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Abstract

Research in mentoring has shown that students may at times be more willing and able to absorb information that is delivered to them by their near-peers, rather than by traditional figures of authority, like teachers and professors. In this study, underrepresented minority high school students participated in an informal learning experience that was led by college students who were "near-peers" to the high schoolers. Students were engaged by participating in interactive MathShows, following a Math Social Media Campaign, and attending a summer Math Internship. Participants in the quantitative component of the study included N = 559 U.S. high schoolers who were from predominantly (>99%) Hispanic ethnic backgrounds. The qualitative component of the study involved another 19 students from the same school. The mixed methods study addresses associations between high schoolers' attitudes toward mathematics and their identity alignment, as well as classes of reasons that students gave for their identity alignment. Interactions with the college near-peers that occurred during the experiential learning intervention are also discussed. Results of this study address the goal of broadening participation of underrepresented student groups in STEM careers.

Introduction

This study investigates the impacts of a novel informal learning experience on the mathematical identity of high school participants. In the course of conducting mathematics community outreach work, the authors of this study stumbled upon an interesting – perhaps intuitive, yet investigation-worthy – result: high school students like to learn from college students that look like them more than they like to learn from older professors. This observation informed the design of a sequence of novel, informal learning experiences targeting high schoolers that features college students as the main personalities interacting with the high schoolers. The informal learning intervention, being empirically tested through this study, is aimed at broadening the participation of minorities and underrepresented groups in mathematics and science careers through improving and sustaining high school students' attitudes and interest in mathematics, as well as their academic choices toward mathematics and science.

Theoretical Framework and Context

The study draws on the body of research concerned with Identity in mathematics and uses a theory of near-peer mentoring that is based on Anderson's (2007) four-face model of identity. Figure 1 depicts the theoretical framework adopted for the study.

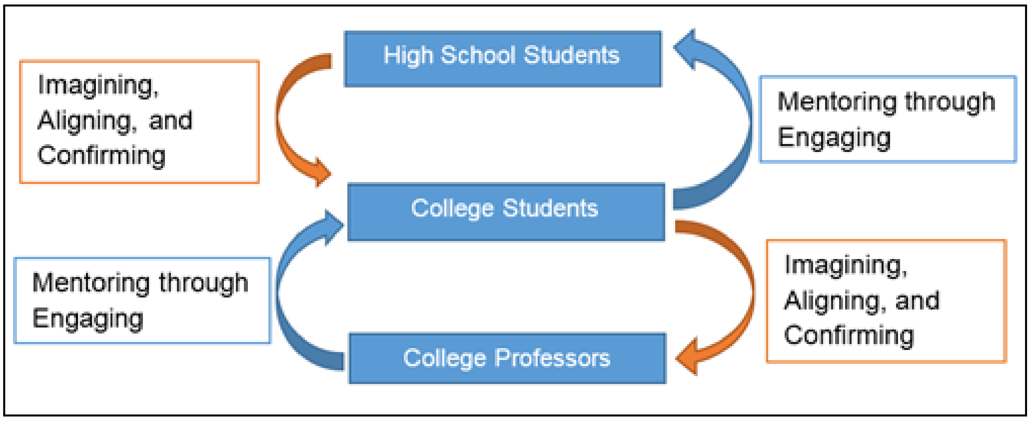

Figure 1. Near-peer Mathematical Mentoring Cycle (Wilson & Grigorian, 2019)

In this model, high school students Engage with their college near-peers around some mathematical activity. We define near-peer as a person to whom one feels a kind of similarity based upon any combination of age, gender, socio-linguistic factors, schooling level, or other shared experiences. The "Engagement" then connects with how students "Imagine" it to fit into their lives. After this comes a decision point when, either consciously or not entirely so, students "Align" themselves within the confines of the experience and especially in connection with others. The last "face" of Anderson's (2007) model is termed "Nature" and expresses students' long-term perceptions of their own mathematical ability. This paper presents results of the study that relate to students' imaginations (i.e., attitudes and perceptions) about mathematics and their alignment with other doers of mathematics as a result of participation in the informal learning intervention.

This study took place in the U.S.-Mexico borderland region with a large Hispanic population (> 90%) and having one of lowest national average incomes ($27,244/per Anum). Furthermore, according to the U.S. Census Bureau, the proportion of adults aged 25 and over with bachelor's degree or higher in this region ranges from 8.6% to 15.9%, compared to 28.8% in the U.S. generally. Consequently, the study is especially insightful for promoting interest and participation of typically underrepresented students in mathematics and STEM.

Review of Literature

Since we investigate mathematics learning that happens in informal outreach situations through structured interactions with older near-peers (college students), we draw in this paper on literature concerned with Mathematical Identity, and with Near-peer Mentoring and Experiential Learning.

Mathematical Identity

As students encounter mathematics by engagement with their peers, their teachers, and others around them in and out of school, they develop a sense of who they are in relation to mathematics. Danny Martin (2006) helps us to see how mathematics learning is a racialized experience for students and their parents. Further, Martin gives excellent examples of the construction of mathematics identities of minority students and a useful definition of mathematics identity: “dispositions and deeply held beliefs that individuals develop, within their overall self-concept, about their ability to participate and perform effectively in mathematical contexts and to use mathematics to change the conditions of their lives” (Martin, 2006, p. 206). Gresalfi & Hand (2019) then explain how students draw upon three classes of resources when constructing their own identities (and being defined by others). These include: a) norms that define opportunities for participation; b) frames that organize students’ understanding about situations and experiences; and c) larger narratives and stories (ideological, stereotypical or imagined) that help them to make sense of themselves with respect to mathematics. Identity construction occurs through the mechanisms of recognition (i.e., legitimizing) and positioning, which are closely related to the design of the informal near-peer intervention of this study.

Near-peer Mentoring and Experiential Learning

We also draw upon near-peer mentorship models that benefit underrepresented minority students (Trujillo et al., 2015). Students may at times be more willing and able to absorb information that is delivered to them by their near-peers, rather than by traditional figures of authority. Studies (Brownell & Swaner, 2010; Carrell & Sacerdote, 2013; Cracolice & Deming, 2001; Quitadamo et al., 2009; Williams, 2009) have shown that peer and near-peer led activities have a strongly positive impact on students. This study also embraces the components of Experiential Learning (Kolb, 1984) of mathematics, which theory posits that learning happens when the following components are present: concrete experience, reflective observation, abstract conceptualization and active experimentation. These processes imply that students play an active role by interacting in multiple ways with concepts and objects. The near-peer led activities are, by design, highly interactive and concrete.

Research Questions and Methods

This paper focuses on three research questions that are central to the larger ongoing study:

1. How are high school students’ attitudes toward mathematics related to the overall alignment of their identities with careers in mathematics and science?
2. How do high school students reason about the alignment of their identities with respect to mathematics and science?
3. How do high school students describe the near-peer college students who led the informal learning experience?

During this study, high school Geometry and Algebra II students participated in up to three kinds of informal learning experiences that were all led by college students: interactive MathShows, a Math Social Media campaign, and a Summer Math Internship. The study used a quasi-experimental and mixed-method design in which students were relegated into one of two treatment groups: the intervention arm which experienced all three components and the control arm that did not participate in any. This paper presents preliminary results from the following quantitative and qualitative components of the study.

To answer research question #1 a modified *Attitudes Toward Mathematics Inventory* (ATMI; Lim & Chapman, 2013) was used, composed of four theoretical subscales of attitudes toward mathematics: *Enjoyment, Motivation, Self-confidence,* and *Value.* Additionally, a series of experimental identity-alignment items such as the one given in Figure 2 were adapted from McDonald (2019). Note that the five levels of alignment on this scale are collapsed to three levels in parts of the subsequent analysis, as explained below. Data in this paper come from N = 559 participants.

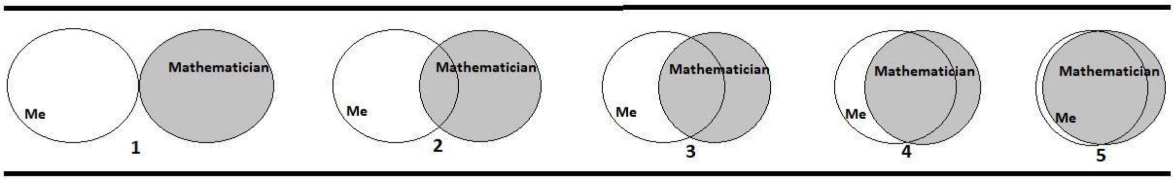

Figure 2. Survey Measure of Mathematician Identity Alignment

To understand the reasons for which students selected their alignment on the above scale (Research Question #2) as well as the interactions of high school students with college near-peers during the informal learning experiences (research question #3), semi-structured focus-group interviews were used. We then employed the qualitative method of *grounded theory* to analyze interview data and construct the theoretical explanation of students' attitudes and perceptions (Charmaz, 2010). Results from nineteen focus group participants are used for answering Research Question #2 and responses from two focus group participants, A1 and J1, are used for answering Research Question #3.

Results

Attitudes towards Mathematics and Identity Alignment

First, we look at ATMI scores and students' self-reported mathematician alignment. The distribution of ATMI scores is provided in Figure 3, panels (a) and (b). We found that ATMI scores were normally distributed with an average of 60.54 and a standard deviation of 10.82.

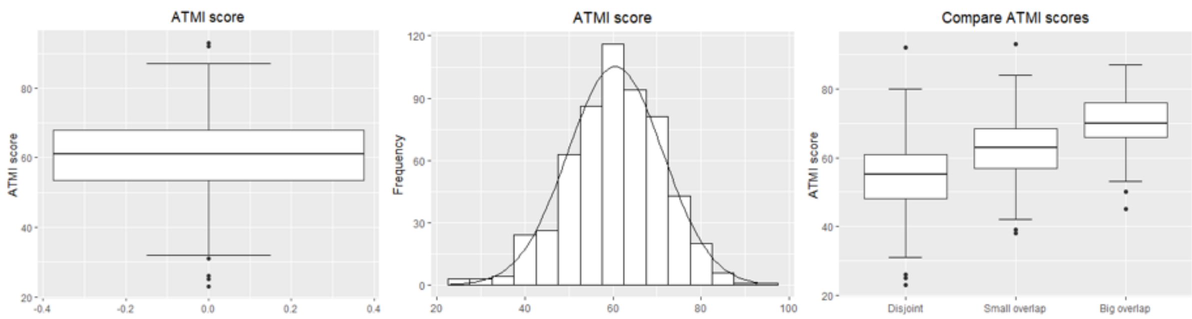

Figure 3. Distribution of ATMI Scores and Comparison with Identity Alignments

Panel (c) compares ATMI scores among three groupings identified in the 5-point Likert scaled mathematician alignment item (see Figure 2).

Table 1 displays the distribution of students' responses to the mathematician alignment item. For instance, there were only 22 (3.9%) students who chose the strong alignment option and 215 (38.5%) that were strongly not aligned (Disjoint) with being a mathematician.

Table 1. Distribution of Mathematician Alignments

	1	2	3	4	5
Mathematician Alignment	215 (38.5%)	158 (28.3%)	113 (20.2%)	51 (9.1%)	22 (3.9%)
	Disjoint	Small Overlap		Big Overlap	
	215 (38.5%)	271 (48.5%)		73 (13.1%)	

As mentioned above, the original five levels of this alignment scale were collapsed to three simpler levels for the analysis: no alignment at all (original disjoint level 1, 38.5% of respondents), small overlap with mathematician identity (original levels 2 and 3, 48.5%), and large overlap with mathematician identity (original levels 4 and 5, 13.1%). Further, we studied how students' ATMI scores differ among the three mathematician alignment groups. Table 2 lists the descriptive statistics of ATMI scores in the three groups.

Table 2. Descriptive Statistics of ATMI Scores

Overlap	N	Min	Mean	SD	Max	95% CI
Overall	559	23	60.52	10.87	93	(59.62, 61.42)
Disjoint	215	23	54.57	10.54	92	(53.16, 55.98)
Small overlap	271	38	62.67	8.83	93	(61.62, 63.72)
Big overlap	73	45	70.03	8.88	87	(67.99, 72.07)

Results from ANOVA ($F=85.11$, $df=(2, 556)$, $p<.001$) showed that there was a significant difference of the average ATMI scores among the three groups. The effect size of the ANOVA test was 0.23, which indicates that the mathematician alignments explained 23% of variation in ATMI scores. Post hoc comparison tests with Bonferroni correction were performed. All three group averages were significantly different from each other. As seen in Figure 3 panel (c) there was a clear ladder pattern from disjoint, to small, and then to big overlap groups. On average, students having a big overlap with the mathematician identity also scored 15 points higher on the ATMI scale than students claiming to be disjoint from mathematician.

Students' Reasons for Aligning with Mathematician and Scientist Identities

In addition to the Venn diagram mathematician alignment item given in Figure 2, we administered the same survey item yet substituting the role of scientist in place of mathematician. Quantitative analyses of students' responses to this item are omitted here since they were very similar to the mathematician alignment. However, the reasons that focus group students later gave for their alignment with mathematician versus scientist are of interest to this paper.

In this section we consider the reasons for which students in this case study sample aligned with the roles of *mathematician* and *scientist*. Data in this section come from responses given by 19 participants to the Venn diagram alignment items referenced above. Students selected the level of their own alignment using the Likert-scaled Venn diagram item, from 1 (no alignment) to 5 (total alignment) and explained their reasons for such selection. For these 19 focus group participants, alignment with role of *mathematician* ranged from 2 to 4.5 on the five-point scale with the average being 3.2. Alignment with the role of *scientist* ranged from 1 to 5, with an average of 2.6. The scores on both scales for this group may be seen as centering around the middle of the scale.

The main goal of this analysis is to understand *why* students made the choices of alignment that they did. Hence, we look at their verbal explanations. As illustrative and typical examples, here are the responses received from four participants with respect to the *mathematician* alignment item:

> <u>Participant A</u>: "*I'm a three or a four because I want to be in accounting… Yeah and I'm good at math. It's just like, if I don't, I never need to study much like in class I don't really pay attention though. But if I were to, I would be like a three or a four.*"
>
> <u>Participant B</u>: "*because it's like a good balance and like we use it for everyday lives… where I wanna with my professional life. So, a 3.*"
>
> <u>Participant C</u>: "*I'm a three too because, honestly, I'm not a big fan of math but I'll, I'll do it, like I try to do math and I have physics so I'm a three*."
>
> <u>Participant D</u>: "*A four because maybe one of my choices is to be a math teacher. And also I'm really good*."

Notice that Participants A, B, and D all made their decisions in part with reference to a *future career* that they were considering: accounting, professional life, and math teacher, respectively. Participant B also mentioned the *utility* of mathematics in our everyday lives. Participants A and D made specific reference to being "good at math", which was taken in this analysis as indicative of *self-confidence*. Participant C claimed to not be a big fan of math, yet was still willing to give the effort of doing math, especially since the student was also taking the math-intensive course of physics. In the analysis, this response was taken as indicative of a level of *interest* or *enjoyment* in math (low in this case) and also of the *necessity* of doing math.

Again, as illustrative and typical examples, the following are responses from the same four participants with respect to the *scientist* alignment item:

> <u>Participant A</u>: "*"A one.... I suck at science ...like I'm just not a fan of it."*
>
> <u>Participant B</u>: "*because uhm being that I wanna go into the medical field and the sciences, so I feel like 2 is a good answer. So, I have to have it.*"

Participant C: "*I would pick a five because I feel like there's more science than there is math, even though math, there is math involved in science but like yeah, I like science a lot. Biology really interests me.*"

Participant D: "*I'm really not like interested in science and also I'm not really good at science.*"

In these responses Participants A and D argued in part with reference to their *self-confidence*, saying that they "suck" or were "not really good" at science. They also both made reference to their level of *enjoyment* or *interest* in the subject, as indicated by their not being a "fan" of it or being "not like interested in science". As with the *mathematician* item above, Participant B again reasoned about aligning with this role with reference to a *future career*, mentioning more specifically this time the "medical field". The additional statement "I have to have it" was taken as indicative of the *necessity* of science to the participant. Participant C made the interesting observation that "there's more science than there is math", concluding with "*I like science a lot. Biology really interests me*". This response was coded as indicating *enjoyment* and *interest* in science.

Responses to these alignment items were analyzed using the grounded theory method through the three phases of summarizing, initial coding, and final coding. The focus was on categorizing the reasoning upon which students drew when aligning themselves with *mathematician* or *scientist*. Final category codes for reasons given in these items were the following:

SC = *self-confidence*
E-I = *enjoyment* or *interest*
TRAJ = *trajectory*
FC = *future career*
UT/NEC = *utility* or *necessity*

As seen in the example responses above, participants often referenced either their *self-confidence* (SC) toward the subject of math or science, their *enjoyment* or *interest* (E-I) in the subjects, or else a *future career* (FC) that they considered that would involve the subject. Other respondents reasoned about their alignment with specific reference to their past, current, or possible future performance in the subjects. Although related to self-confidence, the few participants that reasoned in this way appeared to align themselves with the role of *mathematician* by considering their own long-term mathematical *trajectory* (TRAJ).

Finally, some students mentioned how learning the subject would be particularly *useful* or *necessary*, which was coded as UT/NEC. As with the analysis of definitions above, since students frequently referenced multiple reasons for their alignment decision, multiple categories were allowed to apply to responses. Figure 4 displays the relative frequency with which codes were observed across all explanations for students' alignment with the roles of *mathematician* and *scientist*.

Figure 4 indicates that 12 out of the 19 interviewed students reasoned about alignment with the role of *mathematician* by considering their own mathematical *self-confidence*. This compares to 7 out of 19 students that used *self-confidence* to justify their alignment with the role of *scientist*. Only 2 out of 19 students reasoned about alignment with *mathematician* by referencing *enjoyment* or *interest* in the subject, whereas E-I was central for 16 explanations regarding *scientist* alignment.

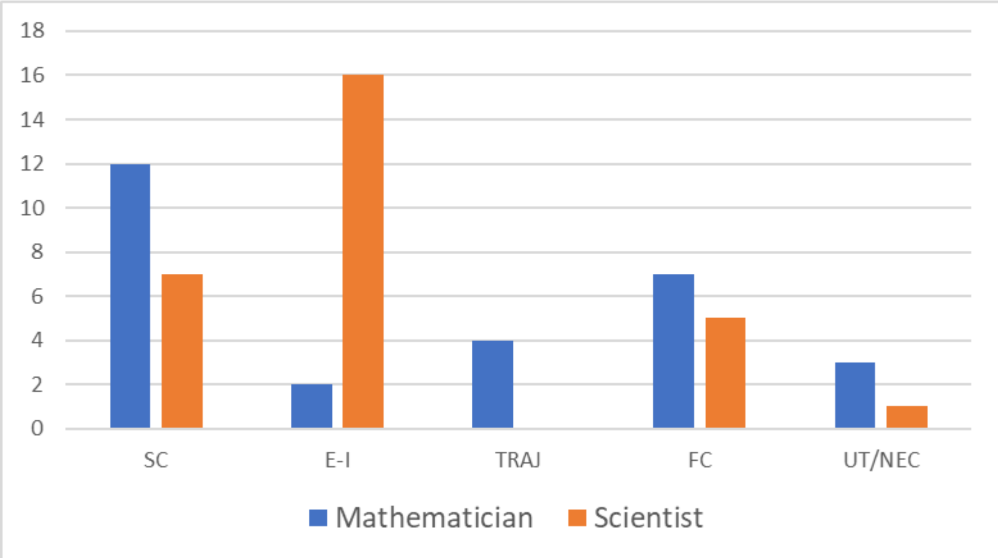

Figure 4. Relative Frequency of Reasons for Aligning with Mathematician and Scientist

Four students thought about their mathematical *trajectory*, while long-term *trajectory* was not considered at all by these students respecting *scientist* alignment. Similar numbers of students considered their alignment with *mathematician* or *scientist* roles in view of a future career that would involve these subjects, 7 for *mathematician* and 5 for *scientist*. A few students, 3 for *mathematician* and 1 other for *scientist*, aligned themselves with these roles by reasoning about the *utility* or *necessity* of knowing or using these subjects in school or in life generally.

Students' Descriptions of the College Near-Peer Presenters of MathShows

We finish this analysis by discussing qualitative findings related to the third research question. Preliminary results from two focus group participants, A1 and J1, indicate that having college students presenting the MathShows and coordinating the interactive activities during the shows positively impacted high school students. For instance, participant A1 mentioned that during the show she "was finally getting interested in math… I actually started paying more attention in math." The innovative nature of the near-peer approach was also surprising to the MathShows participants. For instance, participant A1 stated that "I didn't think there was going to be interesting stuff". Likewise, participant J1 mentioned "I thought it was just going to be like older people, you know, and like nobody of like close to our age range, but it was fun seeing other people involved in such activities… I thought it was going to be like adults like that they're trying to explain math to the kids like me doing regular class that's how I thought it was going to be". Participants also indicated that they were expecting to work with "charts, paper and nothing out of the ordinary … something plain and boring" (participant J1).

In addition, MathShows created opportunities for students to interact with near-peers in informal learning environments. We have observed that in comparison to traditional classroom environments, informal learning environments could provide more comfortable spaces for students to participate because, as stated by participant A1, students do not often participate because “les da pena [*they are shy*]” or because “a lot of people … they have social anxiety… and everybody's more of an introvert now”.

This study investigated the potential to interrupt high school students’ day-to-day mathematics learning in the classroom with a novel informal experience that depends on near-peer interactions. As Lichtenstein et al. (2007, 18) showed in the context of engineering education, “a single positive interaction, excitement about a course’s teaching and/or context…[can] cause a student to confirm his or her choice to stick with engineering”. We have shown above that students’ identity alignment with being a mathematician was related to their attitudes toward mathematics, and that students saw the college near-peer presenters in a positive light, as informal mentors, rather than teachers.

Near-peer mentorship has shown promise of greatly increasing students’ interest and engagement for pursuing STEM (Tenenbaum et al., 2014). An important finding of this study concerns the different reasons that students align themselves with the roles of mathematicians and scientists. Students’ interest and enjoyment, as well as self-confidence have been shown to be two of the main factors considered when students select their alignment with the roles of mathematician and scientist (Taskinen et al., 2013). In particular, in our sample we observed that students considered their own self-confidence most often when selecting their alignment with mathematics, whereas they more frequently considered their own interest and enjoyment when aligning with science.

Conclusion

Broader impacts of this finding, as well as our findings with respect to near-peer interactions, should be elaborated by further studies concerned with facilitating positive interactions between minority high school students and near-peer college students in the context of interesting mathematical activity. Since students from underrepresented minorities—especially Hispanics, which is presently the fastest growing ethnic group in the US—are the primary participants in this study, the study has special meaning for contributing strategies, methods, and results that are of interest to the goal of broadening their participation in STEM careers, thus supporting a more diverse and globally competitive STEM workforce.

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