to their attitudes toward science, locus of control, and self-efficacy (Finson, 2000; Finson, Riggs, & Jesunathadas, 1999; Schibeci, 1989). For example, Kahle (1988) stated that an individual's perceptions of scientists are one aspect of attitudes toward science and that this may have an impact on the attention given to the study or teaching of science. O'Brien, Kopala, and Martinez-Pons (1999) linked self-efficacy in a certain field to the probability of an individual choosing that career, and Zeldin and Pajares (2000) reported similar findings for females. Hence, individuals who have negative perceptions of science or of scientists are unlikely to pursue science courses of study and, subsequently, enter a science/science-related career (Hammrich, 1997). Therefore, having some foreknowledge of students' perceptions of scientists may be important to educators if they are to effectively and positively impact students through instruction.

Early Stages of Exploring Perceptions of Scientists

The formal study of high school children's perceptions of scientists can be traced back to the seminal work conducted by Mead and Metraux in 1957. In this work, Mead and Metraux had 35,000 high school students write an essay in which they described their image of a scientist. Analysis of the essays revealed that the typical high school student perceived a scientist as being an elderly or middle-aged male in a white coat and glasses who worked in a laboratory, where he performed dangerous experiments. This has come to be considered the classic stereotypical image of a scientist.

Studies Using Written Instrumentation

Beardslee and O'Dowd (1961) developed a questionnaire including a 7-point differential semantic scale using ideas and words gleaned from interviews with about 1,200 college students, which provided information similar to that obtained by Mead and Metraux (1957). The researchers compared images between men and women drawers, public versus private school attendees, freshmen versus seniors, students from different socioeconomic backgrounds, and students from different types of communities. No

significant differences were found between subjects in any of these groups, leading Beardslee and O'Dowd to conclude that the image of scientists held by college students was extremely stable.

Surveys conducted by Etzioni and Nunn (1974) and Hills and Shallis (1975) attempted to ascertain information about the image of science and scientists. Following in 1975, Rodriguez developed of a 31-item differential semantic scale used for the same purpose. Basalla's work (1976) verified that the stereotypical images reported by Mead and Metraux (1957) persisted, and this persistence was confirmed the next year by Ward (1977), who arrived at the same conclusion. Ward further found that the perception had come to include aspects making the scientist exceedingly clever, often wise, slightly sinister, and disinclined to pursue mundane things, preferring instead to perform scientific wonders, particularly in chemistry.

In 1982, Krajkovich and Smith developed an instrument called the Image of Science and Scientists Scale, which consisted of 48 position statements having a7-point Likert-type scale and was developed for use with high school students. Throughout the 1960s and 70s, research utilizing these and other instruments demonstrated that children's stereotypical images of scientists remained relatively stable. This stability was also reported to extend across cultural lines, as noted by Chambers (1983) through his systematic study of images of scientists in the People's Republic of China. In this study, he found the images closely matched those from Western culture.

Pion and Lipsey's (1981) review of a number of surveys conducted during the previous two decades led them to conclude that the images of science showed distortions from what an actual scientist did. In other words, the data from surveys up to this point tended to show that children and others had inaccurate perceptions of what scientists really do for work and what scientists are really like. Consequently, the results of the surveys examined must be viewed with the knowledge that respondents' perceptions of scientists are not necessarily a reflection of reality.

Later Stages of Exploring Perceptions of Scientists: Studies Utilizing Drawings

During 1981, Chambers (1983) developed the Draw-a-Scientist-Test (DAST), which was patterned after Goodenough's Draw-a-Man Test. The Draw-a-Man Test was a psychological tool in which no written responses were required by the subject, only a drawing of a man was made and then assessed. Goodenough's effort was a significant departure from earlier tests and opened the way for researchers such as Chambers to consider having students draw a scientist on a blank sheet of paper, which was then assessed at a later time. Unlike most previous studies, Chambers obtained data from 4,807 elementary children in grades K-5. One of his premises was that children in these grades lacked the skills to write or verbalize to the extent necessary for researchers to derive adequate information regarding their perceptions of scientists. Chambers used the drawing method to describe in detail the stereotypical images reflected in children's drawings of scientists.

Through his work, he identified seven specific attributes or elements that consistently appeared in students' drawings of scientists: lab coat (usually white), eyeglasses, facial hair (beards, mustaches, abnormally long sideburns), symbols of research (scientific instruments and laboratory equipment), symbols of knowledge (books, filing cabinets), technology (products of science such as rockets), and relevant captions such as formulae and the "eureka" syndrome, etc. (Chambers, 1983). He also identified characteristics of these elements that may have significance: size of scientific instruments compared to the scientist, signs or indications of danger, light bulbs, basement or underground laboratories, male/female figures, and mythical images such as Frankenstein or Jekyll-Hyde. Chambers further noted signs of secrecy, such as warnings of "Private," "Keep Out," "Top Secret," etc. Chambers reported that only 28 out of the 4,807 drawings done by elementary students were of female scientists.

Cross-Cultural/Race Studies and Media Influences

As noted earlier, Chambers (1983) conducted a systematic study of images of scientists in the People's Republic of China, finding that the images of scientists drawn by students closely matched those from Western culture. In that same year, Schebeci and Sorensen (1993) conducted a study of elementary children in Australia using the DAST. The purpose of their study was to examine the potential of the DAST as a quick and reliable means of assessing elementary school students' images of scientists. The researchers selected two schools for the study, one being from a rural location of western Australia and attended largely by Black children, the other being a school in a metropolitan area in Perth attended predominantly by Caucasian children. Children were asked to draw a picture of a scientist, and the drawings were then analyzed by two raters. Interrater reliability was determined to be 0.86 ($p < 0.01$). Several significant conclusions can be

drawn from this work. Both Black children and Caucasian children appeared to draw images of scientists that were stereotypical in nature. The largest difference between groups was that Caucasian elementary children tended to average more stereotypical indicators at each grade level than did Black children. The second conclusion was that the DAST was a useful and valid instrument for assessing trends across grade levels.

Among their other conclusions, Schebeci and Sorensen conjectured that the media, primarily television, contributed significantly to reinforcement of the stereotypical image. According to Schibeci (1986), the modern television scientist is portrayed as amoral (rather than immoral), insensitive, and obsessive. This was supported by Gardner (1980), who had suggested that cultural models to which students are exposed can contribute significantly to their mental schema, and these influences can be exhibited in drawings made from those schema. Gardner suggested that such models are derived from a multitude of sources, including television, movies, and comic books. Consistent exposure of children to these media and naive educational practices teach conceptions about science and scientists, including how scientists look and behave. Conversely, Flick (1990) noted that programs from the Children's Television Workshop have had positive influences on children's views of the scientific enterprise. The stereotypical perception contributes to the frequent misbelief that a scientist must be a genius, enjoy working alone, and have a limited social life. Students who perceive themselves in such a role will be unlikely to pursue a scientific career (Gardner, 1980). Yager and Yager (1985) noted that scientific work and the scientists who engage in it are often viewed as unpleasant entities, particularly by females.

Rampal (1992) conducted a study in India investigating school teachers' perceptions of scientists. Even though her study did not involve actual drawings, the results are notable in the context of the other studies reported in this paper. She utilized a questionnaire probing, among other issues (e.g., relationships between science and religion), subjects' thoughts regarding their mental images of a scientist. Part of the motivation for this study was concern that too many people in society follow science with blind faith and tend to over-idealize the image of the "expert" scientist. Although Rampal discussed validating the questionnaire, she provided no coefficients nor were reliability data given for it. The questionnaire was administered at the beginning of the program. Part of Rampal's treatment included having scientists speak to the 199 teachers in the program and having participants work with inquiry-based methodologies and work on curriculum development. Eighty first-year teachers, 33 second-year, 45 third-year, and 41 special resource teachers were included in the program and study. Rampal found that the stereotypical image emerging from the data was one of the scientist being distinctly brilliant, looking somewhat lost, often pensive, unemotional, uncaring, and unsocial, and mainly a bald-headed male wearing a white laboratory coat and glasses. The gist of Rampal's study reinforced the notion that a stereotypical image of scientists was alive and well in the minds of teachers.

In Sumrall's 1995 descriptive study using the DAST, 358 students from grades 1-7 were interviewed in an attempt to determine their reasons for drawing the scientists they drew. Students were first asked to draw a scientist and were then asked to describe their scientist and provide a reason for drawing the scientist of a particular race and gender. These reasons were analyzed and categorized into 12 groups by evaluators. Sumrall made various quantitative comparisons reflecting relationships between subject race and gender, the race and gender of the scientist drawn, the number of stereotypical indicators present in the drawing, and possible reasons for selecting a particular race or gender when drawing a subject. One descriptive analysis of the data collected determined that the difference in the average number of indicators decreased with grade level when comparing African-American and Euro-Americans in the study. Euro-American males had the highest percentage of self-image drawings, which Sumrall related to an internal locus of control.

During 2001, Finson (2001) conducted a study to validate the DAST-C for populations other than middle class Caucasian students, the group for which the original instrument was validated. Finson obtained drawings from 191 eighth-grade students, including 30 Caucasians, 67 Native Americans and 93 African Americans. Analysis of the data showed no significant differences existed between drawings of students from these various racial groups. He did note some differences in the frequency of specific elements in drawings from one group that did not seem to be prevalent in other groups' drawings. For example, African American students tended to draw more scientists having only a head or with extra large equipment, and Native American students did not draw any animals in cages. Among his conclusions was that the DAST-C appears to be a valid instrument for use across racial groups.

Perceptions Studies by Gender

Fort and Varney (1989) obtained drawings from 1,600 students spanning grades 2-12. Of those drawings, only 165 were of female scientists, even though 60% of this sample were female students. In addition, only six of the drawings of female scientists were drawn by male students. According to Dickson, Saylor, and Finch (1990), people normally draw an image of their same sex when clinical psychologists have subjects simply draw a person, regardless of personality measures and family composition. This evidently does not hold true when people are asked to draw scientists.

Similar findings were reported by Flick in his 1990 study. Four scientists and a doctoral student from a local university were invited into two fifth-grade classrooms to share their personal enthusiasm for science (through the Scientist in Residence Program) for about 1 hour each week for 3 weeks with 47 students. The students also visited the scientists' laboratories. The scientists visiting one fifth-grade classroom were both female. while one male and one female visited the other classroom. In addition, a control group of sixth graders at another school was included, but did not receive any of the treatment provided the fifth graders. All students were asked to draw a scientist (using the DAST). Analysis of the drawings revealed that more males than females were drawn before female scientists visited the fifth-grade classrooms. Flick noted the presence of stereotypical indicators such as lab coats and instruments being more evident in students' pretest drawings. Smoking test tubes were replaced by plants and animals in many of the posttest drawings. More female images also appeared in posttest drawings.

A study by Odell, Hewitt, Bowman & Boone (1993) revealed that gender and race emerge as two obvious stereotypes when student images of scientists are examined. In their study, Odell et al. involved 93 students of elementary through junior high school age, plus students at the university level. Each student drew a picture of a scientist, and the drawings were then analyzed using the criteria provided by Chambers (1983) in his Draw-a-Scientist Test, with each element appearing in a drawing being coded. After students completed their drawings, they were asked to describe what influenced their descriptions (drawings). Students' answers to this question were coded according to frequency of response. These researchers reported that students of one ethnicity typically drew images of people of that ethnicity, but also noted that minority students drew images of Caucasians, but Caucasians rarely if ever drew images of minorities. Odell et al. further reported that females have poorer self-images with respect to science than do males, and minorities have poorer self-images than do Caucasians.

If students can see themselves in a career, then the likelihood of these students pursuing an educational program to prepare for that career is increased (Beardslee & O'Dowd, 1961;National Science Teachers Association, 1992, 1993; Smith & Erb, 1986). Simply providing support networks and occasional role models is not sufficient. Ross (1993) and MacCorquodale (1984) reported that females having low self-concepts with respect to science are less likely to enter science programs in college than their high self-concept counterparts. MacCorquodale (1984) examined students' images of scientists and those images' effects on career choice. She obtained drawings from 2,442 junior high and high school students and compared the drawings to student attitudes about education, occupational aspirations, adult roles, school subjects, social support for education, and self-image. When comparing gender differences, she found that girls who rated themselves as highly competitive tended to be girls who were more likely to take science than their less competitive peers.

The work by Ross (1993) supported MacCorquodale's findings. Ross utilized the database from the Center for Education Statistics and gathered data from 14,825 high school students across the U.S. to see if certain variables seemed to affect students' pursuit of designated "hard science" college majors. Among the variables examined were high school GPA, internal locus of control, delay of family formation, and liberated views of the role of women. These variables were compared to gender using *t*-tests, which showed a significant difference ($p < .001$) between males and females. Female science majors tended to have higher internal locus of control scores than did male science majors and female nonscience majors. Females who majored in science tended to desire more delay in family formation and had a more liberated view of women than did females pursuing nonscience majors.

Rosenthal (1993) employed the DAST and a short questionnaire to investigate college students' images of scientists. In her study, 90 biology majors and 76 liberal arts majors were asked at the beginning of their entry into the college's education program to draw pictures of scientists, which were later scored using a modified version of the DAST-C. The modified DAST-C was comprised of nine elements, with one point being awarded for each element that appeared in a drawing. The drawings of liberal arts students included 41% more male images than did those of their biology major peers, but the biology majors' drawings were more likely to show scientists of indeterminate gender. The

DAST-C scores for liberal arts majors were 67% higher than were those of biology majors.

In all, few images of female scientists were drawn by the subjects in Rosenthal's study. One factor that may contribute to the reinforcement of these stereotypical images, particularly as they apply to students of different gender, may be the way students are instructed during their precollege schooling. The difficulties associated with encouraging females to enter science programs in college is exacerbated by precollege teachers who possess stereotypical images of scientists, often translating into negative perceptions conveyed through overt as well as subtle ways in their instruction. These negative perceptions may adversely impact females and minorities to a greater extent than they do other groups. What teachers do in the classroom affects student attitudes and achievement, and the environments teachers establish can either ameliorate the effect of pervasive sex-role stereotyping with respect to careers (Mason, Kahle, & Gardner, 1991) or reinforce it.

Attempts to Change Students' Perceptions of Scientists

In 1986, Smith and Erb attempted to change students' images of scientists by providing 286 students in grades 5-8 with visits from female scientists role models, talks by their teachers about important women in science, and readings about young women working in science. Smith and Erb employed the Image of Science and Scientists Scale and the Women in Science Scale before and after the treatment. They found that attitudes toward scientists and women in science improved significantly by posttesting, and that these changes in attitudes were present in both boys and girls.

Mason, Kahle, and Gardner (1991) investigated the effects of a teacher intervention program on the attitudes and stereotypical images of high school students. Fourteen biology teachers were included in the study. Half were provided specific intervention strategies, including career information, weekly visits by the researchers to the teachers' classrooms, use of role models, gender-equitable materials, and innovative practices. The success of the intervention program was measured quantitatively with the Perceptions of Science and Science Scale, the Science Attitudes Questionnaire, Career Interest survey, and Science Experiences Survey. Qualitative measures included the DAST. The instruments were administered to the teachers' 549 high school biology students. DAST data were analyzed using the Chi square test of goodness-of-fit. The treatment group's drawings contained significantly more female images than did those of the control group ($p < 0.01$). In addition, treatment group drawings showed significantly fewer images of scientists doing violent acts than did control group drawings ($p < 0.01$).

Huber and Burton (1995) administered the DAST to a sample of 243 12-year-old students to assess a teacher intervention strategy. The students' teachers ($n = 14$) participated in a 1-week summer course, which included academic year followup. Included in the intervention strategies were the distribution of career information, presentation of role models, examination of sex-equitable materials, and participation in hands-on science investigations. Graduate assistants trained in the DAST protocols administered the DAST to students in the participating teachers' classrooms in the early part of the school year. The drawings were then scored by the graduate assistants. Interrater reliability was determined to be around 99%. Analysis of drawing scores was done using the McNemar test, a variant of the Chi square for samples lacking cell independence. The results showed male students possessed more stereotypical images in their pretest drawings than did female students ($p < 0.05$). Males also made the most improvement toward less stereotypical images due to the planned intervention.

The seven stereotypical attributes Chambers (1983) used in assessing his data were included as the top seven stereotypical indicators in the Draw-a-Scientist-Test Checklist (DAST-C) developed in 1988 by Finson, Beaver, and Cramond (1995). These researchers went beyond Chambers' original seven stereotypical elements to address further stereotypical or alternative images. These additional items incorporated gender and race, as well as indicators repetitively noted in previous studies but not incorporated in Chamber's original list of indicators, allowing for the inclusion of a wider scope of stereotypical images. Chambers himself even noted the presence of significant items such as light bulbs, signs of secrecy and danger, mythical images such as Dr. Jekyll/Mr. Hyde and Frankenstein, and scientists working indoors (often in basement laboratories), but they were not included in the original DAST scoring.

The interrater reliability of the DAST-C was determined to range between 0.94 and 0.98 using ANOVA procedures. Finson et al. (1995) utilized the DAST-C with eighth-grade students to examine the impact of specific treatments, such as carefully identified role models, university faculty and field practitioner mentors, a focused research project, and careers literature, on those students' perceptions of scientists. These efforts were designed to combat stereotypes of science

and scientists through effective education, as suggested by Etzioni & Nunn (1974). Finson et al. employed a pretest-posttest-delayed-posttest treatment group only model. Overall, their findings revealed students' stereotypical perceptions of scientists decreased significantly from pretesting to delayed posttesting. One notable facet of these findings was a slight increase in some students' stereotypical perceptions by the first posttest, which was later attributed to the students' recently concentrated exposure to laboratory scientists who were mainly males with facial hair, who wore white laboratory coats, and most of whom wore glasses. However, this artifact in the data disappeared by delayed posttesting once the students had extended contact with practitioners in the field.

Bohrmann and Akerson (2001) reported a project involving fourth graders which focused on students' perceptions of self and of scientists, as well as their self-efficacy with respect to those perceptions. Of particular interest to Bohrmann and Akerson were ways to positively impact the perceptions of female students, who typically have low expectations of themselves in science classes. Teaching strategies employed during the study included giving specific praise, bringing guest speakers into the classroom, having students view a video on scientists of color, and ensuring equal participation of both boys and girls during science activities in class. Besides having students draw what they thought a scientist looked like (the DAST), Bohrmann and Akerson also had students write a reaction paragraph that further described what a scientist looked like. This was an effort to avoid situations in which students simply draw silly pictures that are inconsistent with their true perceptions (Bielenberg, 1997). These researchers found that the stereotypical scores of student drawings decreased significantly between pretesting and posttesting, as did the scores on their written paragraphs.

Sixty-nine fourth- and fifth-grade students were asked to draw scientists (Bodzin & Gehringer, 2001) in a 4-week long pretest-posttest study. Between test administrations, students were visited by actual scientists, one of whom was female, from the field who visited with students about their careers and who then led students through some science activities. Pretest drawings included many of the classic stereotypical elements reported from earlier research. Analysis of the drawings further supported Barman's (1996) findings that mythic stereotypes were seldom included in students' images. Posttest results showed a significant decrease in stereotypic elements appearing in drawings. Further, posttest drawings showed more females and fewer indications of danger. The major conclusion drawn by the researchers was that interventions including female role models in an elementary classroom may have a positive impact on those students' perceptions of careers for women with regard to science and engineering.

Studies on Preservice and In-Service Teachers' Perceptions

Reap, Cavallo, and McWhirter (1994) examined the perceptions of preservice elementary teachers with regard to scientists. The researchers used a combination of the learning cycle and gender neutral, multicultural intervention techniques in an elementary science methods course. Their intent was to examine the nature of preservice elementary teachers' images of scientists and to investigate possible shifts in those individuals' images of scientists after the treatment (methods course). Thirty-six students (32 females and 4 males) were included in the study. Each was asked at the beginning of the course to draw a scientist. The drawings were sealed in envelopes until the end of the course, at which time the students again made drawings of scientists. At this time, the pretest and posttest drawings were compared and scored, utilizing procedures suggested by Kahle (1988), such as giving a score of "1" if a stereotypical element was present in the drawing and a "2" if it was absent. A *t*-test was used to analyze drawings' scores. Their study's data revealed that the classic stereotypical image was prevalent among these students, including mainly chemists doing work alone in indoor laboratories among elements of danger. Reap et al. designed a treatment in which the preservice teachers were involved in learning cycle and inquiry strategies in both physical and life science contexts. They further employed activities emphasizing a multicultural, gender-neutral view of science. Their data revealed that the treatment had the positive effect of reducing preservice teachers' stereotypical images of scientists. One conclusion they drew was that preservice elementary teachers' images of scientists and attitudes toward science may be affected by the way science is taught in their teacher education programs.

Preservice teachers' views of scientists was the subject of investigation at Oklahoma State University (Moseley & Norris, 1999). A total of 194 preservice teachers were involved in the study, including 38 early childhood majors, 82 elementary education majors, 50 secondary majors, and 24 graduate students. The college students were asked at the beginning of the semester in their science methods courses to draw pictures of a scientist doing science, and the drawings were scored using the the DAST-C (Finson et al.,

1995). Typical stereotypical elements were present in most drawings, which were made at the beginning of the college semester. Moseley and Norris proceeded to discuss the results with students in each class at the end of the semester. Interestingly, the graduate and secondary students quickly realized that they should have drawn a more global representation of a scientist, and reported frustration and even anger with themselves. In contrast, the early childhood and elementary education majors failed to recognize the problem. The researchers concluded that one could not assume preservice teachers come to science education courses with a complete understanding of what a scientist is.

Changing View of What Drawings Convey

Barman's 1996 study looked specifically at elementary students' perceptions of scientists, but examined the issue on a much broader scale than had been done in previous studies. In Barman's study, teachers across the U.S. were enlisted to administer the DAST to their elementary students, which were later scored using the DAST-C. In total, 1,504 student drawings were obtained. Prior to this study, most research in this arena was conducted with relatively localized groups of subjects, potentially unduly predisposing them to the influences not present elsewhere. Barman's findings revealed remarkable consistency, however, in the stereotypical images of scientists held by elementary students not only across grade levels, but also across the nation. His data also began to reveal a decrease in the appearance of "mythic stereotypes" (e.g., Frankenstein-type images), signaling a subtle shift in elementary students' perceptions of scientists. Barman followed this study with another in which he sent interview questionnaires to the teachers of 154 of the original students who made drawings, asking them to interview their students. Interview questions focused on student perceptions of school science and using science outside of school. Results indicated most students pictured themselves doing science in school, and a majority of students saw a use for science outside of school. Barman concluded from these data that elementary students are able to generalize the use of science knowledge and skills to everyday situations (Barman, 1999).

Students may possess more than one definition of the word "scientist" and may thereby draw different images at different times, even without having their perceptions targeted by planned program interventions (Maoldomhnaigh & Hunt, 1989). This finding sounded a caution to the growing body of draw-a-scientist studies. Maoldomhnaigh and Hunt had the subjects in their study draw two pictures of scientists and discovered that the frequency of the appearance of mythic stereotypes changed from one set of drawings to another. This result led the researchers to the conclusion that students may have more than one definition of the word "scientist." In 1990, Maoldomhnaigh and Mhaolain found that changing the wording in directions given to students could alter the types of drawings produced, so that great care needed to be taken in the standardization of protocols and directions provided to subjects regarding drawings.

What This Body of Research Has Told Us

Taken as a whole, the extant body of research on draw-a-scientist tests and perceptions of scientists communicates to educators several things. First, stereotypical perceptions are persistent. Since the Mead and Metreaux (1957) study, the same basic elements comprising the stereotypical image have been revealed time and again in student and adult drawings. The research indicates that this image perception extends across age groups, across grade levels, and across decades. Related to this first matter is the second: There has been a subtle shift in one of the classic stereotypical elements in students' drawings, which has become more and more evident during the past 5 years. Although it still appears in some students' drawings, the "mythic" element, which includes Frankenstein-type or wild/crazed/mad scientist-type features, has become less and less prevalent. The stereotype of scientists being male has largely endured since 1957. In particular, pretest images drawn by students are dominated by male scientists. Similarly, when a type of scientist can be discerned, most are chemists. Exactly what factors influence all these perceptions have been inferred, rather than directly established as a cause, by various researchers. Nonetheless, the influence of media (movies, comic books, television, etc.) has been pointed to as a significant source of information, which students assimilate and consequently incorporate into their perceptions, as shown in the drawings they make.

Another facet of the research literature is that even most minority students draw images of Caucasian scientists. Research has also demonstrated that students may hold perceptions of scientists different than those they draw. Sometimes, students hold multiple images or simply draw what they think is silly. Hence, one needs to view student drawings with the proverbial grain of salt.

There are different ways in which students' perceptions of scientists can be discerned and assessed.

Open-ended questions, Likert-type scale surveys, interviews, and drawings have all been utilized. The combination of drawings with interviews appears to be the most useful of these strategies. Thus, the Draw-a-Scientist Test (Chambers, 1983) and the Draw-a-Scientist-Test Checklist (Finson et al. 1995) have been useful instruments in this line of research. These instruments thus far appear to be valid tools regardless of subjects' ages, race, or gender. Consequent with these perceptions have been efforts to link attitudes and self-efficacy to the degree an image drawn by a student is stereotypical. Although difficult, some research has strongly suggested the link between these things. Students who have strong and positive self-efficacy tend to be those having more positive attitudes and tend to draw images with fewer stereotypical elements in them.

Notable bright spots exist in this overall picture. For example, the research clearly demonstrates that the perceptions students hold of scientists can be positively impacted. This seems to hold true whether the focus of educators' efforts is gender equity, racial equity, or simply making scientists more like "regular people" in the minds of those who draw them. Various strategies have been reported, but most of the successful ones appear to include the use of role models, activities, and targeted career exploration. In terms of role models, female or minority scientists have been brought into classrooms to speak with and work with students. In some cases, students have stepped out of the classroom to work with these individuals. However, simply providing a one-shot exposure to a role model seems insufficient to effect lasting changes in perceptions. Exposure must be well planned and coordinated and must occur over some extended period of time.

Similarly, investigation into careers seems to be most effective when incorporated into instruction over the longer term. With respect to activities, those interventions in which students of targeted groups are actively engaged seem to lead to reduced stereotypical perceptions. As an example, classroom teachers who have made efforts to ensure girls have active roles in working groups or who have created all-girl groups for activities seem to positively impact those girls' perceptions of scientists. In a similar vein, students from minority populations seem to respond well to role models from their own race. Other less targeted interventions have appeared to be successful in reducing the stereotypical perceptions of students at all levels. Overall, interventions appear to have, at least, immediate effects on many students with regard to their perceptions of scientists.

What This Body of Research Has Not Told Us

Aspects of this line of research remain unaddressed, except in occasional lines of discussion in the literature. As-yet unanswered questions include the following: At what age, or grade level, do stereotypical images begin to form? How rapidly do these images form, and how are they reinforced? What are the specific factors influencing these perceptions, and where do they come from? How persistent and enduring are the perceptual changes that occur as a consequence of various targeted intervention strategies (use of role models, etc.)? No long-term studies of these interventions' effects have yet been conducted, so the answer is unknown. What linkage exists, if any (or what correlations exist) between stereotypical perceptions of scientists and cognitive growth or achievement with respect to science skills and content? Do changes in attitudes toward science lead to subsequent changes in perceptions as revealed in drawings, and if so, how strong are those effects? Does a teacher's tendency to be predominantly an expository or constructivist teacher (or somewhere along that continuum) impact the degree to which students' drawings of scientists include stereotypical elements?

What Seems to Lie Ahead: Implications for Science Educators and Teacher Education

If one accepts the assumptions made by those who have conducted and reported their research on student perceptions of scientists, then there are several implications of which one needs to be aware. Some implications lie in the realm of science teaching, while others are in science teacher education.

As Barman (1999) pointed out, a growing number of students are coming to view scientists as realistic people rather than as mythical creatures. However, the perception of scientists being male Caucasians working indoors with chemistry is prevalent, as are the elements of those scientists having glasses, wearing lab coats, having facial hair, and so forth. These concerns can be addressed by helping students connect with scientists through various avenues, including connections via mentoring experiences, classroom speaking, and opening and maintaining communications between students and scientists. Carefully selected visual aids, such as videotapes and photos, as well as science-related careers information (brochures, web sites, etc.) should be utilized. However, one should be cautioned against being too quick to judge some stereotypical images as being negative or positive. For example, one might be

concerned with a laboratory chemist who is not wearing protective eyeware and a laboratory coat while at work, particularly when these are the very types of behaviors teachers should require of their own students in a laboratory setting. Teachers can help students become more aware of specific media depicting scientists in acceptable ways. Teachers may suggest viewing (or provide opportunities to view) certain television programs and/or movies, while making overt efforts to help students see what is stereotypical with others. Providing students access to selected publications may also be appropriate, such as NSTA's *Dragonfly*, a publication in which students actually interview scientists.

Further, teachers and others interested in education should seek opportunities for students to have contact with scientists outside of the classroom and outside of the scientist's workplace. On the one hand, this may help students see that science has applicability outside the school or classroom, and on the other hand that scientists are really more like "regular people" than not. Providing opportunities for students to see and do science at home or in other nonschool venues would be helpful, as well. Classroom discussions of how science is used at home may help students see that one need not be a stereotypical scientist in order to do science.

Science educators have a significant role in helping address these stereotypical perceptions, as well. First, science educators should realize that many of the students sitting in their science methods classes hold the same stereotypical perceptions of scientists as do children. Similarly, many of the teachers with whom science educators work have those same perceptions. Awareness is a key. Those who are not aware they hold a certain perception are unlikely to change that perception. Science educators should help preservice and inservice teachers understand what are stereotypical images and elements and what are effective ways of changing them. Such understanding may be gained through action research projects, classroom discussions, or other means. Science educators can also educate their science colleagues about these same things.

One implication that consistently arises from the studies on students' perceptions of scientists is that the extent to which an individual's perceptions are stereotypical has direct consequences on that individual's likelihood of selecting science coursework and entering a science-related career. The less stereotypical the image one holds, the more probable it is that one will opt to take more science classes and subsequently consider entering a profession in the sciences. Failure to recognize the presence of such images, to identify them and their specific elements, and to design and implement appropriate interventions may eventually lead to increased erosion in the number of scientists in the workforce. Beyond this, researchers need to dig more deeply into the underlying assumptions and root causes behind stereotypical perceptions of scientists. Research needs to move past those studies that basically confirm that students possess stereotypical images and describe how the same tried and true interventions impact them. Educators need to begin now focusing on the more difficult questions that are as yet unanswered, some of which were delineated in the previous section of this paper.

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