Creative Education, 2016, 7, 2293-2304
http://www.scirp.org/journal/ce
ISSN Online: 2151-4771
ISSN Print: 2151-4755

Achieving Diversity in STEM: The Role of Drawing-Based Instruments

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How to cite this paper: McCann, F. F., & Marek, E. A. (2016). Achieving Diversity in STEM: The Role of Drawing-Based Instruments. *Creative Education, 7,* 2293-2304.
http://dx.doi.org/10.4236/ce.2016.715223

Received: September 24, 2015
Accepted: September 24, 2016
Published: September 27, 2016

Abstract

Are drawing-based instruments such as the Draw-A-Scientist-Test (DAST) and its derivatives effective probes for assessing the images of scientists held by girls and children of diverse ethnicities in developed countries, children in Asia, and children in the developing world? This paper is a review of the literature from 2002 to the present designed to answer that question. It also addresses a second research question of what insights these images reveal that can inform development of inclusive science curricula. Scientist image data obtained from drawing-based images reveal that drawings are heavily influenced by culture, gender and socio-economic status. These findings suggest an opportunity to engage girls and ethnic minority children in Science, Technology, Engineering and Mathematics (STEM) learning by integrating gender and ethnic content into STEM curriculum following the model developed by Joseph Banks (1989) for social studies and history curriculum.

Keywords

Draw-A-Scientist Test (DAST), Enhanced Draw-A-Scientist-Test (E-DAST), Multicultural Science Curriculum, Perceptions of Scientists, Scientist Stereotypes

1. Introduction

Over the last fifty years, stereotypical scientist images have remained largely white and male. Despite efforts by educators and the STEM (Science, Technology, Engineering and Mathematics) community to change girls' science identities (Scantlebury, Tal, & Rahm, 2007) and to increase participation of females and ethnic minorities in STEM careers, the STEM workforce likewise remains predominantly white and male (Rawson & McCool, 2014). Women and ethnic minorities have been marginalized and their contributions have been undervalued by the STEM community (Tucker-Raymond, Varelas, Pappas, Korzh, & Wentland, 2007). A Latina second grader in a Midwestern public school indicated when she was interviewed about a drawing of a scientist she had made that she "doubted that a scientist would be named Rachel and remarked that this was 'never gonna happen' (Tucker-Raymond et al., 2007: p. 589)". Scantlebury et al. (2007) tell of a similar experience twenty years earlier with a Midwestern high school girl. When asked by Kathryn Scantlebury about her DAST drawing, this girl responded, "that don't look like me" (Scantlebury et al., 2007: p. 545). Stereotypical perceptions of scientists foster negative attitudes towards science and science careers among females and underrepresented ethnic minorities.

James Banks, a scholar in multicultural social studies and history education, considers the impact of a mainstream-centric, i.e., white and male, curriculum on both the minority and dominant groups in society (Banks, 1989). Guided by his conclusion that such limited mainstream-centric perspectives compromise society's ability to benefit from diversity (Banks, 1989), this review of the literature addresses the use of drawings to examine how girls, under-represented ethnic minority children, and children in developing countries perceive scientists. It examines articles published between 2002, the publication year of Finson's review of the prior 50 years of research on drawing scientists, and the present. His survey of the literature shows the beginnings of a multicultural and global perspective on scientist images. This current review documents progress made since 2002 towards better understandings of girls', special populations' and underrepresented minorities' perceptions of scientists. The insights gained from examination of how female and under-represented minority children perceive scientists can inform development of a multicultural STEM curriculum that is inclusive and pluralistic.

Stereotypical images of scientists 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). A study of primary school children (Year 5) in the United Kingdom indicates 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). 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/racial minority, or scientists, internalizes the stereotypical image thrust upon it by society (Adams, 2000). The power of the scientist stereotype for a female scientist is addressed in a *Materials Research Society Bulletin* article (Saini, 2012), where a female materials chemist, Sujata Kumdu, at University College, London, reflects on the challenges of being 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 realizes that she has 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)".

1.1. Images of Scientists in Mainstream Western Culture

It is encouraging that a recent television series, *Crime Scene Investigation* (*CSI*), realistically portrays scientists (Bort, 2005; Heyman, 2008; Jones & Bangert, 2006) and shows equal numbers of male and female laboratory scientists. There is evidence that this equal gender representation impacts middle girls' perceptions of scientists (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). However, according to Frayling (2005), 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.

In schools throughout the world, children's perceptions of scientists are influenced by science trade books and textbooks. Science trade books are an elementary school classroom resource for teaching that science is a human endeavor (Farland, 2006a; Farland, 2006b). Generally, these trade books avoid the cartoon image of the scientist. Nevertheless, they do perpetuate the image of scientists as old white males (Farland, 2006a; Farland, 2006b). 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 found in their science textbooks (Turkmen, 2008).

1.2. Accessing Stem Images with Drawing-Based Instruments

Drawings have proven to be robust probes for assessing images of scientists for more than half a century. 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).

2. Research Questions and Methodology

The research questions derive from an overarching theme of creating awareness of the need for multicultural STEM curricula and instruction among science educators and science teacher educators. The first research question asks whether the DAST and DAST-based instruments are effective probes for assessing the images of scientists held by girls and children of diverse ethnicities within the United States and other developed countries, Asia and in the developing world. The second research question asks what these DAST and DAST-based instruments reveal about these images of scientists that can inform curriculum development to deliver engaging STEM learning experiences to an ethnically diverse population of girls and boys.

The EBSCO and ERIC data bases were searched using the keywords "scientist images", "perceptions of scientists", "Draw-A-Scientist-Test", "DAST" and "DAST-C". Articles identified in the search were selected for further review if they met the following criteria: 1) were published in a peer reviewed journal; 2) had a publication date after 2002 and 3) related to assessment of scientist images held by girls, special populations of children including identified gifted children, children belonging to ethnic minorities in a developed country, children in Asia or children in a developing country. Criterion 2, the requirement that the article be published after 2002, was established because Finson's comprehensive review article, "Drawing a Scientist: What We Do and Do Not Know after Fifty Years of Drawings" (Finson, 2002), was published in that year. An objective of the present review is to examine progress made since 2002 in developing a multicultural and global perspective that extends research on scientist images to developing countries and ethnic minorities within developed countries, girls, and special populations.

3. Results

The literature since 2002 documents an ongoing modification of the DAST to be a more sensitive indicator of drawing elements related to gender and ethnic diversity. The Enhanced Draw-A-Scientist-Test (E-DAST) (Farland-Smith & McComas, 2009) allows students to construct multiple scientist drawings, thereby providing a broader range of expression for students outside the mainstream culture. The E-DAST scoring rubric characterizes drawings on the basis of three criteria: the scientist's 1) "appearance", 2) "location" and 3) "activity" (Farland-Smith & McComas: 2009: pp. 49-50). These criteria are characterized and scored as "Can't Be Categorized" i), "Sensationalized" ii), "Traditional" iii) or "Broader Than Traditional" iv) (Farland-Smith & McComas, 2009: p. 50). Consideration of details of location and activity highlight elements associated with the culture of the child creating the drawing. 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) DAST instrument. The M-DAST allows for more accurate interpretation of gender and race/ethnicity of scientist images. The M-DAST requires a student to provide a name for a scientist image as well as write and read aloud a story about the image. The name helps in assigning gender to scientist images drawn as stick figures or without any clear indicators of gender. Finally, students explicitly state the race of their scientist images, thereby avoiding possible incorrect racial/ethnic characterization of drawings on the basis of the presence or absence of shaded skin.

Another trend is the use of the DAST and DAST-C with special populations including identified gifted students (Melber, 2003); culturally diverse students, specifically, Native American and African American children in the United States (Finson, 2003); and students from developed and developing countries (Akcay, 2011; Farland-Smith, 2009; Koren & Bar, 2009; Medina-Jerez, Middleton, & Orihuela-Rabaza, 2011).

The DAST and DAST-C provide valuable insights into how students from underrepresented groups perceive scientists. Generally, students from underrepresented ethnic groups in developed countries and students from developing countries tend to draw fewer 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. Rather, results indicate that culture has a strong effect on children's perceptions of scientists. This flawed assumption of a monolithic scientist image, if left unchallenged, can lead to likewise flawed STEM curricula that ignore cultural and gender diversity. Representative studies include Navajo children in the United States (Monhardt, 2003); elementary and middle school children in Israel (Koren & Bar, 2009); Colombian and Bolivian 5th - 11th graders (Medina-Jerez et al., 2010); elementary and secondary school age Turkish children (Akcay, 2011; Buldu, 2007; Korkmaz, 2009; Turkmen, 2008); primary and secondary school students in Hong Kong (Fung, 2002); and elementary school age children in China (Farland-Smith & McComas, 2009).

3.1. Scientist Images Drawn by Ethnic Minorities in Developed Countries

In two developed nations, the United States and Israel, ethnic minorities and females are underrepresented in the mainstream STEM community. Studies in the United States report DAST-based instrument results for three such groups: African-American; Native-American, specifically, Navajo; and female children. African-American third grade students draw images on the M-DAST 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). The M-DAST modification of explicit descriptions of race/ethnicity effectively reveals how these third graders' images diverge from the traditional stereotype.

Navajo elementary school students (grades 4 - 6) in the western United States typically draw European-American scientists on the DAST-C. However, there are notable exceptions where elements of the Navajo culture are expressed, such as one male student's drawing of a Navajo scientist, a medicine man (Monhardt, 2003). Navajo elementary school students incorporate other 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). 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 proposed to account for the low DAST-C scores (Monhardt, 2003) postulates that Navajo children's unfamiliarity with scientists results in an absence of DAST-C stereotypical indicators from their drawings.

Insights regarding image gender also emerge. Only 47% of the Navajo students' DAST-C drawings show male gender. The predominant portrayal of scientists as female may be attributed to the fact that the Anglo female conducting the research study was introduced to the children as a scientist. However, this portrayal may also reflect a Navajo cultural element, namely, a matriarchal structure where women are "generally viewed in roles of power" (Monhardt, 2003: p. 31). Gender as well as culture also affects children's drawings of scientists. Females' drawings indicate an awareness of the personal appearances of scientists they know. The 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)".

Like the United States, Israel includes ethnic minority populations, such as Arabic-speaking Bedouins. The Bedouins are economically deprived, underrepresented in STEM and lack familiarity with western science. Images of scientists drawn by Bedouin students diverge from those drawn by the dominant, Hebrew-speaking student population ages 9 - 14 (Koren & Bar, 2009). The Hebrew-speaking students draw stereotypical images like mainstream students in other developed countries. While both Hebrew-speaking and Bedouin children predominantly draw male scientists, the Bedouin students' images include elements from their culture, such as traditional Muslim dress. 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 the already-described trend observed in Hebrew-speaking and Arabic-speaking children's scientist drawings (Koren & Bar, 2009).

3.2. Scientist Images Drawn by Children in Developing Countries

The scientist images drawn by children in developing countries diverge along ethnic and socio-economic lines. In Colombia and Bolivia, 5th to 11th grade students draw scientist images that diverge according to socio-economic status. Specifically, higher socio-economic status students generally draw stereotypical white male scientist images, while their lower socio-economic status counterparts draw less stereotypical images (Medina-Jerez et al., 2011). A lack of traditional stereotypical elements in the im-

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ages drawn by lower socio-economic status students may be attributed to inadequate school experiences with science. Colombian students from rural and public schools draw stereotypical scientist images, while their less-advantaged Bolivian counterparts draw relatively fewer stereotypical images. However, a difference is observed among wealthy Columbian students attending private schools. They depict scientists less stereotypically than both the Columbian rural and public school students and Bolivian students. It would appear that more privileged students in this developing country are more sophisticated and hold more accurate perceptions of scientists.

Turkish students (Akcay, 2011; Buldu, 2007; Korkmaz, 2009; Turkmen, 2008) generally draw stereotypical white, male scientist images. They draw less stereotypical images as they advance into secondary school (Akcay, 2011). For young Turkish children, 5 - 8 years of age, higher parental education level and higher socio-economic status are associated with less stereotypical scientist images (Buldu, 2007), a result similar to that observed with higher socio-economic status Columbian students. Only female Turkish students draw images of female scientists (Akcay, 2011; Buldu, 2007).

3.3. Scientist Images in Asia

A study of 1350 elementary school students in the United States and China using the E-DAST reinforces the idea 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, and Bedouin students in Israel (Koren & Bar, 2009), Chinese students incorporate elements from their own 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 among United States students' drawings, are absent from the Chinese students' drawings. This absence of the basement element reflects the Chinese cultural norm of high-rise apartment living and unfamiliarity 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). Likewise, primary through secondary school students, ages 7 - 17, in Hong Kong draw stereotypical predominantly male scientist images on the DAST (Fung, 2002). However, male gender and European ethnicity appear to be two elements of the stereotypical scientist image that persist significantly across cultures. As in Turkey, only female students in Hong Kong draw female scientist images.

3.4. Developing Multicultural Stem Curriculum

Scientist image data obtained using DAST-based instruments reveal a broad trend that children's drawings of scientists are heavily influenced by their culture, gender and socio-economic status. Drawings made by children and teachers who belong to ethnic minorities in developed countries depict scientists of their ethnicity and include elements specific to their culture. According to self-to-prototype matching theory (Niedenthal, Cantor, & Kihlstrom, 1985; Setterlund & Niedenthal, 1993), individuals attempt to match their self-perceptions with the prototypical image of a member of a group when making a decision whether or not to join that group. This theory has been applied to explain why adolescents avoid science coursework because of negative images of science and science students (Hannover & Kessels, 2004). Since females and ethnic minorities are unable to match their self-prototypes with the prototypical image of the scientist, i.e., the stereotypical white male, they avoid science coursework and careers. This model is consistent with the fact that science and engineering remain largely white, male fields despite efforts directed at increasing female and ethnic minority participation in these fields (Rawson & McCool, 2014; Scantlebury et al., 2007). Members of ethnic minorities create drawings that show scientists of their ethnicity (Monhardt, 2003; Rubin et al., 2003; Walls, 2012) or gender (Akcay, 2011; Buldu, 2007). These data suggest an opportunity to support ethnic minority children and girls in maintaining scientist images that are more easily reconciled with their self-perceptions than the image of the white male.

These insights can inform the design of an inclusive multicultural STEM curriculum. Applying the guidelines, Banks (1989) proposes for history curriculum to STEM curriculum can provide girls and ethnic minorities with prototypes more closely aligned with their self-prototypes. According to self-to-prototype matching theory (Hannover & Kessels, 2004), such alignment can encourage them to pursue STEM coursework and careers. Banks (1989) identifies four approaches for integrating ethnic content into history curriculum that can be readily adapted for STEM curriculum development and instruction. Banks (1989) organizes the four approaches hierarchically beginning with "Level 1 The Contributions Approach", "Level 2 The Additive Approach", "Level 3 The Transformation Approach" and "Level 4 The Social Action Approach" (Banks: p. 192). "Level 1" and "Level 2" approaches can be implemented within an existing mainstream-centric curriculum and show the most promise for near term development of STEM curriculum that can provide female and ethnic minority children with prototypes aligned with their self-prototypes. "Level 3" and "Level 4" approaches require that the structure of the existing curriculum be changed. The "Level 3 Transformation" approach restructures curriculum so that content is viewed from an ethnic minority or female perspective. The "Level 4 Social Action" approach takes the transformation approach a step farther and encourages inquiry into the nature of issues related to social injustice. Banks (1989: p. 200) acknowledges that these approaches "are often mixed and blended in actual teaching situations". However, since "Level 1" and "Level 2" approaches are more readily implemented than "Level 3" and "Level 4" approaches, their adaptation for STEM curriculum is considered in further detail.

"Level 1 The Contributions Approach" according to Banks (1989: p. 192) "is one of the most frequently used and is often used extensively during the first phase of an ethnic revival movement". With this approach, "ethnic heroes and discrete cultural elements (Banks: p. 192)" are inserted into existing curriculum. They are chosen using the same selection criteria that would be applied to mainstream historical figures and cultural elements. For a STEM curriculum, the "Level 1" approach could involve adding content about female scientists and engineers, ethnic minority scientists and engineers and their contributions. This approach provides images that are more easily reconciled with female and ethnic minority self-prototypes, and these groups represent as female (Akcay, 2011; Buldu, 2007) and ethnic images (Monhardt, 2003; Rubin et al., 2003; Walls, 2012) on the DAST. Moreover, according to Banks (1989: p. 193), it also creates a "sense of structural inclusion, validation and equity" and a "sense of empowerment and efficacy". When using this approach, adequate attention should be given to the particular challenges faced by female and ethnic minority scientists and engineers and how they overcame these barriers. Their contributions should be considered within the context of STEM as a whole, rather than as an isolated or exotic occurrence. A multicultural STEM curriculum especially designed to be inclusive of female contributions to STEM developed according to the "Level 1" approach might consider the lives and work of historical female figures in STEM, such as Marie Curie, Lise Meitner, Emmy Noether, Barbara McClintock, Rita Levi-Montalcini, Rosalind Franklin or Rosalyn Yalow (McGrayne, 2006). While for Arabic speaking students in Israel (Koren & Bar, 2009), a "Level 1" multicultural curriculum might highlight the contributions of Arab scientists from the "Muslim Golden Age" (Koren & Bar, 2009: p. 2506).

Banks (1989: p. 195) describes the "Level 2 The Additive Approach" as "addition of content, concepts, themes and perspectives to the curriculum without changing its basic structure, purposes and characteristics". Applied to development of a multicultural STEM curriculum for the Navajo students of Monhardt's study (2003), this approach might involve adding content to an earth sciences unit that related specifically to the geology of the outdoor settings and geological formations that students drew in their DAST images. Likewise, a unit on genetics might be enriched for female students with content on Barbara McClintock's Nobel Prize winning work elucidating the chromosomal structure of maize (McGrayne, 2006), paying particular attention to the challenges McClintock overcame to have her work taken seriously.

Success achieved with the "Level 1 The Contributions Approach" and "Level 2 The Additive Approach" may lay the groundwork for expansion to the "Level 3 Transformation Approach" and "Level 4 Social Action Approach". The goal of these efforts is to insure that 20 years from now, as a result of curricula developed using the cultural insights obtained using drawing-based instruments, females and ethnic minorities will have access to scientist images that allow them to visualize themselves as scientists.

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