Charting a Course towards Latino Student Success in Science, Technology, Engineering and Mathematics

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Currently Latinos are underrepresented in Science, Technology, Engineering, and Mathematics (STEM) occupations accounting for just seven percent of the STEM labor force (Bureau of Labor Statistics, 2012). The U.S. Bureau of Labor Statistics (2012) projects large employment growth[1] within STEM occupations, the third fastest growing industry, over the next ten years. Additionally, the U.S. Census Bureau calls for exponential growth of the Latino population; estimations suggest the country will have nearly 60 million Latinos by 2020 and over 100 million by 2050.

The exponential growth and youth of the Latino community provides a unique opportunity to bridge the gap between the expanding demand for STEM-educated labor and the country's fastest growing population. In order to realize this opportunity, it is critical to understand and address gaps in the STEM pathway for Latino students, beginning at the K-12 level and continuing through postsecondary education. The purpose of this manuscript is to provide a review of the key factors on the path to success in STEM and to discuss Latino success in this field. We will also provide practical implications and summarize areas for future research.

Science Pathways

To give context to the influences that constrain Latino student success in STEM fields, it is useful to begin with exploring the path for students in general, starting in K-12 and continuing through university graduation (which many do not complete). We will use the "path to college model" (Cabrera, Burkum, & La Nasa, 2005) to describe what matters most for all students first. Then, we will discuss what matters most for Latinos.

[1] Annual average rate of change from 2010-2020, growth of 2.6 percent. Employment projections based on Current Employment Statistics data. The projections are found at http://www.bls.gov/news.release/pdf/ecopro.pdf

There are a variety of possible pathways from K-12 education to a college degree. According to Cabrera et al. (2005), students with high socioeconomic status are most likely to go directly from high school to pursuing a four-year degree, while students from less affluent backgrounds are more likely to enter community colleges. This is partly a function of differences in their degree aspirations; students from low-income backgrounds are less likely to expect to attain a college degree and they are also much less likely to be encouraged by peers and family.

Because students begin to make decisions about their future and degree aspirations even before the eighth grade (Cabrera et al., 2005), high school intervention programs providing resources about college options and academic requirements must begin earlier. A student's choice of courses in high school (frequently connected to the courses taken in middle school) can determine his or her academic future. Mathematics preparation is especially important (Swail, Cabrera, Lee, & Williams, 2005). To enter an accredited degree program in a technical field, students must have high-quality mathematics and science preparation in high school, culminating in pre-calculus, if not calculus. If students experience academic tracking out of college-preparatory classes, low school quality, lack of communication with parents about college requirements, adversarial relationships between students and school staff, stereotypes that they cannot become scientists, or personal difficulties that make it hard for them to study, they may not persist through high school graduation.

Beyond concerns about high school attrition, college preparedness, particularly, in science and mathematics is a major concern across all student populations. A number of recent national reports (i.e. *Rising Above The Gathering Storm*) cite the lack of K-12 student preparation in science and mathematics as impacting the nation's ability to grow the STEM talent pool. General science literacy is lacking among the general population but more

significantly among minority and low-income students. Many young people are likely to grow up with little understanding of concepts such as photosynthesis or DNA (National Science Board (NSB), 2012). Further, science teachers may be unaware of subtle misunderstandings that students bring into the classroom, making it difficult for them to conceptually grasp the material, and results in a smaller number of prepared students to study STEM beyond high school. Most students fail to reach the proficient level in mathematics and science assessments. In 2009, twenty six percent of 12th graders performed at or above the proficient level in science and 21 percent in mathematics (NSB, 2012). A report measuring half of the nation's high school seniors in English, mathematics, reading and science proficiency, found three out of four high school graduates are not fully prepared for college (ACT, 2011).

Science and mathematics proficiency does not guarantee success in STEM at the collegiate level. Cooperative Institutional Research Program (CIRP) Freshman Survey data from 2011, shows that nearly 27 percent of first-time full-time students entering four-year institutions intend to study a STEM field (Pryor et al., 2011). However, retention rates in STEM are dismal and fewer than 40 percent of students who enter college intending to major in a STEM field complete a STEM degree (President's Council of Advisors on Science and Technology (PCAST), 2012). Many students leave STEM majors for a variety of reasons: high-achieving students frequently report uninspiring introductory courses as a factor influencing their choice to switch majors; low-performing students with a high interest in STEM careers experience academic difficulty with the mathematics required in introductory STEM courses and do not receive adequate support; and many students, particularly those underrepresented in STEM fields, women and Latinos and African Americans, cite an unwelcoming atmosphere from faculty in STEM courses as a reason for their departure (Crisp, Nora, & Taggart, 2009; PCAST,

2012; Seymour & Hewitt, 1997).

Women and underrepresented minority students who enter technical fields are less likely than their peers to graduate; however, students in these majors are, on average, more likely to persist than their peers in other majors (Fenske et al., 2000). This suggests that recruitment and retention of women and underrepresented minority students are equally critical to increasing the number of STEM graduates.

Latino Students in STEM

To explore the variety of influences that keep young Latinos out of STEM, it is useful to explore a pathway of educational experiences beginning with K-12, transitioning to postsecondary education, completing a baccalaureate degree in a STEM major, and in some cases, pursuing graduate education. Traveling this "pipeline" highlights the barriers Latino students face in STEM.

Constraints on Hispanic Students' Success Part 1: K-12

Many factors affect Latino educational success well before formal schooling begins. This includes the availability of health care, nutrition, family income, neighborhood environments, and parents' education (as cited in Camacho & Lord, 2011). Preschool provides a foundation for future learning, yet Latino children do not participate in preschool education at the same rate as other children and are more likely to arrive at kindergarten or first grade with lower levels of school readiness compared to White and Asian children; including lower oral language, pre-reading, and pre-mathematics skills (Farkas, 2003; Gándara, 2006; Lee & Burkam, 2002). The Early Childhood Longitudinal Study finds wide gaps in performance for Latino students compared to their White and Asian counterparts; 42 percent of Latino students scored in the lowest quartile and 15 percent in the highest, compared to Asian and White students at 13

percent and 39 percent and 18 percent and 30 percent respectively (Gándara, 2006).

These gaps persist beyond kindergarten and first grade as Latinos consistently perform below their peers in the National Assessment of Educational Progress (NAEP). In both fourth and eighth grades, Latino students lag behind White peers in mathematics (fourth grade: 229 vs. 249; eighth grade: 270 vs. 293). However, from 1990 to 2011, Latino students have increased their average mathematics scores in fourth grade (from 200 to 229) and eighth grade (from 246 to 270) (Aud et al., 2012). While the scores show improvement, a gap persists across racial and ethnic groups. These scores, and mathematics and science classes in general, present major barriers for Latinos, who drop out of these subjects as early as elementary school (Oakes, 1990).

Data from the 1988 cohort of the National Education Longitudinal Study (NELS) shows minority students are equally as enthusiastic about science and mathematics as majority students at a young age, but they face difficulties in developing their skills and pursuing their interests. Both at home and at school, they are in environments that have few resources to foster their learning of these subjects (Peng et al., 1995).

High school quality impacts the development of an interest in mathematics (Eamon, 2005); however, educational quality is not consistent within and across schools. In 2009, higher percentages of Latino students (37 percent) attended high-poverty schools than White students (6 percent) (Aud et al., 2012). Given the concentration of Latinos in low-resourced schools, Latino students are less likely to have access to challenging, high-quality mathematics instruction, computers, and calculators (Berry, 2005; Chacon, 2000; Triana & Rodriguez, 1993).

Latino high school students are less likely to be enrolled in advanced mathematics and science classes (Tyson et al., 2007). High schools with large populations of underrepresented minority students tend to have less rigorous science and mathematics curricula and Latinos have

little access to more demanding classes even when they are offered (Gándara, 2006). Because of limited course offerings or access to high-quality alternatives, Latino students are overrepresented in remedial mathematics courses where teachers are significantly more likely to emphasize drill and practice rather than application of concepts and high thought processes (Gross, 1993). For example, in 2009, Calculus was the highest mathematics class completed in high school for 18 percent of White high school students. In contrast, only 9 percent of their Latino peers completed this course (Aud et al., 2012). Latino students have increased participation in the Advanced Placement (AP) program, more than tripling participation from 1990 to 2008. In 2008, Latinos accounted for nearly 14 percent of all students taking AP examinations (Aud, Fox, & KewalRamani, 2010). While the increased AP participation is promising, because Latino students do not take advanced courses in mathematics and science at the same rate as their peers, high school is a primary point where they exit STEM pathways.

More than losing Latinos in STEM because of course-taking patterns, Latino students are less likely than their non-Latino peers to complete high school. In 2007, the Latino high school drop out rate was 21 percent compared to 5 percent for White students (Aud et al., 2010). High school outcomes for Latino students could benefit from programs designed to reduce dropout rates. Lopez (2009) found that nearly 74 percent of all 16- to 25-year old survey respondents who ended education before or immediately following high school graduation did so because they had to support their family. Additional reasons cited for ending educational pursuits included poor English skills (49 percent), a dislike of school (42 percent), inability to afford to go to school (40 percent) a feeling that they do not need more education for the careers they want (39 percent), and inadequate grades (21 percent).

Constraints on Hispanic Students' Success Part 2: College

While attrition in high school is a major concern for advancing Latino educational opportunities, in October 2010, Latino enrollment (18- to 24-year olds) surged and accounted for 1.8 million, or 15 percent of the overall enrollment of 12.2 million young adults in two- or four-year colleges or universities (Fry, 2011). Despite the recent surge in Latino postsecondary enrollment, Latino students who persist in STEM face complex issues throughout the college application process, choice of a major, acclimation to the expectations of demanding science programs, and college graduation.

The challenges begin with standardized tests frequently used in college admissions decisions. Several studies have found strong relationships between advanced courses in science and mathematics and scores on the SAT and ACT (Adelman, 2006; Riegle-Crumb, 2006; Wimberly & Noeth, 2005). Rigorous course taking, particularly in science and mathematics, strongly influence SAT performance (Riegle-Crumb, 2006) and course sequences as well as highest course completed directly relate to the ACT mathematics score (Wimberly & Noeth, 2005). Further, there has also been a long history of biases in standardized testing that favor English-speaking students. Spanish-speaking and bilingual students have been tested inconsistently or not at all (Figueroa & Hernandez, 2000). Several researchers recommend that institutions not rely solely on standardized tests for admission, but should focus on other factors, such as student talent and years of mathematics taken, since students who do not score highly on the SAT can still be successful (Marwick, 2004; Swail, 1995).

Given inequities in K-12 education, Latino students are not less likely to be prepared for collegiate level academic work. Chacon (2000) found that only 26 percent of Latino high school graduates in his study in the San Francisco Bay Area had completed California's college-

prerequisite courses. A high proportion of Latino students (59 percent) were classified as not qualified for postsecondary education compared to 44 percent of the total NELS cohort and 41 percent for White students. Approximately twice the percent of White students were qualified for higher education than Latinos (Swail, Cabrera, & Lee, 2004).

The lack of college readiness impacts postsecondary choices. Over half of Latino college students enroll in two-year institutions. Fry (2002) suggests that characteristics of these institutions appeal to Latino students, such as open admission, lower tuition compared to four-year institutions, degree programs and course offerings designed to accommodate part-time students, and students can chose to enroll in courses aimed at improving job skills without having to complete a degree. In general, students who begin their postsecondary education at two-year institutions are less likely to attain their baccalaureate (Nevarez, 2001).

Once Latino students enter college, they are less likely to complete their degrees compared to peers. Retention of Latino first-year students is 79 percent, compared to the retention rate of Asian and White students (88 percent and 81 percent respectively) (Center for Institutional Data Exchange and Analysis (C-IDEA), 2010). Latino students are 29 percent more likely to graduate from college when attending a highly selective institution than a less-selective institution (C-IDEA, 2010). This may be related to students' academic achievement and courses taken during high school, which can lead to recruitment by selective institutions.

Regardless of institutional selectivity, students must feel included both socially and academically at college (Tinto, 1993). Factors such as faculty and peer support, and campus involvement are essential for the retention of Latino students (Astin & Astin, 1992; Gloria et al., 2005; Hernandez, 2000; Hernandez & Lopez, 2004; Swail, 1995). Moreover, retention and achievement in science, mathematics, and engineering (SME) for Latinos require "consistent

motivation and strengthening of student interest in the sciences, academic preparation to increase competency in mathematics and analytical thinking, connections with motivated peers who are also pursuing SME careers, and positive interactions with SME faculty on research and independent projects" (Bonous-Hammarth, 2000, p. 93).

Beyond social and academic integration, research supports the important role critical mass plays for Latino students (Hagedorn, Chi, Cepeda, & McLain, 2007). Bonous-Hammarth (2000) suggests that because Latino SME students do not experience critical mass, they "may experience a poor fit between their values and the norms they perceive being upheld by their peers and other reference cohorts on campus" (p. 95). More than a chilly climate, Latino students do not always feel welcome at the colleges they attend (Cabrera & Nora, 1994). Segregation, discrimination, and difficulties with cultural adaptation often face ethnic minority students at majority-serving schools (Hurtado et al., 1999).

Finally, the presence or absence of financial aid also has a strong effect upon retention of Latinos in STEM. Rendon and Triana's (1989) study highlights the barriers to Latinos in mathematics and science and financial aid is critical to their academic success. Malcom and Dowd (2008) found that the need for financial aid continues to play a large role for Latinos in STEM beyond the bachelor's degree as higher levels of relative debt may negatively impact Latino students' decisions to enroll in graduate and professional school.

Successful Science Pathways for Latino Students

Numerous studies call for re-examining the experiences of underrepresented minority students from a success model rather than a deficit model (Harper, 2010; Padilla et al., 1997). Understanding the experiences of successful Latino students who have persisted to bachelor's degree completion or graduate school in STEM provides insight into navigating challenging K-

12 environments and the transition to postsecondary education. While many studies explore the underrepresented minority experience, given the limited number of Latino students in STEM, few projects study their experiences exclusively.

Latinos who persist in STEM majors enter college with adequate mathematics and science preparation. Taking high-level science and mathematics courses, particularly calculus, chemistry, and physics in high school prepare Latinos to persist through STEM course work and obtain a baccalaureate in a STEM field (Tyson et al., 2007).

More than being academically prepared prior to enrollment, Cole and Espinoza (2008) found that once on campus, studying with other students and attending diversity events negatively impacted Latino students' GPA. While these items may connect students to the campus community, they also take time away from academics, which can negatively impact grades (Astin, 1993).

While students who begin their postsecondary education at two-year institutions are less likely to attain their baccalaureate (Nevarez, 2001), more recent research has found two-year institutions play a valuable role for Latino students in STEM (Crisp et al., 2009; Malcom, 2010). For older students and first-generation students who earned a bachelor's degree in STEM, Malcom (2010) found that 61 percent attended a two-year institution at some point in their educational careers and more than 18 percent earned an associate degree before attaining a bachelor's degree. Crisp et al. (2009) found that attending a two-year institution before enrollment at a four-year Hispanic-serving institution (HSI) did not impact Latino students' decision to select or to persist in a STEM major.

Recommendations for Change Part 1: K-12

Latino students face serious deficits in educational opportunity, an educational opportunity that is tied to the schools they attend. In many of the country's schools, overcrowding, high drop out rates, low expectations of students, and limited access to rigorous academics plague a disproportionately high number of Latino students. How can K-12 schools address these situations, given the fact that they often lack resources? A change of attitude appears to be the first fundamental step. The Hispanic Dropout Project recommends that educators connect with students and their families, make course content interesting, hold high expectations for students, and value Latino culture. They also recommend educators let go of beliefs that students are deviant, criminal, unwilling to learn, undeserving, or are victims (Lockwood & Secada, 1999).

Instituting high expectations for Latino students and providing them with quality mathematics education, from algebra through calculus, improves their chances of college graduation and persistence in STEM. Guidance counselors should also encourage students to plan for college from a young age (Swail et al., 2005). A study of the Escalante Mathematics Project yields similar recommendations for rigorous coursework. Connecting mathematics to prior knowledge and emphasizing its relevance for future employment can help to capture students' interest. Thorough explanation of problems, collaborative learning, and teaching study skills can help students develop their mathematical thinking. Mentoring students in character development and helping them discover their talents can help improve the climate. Educators must also be comfortable dealing with behavior problems and managing class time (Kester, 1993).

On a larger scale, the research literature also provides recommendations for change.

Educational leaders and community members across schools, districts, states, regions, and the nation as a whole must work together to reduce the inequities in K-12 education. Steps should be taken to equalize school financial resources and tracking students into college preparatory or vocational courses eliminated (Simpson, 2001). Individual schools or districts should consider offering workshops on culturally relevant teaching, creating handbooks of Latino role models or organizations in the community, and establishing award programs for teachers and administrators who excel in working with bilingual populations, making sure to include Latino representation on awards planning committees or review boards (Triana & Rodriguez, 1993).

When schools do not have sufficient resources to offer advanced mathematics and science courses, they can encourage students to enroll in area college courses. Schools should institute increased learning time and accelerated learning, become more accountable for education, and engage in early intervention with students who are having difficulties (Chacon, 2000). Communication with families about college options and requirements is essential for improving the persistence of Latino students, and strategies can be developed to improve this dialogue (Chacon, 2000; Harrell & Forney, 2003).

Recommendations for Change Part 2: College

Many Latino students perceive, in their college science courses, that doors are closed to them because of poor teaching and a chilly climate. Creating a welcoming and supportive environment for students, and improving the climate and teaching methods in gatekeeper courses, is critical (Seymour & Hewitt, 1997; Triana & Rodriguez, 1993). One technique that has shown promise in reducing student isolation is collaborative learning (Swail, 1995). Cabrera, Crissman, Bernal, Nora & Pascarella (2002) found that students working in collaborative learning settings not only improved their cognitive development, but became more open towards

diversity.

Programs that offer Latino students various types of support and outreach can be helpful. These include leadership activities, financial aid, research experience and work experience (Brazziel & Brazziel, 1995; Morrison & Williams, 1993; Nevarez, 2001; Swail et al., 2005; Triana & Rodriguez, 1993). Also, personal counseling, intervention, individualized advising, peer tutoring, academic assistance, study groups, mentoring (especially by alumni in the sciences), and social integration are valuable (Brazziel & Brazziel, 1995; Morrison & Williams, 1993; Nevarez, 2001; Swail, 1995; Swail et al., 2005).

Partnering with high schools to improve science and mathematics education, recruit students, as well as to develop bridge programs, can aid students in preparing for and making the transition to college (Brazziel & Brazziel, 1995; Morrison & Williams, 1993; Nevarez, 2001; Swail, 1995). Effective bridge programs provide long-term support for students, place them in challenging courses, provide them with a mentor and a supportive peer group, offer financial assistance, and value their cultural background (Gándara & Bial, 2001).

It is also crucial to assess the status of Latinos in education and the long-term effects of retention programs (Morrison & Williams, 1993). Triana (1993) recommends developing a system of assessment and accountability for retention, while Nevarez (2001) suggests studying the academic and social climates at high schools and colleges and communicating the findings to the community, Latinos, and government agencies.

Hiring Latinos at high levels within an institution can aid in changing the environment for students. For example, employing Hispanic faculty and administrators and creating research programs that hire Latino scientists may improve institutional climates (Morrison & Williams, 1993; Triana & Rodriguez, 1993). Simpson (2001) recommends neutralizing institutional racism

by moving minority persons into positions of power on campus.

Addressing diversity issues, committing ample funding and staff time to minority initiatives, instituting a minority student office, and encouraging students to set up chapters of Minorities in Science and Engineering (MSE) organizations can create a more positive environment (Brazziel & Brazziel, 1995; Camacho & Lord, 2011; Morrison & Williams, 1993). These institutional frameworks can become a platform for Latino students to advocate for themselves.

Further Research

To develop successful recruitment and retention programs for Latinos in STEM, more data is needed on what students are currently experiencing on their career paths. While some studies are beginning to qualitatively and quantitative address these gaps, further research is required:

K-12 Preparation

1) What communication strategies are most effective in connecting with Latino parents, middle school students, high school students and communities? How can schools with limited resources implement these strategies?
2) How can we foster high expectations and quality teaching in schools with limited resources?
3) Why are some Latino students, even from a young age, unable to see themselves as scientists, mathematicians, or engineers? What interventions can change this discourse?
4) What are effective ways to dispel myths about Latino student ability that teachers may hold? How can teachers who work with Latino students become more culturally competent?

5) Are there successful programs (district or community based) preparing large numbers of Latinos for STEM majors? Are these activities scalable?

College

1) What influences Latinos' choice of college majors, with a focus on STEM majors?
2) To what degree do science professions demand acculturation? How can undergraduate advisors, counselors and minority program staff assist students in moving between cultures without being alienated? How can students learn to understand scientific culture?
3) Would a sustained program of collaborative learning improve educational outcomes for Latino students in the sciences?
4) What are Latino student experiences across all STEM majors? Are there distinct experiences across specific programs/departments/institutions/etc.?
5) What would successful Latino STEM students themselves recommend to improve the educational experiences of the next cohort of their peers?
6) Are there successful institutions preparing large numbers of Latinos for STEM fields? What role do HSIs play for Latinos in STEM?
7) In what ways can two-year institutions prepare Latinos for STEM fields?

Beyond College

1) Why are Latinos choosing not to attend graduate programs in STEM?
2) What are the experiences of successful Latino STEM graduate students?

Across all three categories for future research, a more nuanced understanding of differences between Latinos from diverse national origins, immigration statuses, English-language skills and length of time in the U.S. would explore the experiences of a complex, heterogeneous

community.

Improving the educational outcomes of Latino students in STEM is both urgent and important. Technical fields are creative, and benefit from a diversity of ideas. These fields will be better equipped to serve the international community if practitioners are comfortable working in multicultural settings and understanding the needs of underserved communities.

Without access to high-paying work which requires technical degrees, Latino students in the U.S. may not be able to succeed economically, and may remain confined to low-paying, often seasonal or temporary work, which is less likely to offer benefits and more likely to pose health risks. It is in the interests of educational institutions, government and the Latino community to connect and begin a dialogue about how to support the next generation of Latinos in taking rigorous science courses, pursuing college and graduate degrees, and believing that they can succeed.

In conclusion, if Latino students are given the message that they are expected to succeed in science and mathematics, and are given quality mathematics instruction and a supportive environment during high school, as well as social, academic and financial support in making the transition to college, they will be much more likely to excel.

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