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College Students' Images of Mathematicians and Mathematical Careers

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Abstract

In this paper we report our findings of college students' images of mathematicians and we reflect on different methodologies used to assess this information. The study reported in this paper was conducted in two stages. During the first stage, we asked 179 college students to "draw a mathematician" and also asked them to list five characteristics and five careers for a mathematician. In the second stage of the study, we conducted four focus group interviews with a total of twelve college students. During the focus group interviews, we showed the students 16 photos of real people and asked them to determine which they think are mathematicians and which are not. We found that college students do hold certain stereotypic images of mathematicians and that different perspectives arose based on the different research methodologies. In this paper, we argue for the need to go beyond relying solely on the "draw a mathematician" test and we conclude with a discussion on the implications that stereotypic images of mathematicians have on the mathematical workforce.

1. Introduction

People generally have strong opinions about the field of mathematics, often citing that they either love mathematics or hate it. Similarly, individuals tend to have specific images and beliefs about people who like and do mathematics. Over the past couple of decades, scholars have begun exploring such beliefs held about mathematics and mathematicians. It has been noted that individuals, both children and adults, often have a shallow understanding of what mathematics is and what mathematicians do [34, 35], and many individuals confuse being a mathematician with other careers [22, 32].

This may not be surprising given that mathematicians are rarely represented in the media, and when they are, they are generally portrayed as doing work at a level much beyond what the average person could understand. Even books written about the practices of mathematicians [6] and about becoming a mathematician [47] do not provide a formal definition of a mathematician. In the classic book, *The Mathematical Experience*, by Davis and Hersh [11], rather than defining a mathematician, the authors describe a portrait of "an ideal mathematician," or as they put it, "the most mathematician-like mathematician" (page 34).

Although scholarly work rarely defines a mathematician, there is often an underlying assumption in these works that a mathematician is someone who conducts research in mathematics. For example, Jean Dieudonné (one of the founders of the Bourbaki group) defined a mathematician as "someone who has published the proof of at least one non-trivial theorem" [13]. Latterell and Wilson state that a mathematician is someone who "creates mathematics" [22, page 73], a definition which they specifically state includes applied mathematicians, as applied mathematicians create mathematical models when working on real-world problems. However, it has been pointed out by others that these definitions are somewhat exclusive, leaving behind many individuals who may consider themselves to be mathematicians. As Steckles [41] notes, with such a restricted definition, it is likely that "most people in the world would probably never meet someone who fits that title." Furthermore, it has been argued that just as individuals can consider themselves to be an athlete without being a professional athlete, and others may consider themselves to be an artist without being a professional artist, why must we only associate the word "mathematician" with a professional mathematician, allowing the title to be permissible only for a select few [18].

In our work, we do not attempt to formally define the word "mathematician." Rather, we are interested in what images college students call to mind when they think of a mathematician. As is noted by Tall and Vinner [43], the formal definition of a concept (if one exists) and one's "concept image" are not the same. "The concept image consists of all the cognitive structure in the individual's mind that is associated with a given concept. This may not be globally coherent and may have aspects which are quite different from the formal concept definition" (page 151). In other words, one's "concept image" is not only restricted to mental pictures but also includes all properties that one associates with a given concept. While Tall and Vinner, in their work, use such terms to refer to mathematical concepts, we argue that the same distinction can be extended to non-mathematical concepts as well. Therefore, when we use the phrase "images of mathematicians" we are not only referring to mental images that may come to mind, but to all characteristics that are associated with mathematicians.

Using the notion of image when studying beliefs about mathematicians is not a new approach [32, 48]. Aguilar, Rosas, Zavaleta, and Romo-Vázquez argue that by studying people's images of a concept, it provides us "insight into [their] belief systems" [1, page 532]. Furthermore, while many individuals may have different concept images for a mathematician, common themes found amongst images of a certain group tend to provide insight into a larger social and cultural perspective on that group [33]. Stangor and Schaller refer to this as a "collective" or "cultural" approach, rather than an "individual" approach in their work with regards to stereotypes [40, page 4]. Therefore, when we refer to stereotypical images of mathematicians, we are using this collective cultural perspective.

1.1. An Overview of the Current Literature

Although scholars have been studying stereotypical images of scientists since the 1950's [25], and substantial work has been done in this area (for a summary, see [15]), the research conducted on the stereotypical images of mathematicians began much more recently. With the notable exception of Brush's 1980 study [5], it was not until around the turn of the 21^{st} century when scholars began investigating students' images of mathematicians. The earlier work on images of scientists, however, paved the way for the research that has been conducted on images of mathematicians.

In particular, Chambers developed what has become known as the "Draw-a-Scientist-Test" or DAST [8]. In his study, Chambers asked approximately 4800 elementary school children in three different countries to "draw a picture of a scientist" in order to assess their stereotypical images of scientists. Through the years, many scholars have employed either the Draw-a-Scientist-Test or a Likert-style survey with students of all ages (ranging from elementary school through college), genders, races, and in different countries in order to better understand society's stereotypic beliefs about scientists [7, 8, 16, 17, 21, 27, 29, 36, 42, 44]. Interestingly enough, the results have been relatively stable amongst all of these different groups and throughout the decades. The most commonly cited stereotypes of scientists found by these studies are that scientists are white, male, wear lab coats and glasses, have unruly hair, are geniuses, work with scientific tools and in dangerous situations, tend to work alone, have a limited social life, and are unemotional and uncaring.

In more recent years, scholars have begun employing the "Draw-a-Mathematician-Test" or DAMT. In their study [35], Rock and Shaw conducted an online survey with school-aged students, to learn more about what children believe that mathematicians do, what types of problems they solve, and what tools they use. They also invited the students to mail them a drawing of a "mathematician at work." They received a total of 132 drawings from children in kindergarten through fourth grade. They found that the majority of the drawings portrayed the mathematician as smiling and in a classroom setting. One notable finding was that while the kindergarten and first grade students drew significantly more female mathematicians than male mathematicians, the second through fourth grade students drew almost an equal number of male and female mathematicians. Given that most of the students appeared to be drawing a teacher, and that at that time 91% of elementary teachers in the U.S. were female [28], these results seem to suggest that many students as young as second through fourth grade were already beginning to develop a belief that mathematicians are men.

Picker and Berry, in [32], also asked students to "draw a mathematician at work," however, they surveyed older students (middle-school age) and in five different countries (U.S., United Kingdom, Finland, Sweden, and Romania). Their results showed many fewer students drawing mathematicians as teachers (only about 21.4%) than the elementary school students in Rock and Shaw's study, and had more students drawing mathematicians as men.

For example, amongst the five countries, only between 16.7% and 56.9% of the female students drew female mathematicians and even fewer, anywhere from 0% to 6.3%, of the male students drew female mathematicians. Furthermore, one of the female students who drew a female mathematician even noted that the reason she drew a female mathematician was because "there seems to be only men mathematicians and I wanted to depict a woman doing the work a man usually does" (page 74). Therefore, as students become older, the belief that mathematicians tend to be men appears to become more wide-spread.

Other visual characteristics that Picker and Berry noted, at least amongst their U.S. participants, were that mathematicians are generally depicted as Caucasian, wearing glasses, having a beard, either balding or having unusual hair, and working either at a chalkboard or a computer [32]. These scholars also found themes throughout the drawings in the five countries that were more related to possible personality attributes of mathematicians. They categorized these as the following: foolish mathematicians, overwrought mathematicians, mathematicians who can't teach, mathematicians who use intimidation or violence as coercion, disparagement of mathematicians, mathematicians with special powers, and "the Einstein effect" [32, pages 74-75].

In a study [20] with Norwegian secondary school students, Grevholm found some results similar to those of Picker and Berry [32]. In this study, twelve secondary school students were asked to draw a picture of a typical mathematician. All twelve of the students drew a male figure. Their images, in general, showed an old man working alone, who often had glasses, a beard, was balding or had wild hair, or was given other unusual physical features. Grevholm also noted that the mathematicians were drawn demonstrating an intensity toward their work in mathematics and she also noted "the Einstein effect" found by Picker and Berry. One distinct difference between the two studies was that Grevholm cited that the drawings of mathematicians in her study often portrayed the mathematician as smiling; there was no tone of violence or intimidation as was found in Picker and Berry's work.

More recent studies have also employed a version of the DAMT and have found some slightly different results. One such study took place in Turkey with prospective teachers [48], while another was conducted with high-achieving high school students in Mexico [1]. In both studies, mathematicians were generally drawn in a positive light, as well-groomed, and wearing either formal or casual clothing. Very few drawings portrayed mathematicians as eccentric, strange, or unkempt. As was with the previous studies, however, the mathematicians in the drawings were overwhelmingly male. Only about 6.3% of the high school students in Aguilar *et al.*'s study drew a female mathematician, and not a single male participant in their study drew a female mathematician. Similarly, in Yazlik and Erdogan's study, only 28.8% of all the prospective teachers drew a female mathematician, which included only 6.4% of the male teacher candidates' drawings.

In addition to asking students to draw a mathematician, scholars have also conducted interviews and/or administered surveys to assess society's stereotypic images of mathematicians. Some common themes found amongst this work is that mathematicians are believed to be exceptionally intelligent, passionate about mathematics, lonely, socially awkward, and boring [1, 14, 22, 34, 45, 48]. These beliefs about mathematicians coincide with individuals' beliefs that mathematical careers are less people-oriented than other careers [26].

Stereotypic images of mathematicians and mathematical careers can affect whether or not individuals see themselves entering such careers. For example, Piatek-Jimenez [30] learned through qualitative interviews that even undergraduate female mathematics majors believe that mathematicians are extremely intelligent, obsessed with mathematics, and socially inept, however each of the women in the study also held a firm belief that she did not exhibit at least one of these traits. The students found the first of the traits (extremely intelligent) to be unobtainable, while they saw the other two traits as being undesirable. Furthermore, when discussing whether they viewed themselves as a future mathematician, the women in the study referenced not identifying with these traits.

In another study, Brush surveyed high school and college students on personality attributes that they associate with mathematicians, writers, and themselves [5]. Brush found that students generally labeled mathematicians with descriptors such as rational, wise, responsible, and cautious, while they viewed writers as creative, individualistic, independent, and sensitive. Brush also noted that students assigned writers to have some characteristics that are traditionally considered feminine and others that are generally seen as masculine, while mathematicians were only assigned traits that are socially viewed as masculine. Furthermore, all groups of students (male high school, female high school, male college, and female college) when rating their own personality attributes rated themselves as being more like a writer than a mathematician. Even though very few gender differences were found, it was noted that female high school students rated themselves farther from mathematicians than male high school students, mostly because female high school students rated themselves higher in categories such as sensitive, affectionate, and sociable.

In addition to deterring some students from choosing mathematical careers, the stereotype that mathematicians are predominately male has also been shown to affect some women's achievement in mathematics [38, 39]. This phenomenon is known as *stereotype threat*. Stereotype threat is when "individuals, fearful of confirming a negative stereotype about their group, display decreased performance on a task relevant to the negative stereotype" [19, page 135]. Therefore, stereotypic images of mathematicians can affect student success in the discipline as well.

Although an analysis of the studies conducted thus far has found differences amongst some of the stereotypic images of mathematicians, there does appear to be some common themes found throughout the majority of the studies. These appear to be that mathematicians tend to be male, wear glasses, are highly intelligent, and are anti-social, focusing solely on their work in mathematics. Given that in many countries there is a shortage of people entering mathematical careers [2, 46], and that it has been suggested that stereotypic images may be deterring individuals from considering such careers [30, 5] and even may be hindering their success in mathematics [38, 39], we find it important to explore these beliefs further. In particular, we are interested in the stereotypic beliefs of college students, as these are critical years when many individuals select their future careers paths. As of yet, very little work has been done on this topic with the college population, and as far as we are aware, no study has used the DAMT to study college students' images of mathematicians.

1.2. Aim of our Study

For this study (approved by our institution's Internal Review Board), we wanted to learn what stereotypical images college students have of mathematicians and what careers they believe that mathematicians hold. Although the Draw-a-Scientist-Test (DAST) has been conducted with many populations to study stereotypic images of scientists, since the Draw-a-Mathematician-Test (DAMT) has not previously been used to study the college student population, we chose to employ this methodology during the first stage of this study. Within the same survey, we also asked students to list characteristics of mathematicians and careers for mathematicians.

Despite the popularity of the DAST and DAMT in assessing individuals' beliefs about scientists and mathematicians, many scholars have critiqued this test, including Chambers [8] who originally designed the test. Chambers noted that when he asked students to "Draw another scientist," some unexpected findings resulted that were not found in the first round of drawings. Maoldomhnaigh and Hunt [24] found similar results when asking students to "draw another scientist." These findings are believed to demonstrate that students may have multiple images of a scientist which cannot be assessed in only one drawing. Furthermore, Thomas *et al.* [44] also question the effectiveness of this methodology in assessing students' true perceptions, noting that 10% of the participants in their study drew stick figures, yet we know that 10% of undergraduate students do not truly believe that scientists are stick people. It is possible that students' drawing skills may also hinder their ability to convey certain images. Therefore, in addition to utilizing the DAMT, we chose to also use an image sort to assess students' beliefs. For the second stage of the study, through focus group interviews, we provided the participants with 16 photos of real people and asked them to determine whether or not they believed each was a mathematician. This process allowed students to share more than one image that they hold of mathematicians and also did not limit them based on their drawing capabilities. The research questions we aimed to address were:

RQ1: What stereotypic images do college students hold of mathematicians?

RQ2: What careers do college students believe that mathematicians hold?

RQ3: Do the two different data collection methods assess different images and beliefs about mathematicians?

For the remainder of this paper, we will first present our method, findings, and discussion for Stage 1 of the study. We will then present our method, findings, and discussion for Stage 2 of the study. We will conclude with an overall discussion of the findings from both stages of the study and will reflect on the implications of this work in light of our overall findings.

2. Stage 1: The Survey

2.1. Method

The participants for the first stage of the study were 179 college students at a large public university in the midwestern United States, who were enrolled in an introductory level communications course. Because this course fulfills a requirement that all students need for graduation, our participants represented a wide variety of students enrolled at the university. Demographic information was collected on the participants. Of the 179 participants, 66 (approximately 37%) identified as male, 112 (approximately 63%) identified as female, and 1 identified as neither. The majority of the participants identified as Caucasian (approximately 79%), with about 11% identifying as African American and 8% identifying as multi-racial. Approximately 4% identified as Hispanic. More than half (approximately 58%) of the participants stated that they were college freshmen, with another 28% identifying as sophomores. A large variety of majors were represented, with majors from every college at the university, and the participants had completed anywhere from zero to six mathematics classes at the collegiate level at the time of the study.

During this first stage of the study, participants were asked to complete a survey. On the top of the survey, it asked the participants to "Draw a mathematician" and the rest of the page was intentionally left blank to provide space for their drawing. We supplied a box of colored pencils for each participant to use in their drawings. On the following page of the survey, the participants were asked to "Write 5 characteristics of a mathematician" and then to "Write 5 careers for a mathematician." After each prompt, five blank lines were provided for the participants to fill in. When asking for the participants to draw a mathematician, we purposely did not state "Draw a mathematician at work" as some previous studies have done, because we did not want to lead the students in any particular direction. We simply wanted to access what image came to mind when they thought of a mathematician.

Prior to analyzing the drawings, we created an initial list of categories to code for, based on previous scholarship utilizing the DAST and DAMT. We found, however, that certain categories were not relevant for our data set (such as the distinction of "tools for research" versus "tools for knowledge" frequently used with the DAST) while other categories naturally arose from our data (such as "affinity for mathematics"). Therefore, as a research team, we reviewed the drawings jointly and modified our initial list of categories to code for. We then each coded all the drawings independently and compared our results. When disagreement occurred, final codes were determined based on consensus of the research team.

2.2. Findings

In our analysis of the drawings of mathematicians, we coded each drawing with one of the following categories: male, female, both genders represented, indeterminable gender, no person drawn, and missing drawing (which meant the page was left blank). Of the 179 participants who completed the survey, 87 (49%) drew a male mathematician, 37 (21%) drew a female mathematician, 6 (3%) made sure that both genders were represented (see Figure 1), 43 (24%) drew a figure that had an indeterminable gender (such as a stick figure with no hair or clothes, see Figure 2), 4 (2%) drew something other than a person (such as a satellite circling the Earth), and 2 (1%) left the page blank.

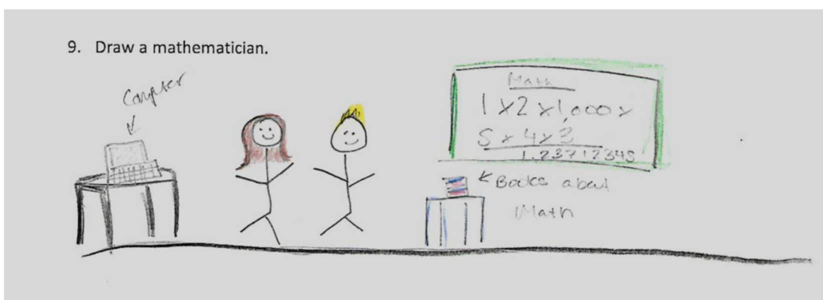

Figure 1: A student drawing where both genders are represented.

When analyzing the drawings by the stated gender of the participant, our results looked much different. Due to the population of the university and the classes that we surveyed, we had substantially more women complete the survey than men. Of the 179 participants, 66 identified as male, 112 identified as female, and 1 identified as neither. See Table 1 for the results for the male participants and Table 2 for the results for the female participants. For the one individual who identified as neither male nor female, the drawing of the mathematician was a male.

Both genders drew male mathematicians more often than female mathematicians, however, male students were substantially more likely to draw a male

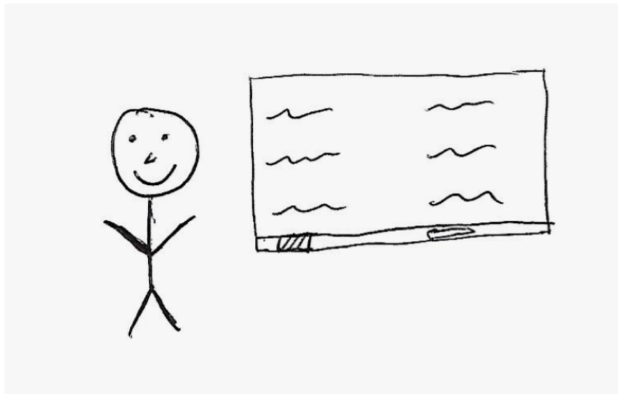

Figure 2: A student drawing of a mathematician with indeterminate gender.

mathematician than female students were. Only 3% of male students drew a female mathematician, while 31.5% of female students drew a female mathematician. Similarly, only one male student ensured that both genders were represented while five female students provided drawings in which both genders were represented. These findings suggest that female undergraduate students either have fewer gender stereotypes when it comes to mathematicians or that they are more conscientious about trying to resist gender stereotypes.

Another interesting finding is that male participants were much more likely to draw a mathematician of indeterminable gender, such as a stick figure with no hair or clothes. It is possible that these figures were intentionally left genderless or, given the pattern found with the other drawings by male students, it is possible that these drawings were intended to be viewed as male, which would make the gender discrepancy of the results even starker.

Table 1: Male Participant Drawings.

Male Participant Drawings		
Gender of Drawings	**N**	**%**
Male	37	56.1
Female	2	3.0
Both genders represented	1	1.5
Indeterminable gender	24	36.4
No person drawn	2	3.0
Missing (blank page)	0	0

Table 2: Female Participant Drawings.

Female Participant Drawings		
Gender of Drawings	**N**	**%**
Male	49	43.8
Female	35	31.5
Both genders represented	5	4.5
Indeterminable gender	19	20.0
No person drawn	2	1.8
Missing (blank page)	2	1.8

We also investigated the implied race of the mathematicians in the drawings, which we compared to the stated race of the participants. When marking their own race, the participants were able to select from the following categories: Caucasian, African American, Asian, Native American or Alaskan Native, Pacific Islander, or Other. Participants had the choice to select more than one option, which we will identify in our results as Multi-racial. To determine implied race of the individuals in the drawings, we used the colored pencil shading of the face to ensure consistency. For shading options, we developed five categories, which included: no shading, brown, black, yellow/orange, and other. None of the participants shaded their mathematician black so that category will not be included in the following results.

Of the 173 surveys that had drawings of people, 155 (90%) did not shade their mathematician, 7 (4%) shaded their mathematician brown, 10 (6%) shaded their mathematician yellow/orange, and 1 drawing was coded as "other" because the participant had drawn multiple stick figures with each figure being a different color (red, orange, green, purple, etc). See Figure 3.

We also analyzed the drawings by the stated race of the participants. Table 3 presents the results for Caucasian participants, Table 4 presents the results for African American participants, and Table 5 presents the results of Multi-racial participants. Tables were not created for the other races due to the small number of participants in these categories. Those data are as follows: The two participants who identified as Asian and the participant who identified as Native American/Alaskan Native did not shade their mathematician's face. The one individual who identified as "other", shaded their mathematician yellow/orange.

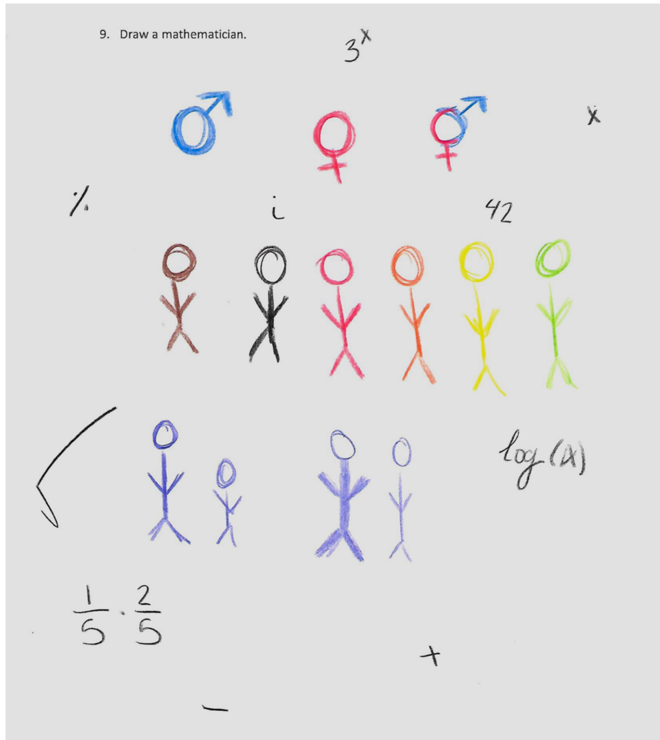

Figure 3: The only student drawing with multiple stick figures with each figure being a different color.

Based on our interpretation, drawings with no shading could be classified as Caucasian (as was also done by Pfeffer [31]) and brown shading could be classified as African American or Multi-racial. It is hard to determine what yellow/orange shading is meant to represent, but given that mostly Caucasian participants chose to shade their mathematician as yellow/orange, it is possible that this, too, was intended to represent a Caucasian mathematician. If that were the case, then 97% (134 of 138) of Caucasian participants who drew a person, drew a Caucasian mathematician.

In addition to gender and race, we coded for other stereotypes typically associated with mathematicians. In particular, we looked at clothing, hair, accessories, facial expressions, environment, math tools, the existence of equations, and expressed affinity for mathematics (such as a speech bubble with the phrase "I love math!"). A summary of these results can be found in Table 6.

Table 3: Caucasian Participant Drawings.

Caucasian Participant Drawings		
Shading of Face	**N**	**%**
No Shading	125	90.6
Brown	3	2.2
Yellow/Orange	9	6.5
Other	1	0.7

Table 4: African American Participant Drawings.

African American Participant Drawings		
Shading of Face	**N**	**%**
No Shading	15	88.2
Brown	2	11.8
Yellow/Orange	0	0.0
Other	0	0.0

Table 5: Multi-racial Participant Drawings.

Multi-racial Participant Drawings		
Shading of Face	**N**	**%**
No Shading	12	85.7
Brown	2	14.3
Yellow/Orange	0	0.0
Other	0	0.0

When analyzing the clothing that the participants drew, no particular style was emphasized. While some students drew their mathematician wearing something formal, such as a button-up collared shirt, it was also just as common for students to draw a mathematician wearing a t-shirt and shorts.

Fifteen students (8.7%) drew their mathematician wearing either a skirt or a dress, but based on the drawings, it was generally unclear if this style was intended to provide a more professional look or simply to emphasize that the mathematician they drew was female. For example, many of the dresses could have been interpreted as casual sun dresses.

Table 6: Other Features Found Amongst the Drawings.

Clothing	
Professional (non-dress or skirt)	40 (23.1%)
Casual (non-dress or skirt)	40 (23.1%)
Dress or skirt	15 (8.7%)
Lab coat	10 (5.8%)
Hair	
Bald/Balding (non-stick figure)	25 (14.5%)
Crazy/Messy hair	21 (12.1%)
Facial hair	15 (8.7%)
Accessories	
Glasses	78 (45.1%)
Tie	19 (11.0%)
Pocket Protector	6 (3.5%)
Hat	6 (3.5%)
Facial Expression	
Smiling	117 (67.6%)
Frowning	2 (1.2%)
Angry	1 (0.6%)
Other (ex: talking)	30 (17.3%)
Environment	
Chalkboard	67 (38.7%)
Classroom (students)	6 (3.5%)
Desk	5 (2.9%)
Works Outside	1 (0.6%)
Math Tools	
Chalkboard	67 (38.7%)
Calculator	26 (15.0%)
Pencil/Pen	16 (9.2%)
Pointer	14 (8.1%)
Paper/Test	10 (5.8%)
Computer	5 (2.9%)
Books	4 (2.3%)
Ruler	3 (1.7%)
Equations	
On chalkboard	57 (32.9%)
In Thought/Speech Bubble	11 (6.4%)
In Air/All Over	4 (2.3%)
On Clothing	3 (1.7%)
On Computer	2 (1.2%)
On Body (Tattoos)	1 (0.6%)
On Paper	1 (0.6%)
Affinity for Math	
Clothing	5 (2.9%)
Speech Bubble	4 (2.3%)
In Air	1 (0.6%)
Tattoo	1 (0.6%)

With regards to hair, images found in past research include that mathematicians are bald/balding, have crazy or messy hair, and/or that they have facial hair. While we did find instances of all of these cases (see Figure 4), none of these features were unusually prominent.

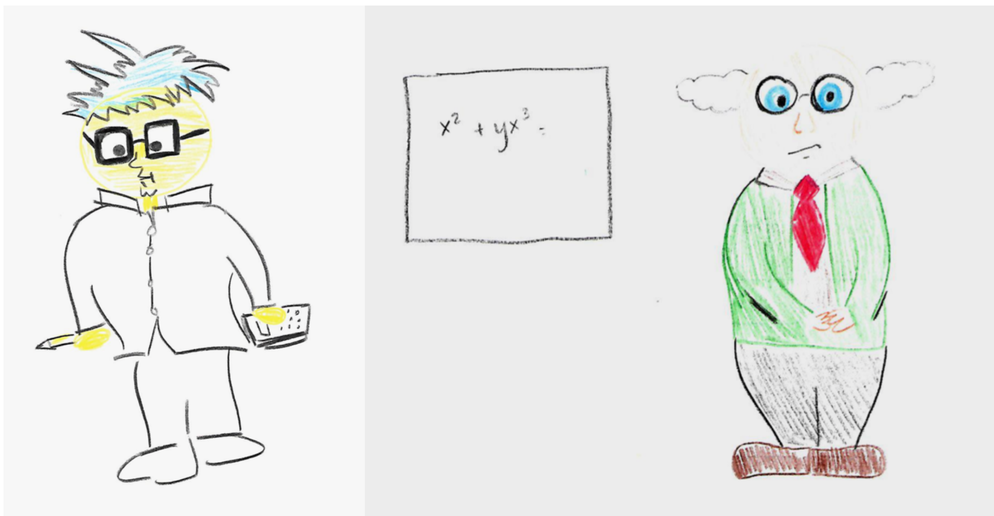

Figure 4: Other examples of student drawings.

In general, mathematicians were rarely drawn with accessories. The one major exception to this was the existence of glasses; 78 (45.1%) of the mathematicians drawn were shown wearing glasses. The next most popular accessory was a tie, which was found in 19 (11.0%) drawings of mathematicians. Furthermore, it is interesting to note that six of these 19 ties were bow ties. The two next most commonly found accessories were pocket protectors and hats, found in six drawings each. Also, worth noting is that three of the six hats drawn were top hats. Of the other three, two were baseball caps and one was a magician's hat. All other accessories that were found appeared in only one drawing, and included a bag, briefcase, name tag, jewelry, tattoo, and an apple.

Although Picker and Berry [32] found that mathematicians were often portrayed as angry, approximately two-thirds of our participants drew their mathematician smiling. Only two drawings appeared frowning and only one looked angry. In all of the other drawings, either the mathematician was speaking, had a straight face, or the mouth could not be seen, for example, because the mathematician was facing a chalkboard.

We also coded for the environment that the mathematician was situated in. Although many of the drawings were just of a person, not in any particular environment, 67 (38.7%) of the drawings included a chalkboard (or whiteboard), which insinuated that the mathematician was likely either in a classroom or an office. We only coded it as a classroom if the mathematician appeared to have students, which was only in 3.5% of the drawings. A desk was shown in only 2.9% of the drawings. Only one of the 173 drawings showed the mathematician outside. When considering the mathematical tools shown, a chalkboard (38.7%), a calculator (15.0%), and a pencil/pen (9.2%) were the most commonly drawn. Other tools included a pointer, paper/test, computer, books, and a ruler.

Mathematical equations frequently appeared in the students' drawings. Often the equations were not very complicated, and included basic arithmetic or an algebraic expression. While the majority of these equations appeared in expected places, such as on chalkboards, in thought/speech bubbles, on computer screens, and on paper, students also drew equations in more unusual places, such as floating in the air, on clothing, and on the mathematician's body (like a tattoo). These additions to the drawings could suggest an obsession of mathematics by the mathematician, which is a stereotype of mathematicians found by previous research [30, 14].

In addition to the prominence of equations, we also noted a theme of an affinity for mathematics within the drawings. Eleven (6.4%) of the drawings involved some sort of expression such as "I love math" or "Math is fun!". Five times it appeared on clothing, four times within a speech bubble, once in the air, and once as a tattoo. Once again, this could be interpreted as mathematicians being obsessed with mathematics.

In addition to the drawings, we also asked the participants to list five characteristics of mathematicians and five careers for mathematicians. Asking about characteristics allowed us to access any personality attributes students associate with mathematicians that cannot be represented within a drawing. When coding the characteristics, synonyms for the same word were grouped together to create a clearer picture. For example, the category "smart" includes all instances when a participant wrote one of the following words: smart, intelligent, genius, or knowledgeable. Table 7 provides our results for the ten most frequently mentioned characteristics.

We also have included how frequently each of these characteristics was written first in the list of five. We find this noteworthy because although "smart" was written 23.8% of the time, it appeared first on the list 69.0% of the time, meaning that it was the first characteristic listed by more than two-thirds of the participants.

Table 7: Student Listed Characteristics of Mathematicians.

Characteristics of Mathematicians		
Characteristic	**Total %**	**Listed First %**
Smart	23.8	69.0
Hard-working	11.6	4.0
Critical Thinker	5.5	3.5
Realistic	5.1	2.9
Precise	4.9	1.2
Number Oriented	4.8	2.9
Problem Solver	4.2	1.7
Loves Math	3.8	2.9
Innovative	3.0	0.0
Educated	2.7	4.0

Table 8 provides a summary of our results for the student listed careers for a mathematician, providing both the ten most frequently mentioned careers and how commonly each was written first. Unlike with the characteristics, we did not frequently group careers together. The only exception to this is that all types of engineers listed were coded simply as "engineer", except for "software engineer" which was coded as "computer programmer". We also chose to code both "teacher" and "professor" as the same category, out of necessity, since it was common for a student to write "teacher/professor" on the same line. As such, we determined that since many of the participants were interpreting these as the same profession, we needed to do the same within our codes. Furthermore, a similar phenomenon that occurred with the characteristics occurred with the careers as well. While teacher/professor was listed most frequently, at 29.7% of the time, this career was listed first by 63.0% of the participants, suggesting that a teacher/professor is the first career thought of for a mathematician by nearly two-thirds of our participants.

Table 8: Student Listed Careers of Mathematicians.

Careers of Mathematicians		
Career	**Total %**	**Listed First %**
Teacher/Professor	29.7	63.0
Accountant	12.5	10.3
Engineer	10.1	9.1
Statistician	5.4	6.7
Scientist	5.1	0.6
NASA/Astronomer	3.1	1.8
Computer Programmer	2.9	1.8
Researcher	2.6	0.6
Banker	2.5	0.0
Business	2.3	0.0

2.3. Discussion

Based on the findings from our survey, we noted some themes arise in our data. As was the case with the previous literature, the majority of our participants drew male mathematicians. This was especially true amongst the male participants. Furthermore, despite being given colored pencils, very few participants shaded their mathematicians' face. Although not shading their drawing does not necessarily mean that the participants were consciously suggesting that their mathematician was Caucasian, it is clear that very few students intentionally shaded their mathematician to imply that their mathematician was not Caucasian. While shading did occur slightly more often amongst students who identify as an ethnic/racial minority, this still was rare.

Previous research has found that when students are asked to "draw a person," they often draw someone of the same gender as themselves [3, 4, 12]. In another study, Räty and colleagues [33] asked students to draw a picture of an intelligent pupil and of an ordinary pupil. They found that 83.5% of the drawings by boys were of male figures and 91.7% of the drawings by girls were of female figures. Therefore, the fact that our female participants were more likely to draw male mathematicians than female mathematicians may suggest that the students in the study, at least the female students, envision mathematicians as men. The fact that our male participants predominately drew male mathematicians, however, is consistent with the results for the

"Draw-a-person" test, and therefore one could argue that these findings may not provide insight into male college students' gendered images of mathematicians. This demonstrates one drawback of the DAMT.

Similarly, previous research suggests that when asked to "draw a person," black children do not necessarily draw a black person [31, 37]. For example, using our coding classification, only 15 out of 157 (9.6%) of black children in Schofield's study drew a black person, which is similar to the numbers in our study for drawing a mathematician. Although these previous studies are old, and were done with young children, they demonstrate the potential need for further assessment beyond the DAMT when attempting to determine college students' racial images of mathematicians.

With regards to the other features frequently found in our drawings, we determined that no particular clothing style or hair style dominated the drawings. We did note that accessories were rare, in general, with the exception of glasses. The other more frequently drawn accessories were also ones that could be classified as "geeky" or "nerdy" such as bow ties, pocket protectors, and top hats. These results complement the work by Räty and colleagues [33] who found that when students were asked to draw a picture of an intelligent pupil and an ordinary pupil, the most notable distinction was that the intelligent pupil was typically pictured with glasses. Other features found more often in the drawings of the intelligent pupil was that they were often drawn more childish or with comical features and wearing less fashionable clothing. Therefore, the accessories found in the drawings of mathematicians could be symbols hinting at the intelligence of mathematicians.

Another stereotype found in the previous literature on mathematicians is their obsession with the subject [30, 14]. There were a number of features in the drawings which hint at this image as well. Students drew mathematicians with math-related tattoos and clothing. We also found mathematical equations and expressions, not only in places like chalkboards and speech bubbles, but also all over the page as if floating in air.

When considering the list of characteristics the students wrote, mathematicians' obsession with mathematics was less emphasized. The expression "loves math" or something equivalent appeared only 3.8% of the time. Some version of the word "smart," however, overshadowed the other characteristics by being cited more than twice as much as any other characteristic at 23.8% of the time, and was listed first 69% of the time. It is also important to note that the category for "hard-working" appeared second most often, but only 11.6% of the time. The fact that mathematicians are more frequently portrayed in our data as intrinsically smart as opposed to hard-working coincides with the perspective in North America and elsewhere that certain people are born with a "math brain" while others are not.

With regards to careers, our data demonstrate that students predominantly think of teachers or professors when they think of careers for a mathematician. Also, as has been noted by other scholars, students tend to confuse mathematicians with other careers, such as engineer, scientist, and computer programmer [22, 32].

Although our survey was able to assess many previously cited stereotypic images of mathematicians, as we have noted, there are some limitations to using the DAMT. We will now describe the second stage of this study, which was used to address some of these limitations.

3. Stage 2: Focus Group Interviews

3.1. Method

During the first stage of the study, we asked participants to mark whether they would be willing to participate in the second stage of the study. Sixty-three participants (48 females and 15 males) volunteered. We invited all 15 male volunteers and approximately half of the female volunteers to participate in the second stage of the study. The female volunteers that we invited were chosen randomly. Due to lack of response or scheduling conflicts, we ended up with a total of twelve students (three males and nine females) participating in the second stage of the study.

We conducted four focus group interviews, with between two to four participants per interview. Because we had substantially more female students participate in the focus groups, in the end we had three all-female focus groups (one which coincidently consisted of only honors students) and one mixed-gender group. During the focus group interviews, we presented the participants with 16 photos of real people that we downloaded from the internet and asked the participants to determine which individuals they believed were mathematicians and which were not, and to explain the reasoning for their choice. The participants were initially asked to do this independently and to record their thoughts in a table provided to them. After each participant independently recorded their decisions about each of the photos, we led a group discussion about what they had determined. The focus group interviews were both audio and video recorded and later transcribed.

Of the 16 photos provided, eight were of females and eight were of males. Four images were of racial minorities: an Asian male, an Asian female, an Indian male, and an African American female. We also made sure to include images that contained characteristics that are and are not traditionally associated with mathematicians, based on previous research. For example, the people in the photos represented a variety of ages and hairstyles, some were dressed professionally while others were more casual, seven of the 16 people were wearing glasses, and one of the men had tattoos covering his arms.

All four focus group interviews were conducted jointly by the second and third authors of this manuscript. The written work of the participants and the transcripts of the interviews were initially analyzed independently by each of the three authors and then were reviewed together as a team, to ensure all interpretations were carefully considered.

3.2. Findings

Each of the 16 photos was selected to be of a mathematician by at least one of the participants, but no photo was selected to be of a mathematician by more than nine participants. For our analysis, we chose to classify an image to be considered of a mathematician by our participants if more than half of our participants (at least seven out of the twelve) chose the image to be of a mathematician. Using this criterion, exactly half (8 of the 16 images) were considered to be of a mathematician. Of the eight considered to be mathematicians, four were of men and four were of women. In other words, the images of males and females were equally considered to be mathematicians by our participants.

Because only three of the twelve focus group participants were male, in general, we did not analyze the results by gender. However, since during the first phase of the study the female participants were much more likely to draw a female mathematician than the male participants, we wanted to check if the gender equal results in this portion of the study occurred because of the high proportion of female participants. When looking at the data, we found that this was not the case. It ends up that our female participants were much more likely than our male participants to choose an image to be of a mathematician (on average, the female participants selected eight of the 16 images to be of a mathematician while the male participants only chose five of the 16 images to be of a mathematician), however, when selecting who they thought was a mathematician, both genders selected an image of a female 47% of the time. Therefore, both our male and female participants were equally likely to select a mathematician to be female.

During the interviews, we asked the participants to both write, and later discuss, why they made the choices that they did with each of the images. The participants rarely brought up the topic of gender on their own and when we specifically asked about gender, most participants were quick to suggest that gender did not play a role in their decisions. However, a few participants did admit to using different criteria for men as they did for women. For example, one participant stated, "I feel like I had different expectations for each gender. Like, I expected girls to look like [Image] 11 and not [Image] 13; and guys to look like not [Image] 8 and more like [Image] 2." Looking at these images, the woman in Image 11 appears to be much older than the woman in Image 13, and she is dressed in a blazer while the woman in Image 13 appears to be wearing a formal dress. As for the men, the man in Image 8 has unkempt hair while the man in Image 2 is a young, professionally dressed, clean cut, Asian man. While the student was not completely clear with which features of each of these images she was referring to, it is clear that she recognized that she was using different criteria for different genders. Furthermore, her comment then led to a conversation about how women's business wear is different than women's formal wear, while men's business wear and formal wear tend to be quite similar, emphasizing the differences in society's expectations between men and women as well.

Even though the researchers had to solicit conversation about gender, our participants frequently brought up race on their own. For example, some participants wrote comments such as "racial stereotyping" or "he looks Indian and smart" as their reason for selecting certain images to be of mathematicians. This occurred for the images of both the Asian male and Asian female, and the Indian male. No comments about race were written for the image of the African American female, though she was selected to be a mathematician by eight of the twelve participants. One thing we found interesting was that the Indian male was only selected to be a mathematician by three of the twelve participants. One reason for this might be because we specifically chose a photo of an Indian male who was playing the drums, to put into conflict the racial stereotype of people from India being good at mathematics with the stereotype that mathematicians do not have hobbies or interests outside of mathematics [30]. While many participants said they considered that he might be a mathematician, they also commented that since he was playing the drums in the photo they determined he must be a musician instead. In the end, based on our criterion, the Asian male, Asian female, and African American female were all considered mathematicians by our participants, while the Indian male was not.

While gender and race seemed to play some role in these participants' decisions about the photos, they certainly were not the only criteria our participants used. Our participants frequently claimed they chose a photo to be of a mathematician because the person in the photo looked smart, nice, professional, or simply "had the look." In general, age and hairstyle did not seem to influence our participants. For example, two of the men with facial hair were selected to be mathematicians and the other two with facial hair were not. Furthermore, whether or not the person was wearing glasses also did not appear to affect their decisions either, as only three of the seven images of someone wearing glasses were considered to be of a mathematician by our participants.

Through our analysis, we were able to classify the criteria that appeared most influential to our participants into the following three categories: 1) how the person was dressed, 2) the backdrop of the photo, and 3) whether or not the person in the photo reminded them of someone they know. We will expand on each of these themes below.

What the individuals in the photos were wearing seemed very important to our participants. In order to be a mathematician, the individual needed to be "dressed professionally" but not be "too dressed up." If the individual was wearing a t-shirt or polo shirt, it was assumed that they were not a mathematician. One participant even commented about one of the photos, "If she was a mathematician, she would have cleaned up a little more." Yet, if they were wearing a formal dress or a sports coat, that also led our participants to assume that they were not a mathematician. For example, one photo was of a woman wearing make-up and what appears to be a sparkly blouse or dress, and our participants frequently argued that she looked like she was "on the red carpet" or "going on a date" and therefore was not a mathematician. Another participant surprised us by writing about one of the men in the photos, "Unless he has a second job, I doubt math would somehow gain a paycheck to allow him that nice of clothes."

The backdrop of the images also influenced our participants' decisions, yet how it influenced them was not consistent amongst all of the participants. For example, some participants assumed someone was a mathematician if they were standing in front of a bookcase, while other participants claimed that was the exact reason that the image was not of a mathematician. The one photo of an individual that was clearly in the science fiction section of a bookstore, however, was the least likely to be assumed a mathematician. Furthermore, one of the photos was of a woman who was camping and one was of a man playing the drums. Both of these were rarely selected to be of a mathematician, with the backdrop of the image often being provided as the reason.

Finally, one of the most cited reasons that participants gave for their determination of an image was whether or not the individual in the image reminded them of someone they know. If the image reminded them of a past mathematics teacher, then they assumed the image was of a mathematician. "[For number] 16, I said yes because he looks like a math teacher at my high school." If the image reminded them of a non-mathematician that they know, then they determined the image was not of a mathematician. "Number 7 literally looks like my librarian in the city library so that was a quick giveaway." This was not only the case with people that they know personally, but also if they thought the person in the photo looked like a famous person. For example, students commented that some of the people in the photos, to them, resembled Keith Urban, Hillary Clinton, Anne Hathaway, or Fred Rogers (from Mister Roger's Neighborhood), which also made them determine that the person in the picture must not be a mathematician.

Though we did not specifically ask the participants about careers for mathematicians or personality traits of mathematicians during the focus group interviews, throughout their discussions these topics frequently came up. Ten out of the twelve participants referred to mathematicians as teachers at some point during the interviews. In fact, one of the participants even stated, "I guess I don't really know exactly what a mathematician does, but I just picked people that look like teachers." All levels of teachers were referred to as mathematicians, ranging from elementary school teachers all the way through tenured professors. Very few other careers were mentioned for mathematicians. Two students referred to people working in information technology as mathematicians, and each of the following were mentioned by only one student: law, business, data entry, scientist, and researcher. Many careers were put in opposition to being a mathematician, but two that we found noteworthy were engineer and scientist. We found these noteworthy because during the first stage of the study, both engineer and scientist showed up in the top five careers mentioned for a mathematician.

Many personality traits and other descriptors were used when describing mathematicians. The most frequently mentioned, by far, was that mathematicians are smart. Some of the terms the students used were: studious, intelligent, intellectual, knowledgeable, wise, and educated. The participants also frequently referred to mathematicians as friendly and nice. These terms were often used when describing mathematicians as teachers. "She looks like the cool mom sort of math teacher. Like nice and fun." Some described mathematicians as relaxed, laidback, and calm, while others referred to them as serious, strict, and unapproachable. While some participants claimed that they saw mathematicians as "put together" and stylish, others described mathematicians as bland and "disorganized in an organized way." Some of the participants seemed to be thinking of specific past mathematics teachers when using these descriptors, but others were using their opinions about the field of mathematics to influence their opinions of mathematicians. "The clothing if it was bland, like all black or something like that, I was more inclined to say they were a mathematician When I think of math, I think bland." In response to this previous student, another student with a more positive view of mathematics shared:

> I keep hearing how they think math is bland. I think of it differently. I find joy in [mathematics] because I think of it like it's a game, like it's a puzzle. So then I take it from more of a game perspective than it's a chore. So I don't think that necessarily the happiness dictates to me whether they are a mathematician or not.

3.3. Discussion

Previous scholars have critiqued the "Draw a Scientist Test" and "Draw a Mathematician Test," questioning whether it truly accesses students' beliefs about scientists and mathematicians. Based on our findings from Stage 2 of the study, we were able to access some different beliefs about mathematicians than we found using the DAMT during Stage 1. From the students' drawings during Stage 1, a prototype for a mathematician would be a white male wearing glasses, standing in front of a chalkboard. He may have wild hair and be sporting a "nerdy" accessory, such as a bow tie or a pocket protector, but not necessarily. When considering our results from the focus group interviews in Stage 2, no prototype for a mathematician appeared. The eight images selected to be mathematicians by our participants represented males and females equally, included a variety of races and ages, and did not overwhelmingly wear glasses. These results seem to suggest that while college students may initially imagine a mathematician to be a "nerdy" white male, they realize that both men and women of all nationalities become mathematicians. As was suggested by Epstein *et al.* [14], when initially asked, students will generally draw a stereotypical prototype, but this does not necessarily imply that this is the only image that they have of a mathematician.

We were pleased to see that race, gender, and other physical traits did not appear to be strong influential characteristics in determining a mathematician, however, assumptions about the personalities of mathematicians seemed to be much more dominating. For example, two influential beliefs that we noted above were that mathematicians are always professional and that mathematicians do not have hobbies. Considering these two beliefs together, it appears that college students believe that a mathematician must be a mathematician at all times. This belief is similar to what has been found by past scholars that mathematicians are obsessed with mathematics [30, 14]. This may also be related to the belief that mathematicians do not have social lives. For example, one of our participants argued that a woman in one of our photos could not be a mathematician because she "looks like she's going out [for the evening]". In other words, college students seem to believe that mathematicians do not do anything other than mathematics.

The occasions that physical appearances seemed to be most influential to our participants is when the person in the photo reminded them of someone they know. We find this to be one of the most critical findings of our study in that it demonstrates the importance of having diversity within the field in order to motivate more diverse images of who is and who can become a mathematician. As students are exposed to more mathematicians and mathematics teachers who do not fit the stereotypical image, they are more likely to see others, including themselves, as viable candidates to become a mathematician.

Furthermore, some results from our study suggest that simply teaching students about stereotypes may influence students' perspectives. As previously mentioned, one of our focus groups unintentionally consisted entirely of honors students. The Honor Program at this particular university works diligently to facilitate acceptance and appreciation of individuals' differences. Because of this, we encountered unique responses from this focus group. In particular, the honors participants stated multiple times that if there were "no discerning factors" that led them to believe that the image was not of a mathematician, then they assumed that the image was of a mathematician. This is the opposite approach the members of the other three focus groups took. Furthermore, the honors students frequently questioned themselves whether or not they were making assumptions or being prejudice. We believe that these results suggest that when college students are exposed to coursework that discusses stereotypes and encourages them to learn about people different from themselves, they become more aware of their own biases and intentionally work to minimize their assumptions.

4. Summary and Implications

In this study, we set out to determine what stereotypic images college students hold of mathematicians, what careers they believe exist for mathematicians, and whether or not the research methodology would affect our results. We found that college students do tend to hold strong beliefs about mathematicians. Beliefs about their physical appearances dominated the results from the DAMT test while beliefs about their personalities seemed to be more commonly expressed during the focus group interviews. With regards to careers, students seemed to have a limited idea of what careers are available to mathematicians, mostly viewing them as teachers or professors. This was even more noticeable during the focus group interviews, in which being a teacher or professor was virtually the only careers mentioned.

In light of our results, we feel that there are two major implications of our work. The first is that our study demonstrates how the two different research methodologies were able to access different information and serve different purposes. When asking students to produce only one image of a mathematician or scientist, such as with the DAMT and DAST tests, it appears that individuals are more likely to provide a stereotypical image or prototype. In order to access a potentially broader, more encompassing perspective of how individuals view mathematicians or scientists in general, however, it appears that other research methods should be used instead of (or in addition to) the DAMT and DAST tests. As we demonstrated in this study, a photo analysis is one such methodology that appears to access a wider range of beliefs about mathematicians. Furthermore, a previously noted benefit of using the DAMT and DAST is that these tests can be used with young children who are pre-literate, however, the type of photo analysis that we conducted has the same benefit in that it can also be used with pre-literate children.

The second major implication of our work is that while students may no longer view a mathematician simply as an old white man, as research has suggested in the past, college students do have strong beliefs about who "fits the image" of a mathematician. Furthermore, this was often influenced by their previous exposure to mathematicians and mathematics teachers. Therefore, in order to allow for a more diverse image of a mathematician, one could suggest that we first need a more diverse workforce.

It has been noted, however, that the media can be quite influential in reshaping stereotypes as well. For example, Picker and Berry [32] noted that amongst the five countries in their study, they found the highest percentage of drawings of female mathematicians were made by their participants in the United Kingdom, and suggest that this was a result of the popular British television show, *Countdown*, that at the time featured a female mathematician. Therefore, diversifying the images of mathematicians within popular culture may also be an effective way to begin diversifying the image of a mathematician.

Previous research shows that altering stereotypes about a field can often alter an individual's interest in pursuing a career in the field [9]. For example, in one such study, Cheryan and colleagues found that women who read an article that stated that current computer science majors no longer fit the stereotype were significantly more likely to demonstrate interest in majoring in computer science than women who were given an article that stated that current computer science majors continue to fit the stereotype [10]. Therefore, changing the stereotype of what it means to be a mathematician may allow more students to develop a sense of belonging in mathematical careers.

Lewis and colleagues, however, argue that it may not be necessary to change societal stereotypes to encourage more students to develop a sense of belonging in STEM fields [23]. Rather, they found that exposing students to successful professionals in the field who do not embody traditional stereotypes allowed students in their study to realize that many individuals within the STEM fields do not identify with the stereotypical image. As such, these scholars suggest that steps can be taken in introductory college level STEM courses to encourage students to reject the belief that one needs to identify with stereotypical images in order to be successful in the field. Furthermore, we found that the honors students in our study who were enrolled in a program that teaches about stereotypes frequently questioned their own assumptions and biases when determining which images were of mathematicians. Therefore, while changing the stereotypical image of a mathematician may be a large undertaking, and out of the hands of many, research suggests that there are steps that parents and teachers can take to help students develop a sense of belonging to the field of mathematics.

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