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Recruiting Minority Students into STEM through Experiences in being a Teacher

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The Academy for Future Teachers (AFT) model has shown promise in preparing and inspiring underrepresented high school students to future science careers. Students were recruited into a 3-week summer program collaboratively taught by K-12 teachers and college professors. Our survey study looked into the nature of their participation in the program and how this participation influenced their a) outlook on teachers, teaching, and learning, b) attitudes in science and mathematics, and c) understanding of science and mathematics content. The AFT experience allowed students to develop greater understanding about science and mathematics teachers, teaching, and learning and the nature of science and mathematics. Results indicate that the AFT program provides students with important experiences that have implications for their future choice of a STEM career.

Introduction

Our study was carried out to examine how a group of African American high school students' participation in a three-week intensive and immersive summer STEM teacher education program called the Academy for Future Teachers (AFT) influenced their *a) outlook on teachers, teaching, and learning, b) attitudes in science and mathematics, and c) understanding of science and mathematics content.* African American students' academic achievement, especially in science and mathematics, lags far behind the White population and most other groups in the United States. This also has a domino effect of having African Americans underrepresented in STEM professions. The reasons for African American students' disengagement and underachievement in science and mathematics are many. Various scholars have also provided recommendations to mitigate these trends. The AFT program, including student experiences, was designed mindfully with knowledge of these recommendations. The underlying focus of the AFT program was to develop a sense of self-efficacy and agency in the students so that they are able to confidently pave an appropriate pathway toward a STEM (or even a non-STEM) career that empowers and enables them to become active, critical, and discerning participants of a democratic society.

Theoretical Framework

The theoretical framework underpinning this work centres upon the idea of identity of individuals from minority populations. Identity has been found to be a key component in programs with goals to recruit future teachers from underrepresented groups (Barton & Tan, 2010). Learning can be seen as knowledge and experiences that are built through social processes and interactions with shared experience that can give people a "sense of self and meaning" (Boaler, William, & Zevenbergen, 2000) that are central to one's identity. Part of the inspiration necessary in recruiting minorities into STEM fields is the importance of focusing upon the role of identity within the individuals. Phinney (2005) contends that ethnic minorities find that having affiliation with an ethnic group identity is essential in providing positive psychological wellness. Additionally, Bandura (2002) believed that individual agency played a role in the cultural and cross-cultural differences in efficacy and knowledge. Ethnic identity is a complex and multifaceted construct which is typically described as an individual's ideas and attitudes pertaining to his or her own ethnic group membership. The multifaceted construct includes ethnic consciousness, subconscious beliefs, ethnic identity formation, ethnic identification, language, and self-esteem. The AFT program provides a way to develop students' identity as they begin to think of themselves as teachers, mathematicians, and scientists.

Methodology

Research Context

In the three-week AFT program, participants in cohorts took part in three unique experiences, each lasting a week. The three unique experiences emphasized mathematics and science content and pedagogy in, i) elementary

science and mathematics, ii) secondary and middle school science, and iii) secondary and middle school mathematics. A team of three individuals, comprising of an experienced K-12 schoolteacher, an experienced STEM education faculty member, and a team leader facilitated each of the three experiences. Data was collected within the AFT program; a three-week long intensive and immersive STEM summer teacher education program intended to empower underrepresented minority high school students by providing them necessary experiences to critically examine possible STEM and STEM education career pathways. To this end, the program offered its participants authentic, engaging, and meaningful experiences to develop their understanding of the nature of science and science learning and teaching, nature of mathematics and mathematics learning and teaching, and conceptual understanding in science and mathematics.

AFT Program Participants

To participate in the AFT program, underrepresented minority students from the metro area high schools were invited to apply into the program through information flyers, brochures, and applications kits sent to the schools. In addition to completing the standard application form, students were required to have a minimum GPA of 2.5, submit a brief narrative on why they wanted to be part of the AFT program, and submit two letters of recommendation from their teachers. A total of 52 students were recruited to participate in the program. We excluded participants who were not able to complete both the pre and post surveys. Of the 42 participants taking part in the research, seven were males. In addition, thirty-six participants were African-American, five were Asian, and one was Hispanic. The participants' ages ranged from 15 to 17 years, with most participants being 16 years of age and rising seniors (going into 12^{th} grade) in their school.

Data Collection and Analysis

Students' application forms to the AFT program were used to gather demographic and academic information such as race, gender, age, school, grade level, and GPA. The students also completed a pre/post AFT experience science and mathematics attitudes (SAM) survey. The SAM survey is a four-level forced response 60-item (30 science and 30 mathematics) Likert survey that inquired about students' attitudes, motivations, identity, and future intentions in science and mathematics. In order to gauge students' learning of select science and mathematics concepts after their experience in the AFT program, a pre/post content assessment was also administered.

Results And Discussion

Students' Notions of STEM Teachers, Teaching and Learning

The pre/post SAM survey enabled us to examine any changes in students' ideas about science and mathematics education as a result of the AFT program. In addition the survey also allowed us to understand students' general notions of science and mathematics. There were six items (three in science and three in mathematics) in the SAM survey that related to students' notions about their science and mathematics teachers. These are presented in Table 1 below. The survey was scored using the following convention: strongly agree = 4, agree = 3, disagree = 2, strongly disagree = 1.

Item	Mean*	Standard Deviation
Teachers encourage me to do well in mathematics	3.48	0.505
Teachers encourage me to do well in science	3.24	0.821
Teachers encourage me to take as many courses as I can in mathematics	3.07	0.778
Teachers encourage me to take as many courses as I can in science	3.10	0.821
Teachers think I am the kind of person who could do well in mathematics	3.17	0.696
Teachers think I am the kind of person who could do well in science	3.21	0.645

Table 1. Students' Notions of their STEM Teachers, *n=42

The results indicated that students felt that their teachers largely support their science and mathematics learning and achievement in the schools. Students reported their teachers encourage them to do well in science and mathematics. Teacher encouragement and other adult and peer encouragement is an important factor contributing to students' participation in science and mathematics. The mean scores of 3.24 and 3.48 from a maximum possible score of 4 for science and mathematics encouragement respectively are relatively high. Students acknowledged that there is encouragement from teachers to do well. The survey also revealed that teachers encourage students to take many courses in science and mathematics. As students take more courses in science and mathematics there's greater potential for shift toward more positive attitudes about science and mathematics (Brotman & Moore, 2008). Students also felt that their teachers thought that they could do well in science and mathematics. To the students, what others, especially caregivers including teachers and parents think of them and how they support and encourage them play a key role in their academic motivation and confidence. Keeves (1975) initially formalized the idea that students' academic attitudes and achievement are influenced by attitudes and expectations of parents, teachers, and peers. Research by Hatchell (1998) and others have found students' views of teacher encouragement in science and mathematics to have a strong relationship to students' attitudes and motivations toward these disciplines. Stake's (2006) study also provided strong evidence that social factors such as parents, teachers, and peers play an important role in the development of students' motivation and confidence to achievement in science and mathematics.

In Table 2 below and the paragraph following it we discuss some of the quantitative results that we obtained about students notions of STEM teaching. Five SAM survey items related to students' notions of teaching.

Item	Mean*	Standard Deviation
Teaching mathematics requires good knowledge of the content material	3.60	0.544
Teaching science requires good knowledge of the content material	3.55	0.550
Teaching is an easy career	1.69	0.715
I expect taking advanced courses in mathematics will be helpful to me in teaching	2.95	0.909
I expect taking advanced courses in science will be helpful to me in teaching	2.95	1.011

Table 2. Students' Notions of STEM Teaching, *n=42

Certain student notions of STEM teaching were revealed through the analysis of the SAM survey (Table 2). Students largely acknowledged that teaching science and mathematics required good knowledge of the content material. This also matched with their idea that taking advanced courses in science and mathematics will be helpful in teaching. Darling-Hammond (2009) also emphasizes the importance of teachers having appropriate subject matter knowledge. Numerous studies show that how teachers are prepared and their knowledge of the subject matter has an influence on student achievement even after teacher and student demographic, including socioeconomic, characteristics are controlled (Wayne & Youngs, 2003). Results of the SAM survey also revealed that students did not think teaching was an easy career (mean = 1.69). It is also important to note that prior to the AFT program, students' notion that teaching was an easy career had a mean of 2.14 with a standard deviation of 0.977. T-test revealed (see Table 3) that the difference between the means was significant, suggesting that students' AFT participation enabled them to have better understanding of what it requires to become a science or mathematics teacher and to teach science and mathematics. It should be noted that our threshold for statistical significance was set at $p < 0.05$.

Item	Pre Score	Post Score	Standard Deviation	T-statistic	p-value
Teaching is easy	2.14	1.69	1.041	2.817	0.007

Table 3. T-Statistic for Teaching is an Easy Career, n=42

Using Table 4 below we discuss some of the quantitative results that we obtained for students' notions of science and mathematics learning. Sixteen items, eight in science and eight in mathematics related to students' views of learning. Students in the survey (see Table 4 above) reported that they are confident in doing science and mathematics and they have the ability to do AP (Advanced Placement) science and mathematics courses. In

comparing the pre/post SAM survey results, it was found that there was a statistically significant increase (from 3.05 to 3.26; p=0.027) in students' confidence in their ability to do mathematics after their AFT experience (see Table 5). Their confidence is also matched with their self-report that they earn good grades in science and mathematics courses. Students' confidence in science and mathematics is also attuned with their ideas on whether learning science and mathematics required special abilities that only some people possessed. We noticed a statistically significant shift in their ideas about needing special abilities to do science (from 2.40 to 2.10; p=0.026) and mathematics (from 2.43 to 2.07; p=0.009) from pre to post AFT experience (Table 5). In the post SAM survey, students believed less strongly in the notion that one requires special abilities to do science and mathematics. There was also a statistically significant shift in how students perceived the difficulty in learning science after their AFT experience. Prior to AFT experience, students rated 'science is hard for me' 3.00. However, after their AFT experience the mean rating decreased to 2.67. This shift (p=0.029) indicates that students perceived science to be less difficult. It is asserted here that the role of the AFT program to impart confidence and empower students to pursue science and mathematics courses and later STEM careers is significant. Several studies report that students' self-confidence is one of the key factors that determine future success. Based on Bandura's (2002) social cognitive theory which describes how individuals exercise personal agency for career development, Lent, Brown, & Hackett (1994) state that students' career interests, STEM related or otherwise, are based on their self-efficacy beliefs, and these beliefs affect career choice and actions.

Item	**Mean***	**Standard Deviation**
I am sure of myself when I do mathematics	3.26	0.665
I am sure of myself when I do science	3.07	0.808
I think I could do Advanced Placement (AP) mathematics	3.07	1.022
I think I could do Advanced Placement (AP) science	2.98	1.047
I can draw upon a wide variety of math techniques to solve a particular problem	3.05	0.764
I can draw upon a wide variety of scientific techniques to solve a particular problem	2.79	0.750
I get good grades in mathematics	3.14	0.751
I get good grades in science	3.36	0.533
I enjoy being in mathematics class more than any other class in school	2.43	0.914
I enjoy being in science class more than any other class in school	2.55	0.993
Learning mathematics requires special abilities that only some people possess	2.07	0.867
Learning science requires special abilities that only some people possess	2.10	0.850
Mathematics is hard for me	2.81	1.065
Science is hard for me	2.67	1.141
Most subjects I can handle, but I just can't do a good job with mathematics	3.10	0.932
Most subjects I can handle, but I just can't do a good job with science	2.95	0.825

Table 4. Students' Notions of Science and Mathematics Learning, *n=42

Item	Pre Score	Post Score	Standard Deviation	T-statistic	*p*-value
I am sure of myself when I do mathematics	3.05	3.26	0.606	-2.291	0.027
Learning mathematics requires special abilities that only some people possess	2.43	2.07	0.850	2.722	0.009
Learning science requires special abilities that only some people possess	2.40	2.10	0.869	2.308	0.026
Science is hard for me	3.00	2.67	0.954	2.264	0.029

Table 5. T-Statistic for Students' Notions of Learning, n=42

While the survey revealed that the AFT students have relatively high confidence in their ability to do science and mathematics, their enjoyment of science and mathematics courses compared to other courses that they take in school was reported to be average. Research based on data collected from the Program for International Student Assessment (PISA) (OECD, 2007) shows that students' reported enjoyment in science predicted their future science engagement. This also falls in line with Dewey's assertion that activities that are 'playful' and 'serious' are most appropriate for learning. Ainley & Ainley (2010) contend that experiences that "generate enjoyment and focused attention" are important requirements for authentic and impactful learning (p. 5). Ainley & Ainley's idea of 'enjoyment' and 'attention' can also be thought of as enjoyment and engagement. We feel that the terms 'enjoyment' and 'engagement' must be treated differently, in the sense that one can be engaged in doing science while not enjoying the experience.

Students' Attitudes in Science and Mathematics

In order to see if there was a general attitude shift in the way students think about science and mathematics we combined survey items that specifically related to science and mathematics attitudes and calculated an aggregate score for attitude pre and post AFT experience. The maximum possible score that could be obtained in the aggregate was 24. T-test on the pre/post AFT scores revealed that there was a statistically significant change in science attitudes ($p<0.001$), but no statistically significant change in mathematics attitude. Positive notions about science increased from a pre score of 14.26 to 17.26 in the post survey. Positive notions of mathematics changed from a pre score of 17.93 to a post score of 18.24. We suggest that the reason that there was not a significant increase in mathematics attitudes is because of ceiling effect. Students' scores were relatively high for attitudes in mathematics in the pre AFT survey, thus they had little room to increase their already high scores.

Using Table 6 below and the paragraph following it we discuss students' specific attitudes in science and mathematics. Sixteen survey items, eight from science and eight from mathematics, related to student attitudes in science and mathematics. The post SAM survey confirmed our assertion that AFT students' high affinity for science (3.10) and mathematics (3.12). This was somewhat expected as students voluntarily apply into the AFT program. knowing that the program focuses on developing their science and mathematics capacities Students also largely agreed on the inherent and potential value of science and mathematics. Students indicated that knowing science and mathematics is an important life skill necessary for both genders. They also did not believe that gender played a role in science or mathematics achievement or performance. While students indicated that knowing and doing well in science and mathematics will help them earn a living and is important for their future (score >3), they also indicated that they do not see themselves using science or mathematics after high school graduation (score > 3). This dichotomy in the perceived value of science and mathematics and students' assumed future usage of science and mathematics is intriguing to us, and we're continuing to seek rational explanations to this.

Item	Mean*	Standard Deviation
I like mathematics	3.12	0.772
I like science	3.10	0.790
Mathematics is an important life skill	3.52	0.634

Item	Mean*	Standard Deviation
Science is an important life skill	3.33	0.786
Males are naturally better than females in mathematics	1.55	0.670
Males are naturally better than females in science	1.52	0.594
Studying mathematics is just as necessary for women as it is for men	3.57	0.703
Studying science is just as necessary for women as it is for men	3.57	0.703
Knowing mathematics will help me earn a living	3.40	0.665
Knowing science will help me earn a living	3.14	0.843
I see mathematics as something I won't use very often when I get out of high school	3.38	0.731
I see science as something I won't use very often when I get out of high school	3.21	0.750
Doing well in mathematics is important for my future	3.26	0.767
Doing well in science is important for my future	3.24	0.821
Math courses will be very helpful to me no matter what I decide to study in future	3.31	0.780
Science courses will be very helpful to me no matter what I decide to study in future	3.17	0.881

Table 6. Student Attitudes in Science and Mathematics, *n=42

The impact of the AFT program is also evidenced in the pre/post analysis of students' attitudes in science and mathematics (see Table 7 below). Pre AFT program, students largely believed that mathematics was not an important life skill (1.40). However, post AFT survey revealed a relatively drastic (mean difference 2.119) shift in this belief (3.52), which was statistically significant at $p<0.000$. Similarly, students' view that science is important for their future showed a statistically significant shift post AFT experience. Students' high attitude toward science and mathematics, and the shift of certain attitudes to even higher scores post AFT is significant and encouraging. While students' high attitude in science and mathematics are associated with high academic achievement and higher probability of future STEM career, many students often develop negative attitudes toward science and mathematics as they progress through the grades. Several researchers have reported that positive attitude toward science and mathematics is linked to students' personal experience in and their perceptions of the importance of science and mathematics. Students' science and mathematics experiences within the AFT program enabled them to experience science and mathematics at a personal and intimate level, thus allowing for the development increased positive attitudes in science and mathematics.

Item	Pre Score	Post Score	Standard Deviation	T-statistic	***p*-value**
Mathematics is an important life skill	1.40	3.52	1.152	-11.922	<0.000
Doing well in science is important for my future	2.88	3.24	0.958	-2.416	0.020

Table 7. T-statistic for Students Attitude in Science and Mathematics, n=42

Students Understanding of Science and Mathematics Content

Since the AFT program required students to teach science and mathematics content to middle grade and elementary students through reform-based practices, the AFT students became engaged in learning science and mathematics content. They also experienced science and mathematics content through authentic and engaging reform-based practices. Analysis of students' pre and post content assessments in science and mathematics revealed that they scored significantly higher ($p<0.002$) in the post assessment. In the science assessment, 89% of students showed improvement from pre to post assessment. Similarly, in mathematics 91% of students showed

improvement in their post assessment. We agree with the notion that improvement from pre to post content assessment would be expected and not terribly surprising. However we also note that from our current and past experiences in the schools and through examining preservice and inservice teachers' pre and post assessments of their students, we know that improvement from pre to post assessment in science and mathematics is normally observed in about 55 to 75% of the students. In the AFT program, approximately 90% of the students showed improvement in content. This significant improvement in science and mathematics content knowledge is indicative of high student disciplinary (science and mathematics) engagement within the AFT program.

Conclusion

Strong encouragement from individuals who are familiar to the students is an important factor influencing their engagement is science and can counter pressures from peers who are not supportive of academic success. Encouragement also has the potential to influence students to take more courses in science and mathematics. When this happens, students' attitudes about science and mathematics increasingly become positive and they come to have greater understanding of the epistemology of science and mathematics. They came to know some of the intricacies involved in teaching science and mathematics and the importance of having appropriate content, pedagogical, and pedagogical content knowledge. They came to know these intricacies through their immersive experience in the AFT program, where they participated in various authentic and contextualized encounters with subject matter and pedagogy. Students' participation in the AFT program also allowed them to become more confident about their abilities to do science and mathematics and have better understanding of the nature of science and mathematics.

We assert that the role of the AFT program to build confidence and empower students is significant. We also assert it is equally important that learning experiences be engaging and enjoyable. As a result of the AFT experience students had more positive attitudes about science. The design and the implementation of the AFT program enabled the students to show higher gains in pre/post assessment of content as compared to gains experienced in the schools. Through the AFT experience students developed greater understanding about science and mathematics teachers, teaching, and learning and the nature of science and mathematics in near authentic contexts. These gains in understanding contribute to the development of self-efficacy and agency, resulting in an identity shift that empowers and enables African American students to increase their STEM educational and career aspirations.

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