Testing assumptions of the Draw-a-Scientist-Test (DAST): Do stereotyped views affect career aspirations?

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Abstract: A growing body of research addresses students' images of scientists using the Draw-a-Scientist-Test (DAST) and its Checklist (DAST-C). These protocols rest on the assumption that stereotypical views of scientists, as identified by the presence of multiple indicators in student drawings (e.g., lab coat, male gender; eyeglasses; facial hair), may affect science career interest. Yet, such an assumption remains unexplored. Therefore, the present study investigated whether stereotyped images of scientists identified by the DAST and DAST-C predicted and affected students' science career interests. A total of 1799 students in grades 3, 6, 9, and 11 in Colombia drew a picture of a scientist at work and reported their interest in a scientific career. Contrary to theoretical expectations, neither the original seven DAST stereotypical indicators nor the eight alternative DAST-C indicators predicted students' science career interests. Similarly, drawings of male or female scientists had no predictive power of students' science career interest. On the contrary, students interested in a science career drew significantly more stereotyped indicators than their counterparts with low interest. This study failed to find evidence supporting the contention that stereotypical views identified by DAST and DAST-C protocols affect science aspirations. Findings are interpreted in the light of the methodological issues inherent to these instruments, such as the possibility that they measure the socially constructed representations of scientists rather than the stereotypical views of students, and the likely influence of science capital on students' drawings. Overall, this study raises questions about the validity of such protocols.

Keywords: Draw a Scientist Test; stereotypes; career aspirations.

Introduction

Students' images of scientists have received much attention for their potential impact on career aspirations (Ferguson & Lezotte, 2020; Finson, 2002; Leblebicioglu et al., 2021; Meyer et al., 2019). Most research relies on the Draw-a-Scientist-Test (DAST), which requests students to "Draw a picture of a scientist" on a blank sheet of paper (Chambers, 1983). Analysis of the drawings reveals a prevailing image of white male scientists, wearing a lab coat while performing experiments (Emvalotis & Koutsianou, 2018; Medina-Jerez et al., 2011; Miller et al., 2018; Ruiz-Mallén & Escalas, 2012). The DAST relies on the intuitive assumption that such a stereotypical image of scientists may discourage students from pursuing a career in science (Ateş et al., 2021; Ferguson & Lezotte, 2020; Kahle, 1993; Maoldomhnaigh & Hunt, 1988; Miller et al., 2018). As a result, this protocol has been regarded as a career aspiration research instrument (Jones & Hite, 2021), and continues to be used globally to investigate students' drawings and ways to infuse positive and non-stereotypical images of scientists (for a review, see Farland-Smith, 2017). However, research has largely overlooked whether such an assumption holds empirically, and the role of stereotyped drawings on career aspirations is poorly understood. Therefore, this study pursues such an inquiry.

Theoretical underpinnings

The formal study of students' perceptions of scientists dates back to the seminal work of Mead and Metraux (1957). Their findings reveal that students describe scientists as tired-looking, middle-aged, or elderly white men, with an unshaven or unkempt beard, often bald, wearing a white coat, and spending his days doing experiments (mostly chemical) in a lab. Research on images about scientists was further stimulated by the DAST test (Chambers, 1983; Finson, 2002). The original protocol analysed students' drawings of scientists for seven stereotyped indicators that portray the standard image of scientists, such as lab coats, eyeglasses, or facial growth of hair. Later, the DAST checklist (DAST-C) was developed to address further stereotypical images of scientists through nine alternative indicators, such as male gender, Caucasian, or mythic drawings resembling Frankenstein or Jekyll-Hyde creatures (Finson et al., 1995).

Throughout the 1980s and into the present day, studies utilizing the DAST and DAST-C documented the stereotypical images of scientists in students, teachers, and faculty members from different countries including Portugal (Martins et al., 2021), Spain (Toma et al.,, 2018), Turkey (Özgelen, 2012), South Africa (Meyer et al., 2019), Fiji (Sharma & Honan, 2020), or Grece (Emvalotis & Koutsianou, 2018), among many others (for reviews and meta-analyses, see Ferguson & Lezotte, 2020; Finson, 2002; and Miller et al., 2018). This research agenda demonstrated that stereotypical views persist regardless of age, gender, or background (Farland-Smith, 2009; Medina-Jerez et al., 2011; Ruiz-Mallén & Escalas, 2012; Türkmen, 2008; Walls, 2012). Indeed, strong evidence supports that such a depiction of scientists is stable over time and pervasive worldwide (Toma et al., 2018; Farland-Smith, 2017; Finson, 2002; Losh et al., 2008).

The educational implications of this body of research are significant. Students' interest in a science career has been steadily declining over the last decade (Aschbacher et al., 2014; DeWitt & Archer, 2015; Gottlieb, 2018; Liou, 2021; Newell et al., 2015; Tytler, 2014; Tytler & Osborne, 2012). This waning interest is highly concerning given the concomitant need for a specialized scientific workforce (Bybee, 2010; Gago et al., 2004; Tanenbaum, 2016). A possible explanation for this disinterest is suggested within the DAST literature. Drawings are meaning-making activities through which children develop new ideas and construct their understandings of life and the world (Deguara & Nutbrown, 2018; Papandreou, 2014). In other words, drawings can help children make their ideas visible and bring something more clearly into consciousness (Brooks, 2009).

As a consequence of the widespread stereotypical image of a scientist, individuals may regard science as “not for me”, especially in the case of girls and minority children (DeWitt et al., 2013; Finson, 2002; Master, 2021; Yoon et al., 2014). Therefore, if students draw stereotyped images of scientists, it may affect their desire to pursue science-related careers (Finson, 2002). Indeed, such an assumption dates back to the 80s and 90s, when children’s stereotyped drawings became a cause for concern (Maoldomhnaigh & Hunt, 1988). For example, Kahle (1993) concluded that “most students hold a masculine image of both science and scientists and that this image probably detracts from a girl’s interest and self-confidence in doing science” (p. 23). This assumption continues to be asserted in recent DAST studies despite the lack of evidence to support it (e.g., Ateş et al., 2021; Ferguson & Lezotte, 2020; Miller et al., 2018).

The Present Research

This study aims to empirically test the underlying assumption of the DAST literature. It focuses on three issues: (i) To what extent are scores of the DAST and DAST-C protocols able to predict students' career interest in science?; (ii) To what extent do students exhibiting stereotypical images of scientists, as identified by the DAST and DAST-C protocols, express less interest in a science career?; and (iii) To what extent does drawing male scientists predict and affects students’ career interest in science? To answer these questions, students drawing of scientists were analysed against the DAST and DAST-C indicators and confronted with scores on a valid and reliable questionnaire measuring interest in a scientific career. The first two research questions are concerned with the DAST and DAST-C protocols as they have been used in the literature, that is, with all stereotypical indicators. The third research question concerns scientists’ gender drawn. This indicator has gotten more attention in recent years. Recent meta-analysis of five decades of U.S. Draw-a-Scientist studies focused solely on gender-science stereotypes linking science with men (Miller et al., 2018). Another meta-analysis revealed that the male gender of the scientist was one of the most frequent indicators in the studies analysed (Ferguson & Lezotte, 2020). Therefore, analysing the relationship between the gender of scientists drawn and interest in a scientific career seems appropriate.

Method

Participants and Design

This study adopted a quantitative methodology in the form of a cross-sectional survey design, with a stage sampling strategy for participant recruitment (Cohen et al., 2018). The inclusion criteria, or sampling stages, were (i) co-educational public schools, (ii) located in Armenia, Quindío (Colombia), and (iii) with educational services for 3^{rd}, 6^{th}, 9^{th}, and 11^{th}-grade levels. The grade levels were chosen in light of prior research indicating that stereotypical drawings do occur and tend to increase during the upper grades school stage (Medina-Jerez et al., 2011; Ruiz-Mallén & Escalas, 2012).

A total of 1826 students attending seven schools were selected. After excluding nine cases with missing drawings and eighteen incomplete questionnaires, a valid sample of 1799 was achieved. Half of the sample were girls (52.3%). Participants' age varied from 7 to 19 (M = 13.21, SD = 3.10) and they were enrolled in 3^{rd} (18.1%), 6^{th} (24.3%), 9^{th} (30.6%), and 11^{th} grades (27%).

Sample size adequacy was determined for alpha = 0.05 and power = 80% using G*Power 3 (Faul et al., 2007). Key analyses comprised hierarchical multiple regression, chi-square, and multifactor ANOVA (Field, 2009; see Data Analyses section). For hierarchical multiple regression analysis, it was determined that a medium effect size (f^2 = 0.15) would require 55 participants. For chi-square, a medium effect size (w = 0.30) would require 122 participants. For multifactor ANOVA, a medium effect size (η^2_p = 0.06) would require 175 participants. Hence, this study has enough statistical power to address the research questions formulated.

Measures and outcomes

Draw-a-Scientist test

The DAST was used to capture stereotypical images of scientists. The original prompt to "Draw a picture of a scientist" (Chambers, 1983, p. 257) often results in a lack of information portrayed in the drawings (Farland-Smith, 2012; Losh et al., 2008; Miele, 2014; Reinisch et al., 2017). Hence, the modified-DAST (mDAST) instruction of Farland-Smith (2012) was used to explicitly address the appearance, the location, and the activity of the scientists. Minor adjustments were needed for the Spanish language and prompt was tested in a pilot study with successful results (N = 149, Toma et al., 2018). It should be noted that similar extended instructions are commonly adopted in studies using the DAST (Farland-Smith et al., 2014; Leblebicioglu et al., 2021; Medina-Jerez et al., 2011; Reinisch et al., 2017).

DAST and DAST-C stereotyped indicators

The drawings were first rated against the seven indicators proposed in the original Draw-a-Scientist protocol (Chambers, 1983), comprising lab coat (usually but not necessarily white), eyeglasses, facial growth of hair (including beards, moustaches, or abnormally long sideburns), symbols of research (scientific instruments and laboratory equipment of any kind), symbols of knowledge (principally books and filing cabinets), technology (products of science), and relevant captions (formulae, taxonomic classification, or the "eureka!" syndrome). A score (0-7) was computed, with higher values revealing more stereotyped views of scientists.

The drawings were re-analysed using the DAST-C (Finson et al., 1995), which added nine alternative indicators, including male gender, Caucasian, indications of danger, presence of light bulbs, mythic stereotypes, scientists doing work indoors, middle-aged or elderly scientists, and open comments (bubbling liquids, hairstyle, etc.). Two scores were computed, as originally recommended and commonly used in the literature (Emvalotis & Koutsianou, 2018; Martins et al., 2021; Meyer et al., 2019). First, including only DAST-C alternative indicators (0-9). Second, including all indicators (0-16).

Inter-rater agreement was measured in various phases. First, each author examined two random subsamples of drawings (5% of the total), with > 80% agreement. Rating differences were mainly present for the open-comments elements, which introduces research bias. Therefore, it was decided to exclude such an indicator from further analysis, as frequently done in the literature (Ateş et al., 2021; Leblebicioglu et al., 2021; Medina-Jerez et al., 2011; Subramaniam et al., 2013; Uçar et al., 2020). Subsequently, remaining discrepancies were resolved by consensus during several meetings, thus establishing common criteria. To ensure maximum agreement, each drawing was then appraised by two authors.

Career interest in science

Interest in a science career was measured using the Spanish version of the "Career interest" scale from the Test of Science-Related Attitudes (TOSRA, Fraser, 1981; Navarro et al., 2016). It consists of ten items, five of which are negatively worded. Examples include "A job as a scientist would be interesting" or "When I leave school, I would like to work with people who make discoveries in science". All items were assessed using a five-point Likert scale (1 = strongly disagree; 2 = disagree; 3 = not sure; 4 = agree; 5 = strongly agree). Higher mean scores reveal a high interest in pursuing a science career.

This instrument is arguably the most robust and popular of its type (Fraser & Lee, 2015). Previous research provided extensive evidence for the reliability and validity of its scores in Spanish speaking population (Navarro et al., 2016). Indeed, two comprehensive evaluations of the literature on measurement instruments found the TOSRA to have the greatest evidence of validity and reliability (Toma & Lederman 2020, Toma, 2020b). Additional psychometric analyses were conducted on this study's sample using exploratory and confirmatory factor analysis, as well as the McDonald's omega and Cronbach's alpha indices, with satisfactory findings (see supplementary file).

Procedure

During a science class, participants were supplied with coloured pencils and a booklet with all the measurements instruments. The opening page stated that the purpose of the study was *to ascertain their views about science and how it was conducted*. It included information about the voluntary, anonymous, and confidential nature of their participation, and reminders that there are no right or wrong answers, so only their honest opinions counted.

Following completion of the demographic questions, participants proceeded to the second page, which featured the modified DAST prompt written at the top. After completing the drawing, participants were requested to answer the career interest questionnaire on the third page, which may be read until after the DAST to avoid item bias. Upon completion of the booklet, participants were debriefed and thanked.

Data Analyses

First, preliminary analyses were conducted. Chi-square and 2 (gender) x 4 (grade levels) ANOVAs were employed to examine DAST, DAST-C, and career interests scores according to gender and grade level variables. Next, to test if the number of stereotyped indicators, as identified following the DAST and DAST-C indicators, predict students' career interest in science (RQ1), three hierarchical multiple regression analyses were undertaken (Knapp, 2018). The first examination focused on the DAST original seven stereotyped elements. The second analysis focused on the eight alternative stereotypical elements proposed in the

DAST-C. The third analysis comprised all elements, as proposed in the DAST-C (Finson et al., 1995, p. 198) and commonly used in the literature (Leblebicioglu et al., 2021; Türkmen, 2008).

To examine if students with less interest in a science career drew less stereotyped elements (RQ2), a 2 (low vs. high career interest) x 2 (gender) x 4 (grade levels) ANOVA was conducted (Field, 2009). The career interest in science scores (ranging from 1 to 5) were transformed into dummy variables, using the median split procedure, such that values of median and below represent low career interest in science (for rationale, see Toma, 2020a; Iacobucci et al., 2015a, 2015b).

Finally, to examine whether drawing male scientists predicts and affects students' career interest in science (RQ3), hierarchical multiple regression analysis was conducted as previously described. Next, a 2 (student gender: girls or boys) x 4 (grade levels) x 2 (scientists gender: male or female) ANOVA was conducted to examine if students who draw a male scientists reported less interest in a science career.

Results

Preliminary Analyses

Stereotyped views

Table 1 presents the frequency of stereotypes found in girls' and boys' illustrations. The prevailing elements in the girls' drawings were Caucasian scientists (75.5%) and research symbols (75.3). For boys, there was a predominance of male scientists (85.1%), research symbols (75.8%), and Caucasian (75.3%). The least present elements were indications of secrecy (0.4% girls; 0.9% boys), followed by mystical creatures (1.5% girls) and lightbulbs (2.2% boys). Chi-square analysis found that boys drew more male scientists than girls, χ^2 (1, *n*

= 1797) = 154.06, $p < .001$, *phi* = - .29, and that girls drew more lab coats than boys, although the effect size was small, χ^2 (1, n = 1797) = 10.95, $p < .001$, *phi* = .08.

[Table 1. Frequency of stereotyped indicators by gender]

Table 2 presents the frequency of stereotypes drawn according to grade level. Overall, 3rd and 6th graders included Caucasian and indoor locations most, and 9th and 11th graders illustrated many symbols of research and male scientists. Indications of secrecy, mythic stereotypes, and light bulbs were seldom drawn in all grade levels. Chi-square analysis failed to find medium-sized differences between grade levels; however, there was a trend in drawing more lab coats [χ^2 (3, n = 1799) = 63.94, $p < .001$, V = .19], symbols of research [χ^2 (3, n = 1799) = 104.25, $p < .001$, V = .24], and male scientists [χ^2 (3, n = 1799) = 57.08, $p < .001$, V = .18] in upper graders. Figure 1 shows a sample of drawings made by students in this study.

[Table 2. Frequency of stereotyped indicators by grade level]

[Figure 1. Sample of drawings from this study]

Career interest in science

Figure 2 displays the estimated marginal means for the career interest in science scale. A 2 (gender) x 4 (grade levels) ANOVA found a significant interaction effect between gender and grade levels, F (3, 1789) = 2.98, p = .03, η_p^2= .005. Follow-up tests revealed that (i) girls' scores in grades 9 and 11 were significantly lower than those of their counterparts in grades 3 and 6, F (3, 936) = 21.62, $p < .001$, η_p^2= .07; (ii) boys in grades 6, 9 and 11 reported significantly lower interests in a science career than those in 3rd grades, F (3, 853) = 24.578, $p < .001$, η_p^2= .05; and (iii) small sized gender differences in 6th graders, with boys reporting significantly lower scores than girls (η^2 = .01).

[Figure 2. Career interest in science by gender and grade level]

Main analyses

RQ 1. To what extent are scores of the DAST and DAST-C protocols able to predict students' career interest in science?

In all three models, gender and grade level variables were entered at Step 1, explaining 4.9% of the variance in students' career interest in science, F (2, 1796) = 46.54, p < .001. When the seven original indicators of the DAST were included in Step 2, the total variance explained by the model as a whole was 5.4%, F (3, 1796) = 34.31, p < .001. Hence, the DAST score explained a negligible additional 0.5% of the variance in students' career interest in science, after controlling for gender and grade level, R squared change = .005, F change (1, 1793) = 9.41, p = .002. Although the DAST variable was statistically significant (*beta* = .07, p = .002), the beta value was positive, thus suggesting an increase in career interest for a unit change in original DAST stereotypes indicators.

In the second model, the eight alternative indicators proposed in the DAST-C were included in Step 2. This model explained 5.1% of the total variance, F (3, 1796) = 32.38, p < .001. Thus, the eight alternative indicators alone only explained a 0.2% of the variance in students career interest in science, R squared change = 0.002, F change (1, 1793) = 3.90, p = .049. The statistically significant value of the DAST-C variable was marginal (*beta* = .05, p = 0.49) and also positive, indicating an increase in career interest for a unit change in the DAST-C stereotypes.

In the third model, all stereotyped indicators (seven from DAST and eight from DAST-C) were entered at Step 2, revealing that the total variance explained by the model as a whole was 5.4%, F (3, 1796) = 30.56, p < .001. Hence, all indicators together explained an additional of 0.5% of the variance in career interest in science, after controlling for gender and grade level, R squared change = .005, F *change* (1, 1793) = 8.67, p = .003. As with previous models, the variable with the fifteen stereotyped indicators was statistically significant (*beta* = .07, $p = .003$). However, the beta value was likewise positive, suggesting an increase in career interest in science for a unit change in stereotyped indicators.

RQ 2. To what extent do students exhibiting stereotypical images of scientists, as identified by the DAST and DAST-C protocols, express less interest in a science career?

Figure 3 represents the means of stereotypical indicators drawn by students with low and high career interests. A 2 (low vs. high career interest) x 2 (gender) x 4 (grade levels) ANOVA identified a significant interaction effect between the career interest and grade level variable, F (3, 1781) = 2.81, $p = .038$, $\eta_p^2 = .005$. Follow-up univariate tests revealed that, contrary to the theoretical assumption of the Draw-a-Scientist-Test literature, students in 9th grade who reported a high degree of interest in a career in science drew significantly more original DAST stereotypical indicators than those who expressed low interest in a science career, F (1, 550) = 11.94, $p = .001$, $\eta_p^2 = .01$ (Figure 3a). This pattern was also common using the DAST-C eight indicators F (1, 550) = 8.04, $p = .005$, $\eta_p^2 = .01$(Figure 3b) and the procedures that combined all fifteen indicators into one single score F (1, 550) = 12.90, $p < .001$, $\eta_p^2 = .02$ (Figure 3c).

[Figure 3. Stereotypical indicators according to low or high interest in a science career]

RQ 3. To what extent does drawing male scientists predict and affects students' career interest in science?

The "male gender scientist" indicator proposed in the DAST-C was included in Step 2, after including gender and grade level in Step 1. This model explained as a whole 4.9% of the total variance in students' career interest in science, F (3, 1796) = 31.02, $p < .001$. However, the "male gender scientist" stereotype alone did not significantly contribute to the predictive power of the model, after controlling for student gender and grade level ($p = .84$).

Table 3 presents students' interest in a science career according to grade level, their gender, and whether they draw a male or a female scientist. Overall, boys who draw a male scientist reported higher career interest in science, with opposite results for girls. ANOVA revealed no tertiary (grade level*gender*scientist gender, p = .31) or secondary interaction (gender*scientist gender, p = 11; gender*grade level, p = .30; grade level*scientist gender, p = .99) effects between the independent variables. Hence, the main findings of the "male gender scientist" can be interpreted with confidence. These results indicate that there is no statistically significant difference in career interest in science between girls or boys students who draw a male or female scientist, F (1, 1797) = .20, p = .65.

[Table 3. Career interest in science according to the gender of the scientist drawn]

Discussion

Decades of research using the Draw-a-Scientist-Test procedure for the assessment of students' views of scientists rests on the assumption that stereotypical drawings may affect their career interest in science (Kahle, 1993; Leblebicioglu et al., 2021; Maoldomhnaigh & Hunt, 1988). However, such an assumption was yet to be empirically tested. Therefore, this study aimed at such an endeavour. To this end, Colombian students in grades 3, 6, 9, and 11 completed the Draw-a-Scientists test and reported their career interest in science using a valid and reliable scale from the TOSRA instrument (Fraser, 1981; Navarro et al., 2016). Drawings were analysed using the original seven indicators included in the DAST (Chambers, 1983), the eight alternative indicators proposed in the DAST-C (Finson et al., 1995), and combining all indicators.

Findings indicate that students from this study drew illustrations depicting the traditional, stereotyped images of scientists found in the DAST literature (e.g., Toma et la., 2019; Emvalotis & Koutsianou, 2018; Özgelen, 2012). In addition, gender patterns of boys drawing more male scientists than girls mirrored previous findings (Farland-Smith, 2017; Miller et al., 2018). Similarly, it was found an increase in the number of stereotyped indicators drawn as grade level increased, which was also consistent with extant international (Finson, 2002; Ruiz-Mallén & Escalas, 2012) and local (Medina-Jerez et al., 2011) literature. Thus, based on the analysis of the drawings following the DAST assessment procedure and rationale, it can be concluded that Colombian students possess stereotypical images of scientists which dissuade their interest in a science career.

However, contrary to such longstanding assumptions, the results reveal that none of the DAST scoring procedures predicted a significant amount of variance in students' science career interests. Likewise, findings did neither support the contention that girls drawing male scientists have less career interest in science. In addition, the results suggest that, surprisingly, a greater number of indicators drawn would be associated with a stronger interest in a career in science. Thus, 9th graders interested in a science career drew more stereotyped indicators than students reporting low interest in a career in science. Overall, these findings challenge the longstanding notion that stereotyped views of scientists as captured by the DAST protocols may affect students' career interest in science. Rather, the findings do not indicate any evidence to support the assumption that students' disinterest in science may be a result of prevailing DAST-related stereotyped views of scientists.

The lack of relationship between stereotyped drawings of scientists and career interests may be explained by (i) methodological concerns related to the DAST procedure, (ii) that drawings represent students' views instead of socially recognizable images of scientists, and (iii) science capital.

Methodological Concerns

For decades, the DAST has been presented as a valid and reliable procedure to measure individuals' views of scientists, regardless of age, nationality, race, or gender. However, such a protocol has been questioned by some investigations (Andersen et al., 2014; Losh et al., 2008; Reinisch et al., 2017). Criticisms focus on the ability of the DAST (or DAST-C) to identify stereotypical views of scientists. Indeed, gender and grade level disparities frequently reported and also observed in this study, might be explained by females' better fine motor development relative to boys, with the same being true for children at higher levels (Losh et al., 2008).

Likewise, the polysemous meaning of symbols/indicators included in the drawing can also be a threat to the validity of the interpretation. This was illustrated in Reinisch et al.'s (2017) study, where many indicators had multiple meanings for the participants, such as laptops (referred to as "analysis - collate results" or "writing emails and publications), glasses (much time reading or scientists as nerds), books and notes (high literacy or heavy workload), and cell phones ringing, which could represent forgetful and disorganized scientists who miss a meeting, important people receiving many phone calls, or just busy scientists communicating with their research group.

Thus, it is likely that female students and students in higher grades drew a greater number of stereotypical indicators not because they hold a more stereotypical view, but because they possess greater artistic ability than male students or students in lower grades of primary education. If this is the case, it's reasonable to assume that the number of stereotypical elements in their drawings does not correspond to their genuine (lack of) interest in science.

Stereotypical Views or Socially Constructed Representations?

Another possible explanation relates to the elements considered stereotypical. Indeed, questions are raised about the extent to which the stereotypes identified in the drawings (e.g., lab coats, glasses, labs environments) reflect social stereotypes from the media rather than students' ideas about scientists (Toma et al., 2018). In other words, to what extent do students draw what they "know" about scientists or whether the DAST leads them to draw a socially recognizable image of a scientist. Such critiques were first raised by Symington & Spurling (1990) who found that the standard instruction of “Draw a picture of a scientist” led to stereotyped drawings; however, drawings produced in response to “Do a drawing which tells me what you know about scientists and their work” resulted in different, less stereotyped conceptions of scientists. Further studies changing the prompt when using the DAST led to similar results and less stereotyped drawings (Maoldomhnaigh & Hunt, 1988; Maoldomhnaigh & Mhaoláin, 1990). Thus, students may interpret the DAST protocol as requiring the use of known-public stereotypes (e.g., lab coats) to make their drawing recognizable as a scientist to other people (Reinisch et al., 2017), in the same way, that a triangular roof with a chimney and a rectangular wall is frequently used as a symbol for a house. If this is the case, it follows that these drawings do not accurately reflect the students' perceptions of scientists, resulting in a lack of a causal link between their drawings and their expressed interest in a career in science.

Science Capital

Another speculative explanation of these findings is the concept of science capital (see Archer et al., 2015). Cultural (qualifications, dispositions, knowledge) and economic (financial resources) capital offer potential insight into explaining students' engagement in science-related studies (DeWitt et al., 2016). In this sense, a review of extant Draw-a-Scientist literature using the science capital lenses may help understand the results reported in this study. For example, in his seminal investigations, Chambers (1983) found that whereas stereotypical indicators were uncommon in early grades, they become more prevalent in higher grades, coinciding with increased access to formal science education.

Likewise, he found socio-economic differences, with remarkably less stereotyped views in lower-income schools. Such socio-economic trends have also been reported in other countries (c.f. Finson, 2002). Monhardt (2003) found much less stereotypical views of scientists in Navajo students; she concluded that this may reflect a lack of any understanding of what a scientist is. In the same vein, Schibeci and Sorensen (1983) investigated Australian children's views of scientists using the DAST. They found that Caucasian students attending a metropolitan school draw significantly more stereotypical indicators than black children attending a rural school.

Similarly, Medina-Jerez et al., (2011) found grade level differences in Colombian, but not Bolivian students, with an increase in the number of stereotyped indicators illustrated in higher graders. This discrepancy was explained by the fact that Bolivia’s emerging school science curricula were less specialized and advanced than Colombia’s. In other words, Colombian students had more exposure to formal science education than their Bolivian counterparts. They also noted socio-economic differences, with students from Colombia depicting more stereotype indicators than Bolivian students.

The science capital lens could also explain why drawings of male scientists outnumbered female scientists in the different age groups examined (grades 3-11). That is, the sample in this study may lack awareness and knowledge of diverse science-related professions, hence drawing the classic image of a scientist working in a laboratory, just as the students in Losh et al. (2008) investigation mostly included animals in their drawings of veterinarians. One should not, however, rule out the possibility that students tend to draw scientists who are primarily male because they perceive science as a masculinized profession.

This point is particularly significant because, when asked to draw teachers and scientists, students tended to depict men as scientists and women as teachers (Losh et al., 2008).

In light of these findings, a plausible explanation for why students with a greater interest in a career in science drew more stereotypical indicators than students with lower interest may be due to their higher science capital. That is, individuals who have an interest in science are likely to engage in more science-related activities, which results in greater exposure to the scientific enterprise and an increase in their science capital. As a result, they are more familiar with science-related commodities (e.g., symbols of research; symbols of knowledge) than individuals with a lower science capital. While the DAST protocols interpret such indicators as stereotypical, it may be that they reflect a greater *understanding* of the scientific endeavor, which results in more detailed and richer images of scientists and their work. This may account for the positive beta values in the regression analyses, which appear to indicate that science career interest increases as the number of stereotypes drawn increases.

Limitations, Implications, and Avenues for Future Research

The findings of this study should be interpreted considering the following sample-related limitations. The participants were recruited from a developing country, Colombia. Science is viewed in this context as a source of employment that will improve social and economic status. As a result, there is generally more interest in science than in other countries. Indeed, PISA data show that students in low-performing countries are more interested in science than those from high-performing countries, with Colombians displaying the highest average interest in science (Bybee & McCrae, 2011). Hence, it may be that the findings here reported are not generalizable beyond a similar context as the one in this study. Future research should replicate these research endeavours in European and Anglo-Saxon countries in which students' interest in science is low.

Despite this aspect, the findings of this study have major implications. Science education research attributes great importance to the DAST protocols, as it represents a pioneering instrument that has helped to increase understanding of students' images of scientists (Farland-Smith, 2017). However, given that the basic assumption of the DAST (i.e., stereotypical drawings affecting career interest in science) lacks empirical support, it seems reasonable to avoid using the DAST in future studies as the single instrument in identifying stereotypes. Likewise, based on DAST data, numerous studies advanced several strategies that may help improve students' image of scientists, such as female role models, researchers' visits to teachers' classrooms, gender-equitable materials, science camps, or science festivals (Finson, 2002; Leblebicioglu et al., 2021). Given the outcomes of this study, it is unclear what confidence can be placed in such investigations that only used the DAST to collect data. Therefore, at the very least, it should be avoided using the DAST as a single instrument to assess students' views of scientists (Reinisch et al., 2017). Measurement instruments of documented validity and reliability evidence are recommended instead. This is especially the case in populations with good reading and written abilities that can effectively complete other measurement procedures, such as the *Normality of Scientists* (Fraser & Lee, 2015) or the *Trust in Science and Scientists* questionnaires (Nadelson et al., 2014).

On the other hand, the different adaptations of the DAST protocol should be tested. Past studies hypothesized that children may have several images of scientists (Farland-Smith, 2017; Finson et al., 1995; Losh et al., 2008). Indeed, when students were asked to draw consecutive images of scientists, stereotypical views decrease after the first illustration. This approach, named enhanced-DAST (E-DAST, Farland-Smith, 2017), asks students to draw three pictures of scientists consecutively, thus allowing a broader range of expression. Another protocol worth investigating is the modified-DAST (m-DAST, Farland-Smith, 2012), which analyses drawings holistically using rubrics rather than counting the number of stereotypical indicators drawn. Such adaptations of the DAST may be able to better predict students' interests in a science career and therefore, future studies testing such an assumption are warranted.

Finally, it is worth noting that, under the same assumption refuted here, the DAST is currently being adapted to other disciplines, such as Draw-an-engineer (DAET, Capobianco et al., 2011; Thomas et al., 2020), Draw-a-mathematician-at-work (Picker & Berry, 2000) or Draw-a-Science-Teacher-Test (DASST, Thomas et al., 2001). While the validity of such protocols would seem to be taken for granted, it may well be the case that such instruments are also based on an assumption yet to be empirically supported. Thus, future research addressing the rationale for their use is needed.

Conclusion

The purpose of this study was to test the central assumption of the Draw-a-Scientist-based literature. According to longstanding investigations, students draw stereotyped images of scientists, which may harm their interest in a science career. Overall, the findings of this investigation suggest that students drawing stereotypical illustrations of scientists did not display less career interest in science than their counterparts with less stereotypical views. Likewise, findings suggest that stereotypical indicators in the DAST and DAST-C have no predictive power on students' career interest in science. These results raise questions about the validity of the DAST and DAST-C protocols as adequate tools to accurately identify scientists' stereotypical images and call for a reconsideration of its basic assumptions.

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Table 1. Frequency of stereotyped indicators by gender

Stereotyped elements	Gender	
	Girls	Boys
Lab coat	54.3	46.4
Eyeglasses	33.9	30.6
Facial hair	10.6	12.7
Symbols of research	75.3	75.8
Symbols of knowledge	36.3	28.9
Technology	12.4	12.2
Relevant captions	13.3	9.2
Male gender	58.5	85.1
Caucasian	75.5	75.3
Indications of danger	4.9	5.8
Light bulbs	6.2	2.2
Mythic stereotypes	1.5	5.1
Indications of secrecy	0.4	0.9
Work indoors	68.7	69.7
Middle age/elderly	22.4	27

Note: the dotted line distinguishes between DAST and DAST-C indicators.

Table 2. Frequency of stereotyped indicators by grade level

Stereotyped elements	Grade level			
	3rd	6th	9th	11th
Lab coat	24	46.5	53.9	61.4
Eyeglasses	25.2	27.9	31	42.5
Facial hair	4.9	9.8	15.1	13.8
Symbols of research	53.7	78.9	80	82.1
Symbols of knowledge	24.8	24	34.7	43.9
Technology	8.6	17.2	14.7	13
Relevant captions	12	7.8	10.7	14.8
Male gender	54.3	72.7	75.1	76.7
Caucasian	70.5	86.2	72.2	69.4
Indications of danger	4.6	6.9	4.2	5.8
Light bulbs	4.9	2.7	4.5	4.9
Mythic stereotypes	2.5	2.1	3.6	4.3
Indications of secrecy	1.2	0.5	0.5	0.6
Work indoors	58.9	80.3	60.6	75.7
Middle age/elderly	21.2	31	23.2	22.7

Note: the dotted line distinguishes between DAST and DAST-C indicators.

Table 3. Career interest in science according to the gender of the drawn scientist

		Male scientist drawn		Female scientist drawn	
		M	SD	M	SD
3^{rd} graders	Girls	3.88	.97	4.12	.87
	Boys	4.15	.88	3.82	1.13
6^{th} graders	Girls	3.85	.95	3.79	1.01
	Boys	3.59	1.04	3.62	.77
9^{th} graders	Girls	3.55	.92	3.55	.83
	Boys	3.48	.96	3.41	1.12
11^{th} graders	Girls	3.38	.91	3.45	.90
	Boys	3.53	.97	3.44	.95

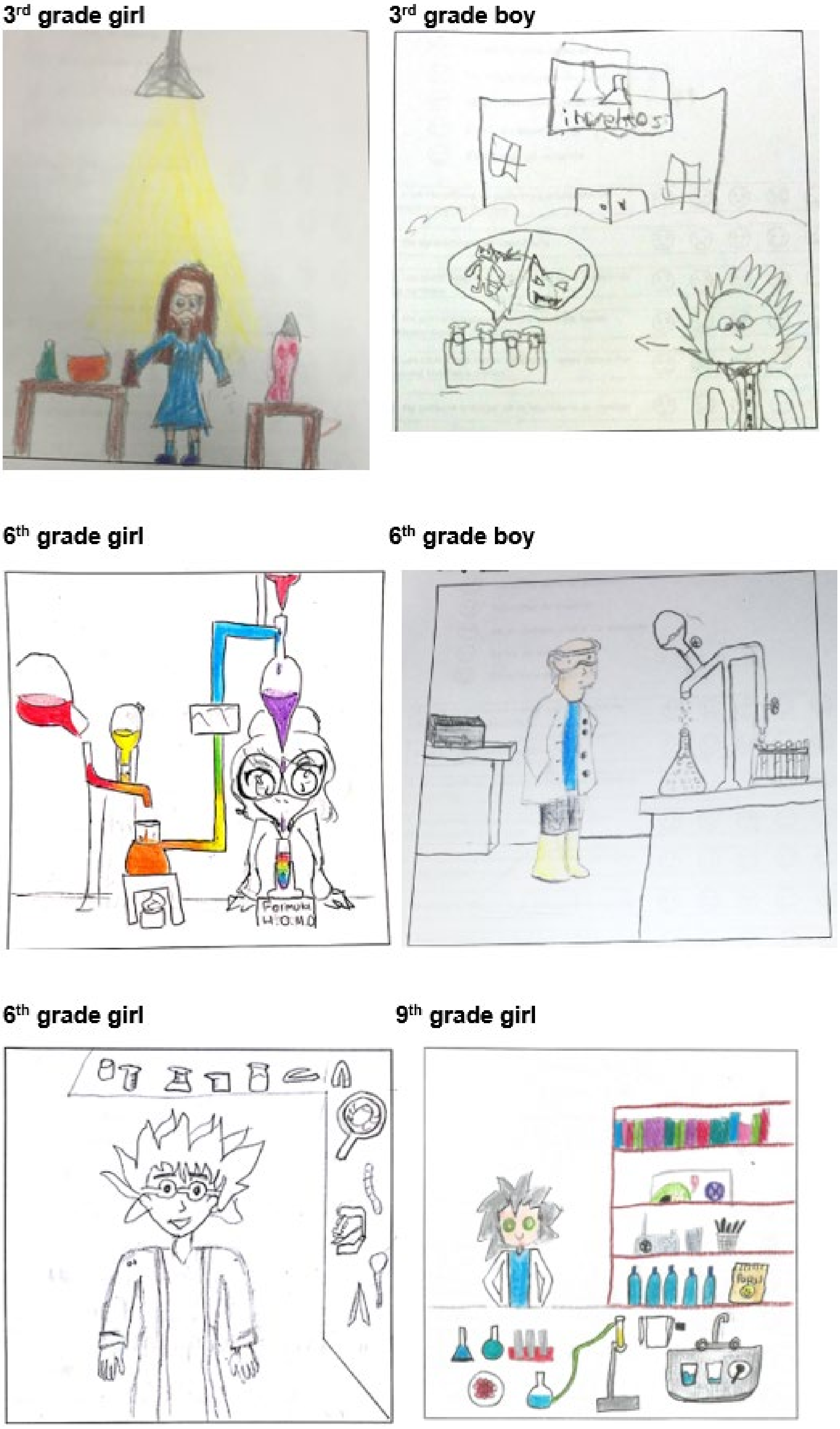

Figure 1. Sample of drawings from this study

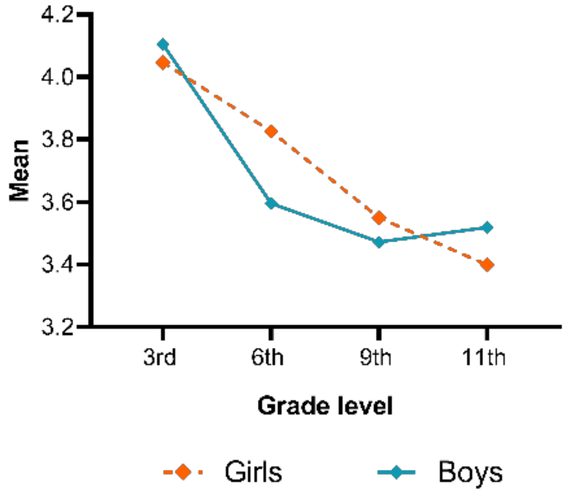

Figure 2. Career interest in science by gender and grade level

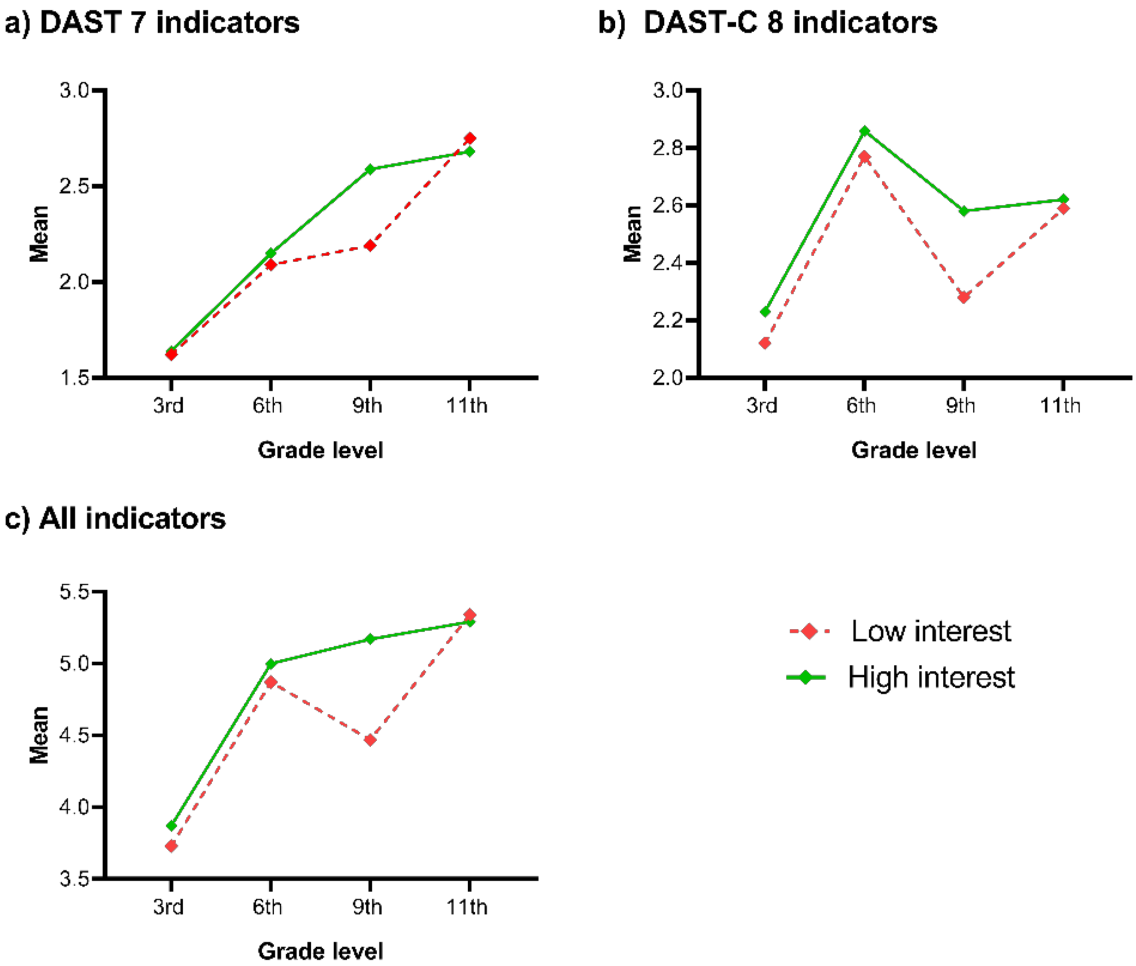

Figure 3. Stereotypical indicators according to low or high interest in a science career

Supplementary file for the parent article entitled "Testing assumptions of the Draw-a-Scientist-Test (DAST): Do stereotyped views affect career aspirations?"

Introduction

The *Career interest in Science* scale was originally translated into Spanish and tested with Chilean secondary school students (Navarro et al., 2016, p. 1462). Therefore, the scale's construct validity and internal consistency reliability for the Colombian sample were first explored.

Method

The 1799 valid questionnaires were randomly split into two groups using the random function in SPSS v. 26 (see ESM_1). The first half (n = 870) was assessed against exploratory factor analysis (EFA) with Unweighted Least Squares extraction on Polychoric rather than Pearson correlation matrices, as this procedure provides more accurate results for ordinal, Likert-type items (Gaskin & Happell, 2014; Holgado-Tello et al., 2010). The Minimum Average Partial (MAP) and Horn's parallel analysis (PA) were used as criteria for factor extraction (O'Connor, 2000). Items with loadings below 0.45 were not retained (Tabachnick & Fidell, 2007). Analyses were conducted using SPSS v.23 and FACTOR 10.10.03 (Lorenzo-Seva & Ferrando, 2006).

For the second half of the sample (n = 929), confirmatory factor analysis was used to assess model fit of the hypothesized EFA model against conventional goodness-of-fit criteria (Brown, 2006): (i) RMSEA of .06 or less; (ii) CFI of .95 or greater; (iii) TLI of .95 or larger; and (iv) GFI of .95 or greater. The analyses were performed using AMOS v.23 (Arbuckle, 2014). Lastly, the reliability of the scale was assessed with the total sample responses using Cronbach alpha (α) and McDonald's omega (ω), a more robust index for ordinal data (Crutzen & Peters, 2017; Hayes & Coutts, 2020; Peters, 2014; Watkins, 2017).

Results

Exploratory factor analysis

The Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) was .92 (very good) and Bartlett's Test of Sphericity was statistically significant ($\chi^2(870) = 4490$, $p < .001$), thus supporting the factorability of the data. Both the MAP and PA tests suggest the extraction of one dimension. The ULS extraction method on Polychoric correlation matrices revealed three items with loadings below the minimum cutoff of .45 (items 5, 7, and 9). Deletion of such items resulted in a final model composed of a 7-item unidimensional factor with an eigenvalue of

4.92 that explains 70.3% of the variance. The exploratory factor analysis by grade level revealed similar results. Table 2 reports the pattern matrix of the final model.

Table 2. Polychoric pattern matrix.

Items	Loadings	h^2
1. I would dislike being a scientist after I leave school	.84	.71
2. When I leave school, I would like to work with people who make discoveries in science	.64	.41
3. I would dislike a job in a science laboratory after I leave school	.87	.75
4. Working in a science laboratory would be an interesting way to earn a living	.81	.66
5. A career in science would be dull and boring	-	-
6. I would like to teach science when I leave school	.84	.70
7. A job as a scientist would be boring	-	-
8. A job as a scientist would be interesting	.85	.72
9. I would dislike becoming a scientist because it needs too much education	-	-
10. I would like to be a scientist when I leave school	.80	.64

Note: h^2 = communality; n = 870

Confirmatory factor analysis

Figure 1 reports the standardized coefficients of confirmatory factor analysis. All goodness-of-fit indices, except RMSEA, meet the established standards (RMSEA = .097; CFI = .966; TLI = .949; GFI = .956), and items had strong loadings, thus suggesting that the EFA model has an acceptable fit.

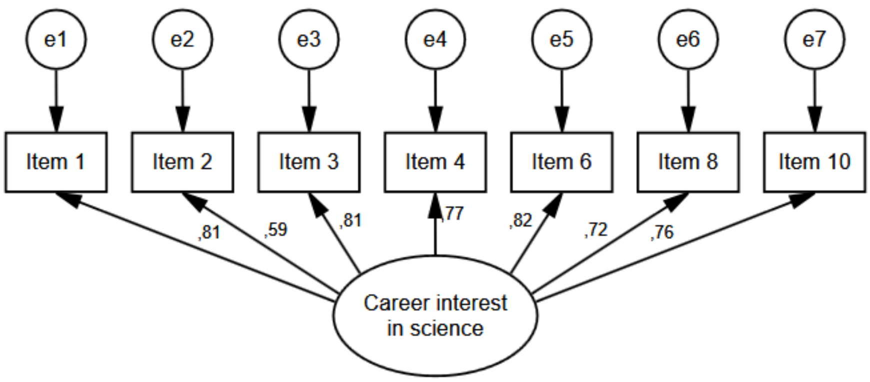

Figure 1. Confirmatory factor analysis with standardized coefficients

Reliability

All grade levels had Cronbach's alpha and McDonald's omega values above .80 (Table 3). Thus, the instrument's data on career interest in science is reliable.

Table 3. Reliability results

Reliability index	Grade level			
	3rd	6th	9th	11th
Cronbach's alfa (α)	.848	.897	.916	.919
McDonalds' omega (ω)	.854	.899	.919	.921

Conclusions

Overall, these findings suggest that the *Career interest in Science* scale produces valid and reliable results with Colombian students.

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