A STEM DOCTORAL FELLOWSHIP REPORT

Factors Promoting Inclusion and Success for Underrepresented High School Students in STEM

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ABSTRACT

The focus of this study was to ascertain the best practices and policies for school leaders in recruiting, supporting, and retaining underrepresented students in Science, Technology, Engineering and Mathematic (STEM) courses while encouraging STEM related career fields. This report synthesizes empirical research at two comprehensive high schools in Northern California funded through a CSU Doctoral Research Fellowship. The policy implications from this study are central to promoting access and inclusion in STEM education and future career pathways. Schools need to market and advertise their STEM programs and begin recruiting within their school, particularly at the middle school level. It was clear from this research that the initial "curiosity" that is promoted by the STEM curriculum needs to be fostered so that students continue to be interested in STEM once they get to high school.

Editor's Note: This research was conducted through a California State University (CSU) STEM doctoral research fellowship. STEM, as a paradigm, focuses on the integration of the related fields of Science, Technology, Engineering and Mathematics.

Meeting the challenges and fulfilling the promises of integrating STEM programs within diverse student populations are central to a democratic and equitable society in our new marketplace (State of the Union Address, 2011). The 21st century poses to be the century where technology and innovation lie at the fore of transformational change in a globalized marketplace. Schooling also has to embrace this focus. In a clear sense, Science, Technology, Engineering and Math or STEM has become the beacon for this change in educational settings, a change that must permeate K-12 and higher education. A corresponding challenge in our urban schools is providing access and inclusion to underrepresented students, which includes racial and ethnic minorities and women, particularly as it relates to STEM. The factors which correlate to degree completion and STEM career success have been researched and agreed upon by many in the emerging STEM fields. These factors range from what has been called instrumental aspects of schooling such as access to technology and instructional materials to other aspects that are known as expressivist and include issues that are more pedagogical in nature. As with other aspects of schooling, leadership can influence minority students and women in STEM career fields and has yet to be investigated in depth to determine best practices and school policies that promote access and inclusion. This report synthesizes empirical research at two comprehensive high schools in Northern California. This report summarizes the factors that promote access and inclusion for underrepresented students in STEM.

A big movement nationwide is to incorporate a "Pathway to Engineering" curriculum. This curriculum has been piloted and industry supported to be incorporated into middle and high schools to assist with closing the achievement gap for all students, but especially for underrepresented students. One such curriculum is the coursework entitled "Project Lead the Way" (PLTW). This curriculum is the pathway into an engineering paradigm shift in schools and provides the experience needed to be successful in a college engineering program. By incorporating relevant project-based, hands-on and communication strategies from design to implementation of a resolution of a problem for the 21st century worker, students enrolled in PLTW "are introduced to the scope, rigor and discipline of engineering, technology and biomedical sciences and provided with a foundation and proven path to college and career success in STEM-related fields" (Planting the Seeds for a Diverse US STEM Pipeline, 2010, p. 64). PLTW teachers are highly motivated and are mandated to seek certification and recruit local practicing subject matter engineers to mentor PLTW students. All PLTW teachers receive intense training in their certification courses. They do every assignment and project that students will be expected to complete, allowing them to know the curriculum well and eliminate non-critical items if time is a factor in the school year. PLTW students pursue coursework projects from project identification through completion with justification presentation to the industry mentor. In addition, this curriculum supports the state's transition to the Common Core State Standards for the oral and written communications portion of English Language Arts, the Career and Technical Education portion, as well as math and science yet to be finalized in the application of these core subjects, and will assist in preparing all students to be college and career ready. In turn, the PLTW curriculum can assist our state and nation to meet the needs of the global economy by filling highly skilled positions with qualified workers. It also supports traditionally underrepresented students in STEM and affords them both access and inclusion as they pursue STEM programs at the college level.

The Nature of the Study

Given the current economic trends in our globalized economy, competition for jobs in STEM fields has intensified as the global market will find those who are already trained and available at a cost that makes corporate economic sense. STEM has become a hybrid or composite of knowledge, skill and disposition that permeates across each of the respective fields of math, science, engineering or technology. This requires a new curriculum that embeds these discrete areas of knowledge into a composite. As an emerging discipline, STEM is grounded in the traditional disciplines of science and math and creates a disciplinary hybrid that caters to the needs of our emerging new technologies.

The focus of this study seeks to ascertain the best practices and policies for school leaders in recruiting, supporting, and retaining underrepresented students in STEM courses while encouraging STEM related career fields. Several questions were asked in this study. How are districts/schools recruiting, supporting, and retaining students who are underrepresented in STEM classes and does this make a difference in terms of career choices? How does the school leadership view PLTW and what are their perspectives on this program as an opportunity for their school, staff, community, and most importantly, their students who fit the above criteria to assist with narrowing the achievement gap and enter a STEM career field? Lastly, what is the student perspective of the effectiveness of their recruitment, on-going support, and factors which resulted in their persistence and retention in STEM while comparing their STEM involvement and metrics to the school's general population for common themes or discrepancies?

Perspectives on STEM

A brief review of the literature, such as GPA, SAT math scores, and a student's perception of academic abilities, provides a framework for understanding student success in STEM and related career fields. By understanding the challenges and opportunities that affect both access and inclusion of students, especially underrepresented students, we can influence public policy and programming in order to provide gateways to successful STEM careers and the opportunity to contribute to meaningful STEM innovations.

"The United States is losing its competitive edge because of insufficient investments being made in education and research and because only a small number of American citizens are entering STEM fields" (Ehrenberg, 2010, p. 887), which the "National Science Foundation defines as computer science, mathematics, life sciences, physical sciences, behavioral and social sciences, and health-related fields" (Malcom, 2010, p. 31). Without replenishing this workforce, "the U.S. will face a major talent deficit in fields typically associated with experimentation and technological advancement" (Schneider, Judy, & Mazuca, 2012, p. 62), especially when considering the vast number of current STEM workers that will leave the workforce for retirement over the next thirty years. Therefore, "Policymakers, industry leaders, and educators must improve the quality of mathematics, science, and technology education at K-12 levels and increase the number of students who are interested in STEM fields" (Greene, Destefano, Burgon, & Hall, 2006, p. 53).

The new STEM workforce must be diverse as "Many inventions, breakthroughs, and significant leaps in science-related understanding and applications are less likely to happen under conditions of homogeneity of thought and perspective" (Greene et al., 2006, p. 53). White and Asian males have and continue to dominate the STEM professions leading to the underrepresentation of women and ethnic minorities in STEM (Schneider, Judy, & Mazuca, 2012). This homogenization has contributed to a lack of diverse role models and "diversity in science classrooms and laboratories [which] is not only socially unjust but also compromises the vitality and creativity of STEM endeavors" (Greene et al., 2006, p. 430). In fact, "all racial and ethnic minorities combined receive only 28%, 24%, and 21% of the total number of bachelor's, master's, and doctoral STEM degrees, respectively, awarded in the United States (…); [and] although women occupy almost half the jobs in the U.S. economy, they hold less than 25% of STEM jobs" (Dailey & Eugene, 2013, p. 683).

Increasing access and inclusion to these diverse populations potentiates a solution to the STEM crisis both quantitatively and for the purpose of innovation. "Racial and ethnic minorities were responsible for 91.7% of the U.S. population growth between 2000 and 2010[...]and 50.4% of the children born in 2011 were part of a racial or ethnic minority" (Dailey & Eugene, 2013, p. 683). This, coupled with estimates by the US Census Bureau, which projects that by 2023 more than half of all children in the United States will be children of color" (Linley & George-Jackson, 2013, p. 97), is a strong indicator that attracting, recruiting and retaining these individuals in STEM fields will both replenish and diversify the STEM workforce needed for a healthy U.S. economy.

Recruitment and programming efforts must be deliberate if they are to attract, recruit and then support and retain underrepresented students in STEM. This mean that the exposure to STEM-issues and to diverse STEM role models must begin early in K-12 education as "children as young as ages six to eight years begin to eliminate career choices because they are the wrong gender, [and] by early adolescence, students already have strongly defined gender-role expectations about work [that is] influenced by parental socioeconomic status, parents' occupations and education levels, and parental expectations" (Tolgia, 2013, p. 15). Summer programming has been shown to be effective in exposing children and adolescents to the sciences as well as in providing mentorship by STEM professionals. This is extremely important for underrepresented students who may not have been afforded the exposure to diverse career options and role models as their more represented peers; "Seeing and interacting with successful figures enables adolescents to envision themselves in similar roles, thereby strengthening their identities" (Syed, Goza, Chemers, & Zurbriggen, 2012, p. 906) as science students. High-schools can serve as beacons for attracting and recruiting students to the STEM fields. Providing pathways to STEM through course counseling and advising, college campus visits to help students envision life after high school, and financial aid guidance are extremely important for individuals from lower socioeconomic backgrounds and those who have a lack of insight regarding navigation through college systems (Schneider et al., 2012).

Academically, to be successful in STEM students must be afforded "the exposure to coursework in middle and high school that would prepare one for advanced-level math and science" (Abdul-Alim, 2010, p. 10). However, underrepresented racial minorities may have "limited exposure to rigorous math and science courses in high school, lack of nurtured interest in STEM, and poor performance on college entrance and placement exams" (Strayhorn, 2010, p. 1). These issues of access are extremely important as "high school experiences determine students' academic preparation, educational expectations, and career knowledge; all of which are critical for postsecondary success" (Schneider et al., 2012, p. 62). For example, "high school AP classes and higher SAT scores were found to enhance persistence to graduation in STEM field majors" (Erhenberg, 2010, p. 890). To promote access, it is imperative that underrepresented minority students receive academic supports such as faculty mentoring and tutoring that will increase their efficacy and persistence in STEM courses.

Students choosing one of the pathways of STEM must be supported for their retention and success in the program. "The transfer function of community colleges is paramount to increasing the representation of women and underrepresented racial minorities baccalaureate degrees in STEM fields" (Jackson, Starobin, & Laan, 2013, p. 70), as "about 50% of college students started their postsecondary education at two-year public institutions" (Jackson, Starobin et al., 2013, p. 69). In addition to access, inclusion is extremely important for underrepresented minority students as they experience unique challenges related to familial and cultural responsibilities and expectations and often generational differences which challenge their success while pursuing a college degree, in comparison to their peers (Reyes, 2011). This means there must be a "mutual sense of responsibility and commitment by community colleges and universities for ensuring the transition and success of women and ethnic/racial minorities in STEM disciplines" (Jackson et al., 2013, p. 74), as many of these students experience transfer shock their first year at four-year institutions. Transfer shock is the phenomenon in which underrepresented minorities thrive in community college, but experience a drop in academic performance in the university environment (Reyes, 2011). Reasons for this include feelings of "Isolation, invisibility, and the sense of not belonging, along with the academic pressures of bigger classes, rigorous requirements, and insufficient attention to individual students [and] often lead women and underrepresented minorities to switch out of STEM majors or to switch within STEM" (Jackson et al., 2013, p. 71). Therefore, it is critical that both social and academic supports be made available during and following the transfer from the community college to the university (Hurtado, Newman, Tran, & Chang, 2010).

"Persistence in STEM education not only requires mastering the technical skills needed to be a scientist, but also entails a social psychological process by which students begin to see science as a salient part of their identities" (Merolla & Serpe, 2013, p. 580). "Having a strong sense of identity as a science student may be particularly important for underrepresented minority students given the immense barriers they experience pursuing careers in STEM" (Syed et al., 2012, p. 906). Enrichment research programs (Merolla & Serpe, 2013) and "structured undergraduate science research opportunities have shown to positively impact persistence and identity development as a scientific researcher" (Hurtado et al., 2010, p. 12) as they allow students to work on STEM-related issues and with STEM peers and faculty. This is important because "when students are able to view themselves as a member of the STEM enterprise, they are able to commit to the challenges and obstacles that are presented as a result of their identification within the field" (Jackson et al., 2013, p. 74). Moreover, research indicates that "a student who participated in research during half of his or her undergraduate career is about 171% more likely to attend graduate school compared to a student that never participated" (Merolla & Serpe, 2013, p. 589). For underrepresented minority students, STEM faculty members were found to have significantly influenced their persistence in STEM and higher education. By "serving as teachers, facilitators, coaches, confidants, and mentors who developed a vested interest in [their] success, cared about his/her development as a young, emerging professional, and with whom [they] had developed trust" (Strayhorn, 2010, p. 5), they were able to develop both the knowledge and an identity integral to succeeding in STEM.

Meeting the academic and social needs of underrepresented students is crucial if access and inclusion, and their ultimate success in STEM fields, are to become actualized. "At both precollege and postsecondary levels, much effort is needed to create and implement powerful STEM curricula, prepare and support highly qualified teachers, deliver effective instruction, and give diverse groups of students rigorous and engaging STEM educational experiences throughout their school years" (Greene et al., 2006, p. 54). This however necessitates the need for the professional development of STEM faculty to ensure that STEM students receive equitable and diversity sensitive instruction and support. "No assumptions about the multicultural competency of faculty should be made. All faculty need to be provided with resources and support on issues of diversity and difference" (Linley & George-Jackson, 2013, p. 101) in order to better support all STEM students, but especially those traditionally underrepresented. This is vitally important as "teacher behavior and attitudes can provide the greatest influence on their student's success in achieving equity in the educational and occupational spheres" (Tolgia, 2013, p. 17) of STEM.

Table 1
Informal Interview Responses for STEM

Categories	Find	Choose	Recruiting	Retain
Teacher	12	2	7	3
Friend	1	3	3	1
Parent	5	2	5	6
Counselor	0	0	0	0
Other	2	Building/robotics/enjoy it/family are engineers 13	4	Career and interest 12

Note. The table data summarizes finding out about STEM and subsequent choosing, recruiting, and retention.

Scope of the Study and Approach

This study focused on two high schools in two Northern California cities. As such, this was a comparative study to ascertain how two distinct schools promote inclusion and success for underrepresented students in STEM. Specifically, the focus will be on understanding leadership perspectives, perceptions, recruitment practices, support, and retention of underrepresented students in their STEM programs. For the purposes of this paper, the first school will be referred to as Access High School and the second school will be Central High. Although Access and Central High are located in Northern California, they are actually located in two separate geographical regions. Access High is in its second year of implementation and can be considered a start up program and uses a STEM curriculum developed by a mechanical engineer for his students. In turn, Central High uses a Project Lead The Way (PLTW) curriculum. This allows for an interesting comparison as it juxtaposes curricular differences on the implementation of STEM. "PLTW is the nation's leading provider of rigorous STEM education programs. The nonprofit organization partners with middle schools and high schools to prepare students to become the most innovative and productive in the world (Planting the Seeds for a Diverse US STEM Pipeline, 2010, p. 64). ""PLTW is a rigorous four-year program of honors-level math and science, plus engineering, culminating in at least pre-calculus and advanced science classes, along with an intensive, hands-on collaborative engineering project" (Cech, 2008, p. 39). The hands-on, project-based program engages students by showing them how what they are learning in mathematics and science applies to the real world" (Planting the Seeds for a Diverse US STEM Pipeline, 2010, p. 64). Students in PLTW programs outperform non-PLTW students and are effectively closing the achievement gap, thereby making high school graduates college and career ready (PLTW Fact Sheet, 2010). Both the Mechanical Engineering and PLTW teachers play a significant role in student success by working closely with students to provide academic support and exceptional mentoring (Planting the Seeds for a Diverse U.S. STEM Pipeline, 2010, p. 64).

The research strategy for this analysis is both exploratory and explanatory using a qualitative method approach. This strategy investigates the structure and essence of experiences of PLTW school leaders and teachers, and the experiences of underrepresented students while in the STEM, PLTW curriculum. The value of this qualitative approach will be enhanced by persistent observation spread over two schools and triangulated with the common themes emerging from the data. To increase validity and reliability parameters, quantitative measures in a broad sense will be used. Three sources of qualitative data will be used. A standardized, open-ended interview technique will be used to reduce researcher bias and increase reliability. The second qualitative source of data will be a student questionnaire. This questionnaire will ask STEM related questions regarding their recruitment, support, and retention in their STEM/PLTW curriculum. The third

Table 2
Student Indicators of English, Writing and Math Support for STEM Classes

	English Spt		Writing Spt		Math Spt		Gender: Math Support			
Status	Freq	%	Freq	%	Freq	%	Female Freq.	%	Male Freq	%
No	16	84.2	13	68.4	11	57.9	3	50	8	61.5
Yes	3	15.8	6	31.6	8	42.1	3	50	5	38.5

Note. Gender requests for math support are about the same percentages as math is seen as "gateway" into retaining students in STEM curriculum and future careers.

method will utilize participant observation by maintaining a journal to record reflections throughout the study. These field notes were both descriptive and interpretive.

Understanding the Data

The analysis of this data was conducted by triangulating between a series of interviews, a questionnaire and field observations at each of the two schools. First, data analysis was conducted by carefully evaluating all of the qualitative data collected from the three sources of data. A linear descriptive summary of the data will be provided followed by a synthesis that addresses how this research informs access to STEM for underrepresented minorities. The first phase of analysis consists of defining variables in the student data and will be analyzed using the Statistical Package for the Social Sciences, version 22 (IBM Corporation, 2013). It will generate frequency tables to assist in determining student perspectives regarding their recruitment, support, and retention in the STEM related programs. The nature of the analysis will be both descriptive and inductive.

The participants of this study attended one of two schools sites. Access High had 15 students participate while Central High had 4 participants. All together there were 13 male participants and 6 female participants in this study. A summary of the participants is provided in Table 1. This summary lists how students became aware of the program as well as their recruitment and retention into this curriculum. From the beginning of this project it was evident that the major factor affecting recruitment was teacher contact with individual students. Choosing to enter a STEM program seems to revolve around their interests, wanting to build, enjoying the robotics aspect of the curriculum, and their wanting to become engineers in the future. Recruiting students into the STEM program is influenced by teachers and parents while retention in the program is a career or natural interest which parents play a significant role in as well.

Policy Recommendations that Promote Access to STEM

Policymakers, industry leaders, and educators should take notice of this study's results.

The significance of the findings can assist in advocating for equity and inclusion of all STEM students, but especially for the underrepresented. Society and its future economic base and stability depend on replenishing and diversifying a strong STEM workforce. Future jobs and becoming economically viable while in a global market can provide opportunities for underrepresented groups to excel and thrive here and abroad, thereby redressing disparities and social injustice. Therefore, the commitment by key stakeholders to both providing access and inclusion of these students will narrow the achievement gap and encourage others to do the same if it is presented as another viable opportunity available to all groups.

The potential to improve practice is also a key aspect of the study. As our graduation rate is 70% nationwide, it seems to reason we need to look at current practices of "teaching to the test", lectures, and overall lack of building student engagement, and a student's prior knowledge. This study's findings could lead to some insight on how PLTW curriculum could assist all teachers with key strategies for increasing student achievement. As a result, continued replication and use of the new strategies could result in key policy changes that could further narrow the achievement gap of future generations. PLTW embraces the funds of knowledge students possess with family and life experiences, combined with past and current coursework, and provide the foundation for the opportunities to solve proposed coursework problems thereby increasing understanding and applicability of STEM issues. In addition, PLTW's distributed learning opportunities for both teacher and student provide exponential growth as students work as a team to solve complex problems while the teacher is a "guide by the side".

Teachers have a significant role in informing districts on the classes a school offers and is where school districts and schools need to direct their energies to begin marketing their programs. Students overwhelmingly choose to enter STEM curricula because they have the "need to build" or "Bob the Builder" mentality. They enjoy this aspect of STEM immensely. The robotics club or robotics embedded curriculum is the carrot to bring students in to further investigate the possibilities. As expected, teachers and parents play a critical role in recruiting students into STEM curricula for a possible STEM career in the future. They have the most direct influence over the student while at school or while at home. Lastly, students stay in the program because it is a future career choice and an interest they want to pursue. Parental influence is still a strong motivator in encouraging their student to stay in the program as well.

Recruitment efforts must be deliberate if they are to attract students and increase the number of STEM interested students. A somewhat surprising find was that friends and counselors have little to no influence on STEM recruitment, support, or retention. Peer pressure and program knowledge aside, this finding contradicts what one would expect in friends and signifies that the counselor's knowledge of programs are not being sought out or are ignored. Friends do play a small role however, and the researcher suspects with more subjects and the completion of the student questionnaire results, there might be some hope yet for these two viable options in the future to increase our underrepresented student populations into a future STEM career. The more visible the STEM programs are, the more attractive and popular as a career they will become. Consequently, schools need to advertise or market them more to get the word out about the innovations, career options and pathways to STEM. Opportunities for educating students and parents and creating excitement about the STEM fields include open houses, back to school events, and robotic events and competitions. There is nothing like being able to advertise and market your own program by observing the students involvement within the program and the activities they do.

Academic supports are integral to student's success in STEM. Writing and math were subjects that the participants responded they sought extra assistance with. Conversely, there were no requests for reading or science support as indicated on a survey. The sample size (n = 19) was small, but it seems a reasonable response overall. In order to enter and perform in a STEM program, one needs to have the ability to read and have science analysis skills to maintain their ability to work within cooperative groups and perform tasks asked of them. This will be especially true as California transitions into the Common Core State Standards (CCSS). The integrative testing module using the Smarter Balanced question database will require solving problems asked using the assimilation of all core subjects and prior knowledge attained in and out of school. This will be a transition from the state standardized multiple choice exams measuring test taking strategies to using actual core subjects for solving real world problems with a project based mentality.

This project-based approach was observed in the field notes during two observations at each school. During each visit the class was provided instructions on what was to be done and within their assigned groups were asked to work on the assignment at their pace with a due date set ahead of time. All students were participating at different levels and within their assignments. They needed to know key mathematical equations and scientific theories and perform calculations in order for their project to be operational. In addition, the ability for students to communicate orally and in written format was a definite advantage. This will also be helpful to them in the future as 21st century employers prefer team collaboration, communication skills, critical thinking, and a can-do attitude.

Conclusion

The policy implications from this study are central to promoting access and inclusion in STEM education and future career pathways. Schools need to market and advertise their STEM programs and begin recruiting within their school, particularly at the middle school level. It was clear from this research to the initial "curiosity" that is promoted by the STEM curriculum needs to be fostered so that students continue to be interested in STEM once they get to high school. Recruitment efforts must ensure that STEM programs are made visible to all students. Outreach opportunities can and should be encouraged with newsletters, back to school nights, open houses, parent teacher associations, school web sites, schools' Facebook pages and any other avenue. It is important to continue encouraging teachers, parents, and students to ask questions and provide them with information on the STEM curriculum offered at school. This also needs to be done more effectively on the part of high school counselors. They need to be knowledgeable about both STEM curriculum and know their students well to determine if STEM is a good fit for the student.

Academic programming must be made available to support STEM students. Tutoring support in the areas of math, writing, and English, are extremely important if underrepresented students' retention and success in STEM classes is to occur. Lastly, schools need to recruit underrepresented minority students and provide incentives to explore the pathways to STEM in their program offerings. These actions have the potential of influencing a student's future career pathways in STEM and for resolving the disparity related to the STEM fields critical for US competitiveness in our new global economy. As seen in the literature review, there is no definitive research in a leadership defined role in the recruitment, support, or retention of underrepresented students in STEM coursework or career fields in their own perspective and school practices. This study identified some practices and policy changes needed to increase underrepresented minorities in STEM. Promoting inclusion for those underrepresented is an issue of equity and social justice that schooling and programming must address along the K-16 continuum.

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