PROJECT REPORT

Cultivating STEM Identity and Belonging through Civic Engagement:

Increasing Student Success (Self-efficacy and Persistence) for the Two-year College STEM Student

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Abstract

Retention efforts in STEM have become a priority of colleges and universities. Two-year college STEM students are particularly affected by factors that contribute to low retention and persistence. To address STEM retention problems, a student support program was developed through National Science Foundation funding to support STEM student success. The program sought to enhance STEM identity, thereby increasing persistence. Participants were required to engage in STEM civic engagement, using their STEM knowledge and skills for community betterment. This study sought to examine the effects of these activities on students' STEM identity and ultimate persistence. Data were collected over years from participant surveys and interviews. We found that students had cultivated a sense of STEM identity, and that graduation and transfer rates increased as a result of their increased civic engagement. Students who engage in their community develop cultural competency, communication skills, and critical thinking ability and have opportunities to apply their knowledge.

Introduction

The Role of Two- year Colleges in STEM Education

Two-year colleges are an often overlooked but essential component in the pathway to Science, Technology, Engineering, and Mathematics (STEM) higher education (National Academies of Sciences, Engineering, and Medicine [NASEM] 2016; National Research Council [NRC] 2012). They play a unique role in STEM education, enrolling nearly half of the nation's undergraduate students (American Association of Community Colleges [AACC] 2014). Community colleges in the United States enroll more than eight million students annually, including 43% of U.S. undergraduates (AACC 2011; Mullin 2012). Approximately 50% of all college students who eventually earn bachelor's degrees in STEM begin their undergraduate education at two-year colleges (Tsapogas 2004; Starobin & Laanan 2010), and 20% of students who were awarded science and engineering doctoral degrees earned credits at a two-year college at some point in their academic careers (Chen 2013).

Community colleges provide a diverse student body (people of color, women, older students, veterans, international students, first-generation college students, low-income students, and working parents) with access to higher education. According to the American Association of Community Colleges, 52% percent of Hispanic students, 44% of African American students, 55% of Native American students, and 45% of Asian-Pacific Islander students attend two-year colleges (AACC 2011). Additional reports (Provasnik & Planty 2008) show the median age of two-year college students is 24, with 35% of the student population 30 or older. Further data show that 20% of two-year college students are married with children, and an additional 15% are single parents (Provasnik & Planty 2008; Li 2007). Almost half of college-going students attend community colleges at some point in their academic careers; low-income, first generation, and under-represented minority students are more likely to enroll in two-year institutions (NASEM 2016).

Two-year colleges attract many students by providing affordable tuition, flexible scheduling, small class sizes, and access to faculty. These institutional attributes accommodate those two-year college students who take a nonlinear path to degree completion due to family and work obligations (Pérez & Ceja 2009). On account of the rich diversity of their student population, two-year colleges have the potential to increase participation of non-traditional and underrepresented students in STEM.

Retention and Persistence for Community College STEM Students

Retention and persistence of all STEM students continue to be of significant concern as data reveal that more than half of freshman who initially declare STEM majors leave these fields before graduation (President's Council of Advisors for Science and Technology [PCAST] 2012; Chen 2009; Chen 2013). Among all students who declared their intentions to pursue STEM majors, only 43% were still in a STEM major at the time of their last enrollment, with the others all transitioning to other majors. Even more problematic, only 7.3% of STEM students who began at a two-year college received a STEM bachelor's degree after six years, compared with 45% of students who started in a four-year program (Chen 2013).

Factors influencing retention and persistence in STEM majors are diverse and often interconnected. Leading reasons for low STEM retention and persistence at both the two-year and four-year colleges are uninspiring introductory courses, lack of math preparation, and an academic culture not welcoming of women, minorities, and non-traditional students (PCAST 2012; Seymour and Hewett 2000; Griffith 2010; Huang, Taddese, & Walter 2000). Additionally, STEM students at the two-year college are affected by external circumstances such as work and family obligations and have fewer economic and social resources and fewer STEM role models than their four-year traditional student counterparts. For the two-year college STEM student, these external circumstances coupled with an unwelcoming STEM culture undermine their sense of identity, belonging, and self-efficacy, which are critical to their STEM retention and persistence.

The Culture of STEM

The explicit and implicit customs, behaviors, and values that are normative within STEM education make up the culture of STEM (NRC 2009). An examination of the culture of STEM education is important because the social, psychological, and structural dimensions of STEM education in two-year and four-year colleges influence student identity, belonging, self-efficacy, and encouragement. The experiences students gather during their

interactions with the "STEM culture" of the department or institution drive student awareness and understanding of program standards, academic expectations, STEM identity, and their sense of belonging in the program. More importantly, student experiences within the STEM culture and the encouragement or lack thereof can have a profound impact on the student's self-efficacy and desire to persist (Cabrera et al. 1999; Eccles, Wigfield, & Schiefele 1998; Reid & Radhakrishnan 2003; Pérez, Cromley, & Kaplan 2014).

Identity/Belongingness, Encouragement, and Self-efficacy

Self-perceptions regarding academic competence are framed by personal and collective identities. Each student has many such identities—racial, ethnic, socioeconomic, professional, sexual/gender, and family. These identities are framed by upbringing, experiences, and society at large and can shift across time either unconsciously or through deliberate effort (Good 2012). Students' positive identification with their discipline can enhance academic engagement and belongingness and prove to be a great source of encouragement. However, more commonly the obverse is true, especially for non-traditional and underrepresented STEM students. These students often experience challenges such as isolation, invisibility, discrimination, and a sense of not belonging and disconnectedness from external social and cultural networks (Ong 2001; NRC 2012).

Belonging to valued social groups is a fundamental human need; a sense of inclusion is particularly important for underrepresented groups in STEM when stereotypes imply that they might be unsuited to certain settings, such as rigorous academic classes (Baumeister & Leary 1995; Dovidio, Major, & Crocker 2000; Walton & Cohen 2007; Cohen & Steele 2002). Feeling a sense of belonging and acceptance by others in STEM (faculty and peers) is crucial to retention and persistence for these STEM students (Johnson 2012; Palmer, Maramba, & Dancy 2011).

Stereotypical ideas about what constitute appropriate fields of study for two-year college students or comments regarding academic preparedness/achievement in math and science can serve as critical barriers to retention and persistence. According to Starobin & Laanan (2008), even when these students possess a strong math or science background, they often receive little encouragement or support from faculty. Creating a sense of encouragement and a support system for two-year college STEM students is paramount to increasing retention and persistence. Studies show non-traditional and underrepresented minorities need proactive personal encouragement and positive media messages to counteract the status quo "culture of STEM" (Hanover Research, 2014). Programs and activities that facilitate healthy positive relationships and offer encouragement among peers and from faculty promote student engagement and feelings of belonging.

Academic self-efficacy is commonly defined as the belief in one's capabilities to achieve a goal or an outcome using one's skills under certain circumstances, and that performance and motivation are determined by how effective people believe they can be. (Snyder & Lopez 2007; Bandura 1982). More specifically, for many two-year STEM students, academic self-efficacy is entangled with STEM identity as it refers to the belief or conviction that they can successfully obtain a STEM degree (Marra et al. 2009).

A major source of academic self-efficacy is simply having the raw knowledge, skills, and experience required to successfully reach a goal or to complete a task; this source of efficacy is commonly referred to as mastery experience (Bandura 1997). In the context of two-year STEM students, this means having a positive experience in completing a STEM task, specific course, and/or obtaining an associate's degree.

STEM Civic Engagement through Peer Tutoring

STEM civic engagement covers a wide array of activities and learning outcomes in which students participate in the formal and informal STEM processes that address community needs and seek to improve the quality of life for individuals, groups, and entire communities. In this context, STEM civic engagement contributes to student growth by connecting authentic and meaningful service to communities with content and skills acquired in the classroom. Civic engagement activities, such as tutoring others in STEM content, present students with opportunities to reflect upon their own academic goals (also known as metacognition) (NRC, 2000), transform their communities, and identify and address social challenges that are specific to our society, i.e. the lack of STEM

subject understanding, the lack of STEM role models, etc.

It is well documented that tutoring has beneficial effects on both the tutor and the tutee. In particular, many studies have shown that tutoring increases the content knowledge as well as the self-concept of the tutor (Britz, Dixon, & McLaughlin1989; Cohen, Kulik, & Kulik1982; Early 1998). Students who tutor feel more positive towards themselves as students, and they display an improved academic self-concept. Through this enhanced self-concept, students identify themselves more strongly as students of their discipline (Early 1998). Furthermore, students in STEM disciplines who serve as leaders among their peers experience increased self-efficacy and retention, and studies have shown that this trend applies to both majority and underrepresented students. Thus, peer leadership may provide a path for improving retention of underrepresented groups in the field (Hug, Thiry, & Tedford 2011). Additional outcomes for STEM leaders (mentors or tutors) include increased participation in internships and higher GPAs (Monte, Sleeman, & Hein 2007). Other studies indicate that the opportunity to tutor or mentor others allows STEM students to develop a sense of belonging and social relationships that aid in student retention; to some extent, this can be attributed to improved experience with and understanding of STEM culture at the students' institutions (Kiyama 2014; Kiyama et al. 2014).

Existing research provides a limited understanding of the relationship between identity/belonging, encouragement, self-efficacy, civic engagement, and retention rates for two-year college STEM students. Our study explored the effects of civic engagement volunteer activities on student identity/belonging, encouragement, and self-efficacy. The results show a relationship between these activities and STEM persistence and retention for two-year college STEM students.

Institution and Program

Perimeter College is part of Georgia State University, a diverse, multi-campus urban research university in metropolitan Atlanta. The college is the major provider of associate's degrees and student transfer opportunities in Georgia and a gateway to higher education, easing students' entry into college-level study. More than 21,000 students, representing all ages and backgrounds, are enrolled in Perimeter College. Through the college, Georgia State serves the largest number of dual enrollment, international, online, transfer, and first-time freshman students in the University System of Georgia.

Beginning in Spring 2012, through National Science Foundation funding, a Science, Technology, Engineering, and Mathematics Talent Expansion Program (STEP) was developed for two-year, full-time students, with a minimum 2.8 grade point average. To participate, students must have U.S. citizenship or status as permanent resident alien or refugee alien and be majoring in a STEM field of study, declared at any point but usually after the first year of coursework. The objectives of the program are two-fold: (a) to increase the number of students who persist in all STEM fields at the institution (chemistry, biology, math, geology, physics, computer science, and engineering) and (b) to increase the number of students who graduate and/or transfer to four-year colleges/universities to complete their STEM baccalaureate degrees. The demographic breakdown of the STEP participants throughout the lifetime of the program mirrored that of the STEM majors in the institution; the majority of STEP students are underrepresented minorities.

Students participate in the program for an average of three semesters (including a summer semester). Stipends are given to those participants who meet the following criteria each semester: (a) are enrolled as a full-time student (12 credit hours during the fall and spring semester); (b) maintain a cumulative minimum GPA of 2.8 and a minimum semester GPA of 2.5; (c) participate in a minimum of 10 hours of STEM civic engagement activities per semester; (d) participate in a minimum of six STEM–related activities (STEP-sponsored and others). Stipend amounts vary depending on the academic classification of the participant. Additional stipends are given for participation in the Summer Bridge I undergraduate research experience (three weeks), Summer Bridge II undergraduate research experience (eight weeks), and participation in the NSF's Research Experiences for Undergraduates program. STEP sponsors multiple STEM activities each semester, including STEM industry visits and college visits.

STEM Civic Engagement Activities

Program participants are engaged in the STEM community in a number of ways, some of which are required

elements and others that are optional. All program participants are required to attend a number of career workshops and to visit industry sites and four-year institutions. Additionally, throughout their tenure in the program, participants are required to complete a minimum of 10 hours of civic engagement per semester. Many of the students fulfill this requirement by serving as tutors in on-campus student support facilities or off campus in their communities. Additional civic engagement opportunities are available to the students through outreach activities (such as science festivals), environmental clean-ups, and other STEM-related events. Many students (73%) completed more than the required 10 hours per semester of service; the average contribution per semester is 12 hours of service.

Methods

In order to determine student outcomes, we tracked students through their program experience and after graduation and transfer to four-year institutions. During their tenure in the program, participants were asked to complete a number of surveys and focus group interviews to determine their reactions to and the perceived outcomes of the various student support activities. Surveys were retrospective in design: students were asked to think back to how they felt at the beginning of the program and compare that to how they felt at the time of taking the survey (usually after one year in the program). This approach maximizes ability to match responses and also eliminates pretest sensitivity and response shift bias, wherein students tend to underestimate or overestimate their attitudes towards the unknown prior to the start of an intervention (Howard 1980; Pratt, McGuigan, & Katzev 2000). In addition to surveys given during students' tenure in the program, we also administered an alumni survey to those who had completed the program.

In particular, our 23-item student survey drew upon existing instruments designed to assess changes in STEM engagement (Fredricks et al. 2005), STEM identity and belonging, encouragement (Leonowich-Graham & Condley 2010), math and science anxiety (Bai et al. 2009; Glynn and Koballa 2006), commitment to research, and intent to persist (Tocker 2010). Further definition of these psychosocial constructs is presented in Table 1,

TABLE 1.
Psychosocial Constructs Measured by the STEP Student Survey

Construct	Definition	Sample Item
STEM Engagement	Student engagement can be examined in terms of behavioral engagement (demonstration of interest), emotional engagement (positive reactions), and cognitive engagement (student investment in learning).	I enjoy my STEM coursework.
STEM Identity and Belonging	A sense of belongingness and identifying with STEM contributes to student pursuit of STEM careers.	I can see myself in a STEM career.
Comfort with Math and Science	Previous research on math and science anxiety has shown that it is a multi-dimensional psychological construct that involves complex factors, such as feelings of pressure, performance inadequacy, and test anxiety that interfere with the manipulation of numbers and solving math problems. The comfort with math and science measure is intended to assess the feelings of anxiety, dread, and nervousness associated with mathematics.	I am comfortable with science.
Encouragement	Studies attempting to get at influences that lead students to major in Computer Science have elucidated encouragement as a major factor in this decision. Furthermore, feeling encouraged can be a predictor of whether or not students are likely to major in a STEM discipline.	I feel encouraged to get a STEM degree.
Intent to Persist	Student intention to persist is highly indicative of actual persistence. Intent to persist can be examined in a temporal manner, looking at short-term degree attainment and long-term commitment.	I intend to take more courses in STEM.

TABLE 2.
Growth in Student Attitudes towards STEM and Self as Measured by Annual Student, Surveys throughout the Program

Construct		Fall 2012 (n=23)		Spring 2013 (n=29)		Spring 2014 (n=33)		Spring 2015 (n=36)		Spring 2016 (n=25)	
		Mean[1]	Change[2]	Mean[1]	Change[2]	Mean[1]	Change[2]	Mean[1]	Change[2]	Mean[1]	Change[2]
STEM Engagement	Before	4.11	+0.22 (p=0.017)	4.04	+0.36 (p<0.001)	4.28	+0.23 (p=0.008)	3.83	+0.46 (p=0.002)	4.28	+0.35 (p=0.002)
	Now	4.33		4.40		4.51		4.30		4.63	
STEM Identity & Belonging	Before	4.00	+0.54 (p<0.001)	4.16	+0.29 (p=0.004)	4.28	+0.31 (p=0.014)	3.78	+0.61 (p<0.001)	4.40	+0.32 (p=0.005)
	Now	4.54		4.45		4.59		4.39		4.72	
Comfort with Math & Science	Before	4.12	+0.18 (p=0.008)	4.37	+0.06 (p=0.491)	4.23	+0.24 (p=0.008)	3.78	+0.37 (p=0.014)	4.37	+0.22 (p=0.029)
	Now	4.30		4.43		4.48		4.15		4.59	
Encouragement	Before	4.04	+0.52 (p=0.030	4.07	+0.32 (p=0.059)	4.31	+0.32 (p=0.023)	3.82	+0.76 (p<0.001)	4.36	+0.36 (p=0.026)
	Now	4.57		4.39		4.64		4.59		4.72	
Intent to Persist	Before	4.33	+0.30 (p<0.001)	4.40	+0.21 (p=0.024)	4.44	+0.19 (p=0.073)	3.98	+0.49 (p=0.002)	4.53	+0.16 (p=0.056)
	Now	4.64		4.61		4.64		4.47		4.69	

Note. [1]Scale=1, Strongly Disagree to 5, Strongly Agree. [2]Change is calculated by subtracting the Before scores from the Now scores. Only students with matched Before and Now data were assessed for significance.

along with example survey items. Students were asked to respond to survey items using a 5-point Likert scale of agreement (1=Strongly Disagree to 5=Strongly Agree).

To collect qualitative data, students were assembled in groups of 8l2 to participate in annual focus group interviews. During these interviews, students were asked probing questions regarding their experiences in the program and how they affected their identity, engagement, and intent to persist in STEM. The focus group interview protocol included questions such as the following:

- Describe civic engagement activities that you participated in.
- Did these activities change the way you think about yourself? About your intended career?
- Are you making different decisions because of participating in this program? Explain.

To further explore the link between persistence and gains made by students as a result of the program and civic engagement activities, a multiple regression analysis was conducted whereby the outcome variable was Intention To Persist and the predictor variables were STEM Engagement, STEM Identity and Belongingness, Math and Science Anxiety, Research, and Encouragement. To compute the outcome and predictor values for this analysis, items from the student survey were averaged for each corresponding construct.

Results

Qualitative data gleaned from participants' open-ended responses to surveys and during focus group interviews suggested that the STEP program positively impacted their motivation to pursue STEM education and careers by enhancing their sense of STEM identity and belonging and by providing social support and encouragement.

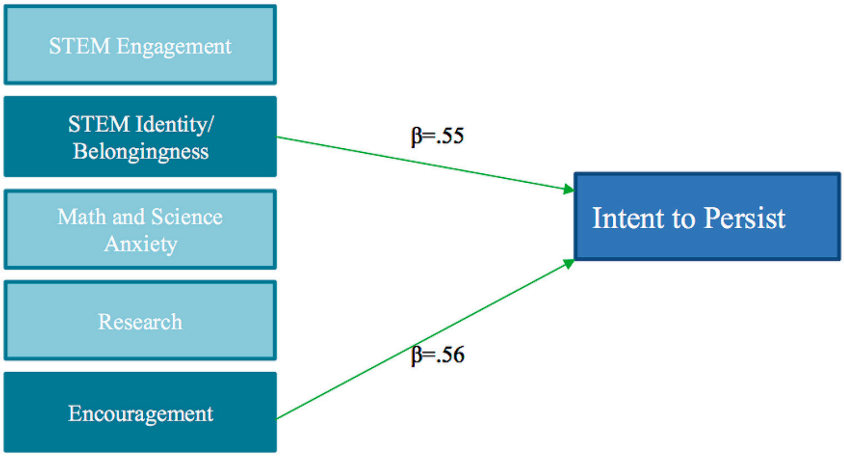
> *[STEP] helped me to be confident and to trust myself that I can do better things if I have the will. It also helped me make the decision that I belong to a STEM family.*

> *STEP enhanced my vision of being a scientist.*

> *I was about to give up on my school.…[A]fter meeting and getting help from different people, I was able to rethink my major and continue my studies.*

Additionally, annual surveys completed by program participants demonstrated that they made significant gains in terms of STEM engagement, STEM identity and belongingness, comfort with math and science, encouragement, and intent to persist. Table 2 shows statistically significant gains in attitude measured by these surveys over the course of the program.

FIG 1.
Regression Analysis of Aalumni Survey Data (n=39)



Note. Numbers along directional paths represent standardized ß. Solid green line= significant at p<.05.

Figure 1 summarizes the results of the regression analysis, conducted using data from the alumni surveys administered in 2013 and 2015 (n=39). Students taking the alumni survey had all completed their program and/or transferred to a four-year institution. Alumni survey data were chosen for this regression analysis in order to limit the findings to that of a longer-term student perspective; these students had the benefit of looking back over their entire program experience, and these data represent a more complete picture. The regression model with all five predictors explained 95% of the variance in the outcome variable ($R2=.948$, $F(5,33)= 119.18$, $p<.001$). Controlling for other variables in the model, the results indicate that two variables statistically significantly predict intent to persist:

- STEM Identity and Belongingness (ß=.55, p<.001)
- Encouragement (ß=.56, p<.001)

This suggests that students' motivations to pursue additional STEM education and/or careers is contingent on the degree to which the program was able to (a) improve their sense of belonging in STEM and (b) provide encouragement for attaining a STEM degree. This finding corroborates previous research which indicates that STEM persistence increases as students experience a greater sense of belonging and general social support from mentors and colleagues (London et al. 2011).

Quantitative data analysis was limited in that the response rate for the student surveys was not 100%. (Response rate was roughly 85% across all items and multiple administrations of the survey.) Thus, responses might demonstrate a bias towards the positive, as students who felt less compelled to respond to the program survey were often those who had left the program (and usually the institution). Additionally, due to the low sample size, we must use caution when interpreting the results of the regression analysis. Correlations among constructs suggest that multicollinearity may have impacted the results of the regression. To mitigate the effects of multicollinearity, each predictor variable in the regression model was standardized (e.g., converted to a z-score). Furthermore, the results provided in the current report are preliminary and should be replicated using a larger sample size. It is also important to note that disaggregation of data by gender or race/ethnicity did not reveal significant differences among the participating groups of students.

Qualitative Findings

During annual interviews, students were asked about their experiences in program activities, and how they thought these experiences affected them. In particular, we explored which facets of the program led to increased STEM identity and encouragement. Students explained that the volunteer work they did to meet their civic engagement requirements helped them in many ways. Specifically, they were able to solidify their STEM content knowledge and improve their communication and leadership skills:

> *Being part of [tutoring]… helps you refresh your mind. When you are helping them it helps you refresh your mind. You refresh communication skills.*

> *It improves your leadership skills. One thing that I've learned is that you're more involved in the community and you're more exposed to the problems of the community. I think that it really improves your communication skills, your leadership, and it helps you learn more about your community.*

TABLE 3.
Comparison of Outcomes for Program and Non-program STEM Students at Institution

	GSU-PC STEM Students Entering 2011-2012	STEP program students entering 2011-2015	STEP program students entering 2011-2015 who completed at least 10 hours of civic engagement per semester
Enrollment by FTE	4402	214	116
Graduates within 2 years – Associate's degree	154 (3%)	47 (22%)	34 (29%)
Transfers within 2 years to a 4-year institution	542 (12%)	48 (22%)	50 (43%)

Participants also felt that civic engagement motivated them to work harder in STEM and gave them a broader perspective on their futures.

> *It opens your mind up to all that's out here. It's opened my mind to what's out there and made me think that I want to help people. It's an unselfish thing.*

> *Even being around the other members, outside of class, you get to know them—being around people that are really smart, makes me want to be really smart.*

> *You become more motivated. You want to learn as much as you can. You want to help as much as you can. You want to put things out there so that people can learn from you.*

> *It's not about improving myself, but improving other people's lives. I started thinking about non-profits. I started thinking about things that I didn't think about before.*

In short, students explained that participation in civic engagement improved their STEM and soft skills and motivated them to consider a broader range of career options. Their sense of identity as part of a STEM community was solidified through exchanges with their peers as well as with those they were helping.

In order to examine the effect of programmatic activities on actual persistence, we tracked transfer and graduation rates of the scholars, and compared those to non-participant STEM students. Table 3 indicates that program participants were more than twice as likely to complete their program of study and /or transfer to a four-year institution to pursue a STEM degree. Furthermore, STEP students who completed at least 10 hours per semester of civic engagement activities were even more likely to graduate and/or transfer (Table 3).

Discussion

The culture that students encounter when studying STEM has an effect on their interest, self-concept, sense of connectedness, and persistence in STEM. Students who persist often have to draw upon personal, cultural, and co-curricular resources to counter messages about the nature of ability and stereotypes that they encounter in interactions with faculty and that are embedded in organizational norms and practices.

Interventions aimed at improving participant identity and belonging have been shown to enhance achievement and persistence (Cohen & Garcia 2008). Not surprisingly, students in highly evaluative environments (such as STEM courses) are sensitive to stereotype threat when facing difficult coursework and feedback, suggesting that it is particularly important to focus on improving STEM identity in an effort to increase student success (Cohen & Steele 2002).

Despite limitations of the study discussed in the results section, we found that an increase in STEM identity and belongingness and encouragement predicted an increase in intent to persist, and that actual persistence was improved with civic engagement. We posit that opportunities to guide others through tutoring and other civic engagement activities enhanced STEM identity, as scholars explained to us during interviews. In concurrence with STEM achievement, improved identity and belongingness in STEM led to a substantially higher likelihood of graduation and or transfer, as evidenced by participant graduation and transfer rates in comparison to those of non-participant STEM students at the institution. Participating students still face a number of challenges, as do their non-participating counterparts; though the overall

graduation and transfer rate for participants is still alarmingly low, the trend towards success is encouraging and suggests that interventions aimed at increasing STEM identity through civic engagement will increase overall STEM diversity in academe and the workforce

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