



Community Colleges in the Evolving STEM Education Landscape: Summary of a Summit

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Appendix D

Developing Supportive STEM Community College to Four- Year College and University Transfer Ecosystems

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EXECUTIVE SUMMARY

Two-year to four-year college and university transfer pathways in science, technology, engineering, and mathematics (STEM) fields are too narrow and must be expanded to meet the social and economic demand in the United States for a greater number and a more diverse membership of scientists, engineers, and technicians. Faculty members have a critical role to play in expanding STEM transfer pathways. The value of structural, informational, and policy solutions, such as state and institutional articulation agreements, transfer information websites, state longitudinal data bases, and the accountability reporting made possible by such data, should be strengthened through initiatives to change the “culture of science” in ways that will foster culturally inclusive pedagogy and practices.

Any form of cultural and deep-seated organizational change requires a concerted effort over an extended period of time. Such an effort requires thought leaders, strategic communications, dedicated “change agents,” and a growing perception that norms are changing for the good. Prominent STEM scholars and educational leaders have recently provided a blueprint for change in comprehensive national reports, including the National Science Board’s *Preparing the Next Generation of STEM Innovators: Identifying and Developing our National Human Capital* and the National

*With valuable research assistance provided by Svetlana Levonisova, Raquel Rall, Cecilia Santiago, Misty Sawatzky, and Linda Shieh.

Academies' Expanding Underrepresented Minority Participation: America's Science and Technology Talent at the Crossroads.

The recommendations of these reports emphasize the need for greater access for all students to academic excellence in STEM and the necessity of improving talent assessment systems in order to identify currently overlooked abilities. Transfer admissions in general and in STEM in particular are particularly hampered by poor signaling of student talents and accomplishments because the quality of the community college curriculum is viewed with suspicion by university and liberal arts faculty. To address this problem, the National Science Board's recommendation to foster a supportive ecosystem is paramount. Creating a supportive ecosystem for transfer students requires the formulation of new incentives and rewards for college faculty in all sectors as well as professional development in teaching, curriculum development, and collaboration. Such professional development activities will be well received if they are accorded prestige and allocated time and resources for the production of new knowledge through research, design experiments, and inquiry, which is the systematic use of data, reflection, and experimentation to improve professional practices.

Taking into account the prestige associated with success in STEM fields and the generally separate nature of faculty networks in different sectors and disciplines, this report endorses the following recommendations:

- (i) Create Evidence-Based Innovation Consortia (EBICs), involving STEM faculty, deans, and department heads in geographic and market-based groupings of two-year and four-year colleges and universities to review, invent, experiment with, and evaluate innovative curricula, pedagogies, and assessments of student talents and learning.
- (ii) Devote institutional, private, and federal funds to STEM-specific work-study awards and transfer scholarships for transfer students and charge EBICs with the recruitment and selection process.
- (iii) Develop a pool of eligible cohorts of students at community colleges through jointly administered two-year and four-year college learning communities and bridge programs, recruiting and retaining a diverse group of students using holistic admissions and assessment criteria developed through the EBICs.
- (iv) Accord prestige to EBIC membership and the recipients of the transfer work-study awards and scholarships through high-profile communications and selection procedures.

CREATING MORE ROBUST STEM TRANSFER PATHWAYS: NATIONAL CONTEXT

No single data source provides a comprehensive estimate, but the available evidence suggests two-year to four-year college and university transfer in STEM fields is small relative to the need for a greater number of STEM-educated citizens, workers, and professionals in the United States. The barriers and potential solutions to increasing access through transfer to STEM bachelor's and graduate degrees for transfer students are the subject of this report. This consideration takes place in a broader national context. In May 2010, as mentioned above, the National Science Board (NSB) issued its comprehensive report entitled *Preparing the Next Generation of STEM Innovators: Identifying and Developing Our National Human Capital*, and in 2011, the National Academies issued *Expanding Underrepresented Minority Participation: America's Science and Technology Talent at the Crossroads*. The three keystone recommendations of the *Next Generation* report (National Science Board, 2010) and several of its policy actions deserve particular attention when examining the evolving relationships between community colleges and four-year colleges and universities for the purpose of broadening STEM transfer pathways. These are

- (1) NSB Keystone Recommendation #1: Provide opportunities for excellence
- (2) NSB Keystone Recommendation #2: Cast a wide net
 - (a) Policy Action: Improve talent assessment systems
 - (b) Policy Action: Improve identification of overlooked abilities
- (3) NSB Keystone Recommendation #3: Foster a supportive ecosystem
 - (a) Policy Action: Professional development for educators in STEM pedagogy

These particular recommendations and policy actions, excerpted from among others in the NSB's *Next Generation* (2010) report, are highlighted here because the challenges of (1) providing quality science and mathematics teaching to all students (i.e., "opportunities for excellence"), (2) improving assessment and talent identification, and (3) creating supportive ecosystems through professional development for STEM educators are particularly central to the challenge of creating more robust STEM transfer pathways. They are also essential in light of the urgency articulated in the *Crossroads* report (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2011) to substantially increase the racial-ethnic diversity of participation in STEM fields. The dimensions of these problems are cultural as well as structural; yet prevailing attempts to improve transfer, such as articulation agreements, curriculum alignment through common course numbering, and policies guaranteeing transfer of credits, have most often been structural. However, to improve

transfer in STEM, it will be necessary to consider the cultural characteristics of STEM learning environments and those who have traditionally succeeded in them in formal educational systems in the United States.

Before discussing the culture of science and how it pertains to the issue of the improvement of transfer access to STEM bachelor's and graduate degrees (see section III below), I first present statistics to provide a sense of the potential supply of STEM transfers and sources of data to estimate the number of transfers in STEM fields (section I). Then, I briefly review the barriers and potential solutions to improve transfer access from community colleges (section II). The report then concludes with discussion of recommendations to create Evidence-Based Innovation Consortia (EBICs) as place- and market-based entities with a focus on improving STEM transfer pathways (section IV).

I. POPULATION AND TRENDS IN THE NUMBER OF POTENTIAL STEM TRANSFER STUDENTS

Data provided by the National Center for Education Statistics (NCES) include the total number of credential-seeking undergraduates, distinguishing those enrolled in subbaccalaureate programs from those enrolled in bachelor's degree programs. In 2007-2008, the subbaccalaureate population numbered 9,822,000, with 6,383,000 classified as enrolled in career education, 2,361,000 enrolled in academic education, and the remainder undeclared (National Center for Education Statistics, n.d.-b). Career education includes some technical fields such as agricultural and natural resources, computer and information services, engineering, and health services, as well as non-STEM fields such as business management, communication and design, and legal and social services. Vocational degrees such as cosmology and protective services are also included. Academic education includes general education courses in science and mathematics. These numbers represent students in public two-year colleges (community colleges) and in for-profit, proprietary colleges combined. In the very broadest terms, these nearly 10 million students represent the total potential pool of transfer students. In Fall 2008, the count of students enrolled in community colleges for credit numbered 7.4 million (Mullin, 2011).

However, many of these students are strictly seeking vocational training, do not aspire to transfer, and earn certificates in short-term programs rather than associate's degrees (Mullin, 2011). The growing interest in applied baccalaureate degrees (Ruud and Bragg, 2011) notwithstanding, the nearly two-to-one ratio of students in career education versus academic education reflected in the figures above indicates that the majority of students enrolled at the subbaccalaureate level are earning credits in vocational courses that would not count toward a bachelor's degree.

The American Association of Community Colleges reports on degrees awarded by public two-year institutions. In 2009-2010, approximately one million degrees and certificates were awarded, including 630,000 associate's degrees (Mullin, 2011, p. 6). Of these, 40 percent were classified as degrees in the liberal arts and sciences or humanities, which align with a general education focus within a transfer-directed curriculum. The number of associate's degrees awarded by community colleges represents an overall increase of 86 percent from two decades earlier, but growth rates were much higher for Hispanics (383%), blacks (204%), and Asian-Pacific Islanders (APIs, 230%) (Mullin, 2011, pp. 17-18). Currently, Hispanics, American Indians and Alaska Natives, and African Americans all earn associate's degrees at higher rates than white and Asian-Pacific Islander students. For example, in 2007-2008, 36 percent of degrees earned by Hispanics and 30 percent earned by blacks were associate's degrees, compared to 23 percent for whites and 19 percent for APIs. Conversely, bachelor's degree completion rates were lower, with only 11 percent of Hispanics in the 25-29 year age group having at least a bachelor's in 2008 and 17 percent of blacks. These figures compare with 33 percent of whites and 60 percent of APIs in the same age group (Aud, Fox, and KewalRamani, 2010). NCES (2011) reports that 14.4 percent of all students who began their studies in public two-year institutions earned an associate's degree within the six-year period of 2004-2009.

Certificates were awarded at community colleges for programs ranging from less than one year to four years in duration. The increase in certificates was much greater than the growth in associate's degrees, growing 776 percent and 338 percent for Hispanic and black students, respectively (Mullin, 2011, pp. 17-18). This trend mirrors the increases in degrees and certificates awarded by for-profit postsecondary institutions, which has been the fastest growing sector of higher education over the past decade, with enrollments doubling from 192,000 to 385,000 from 2000 to 2009 (National Center for Education Statistics, 2011). These numbers are significant because they show a shift in demand for subbaccalaureate education away from community colleges toward the for-profit sector. Some attribute the rise of the for-profit sector to the inability of public colleges to meet the demand for higher education (Lee and Ranson, 2011). A notable part of the changing STEM education landscape is the growing number of students earning associate's degrees at for-profit institutions and the growth in the number of short-term certificates awarded in both sectors. Data from the NCES indicate that nationally the most popular STEM-related career education fields of study at the associate's degree level in 2007-2008 were health sciences, enrolling 1,627,000 students (and 21% of the total); engineering and architecture, enrolling 396,000 (6.7%); computer and information services, enrolling 336,000 (3.8%); and agri-

culture and natural resources, enrolling 50,000 (.7%) (National Center for Education Statistics, n.d.-c). The number of associate's degrees awarded in the health sciences in 2008-2009 represents a 77 percent increase over 1998-1999. Computer and information sciences also saw overall growth of nearly 34 percent during that time period, but nevertheless experienced a loss of 27 percent in the number of degrees awarded to women. Engineering and engineering technologies experienced a decline in degrees awarded of nearly 8 percent for men and women combined, but of 24 percent for women (National Center for Education Statistics, n.d.-a). Agriculture and natural resource fields experienced a decline among both men and women, with a nearly 14 percent loss overall. These trends mirror declining proportions of women in engineering and computer sciences at the bachelor's degree level (National Science Foundation, 2011).

Hardy and Katsinas (2010) investigated a longer period of time by analyzing institutional data captured by the annual snapshot of higher education in the Integrated Postsecondary Education Data System (IPEDS). They compared the number of associate's degrees awarded over three decades (1985-1986, 1995-1996, and 2005-2006), focusing on broad STEM codes including engineering, engineering technologies/technicians, biological and biological sciences, mathematics and statistics, physical sciences, and science technologies/technicians. The article focuses on gender, in particular, and shows that although the overall number of associate's degrees awarded in STEM is increasing, the percentage awarded to women is not.

Contested but Inadequate Transfer Rates

The estimation of transfer rates is contested (Horn and Lew, n.d.). Depending on how broad or restrictive the denominator is, the determination of who "counts" in estimating the rate and the length of time allowed for transfer to take place, transfer rates vary widely. A broad-based national estimate of the proportion of community college students who transfer to a four-year institution is 25 percent (Melguizo and Dowd, 2009). However, this number varies by state, socioeconomic status (SES), and students' demographic characteristics. Students from higher SES households are more likely to transfer than those from lower SES households, with a difference of 45 percentage points between the 10 percent transfer rate for low-SES students and the high end at 55 percent (Dougherty and Kienzl, 2006). Using a broad denominator of Latinos entering community colleges in California, Ornelas and Solorzano (2004) report an analysis of California Postsecondary Education Commission (CPEC) data indicating that only 3.4 percent of Latinos transfer to a California four-year public institution.

Another point of contention is whether transfer students experience a penalty in their pursuit of a bachelor's degree from starting at a community college. Utilizing statistical models to compare students of equivalent characteristics and qualifications, some find that there is a "diversion effect" (e.g., Cabrera, Burkum, and La Nasa, in press), by which transfer students become diverted from bachelor's degree attainment. Others find a "democratization effect," meaning that the open access community college ultimately democratizes access by providing an effective pathway to the bachelor's degree (Melguizo and Dowd, 2009).

Arbona and Nora (2007), analyzing National Longitudinal Educational Survey data of a sample initially collected in 1988 (NELS: 88), found that among those Latino students who first attended a community college, only 7 percent had obtained at least a bachelor's degree by 2000. Similarly, an estimate obtained from the Beginning Postsecondary Students Longitudinal Study (BPS:96/01) showed that although 25 percent of Hispanic students who attended a two-year college initially intended to transfer to a four-year institution and obtain a bachelor's degree, six years after first enrolling in community colleges only 6 percent had been awarded a bachelor's degree (Hoachlander, Sidora, and Horn, 2003). Notwithstanding these debates, few analyses conclude that transfer rates are high enough to fulfill the potential of community colleges to provide first generation, low-income, and underrepresented racial-ethnic minority group students with a satisfactory chance of earning a bachelor's degree.

An Initial Profile: Latina and Latino STEM Bachelor's Degree Holders Who Transferred

None of the studies and reports above provides estimates of the numbers of community college transfer students in STEM fields, revealing that further research is needed to produce such estimates. In this subsection, I present a brief profile of Latina and Latino STEM transfers based on a study conducted by the Center for Urban Education at USC with funding from the National Science Foundation to begin to fill this research gap. Transfer is of particular importance for increasing Latina and Latino participation in STEM because Latinas and Latinos are disproportionately enrolled in community colleges (Adelman, 2005), particularly in populous states with growing Latino populations, such as California, Florida, and Texas. Estimates vary, but roughly 60 percent of Latino students enrolled in postsecondary education attend a community college (Arbona and Nora, 2007; Snyder, Tan, and Hoffman, 2006).

Expanded transfer access is necessary because although Hispanic participation in STEM fields has risen, it has not kept pace with Hispanic population growth. Growth in the number of bachelor's degrees

awarded to Hispanic students has occurred primarily in nonscience and engineering fields. From 1998 to 2007, there was a 64 percent increase in the number of nonscience and engineering bachelor's degrees awarded to Hispanic students, as compared to an increase of only 50 percent in science and engineering degrees awarded to Hispanic students. Further, the proportion of STEM doctoral degrees awarded to Hispanic students (estimated at less than 5 percent) severely lags the proportion of Hispanics in the U.S. population (around 15%).

Analyses conducted by Lindsey Malcom (2008a) and Alicia Dowd (Dowd, Malcom, and Macias, 2010) of the NSF's National Survey of Recent College Graduates (NSRCG:2003) present a portrait of the fields of study of Latina and Latino STEM¹ bachelor's degree holders who transferred from community colleges with associate's degrees, based on a sample of students who earned bachelor's degree in 2003. The analyses examine the fields of study in which Latino STEM bachelor's degree holders earned their degrees, comparing degrees awarded at Hispanic-Serving Institutions (HSIs) and those at non-HSIs.

Degrees awarded at HSIs (which are defined by enrollment of Hispanic students equal to or exceeding 25% of full-time students) and non-HSIs were differentiated because only 10 percent of institutions in the United States enroll the majority (54%) of Latino undergraduates (Horn, 2006). HSIs tend to be less selective nonresearch colleges and universities. Traditionally they have received less federal funding than research universities and selective institutions. Although nearly 40 percent of bachelor's degrees awarded to Latinas and Latinos in all fields of study are granted by HSIs (Santiago, 2006), that figure shrinks to 20 percent when the analysis is limited to STEM degrees (Malcom, 2008a; Malcom, Dowd, and Yu, 2010). This indicates that HSIs do not do as well at retaining Latinos in STEM fields as in other fields.

Our analysis of the NSCRG data, in which transfer students were defined as those who had first earned an associate's degree, showed that most transfer students who ultimately earn bachelor's degrees in STEM fields major in the social and behavioral sciences. This is true at HSIs, where these majors account for 60 percent of STEM baccalaureates, as well as at non-HSIs, where the share is 70 percent. There is one critical area of study in which HSIs graduate a substantially larger percentage of STEM transfers than non-HSIs. Of Latino STEM baccalaureates who graduate from HSIs, 18 percent earn their degrees in computer science and mathematics compared with only 5 percent of STEM transfer graduates

¹The definition of STEM fields employed by the National Science Foundation includes computer science, mathematics, life sciences, physical sciences, behavioral and social sciences, and health-related fields.

at non-HSIs. On the other hand, HSIs appear to be lagging behind non-HSIs in terms of awarding bachelor's degrees to Latinos in the biological, agricultural, and environmental sciences (3% as opposed to 11%) and in engineering (1% as opposed to 7%).

These statistics present a portrait of Latino STEM transfer in which we see that (1) transfer pathways from community colleges are narrow; (2) the majority of degree holders who earned an associate's degree before earning a bachelor's degree in STEM earned their degrees in social and behavioral sciences, rather than in computer science, mathematics, biological, agricultural, and environmental sciences, engineering, physical science, or in fields designated as science and engineering related; (3) Latino students had a better chance of earning a STEM degree outside of the social and behavioral sciences if they did not earn an associate's degree first. These figures would change if we used a different definition of transfer students (for example, those who transferred after the equivalent of one year of study, or 30 credits), but they illustrate that certain pathways to STEM bachelor's degrees are not as readily accessible for students who start out in community colleges.

Clearly, similar portraits must be created for other groups of students. However, given that HSIs are typically nonselective four-year institutions and that Latino students are the fastest growing demographic group, this portrait of Latino transfer in STEM provides a good starting point for gaining an understanding that STEM transfer pathways are not nearly as robust as they need to be. Latino community college transfers who first earn associate's degrees have lower access to STEM bachelor's degrees at academically selective and private universities than their counterparts who do not earn an associate's degree prior to the bachelor's. Available studies of transfer trends, in which the analyses were not restricted to STEM fields or to Latinos, suggest that transfer has become more limited to selective institutions while fluctuating and leveling off in nonselective institutions during the 1980s and 1990s (Dowd, 2010; Dowd and Melguizo, 2008; Dowd et al., 2006). These results are not based on the most current data, but the forces that likely diminished transfer during those decades are still active today, including intensive demand for elite education that make transfer applicants less attractive to selective institutions (Dowd, Cheslock, and Melguizo, 2008). The loss of transfer access to selective institutions is of concern in regard to STEM graduate degree production because the competitive, "top 100" STEM research universities are the main gateways to STEM doctoral and professional degrees. As long as selective institutions restrict transfer access, the challenge of creating more robust transfer pathways in STEM for community college students will fall largely to nonselective institutions.

Generating Portraits of Transfer in STEM for Other Groups

How would the figures presented above change if the focal group of interest changed from Latina and Latino students to white and Asian students or to African Americans, Native Americans, women, students with disabilities, or other underrepresented groups? Replicating the results presented above for other groups of interest using the NSRCG data would be one way to answer this question. Arbona and Nora (2007) have analyzed the NELS database to examine transfer of Latino students; other researchers might conduct similar analyses, although they might encounter difficulties in estimation due to small sample sizes.

Wang (2011) has valuably proposed to examine transfer pathways in the new Educational Longitudinal Study (ELS) data, which will provide more current estimates disaggregated by a variety of demographic groups of interest. The ELS monitors a nationally representative cohort of students in their sophomore year of high school. In 2006, data about this sample were collected regarding the colleges the students applied to, the financial aid they received, and their postsecondary enrollment, among other information. In 2012, members of the cohort will be interviewed again to learn about their outcomes, including persistence and experience in higher education, and/or transitions into the labor market. Another, more specialized dataset may be especially useful for examining student pathways to and within engineering. The MIDFIELD database is a longitudinal database containing information from 11 public institutions for 226,221 students that have ever declared engineering as a major from 1988 through 2009. It includes data regarding student behaviors, including the majors they change to, and the major students subsequently graduate in. It contains student demographic information, history of courses taken, and grades received, as well as degrees awarded. Consequently, this dataset is a resource for mapping the types of paths students take after matriculating in engineering. It holds potential use for studying choices taken by students leaving engineering, and whether this group disproportionately comprises members of underrepresented student populations. In addition to information on first-time students admitted to college engineering programs, the MIDFIELD database also includes information regarding the pathways of transfer students who are admitted to engineering programs.

II. STRUCTURAL BARRIERS TO STEM TRANSFER AND PROMINENT SOLUTION STRATEGIES

Before moving into a discussion of cultural barriers to STEM transfer, it is important to acknowledge structural barriers to transfer and take stock of the most prominent contemporary strategies to broaden transfer pathways. The primary curricular barriers are lack of articulation of

coursework in the two-year and four-year sectors; lengthy remedial, basic skills course sequences (particularly in mathematics); and the separation of special programs from the core curriculum. Challenges students encounter in financial aid and advising include “sticker shock” when contemplating four-year college and university prices, lack of information about the multiple sources of financial aid, poor access to counselors, and the lack of participation of faculty members in transfer advising.

Transfer and Articulation Policies Are Insufficient to Improve STEM Transfer Access

The goal of establishing curriculum “articulation” and alignment between the community college and four-year college and university curricula has been a policy focus for several decades. Although Zinser and Hanssen (2006), based on an analysis of national data from the Advanced Technological Education (ATE) program, conclude that articulation agreements for the transfer of two-year technical degrees to baccalaureate degrees are valuable, other analyses of secondary databases indicate that state-level articulation agreements have statistically insignificant effects on the likelihood that community college students will transfer (Anderson, Alfonso, and Sun, 2006; Anderson, Sun, and Alfonso, 2006; Kienzl, Wesaw, and Kumar, 2011).

These results indicate that articulation agreements are not likely to be effective on their own in substantially broadening STEM transfer pathways. California’s recent experience in the early stages of implementing a guaranteed transfer degree, legislated in Fall 2011, illustrates some of the challenges in state policies intended to improve curriculum alignment. The new law stipulates that community colleges offer associate’s degrees for transfer that the California State University (CSU) campuses would be obliged to accept. The mandated degree is 60 credits, including 18 credits in an area of academic focus that should provide a transfer student access to a similar major field of study at the university. The adoption of this law led to a process of negotiations between community college and university curriculum committees to identify articulated degree programs. By December of 2011, 16 associate’s degrees were approved for transfer and priority admissions, but only two of these were in STEM fields (mathematics and physics) and about a third of the CSU campuses had yet to confirm availability of a matching degree program in those fields.

States have had varying success in using postsecondary policy to improve transfer pathways in STEM. Malcom (2008a, 2008b) illustrated this through analysis of the share of Latina and Latino STEM baccalaureates in NSF’s 2003 National Survey of Recent College Graduates (NSRCG) who earned associate degrees. Examining the five states with the larg-

est populations of Latinos—California, Florida, Illinois, New York, and Texas—she found that nearly half of all Latinos in Florida who were awarded a STEM bachelor’s degree had also earned an associate’s degree. This represents a much greater reliance on community colleges for STEM degree production in Florida, which has strong statewide articulation policies, than elsewhere. In New York, California, and Illinois, the share of Latino STEM bachelor’s degree holders who had first earned associate’s degrees (27.9%, 22.2%, and 16.3%, respectively) was closer to the national average of 20 percent. The proportion in states other than these five, which would include states with smaller community college systems, was considerably lower, at 9.2 percent.

The Substantial Challenge of Developmental Education in Mathematics

There is a growing recognition of the need to improve the teaching of foundational mathematics to young adults and adults in order to improve the persistence, degree completion, and transfer of community college students (Attewell et al., 2006; Bailey and Morest, 2006; Dowd, 2008; Grubb et al., 2011; Kirst, 2007; Levin and Calcagno, 2008). Many community college students are placed in classes, typically in mathematics, English, or writing, that do not carry credit towards an associate degree or bachelor’s degree. These courses are referred to as remedial, basic skills, or developmental. Nationally, 42 percent of students enrolled in public two-year institutions in 2007–2008 took at least one remedial course, a share that is higher than in any other postsecondary sector. Eight percent of students required two remedial courses and 5 percent required three (Aud, Fox, and KewalRamani, 2011). Mathematics is the most common subject in which students require remediation, with national estimates hovering around 50 percent (Bahr, 2010; Parsad, Lewis, and Greene, 2003). Remedial testing and the long basic skills curriculum have disparate impacts on African Americans and Latinos, who are more likely to be placed in remedial courses and less likely to complete them successfully (Aud, Fox, and KewalRamani, 2011). By some national estimates, approximately half of black and Hispanic community college students earn remedial credits in mathematics (Bahr, 2010). In California, where the sheer size of the community college sector, with its 110 colleges, drives attention to community college issues, some estimate that 80 to 90 percent of students require remediation, with math being the greatest area of need (Grubb et al., 2011).

These statistics indicate that the challenge of remedial education is not unique to community colleges. However, the need for remediation and the often lengthy, skills-based remedial curriculum impedes students’

ability to transfer or even contemplate transfer, as the lengthy time frame is discouraging. Students who test and are placed in courses such as arithmetic and pre-algebra, as well as remedial writing or English language courses, can face several semesters, or even years, of coursework that does not count for transfer to a four-year institution. Two recent studies from California are informative to illustrate the magnitude of the demand and the racial-ethnic equity implications of remedial education in community colleges. Hagedorn and colleagues (Hagedorn and DuBray, 2010; Melguizo, Hagedorn, and Cypers, 2008), analyzed transcripts of more than 5,000 students enrolled in the Los Angeles Community College District (LACCD) and examined basic skills mathematics course placements and completion. Over a third of students who had declared a STEM focus for their studies were initially placed in the lowest level course. Seventy-five percent of students were able to pass their first course on their first attempt. However, African American students were less likely to pass on the first attempt and both African American and Hispanic students emerged with lower mathematics GPAs. Mathematics appeared to pose a particular challenge; for example, African American students had equal rates of success to other student groups in science courses.

These results from Los Angeles are mirrored in California as a whole. Analyzing data from the California Community College Chancellor's Office for the Fall 2005 cohort, Bahr (2010) found that black and Hispanic students were disproportionately enrolled in mathematics basic skills courses and experienced low rates of successful remediation. His findings indicate that the rates of successful remediation in mathematics ranged from one-quarter to one-third of white and Asian students, in comparison to one-fifth of Hispanic and one-ninth of black students (Bahr, 2010, p. 232).

The equity implications of the remedial education challenge are evident given that lower income and underserved racial-ethnic minority students are less likely to receive adequate mathematics preparation in high school (Attewell et al., 2006; Bahr, 2010; Dowd, 2008) and less able to bear the opportunity costs of time spent in remediation (Melguizo, Hagedorn, and Cypers, 2008). Further, more affluent students can avoid strict remedial policies in the public sector by enrolling in private colleges and universities, where they receive stronger academic support to progress from remedial to degree-credit coursework. In addition, the reliability and validity of the placement tests have been questioned (Attewell et al., 2006; Brown and Niemi, 2007; Hughes and Scott-Clayton, 2011), in part because students with similar levels of academic preparation and test results can experience very different course placements, depending on their state of residence and their choice of institution within the same state.

Finally, it is not clear that students who are placed in remedial courses

achieve better academic outcomes, in terms of persistence and credit accumulation, when compared with similarly qualified students who were not placed in developmental courses, because the available quasi-experimental evidence is mixed (Hughes and Scott-Clayton, 2011). All the available evidence indicates that the demand for mathematics basic skills education is substantial and that the current curriculum and instructional methods are not up to the task. The goal of improving transfer access to STEM degrees, therefore, is intertwined with the need to improve basic skills mathematics education.

Curricular and Programmatic Barriers and Potential Reforms

Educational researchers have conducted numerous case studies of transfer involving particular groups of students or institutions (Bensimon and Dowd, 2009; Bensimon et al., 2007; Cejda, 1998, 2000; Gabbard et al., 2006; Laanan, 1996; Lester, 2010; Ornelas and Solorzano, 2004; Townsend and Wilson, 2006). Common themes in the findings identify institutional barriers to transfer such as lack of information, confusing transfer curriculum requirements, the demands of remedial education (as noted above), and the struggle many students face becoming acclimated to a new campus environment at the four-year institution. Many students who transfer experience a “border crossing” (Bensimon and Dowd, 2009; Pak et al., 2006) that produces “transfer shock” (Laanan, 2003). In consideration of these challenges, these studies have highlighted a number of prominent solution strategies including summer bridge programs, student cohorts of learning communities, more robust faculty advising, various types of mentoring, and institutional self-studies of transfer to create a more “transfer-amenable” culture (Dowd et al., 2006).

Similarly, researchers have examined the impacts of the STEM curriculum and learning environments on student recruitment and retention in STEM fields, often with a focus on understanding the disproportionate loss of women and underrepresented racial-ethnic minority students from STEM majors at four-year institutions (Aguirre, 2009; Carlone, 2007; Cole and Espinoza, 2008; Crisp, Nora, and Taggart, 2009; Fries-Britt, 1998; Howard-Hamilton et al., 2009; Hurtado et al., 2007, 2009, 2010, 2011; Johnson, 2007; Jones, Barlow, and Villarejo, 2010; McGee and Martin, 2011; Seymour and Hewitt, 1997; Strenta et al., 1994). These case studies characterize concepts such as the culture of science, the notion of a science identity, and the factors that contribute to a sense of belonging or marginalization in STEM classes, majors, and programs. The finding that science and mathematics courses too often function as “weed out” or “gatekeeper” classes that turn students away from STEM majors is a prominent one. Related themes included the emphasis on rigor over instructional

support, the demoralizing impact of grading on a curve, stressful and competitive learning environments, and an emphasis on memorization and facts over learning, contextualized problem solving, and application. Enabling students to develop a sense of belonging through faculty and peer interactions in authentic learning activities, particularly research, emerges from these studies as an essential ingredient for STEM reform. The best known and most commonly used innovations that have been developed to address these concerns include various types of active learning and design projects, service learning, bridge programs, learning communities, and other approaches to integrating interdisciplinary curricula (Borrego, Froyd, and Hall, 2010; Henderson, Beach, and Finkelstein, 2011; Vanasupa, Stolk, and Herter, 2009). The need to increase faculty diversity is acknowledged, as is the limited progress in that direction (Stanton-Salazar et al., 2010).

Concerned with the large number of students enrolled in remedial mathematics classes, a special strand of the STEM education literature is focused on developmental education in community colleges. This literature highlights the inadequacies of current practices relative to the scale and complexity of the problem. The prevalence of decontextualized, skills-based instruction and the extended length of the mathematics remedial pathway are often emphasized. Emerging curricular strategies for improved outcomes (in mathematics as well as writing and English language instruction) include placing students in learning communities (Weissman et al., 2011) and implementation of various types of “acceleration” or curricular redesign models, which compress or modularize the curriculum to the essential skills that students need to succeed in their degree-credit courses. Enhanced instructional supports in the form of tutoring, technology-assisted learning, supplemental instruction, intensive advising, and student success courses have also received attention as potential remedies. Another strand of instructional intervention focuses on faculty development through inquiry, data-informed decision making, and institutional self-assessments (Carnegie Foundation for the Advancement of Teaching, 2008). Policy interventions include allowing dual enrollment in high school and college courses and state testing to assess students’ college-readiness early enough in their high school years to inform students that they need to increase their level of academic preparedness (Bragg, 2011; Packard, 2011; Rutschow and Schneider, 2011).

A smaller number of studies has specifically examined the transfer experience for STEM students (Malcom, 2008a; Packard et al., 2011; Reyes, 2011; Stanton-Salazar et al., 2010). Bensimon, Dowd, and colleagues examined STEM transfer pathways from community colleges to public universities with the formal designation of Hispanic Serving Institutions (HSIs) (Dowd, Malcom, and Bensimon, 2009; Stanton-Salazar et al., 2010).

Through a case study involving 90 faculty, administrators, and counselors at three universities and three “feeder” community colleges selected as potential exemplars of good practice, they interviewed individuals who had active roles in transfer or STEM transfer programs. The respondents described and shared data showing programs intensively focused on a small number of Hispanic students relative to the entire Hispanic student body at these institutions. As often as not, respondents worked in isolation and were not part of robust networks of faculty and administrators engaged in changing the STEM curriculum. For some, the isolated nature of the work led to a sense that the goal of improving Hispanic student participation and degree completion in STEM fields was not supported by the college leadership. These results highlight the concern that special programs are not adequate to the task of substantially increasing the number of Hispanic students being awarded STEM degrees and the “institutional agents” who work to change the culture of STEM are too few in number to have a systemic impact.

Similarly, Packard (see Appendix B, this volume) emphasizes the importance of faculty mentoring, networks, and advising to encourage women to transfer in STEM fields (see also Packard, 2011). She also found evidence of the value of family and peer academic support. Financial constraints placed stress on many of the 30 women in her sample, two-thirds of whom were first-generation college students and one-quarter were members of racial-ethnic minority groups. As in other studies that have documented the experience of “transfer shock,” these transfer students were initially set back by the much quicker pace and rigor of the baccalaureate coursework, especially given that the level of academic support was also lower.

The body of literature focusing specifically on transfer in STEM is not robust enough to substantiate conclusions about the unique programmatic features that are necessary to design effective STEM transfer pathways. However, the intersections in the literature on “choosing and leaving” STEM (Strenta et al., 1994) and the literature on the supports needed for successful transfer suggest that undergraduate research and summer or supplementary bridge programs involving contextualized and active learning are of particular importance. These programs bring students into meaningful relationships with faculty, helping students to develop a science identity and sense of belonging. They also provide a chance for students to see how science is meaningful to their own lives and communities, a factor that is thought to have particular salience for students from underrepresented racial-ethnic minority groups because the STEM faculty and workforce lack role models and mentors with similar backgrounds.

Community College Student Concerns About the Affordability of Higher Degrees

Community college students are often first-generation students from low-income households (National Center for Education Statistics, 2011, Table 8). Most work either full- or part-time (National Center for Education Statistics, 2011, Table 7). For many, concerns about the affordability of enrolling in a four-year institution cast doubt on the feasibility of transfer (Bensimon and Dowd, 2009; Malcom, 2008a; Ornelas and Solorzano, 2004; Packard et al., 2011). In part, this is due to poor quality financial aid advising and misperceptions of the net price of study at the baccalaureate level once various forms of financial aid are factored in. However, it also reflects a pragmatic outlook and a desire to avoid taking on undergraduate loan debt that they might be unable to pay in the event they do not earn a degree. While students in community colleges and in four-year colleges receive Pell grants (National Center for Education Statistics, 2011, Table 2) and take out loans at similar rates, on average, the amount borrowed by bachelor's degree recipients who started out in public two-year institutions exceeds the amount borrowed by those who started at public four-year institutions (Cataldi et al., 2011, Table 4). In addition, those who start in community colleges have a lower likelihood of earning a bachelor's degree and a higher risk of default (Dowd and Coury, 2006). Data reflecting the period from 2004 to 2009 show that only 19.5 percent of 38 percent of STEM students² who begin their studies at public two-year institutions attain a degree or certificate within six years (National Center for Education Statistics, 2011, Table 7). For those who do complete a bachelor's, the time to degree (and opportunity costs for earning and career advancement) is longer (National Center for Education Statistics, 2011, Table 3).

Specifically in regard to STEM, Malcom and Dowd (2012), analyzing NSF's NSRCG data, found that cumulative undergraduate debt among STEM bachelor's degree holders (measured in relative terms in comparison with the typical amount of debt at the graduate's institution) had a negative effect on graduate school enrollment right after college among STEM bachelor's degree holders. Focusing on Hispanic students, they also found that STEM transfer students were more likely to use "self-support" financing strategies, where they used a mix of grants, loans, and earnings, and employer support. This financing profile is consistent with the funding strategies of older, first-generation, and lower-income students who cannot take advantage of parental contributions or loans

²Includes life sciences, physical sciences, mathematics, computer and information sciences, and engineering and engineering technologies.

(Malcom, Dowd, and Yu, 2010). The available evidence suggests that affordability is a concern for potential STEM transfers, that working off campus may detract from a focus on coursework (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2011), and that aspirations for professional and doctoral degree attainment are dampened due to concerns about debt.

III. PRESTIGE AND THE CULTURE OF SCIENCE

Engineering, the sciences, whether physical, biological or technical, and computing all require mathematical knowledge, reasoning, and skills. These are fields in which epistemic knowledge, which is to say knowledge viewed as objective, rational, and value-neutral, is highly valued (Greenwood and Levin, 2005; Polkinghorne, 2004). Academic disciplines have distinctive cultures and norms (Becher, 1989), in part derived from epistemological paradigms. In academic typologies, STEM fields are considered “hard-pure” (e.g., mathematics and physics) or “hard applied” fields (e.g., engineering), in contrast to “soft-applied” fields (e.g., education and social work) at the other end of the continuum (Austin, 1990). In the hard-pure sciences “knowledge is cumulative and the goals are discovery, explanation, identification of universals, and simplification” (Austin, 1990, p. 64). The hard-applied fields apply such universal knowledge through various forms of engineering, research, and technical design. Despite the fact that engineering, for example, is inherently concerned with social contexts and the public good, these aspects of the engineer’s professional responsibilities and identity have become diminished in modern society (Vanasupa, Stolk, and Herter, 2009).

The abstract and generalized truths of hard-pure fields are produced through certain ways of knowing, learning, and thinking, which are called “rational.” Success in STEM fields holds prestige in ways that success in other fields does not, because rational knowledge is currently accorded status in U.S. society as an elevated form of knowledge held by experts (Polkinghorne, 2004). Scientists, engineers, and mathematicians, therefore, have a strong identity as rational thinkers. They are also acknowledged survivors or victors who have prevailed in competitive learning environments where producing correct answers and earning high grades are valued. The importance of persistence in the face of repeated error in the inevitable trial and error of scientific research is less clearly acknowledged. Scientific identities are forged in a distinctive “culture of science,” with its “gatekeeper” courses and competitive grading (Hurtado et al., 2011). The science culture also promotes ongoing reidentification and association with the scientific community (Austin, 1990; Bergquist and Pawlak, 2008).

It is important to recognize that when scientists, mathematicians, and engineers are asked to invest their professional energies in developing new pedagogies, teaching strategies, and curricula, or to engage in inquiry about the effectiveness of their educational practices, they are being asked to elevate their attention to those aspects of their professional knowledge that are typically accorded less prestige. Education, like social work and counseling, is a soft-applied field, where “knowledge is holistic, and the emphasis is on understanding, interpretation, and particulars” (Austin, 1990, p. 64). In fact, expertise in these fields is defined by one’s ability to draw on an extensive repertoire of “particularized” cases and unconsciously select appropriate responses to meet the needs of students or clients. The hallmark of an expert in these fields is the ability to examine an “indeterminate situation,” where generalized practices are ineffective in particular cases, and to function effectively under conditions of ambiguity. Educational practice is inherently ambiguous because the teaching-learning relationship is made up of dynamic interactions between teacher and learner (Polkinghorne, 2004)

Without introducing an expectation of adopting reduced academic standards, the Keystone Recommendations of the *Next Generation* report emphasize that the standards of instruction, assessment, and selection into STEM have become too narrow. “Grading on the curve” and the use of “weed out” and “gatekeeper” courses have failed to ensure “opportunities for excellence” or high-quality learning environments for all students across the educational spectrum. Although such practices may be viewed as academically rigorous and necessary by many of those within the STEM professions, researchers have highlighted their negative effect on racial-ethnic minority students and on women (Hurtado et al., 2007, 2009; Seymour and Hewitt, 1997). Subject content and learning environments viewed as value-neutral and objective to some are experienced as “racialized” (Martin, 2009; McGee and Martin, 2011), unsupportive (Lester, 2010), and alienating (Pascarella et al., 1997; Starobin and Laanan, 2008) by others. It may seem paradoxical to individuals steeped and successful in the science culture that the pursuit of scientific knowledge and learning are not neutral and objective activities, experienced in universal terms independent of one’s ascribed racial and gender characteristics. Yet, numerous studies (e.g., Howard-Hamilton et al., 2009; Hurtado et al., 2007, 2011; McGee and Martin, 2011) and reports (Institute for Higher Education Policy, n.d.; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2011; Sevo, 2009; Steinecke and Terrell, 2010) provide evidence that students of color and women experience formal STEM postsecondary learning environments as discriminatory, hostile, and alienating. There is now a long history of calls for cultural change in STEM and increased diversity, but the incremental

changes have not been sufficient. As observed in the *Crossroads* (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2011) report, the number of African Americans, Hispanics, and Native Americans in certain STEM fields would need to double, triple, or even quadruple to reach parity with the representation of these groups in the U.S. population. Therefore, programs that do not address the fundamental problem of the negative racial climate in STEM fields are unlikely to have a substantial impact to increase diversity.

At this juncture, it is important to note why these considerations are of particular importance when considering strategies to expand STEM transfer pathways between two-year and four-year institutions. First, it is due to the fact that the status differences among fields of study are compounded by the status differences between two-year and four-year college and university faculty. Second, the “chilly climate” of STEM is only harsher for students experiencing the initial “shock” of transfer. Third, students of color are found in community colleges in numbers disproportionately larger than their enrollment in postsecondary education as a whole, which means that efforts to broaden transfer pathways in STEM will have positive equity implications.

The status differences between the two-year and four-year sectors introduce distrust of the quality of the community college curriculum among faculty and administrators who serve on the admissions and curriculum committees of four-year institutions. As a result, the curriculum is poorly aligned and collaboration among faculty is rare (Dowd, 2010; Gabbard et al., 2006; Stanton-Salazar et al., 2010). The negative impact of these poor relationships on students is exacerbated when it comes to transfer in STEM because of the sequential nature of the curriculum.

SECTION IV: EVIDENCE-BASED INNOVATION CONSORTIA

Recent studies of curricular and pedagogical reforms in STEM fields provide evidence that strategies that involve the use of inquiry, reflective practice, and faculty professional development networks are the most promising approaches to bringing about cultural and organizational change (Borrego, Froyd, and Hall, 2010; Henderson, Beach, and Finkelstein, 2011). The dissemination of “best,” innovative practices can bring about awareness, but is less effective in leading those on the receiving end of an innovation to the final stage of Rogers’ model of diffusion and adoption. These findings are consistent with theories of organizational learning and professional development that emphasize professional knowledge, academic norms, and expertise (Bensimon, 2007; Dowd and Tong, 2007; Kezar and Eckel, 2002; Polkinghorne, 2004; Schein, 1985). They also resonate with models of individual and organizational change, particularly in a situation where professionals are being asked to act

as institutional agents to bring about change in their own settings (Seo and Creed, 2002; Stanton-Salazar, 2010). Consequently, recognition of the importance of collective, faculty-based responses to bring about change are growing (Asera, 2008; Kezar, 2012).

Therefore, this report introduces a proposal for the creation of Evidence-Based Inquiry Councils (EBICs), adapted from Dowd and Tong (2007), with a focus on creating effective STEM transfer pathways through the use of inquiry, professional development, and networks. EBICs, as proposed and renamed here as Evidence-Based Innovation Consortia to place the emphasis on *innovation*, would provide an organizational structure to support five institutional roles described in the *Crossroads* report and to foster the “supportive ecosystem” called for in the NSB’s *Next Generation* report. To move deliberately in creating STEM learning environments in which a greater number and a more diverse body of students are successful, the *Crossroads* report charged institutions with five roles: leadership, creating a campus-wide commitment to inclusiveness, self-appraisal of the campus climate, plans for constructive change, and ongoing evaluation of implementation efforts.

The EBIC design supports these goals. It also tackles the problem that the transfer structures are not sufficient to support robust transfer pathways in STEM in the absence of interpersonal relationships and shared cultural norms across sectors. Professional development for faculty and college administrators in STEM pedagogy and culturally inclusive practices (Dowd et al., in press) are needed to create such an ecosystem. Such professional development activities will be well received only if they are accorded prestige and provide resources for the production of new knowledge through research, design experiments (Penuel et al., 2011), and inquiry, which is the systematic use of data, reflection, and experimentation to improve professional practices.

The following Keystone Recommendations for the EBIC design are based on those of the *Next Generation* (2010) report:

- (1) Keystone Recommendation #1: Provide opportunities for excellence
 - (i) Create prestigious research and design centers, called Evidence Based Innovation Consortia, involving STEM faculty in geographic and market-based clusters of two-year and four-year colleges and universities to:
 1. Invent, experiment with, and evaluate innovative approaches to teaching adults foundational mathematics skills and knowledge
 2. Invent, experiment with, and evaluate innovative approaches to active and applied learning
 - (ii) Create more intentional mechanisms for diffusion of innovative practices in use in special and supplemental programs to the core curriculum

- (iii) Create a STEM transfer research work-study program through the HEA Reauthorization (for details, see Malcom, 2008a, 2008b) and involve industry in identifying mechanisms to provide work-study positions in collaboration with academic institutions
 - (iv) Create public (federal and state) and privately funded STEM transfer scholarships and allocate these to STEM transfer students enrolled in learning communities at the community college and the four-year institution.
- (2) Keystone Recommendation #2: Cast a wide net
- (a) Policy Action: Improve talent assessment systems
 - (i) Create prestigious research and design centers involving STEM faculty in geographic and market-based clusters of two-year and four-year colleges and universities to develop and validate new forms of diagnostic assessment, student learning assessment, and testing.
 - (b) Policy Action: Improve identification of overlooked abilities
 - (i) Ensure that students who are successful in special STEM programs find a place in a STEM program and receive necessary mentoring, institutional supports, and opportunities for undergraduate research under the guidance of a faculty member
 - (ii) Provide greater investment in the development of a more diverse faculty and administrative workforce in postsecondary education
 - (iii) Replace “weed out” and gatekeeper assessments of student learning with talent development assessments
- (3) Keystone Recommendation #3: Foster a supportive ecosystem
- (a) Policy Action: Professional development for educators in STEM pedagogy
 - (i) Support the development, dissemination, and use of assessment instruments that support deliberate processes of self-appraisal focused on campus climate in STEM learning environments
 - (ii) Develop and disseminate models of Culturally Inclusive Pedagogies in STEM
 - (iii) Involve STEM educators and educational researchers in joint design and implementation of design experiments, developmental evaluation, and summative evaluation
 - (iv) Develop and offer a STEM deans and directors’ Leadership Academy and teach participants principles of inquiry and strategies for effective collaboration and institutional self assessment.
 - (v) Enroll participants through a three-year membership with staggered terms so that newcomers and experienced members overlap.

REFERENCES

- Adelman, C. (2005). *Moving into town—and moving on: The community college in the lives of traditional-age students*. Washington, DC: U.S. Department of Education.
- Aguirre, J. (2009). Increasing Latino/a representation in math and science: An insider's look. *Harvard Educational Review*, 79(4), 697-704.
- Anderson, G.M., Alfonso, M., and Sun, J.C. (2006). Rethinking cooling out at public community colleges: An examination of fiscal and demographic trends in higher education and the rise of statewide articulation agreements. *Teachers College Record*, 108(3), 422-451.
- Anderson, G.M., Sun, J.C., and Alfonso, M. (2006). Effectiveness of statewide articulation agreements on the probability of transfer: A preliminary policy analysis. *Review of Higher Education*, 29(3), 261-291.
- Arbona, C., and Nora, A. (2007). The influence of academic and environmental factors on Hispanic college degree attainment. *Review of Higher Education*, 30(3), 247-269.
- Asera, R. (2008). *Change and sustain/ability: A program director's reflections on institutional learning*. Stanford, CA: Carnegie Foundation for the Advancement of Teaching.
- Attewell, P., Lavin, D., Domina, T., and Levey, T. (2006). New evidence on college remediation. *Journal of Higher Education*, 77(5), 887-924.
- Aud, S., Fox, M., and KewalRamani, A. (2010). *Status and trends in the education of racial and ethnic groups*. Washington, DC: U.S. Department of Education, National Center for Education Statistics.
- Aud, S., Hussar, W., Kena, G., Blanco, K., Frohlich, L., Kemp, J., et al. (2011). *The condition of education 2011*. Washington, DC: U.S. Department of Education, National Center for Education Statistics.
- Austin, A.E. (1990). Faculty cultures, faculty values. In W. G. Tierney (Ed.), *Assessing academic climates and cultures* (vol. 68, pp. 61-74). San Francisco: Jossey-Bass.
- Bahr, P.R. (2010). Preparing the underprepared: An analysis of racial disparities in postsecondary mathematics remediation. *Journal of Higher Education*, 81(2), 209-237.
- Bailey, T., and Morest, V.S. (Eds.). (2006). *Defending the community college equity agenda*. Baltimore: Johns Hopkins University Press.
- Becher, T. (1989). *Academic tribes and territories: Intellectual enquiry and the cultures of disciplines*. Buckingham, UK; Philadelphia, PA: The Society for Research into Higher Education and Open University Press.
- Bensimon, E.M. (2007). The underestimated significance of practitioner knowledge in the scholarship of student success. *Review of Higher Education*, 30(4), 441-469.
- Bensimon, E.M., and Dowd, A.C. (2009). Dimensions of the "transfer choice" gap: Experiences of Latina and Latino students who navigated transfer pathways. *Harvard Educational Review*, 79(4), 632-658.
- Bensimon, E.M., Dowd, A.C., Alford, H., and Trapp, F. (2007). *Missing 87: A study of the "transfer gap" and "choice gap."* Long Beach and Los Angeles: Long Beach City College and the Center for Urban Education, University of Southern California.
- Bergquist, W.H., and Pawlak, K. (2008). *Engaging the six cultures of the academy*. San Francisco: Jossey-Bass.
- Borrego, M., Froyd, J.E., and Hall, T.S. (2010). Diffusion of engineering education innovations: A survey of awareness and adoption rates in U.S. engineering departments. *Journal of Engineering Education*, July, 185-207.
- Bragg, D.D. (2011, December 9). *Two-year college mathematics and student progression in STEM programs of study*. Paper presented at the Community Colleges in the Evolving STEM Education Landscape, Washington, DC.
- Brown, R.S., and Niemi, D.N. (2007). *Investigating the alignment of high school and community college assessment in California* (No. 07-3). San Jose, CA: National Center for Public Policy and Higher Education.

- Cabrera, A.F., Burkum, K.R., and La Nasa, S.M. (in press). Pathways to a four-year degree: Determinants of transfer and degree completion. In A. Seidman (Ed.), *College student retention: A formula for student success*. Westport, CT: ACE/Prager.
- Carlone, H.B. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of Research in Science Teaching*, 44(8), 1,187-1,218.
- Carnegie Foundation for the Advancement of Teaching. (2008). *Strengthening pre-collegiate education in community colleges: Project summary and recommendations*. A report from Strengthening Pre-collegiate Education in Community Colleges (SPECC). Stanford, CA: Author.
- Cataldi, E.F., Green, C., Henke, R., Lew, T., Woo, J., Shepherd, B., et al. (2011). *2008-2009 Baccalaureate and Beyond Longitudinal Study (B&B:08/09): First look*. Washington, DC: U.S. Department of Education, National Center for Education Statistics.
- Cejda, B.D. (1998). The effect of academic factors on transfer student persistence and graduation: A community college to liberal arts case study. *Community College Journal of Research and Practice*, 22(7), 675-687.
- Cejda, B.D. (2000). Use of the community college in baccalaureate attainment at a private liberal arts college. *Community College Journal of Research and Practice*, 24, 279-288.
- Cole, D., and Espinoza, A. (2008). Examining the academic success of Latino students in science technology engineering and mathematics majors. *Journal of College Student Development*, 49(4), 285-300.
- Crisp, G., Nora, A., and Taggart, A. (2009). Student characteristics, pre-college, college, and environmental factors as predictors of majoring in and earning a STEM degree: An analysis of students attending a Hispanic-serving institution. *American Educational Research Journal*, 46(4), 924-942.
- Dougherty, K.J., and Kienzl, G.S. (2006). It's not enough to get through the open door: Inequalities by social background in transfer from community colleges to four-year colleges. *Teachers College Record*, 108(3), 452-487.
- Dowd, A.C. (2008). The community college as gateway and gatekeeper: Moving beyond the access "saga" to outcome equity. *Harvard Educational Review*, 77(4), 407-419.
- Dowd, A.C. (2010). Improving transfer access for low-income community college students. In A. Kezar (Ed.), *Recognizing and serving low-income students in postsecondary education: An examination of institutional policies, practices, and culture* (pp. 217-231). New York: Routledge.
- Dowd, A.C., and Coury, T. (2006). The effect of loans on the persistence and attainment of community college students. *Research in Higher Education*, 47(1), 33-62.
- Dowd, A.C., and Melguizo, T. (2008). Socioeconomic stratification of community college transfer access in the 1980s and 1990s: Evidence from HS&B and NELS. *Review of Higher Education*, 31(4), 377-400.
- Dowd, A.C., and Tong, V.P. (2007). Accountability, assessment, and the scholarship of "best practice." In J.C. Smart (Ed.), *Handbook of higher education* (vol. 22, pp. 57-119). New York: Springer.
- Dowd, A.C., Bensimon, E.M., Gabbard, G., Singleton, S., Macias, E.E., Dee, J., et al. (2006). *Transfer access to elite colleges and universities in the United States: Threading the needle of the American dream*. Lansdowne, VA: Jack Kent Cooke Foundation.
- Dowd, A.C., Cheslock, J.J., and Melguizo, T. (2008). Transfer access from community colleges and the distribution of elite higher education. *Journal of Higher Education*, 79(4), 442-472.
- Dowd, A.C., Malcom, L.E., and Bensimon, E.M. (2009). *Benchmarking the success of Latina and Latino students in STEM to achieve national graduation goals*. Los Angeles: Center for Urban Education, University of Southern California.

- Dowd, A.C., Malcom, L.E., and Macias, E.E. (2010). *Improving transfer access to STEM bachelor's degrees at Hispanic-serving institutions through the America COMPETES Act*. Los Angeles: Center for Urban Education, University of Southern California.
- Dowd, A.C., Sawatzky, M., Rall, R.M., and Bensimon, E.M. (in press). Action research: An essential practice for Twenty-First Century assessment. In R.T. Palmer, D.C. Maramba, and M. Gasman (Eds.), *Fostering success of ethnic and racial minorities in STEM: The role of minority-serving institutions*. New York: Routledge.
- Fries-Britt, S. (1998). Moving beyond black achiever isolation: Experiences of gifted black collegians. *The Journal of Higher Education*, 69(5), 556-576.
- Gabbard, G., Singleton, S., Macias, E.E., Dee, J., Bensimon, E.M., Dowd, A.C., et al. (2006). *Practices supporting transfer of low-income community college transfer students to selective institutions: Case study findings*. Boston and Los Angeles: University of Massachusetts and University of Southern California.
- Greenwood, D.J., and Levin, M. (2005). Reform of the social sciences and of universities through action research. In N.K. Denzin and Y.S. Lincoln (Eds.), *Handbook of qualitative research* (3rd ed., pp. 43-64). Thousand Oaks, CA: Sage.
- Grubb, W.N., Boner, E., Frankel, K., Parker, L., Patterson, D., Gabriner, R., et al. (2011). *Understanding the "crisis" in basic skills: Framing the issue in community colleges*. Berkeley: Policy Analysis for California Education.
- Hagedorn, L.S., and DuBray, D. (2010). Math and science success and nonsuccess: Journeys within the community college. *Journal of Women and Minorities in Science and Engineering*, 16(1), 31-50.
- Hardy, D., and Katsinas, S.G. (2010). Changing STEM associate's degree production in public associates' colleges 1990 to 2005: Exploring institutional type, gender, and field of study. *Journal of Women and Minorities in Science and Engineering*, 16(1), 7-30.
- Henderson, C., Beach, A., and Finkelstein, N. (2011). Facilitating change in undergraduate STEM instructional practices: An analytic review of the literature. *Journal of Research in Science Teaching*, 48(8), 952-984.
- Hoachlander, G., Sidora, A., and Horn, L. (2003). *Community college students: Goals, academic preparation, and outcomes* (Postsecondary Education Descriptive Analysis Reports No. 2003-164). Washington, DC: National Center for Education Statistics.
- Horn, L. (2006). *Placing college graduation rates in context: How 4-year college graduation rates vary with selectivity and the size of low-income enrollment* (No. 2006-184). Washington, DC: U.S. Department of Education. National Center for Education Statistics.
- Horn, L., and Lew, S. (n.d.). *California community college transfer rates: Who is counted makes a difference*. MPR Research Brief #1.
- Howard-Hamilton, M.F., Morelon-Quainoo, C.L., Johnson, S.D., Winkle-Wagner, R., and Santiago, L. (Eds.). (2009). *Standing on the outside looking in: Underrepresented students' experiences in advanced-degree programs*. Sterling, VA: Stylus.
- Hughes, K.L., and Scott-Clayton, J. (2011). *Assessing developmental assessment in community colleges*. New York: Community College Research Center, Teachers College, Columbia University.
- Hurtado, S., Han, J.C., Sáenz, V.B., Espinosa, L.L., Cabrera, N.L., and Cerna, O.S. (2007). Predicting transition and adjustment to college: Minority biomedical and behavioral sciences. *Research in Higher Education*, 48(7), 841-887.
- Hurtado, S., Cabrera, N.L., Lin, M.H., Arellano, L., and Espinosa, L.L. (2009). Diversifying science: Underrepresented student experiences in structured research program. *Research in Higher Education*, 50(2), 189-214.
- Hurtado, S., Pryor, J., Tran, S., Blake, L.P., DeAngelo, L., and Aragon, M. (2010). *Degrees of success: Bachelor's degree completion rates among initial STEM majors*. Los Angeles: Higher Education Research Institute, University of California.

- Hurtado, S., Eagan, M.K., Tran, M.C., Newman, C.B., Chang, M.J., and Velasco, P. (2011). "We do science here": Underrepresented students' interaction with faculty in different college contexts. *Journal of Social Issues*, 67(3), 553-579.
- Institute for Higher Education Policy. (n.d.). *Diversifying the STEM pipeline: The Model Replication Institutions Program*. Washington, DC: Author.
- Johnson, A.C. (2007). Unintended consequences: How science professors discourage women of color. *Science Education*, 91(5), 805-821.
- Jones, M.T., Barlow, A.E.L., and Villarejo, M. (2010). Importance of undergraduate research for minority persistence and achievement in biology. *Journal of Higher Education*, 81(1), 82-115.
- Kezar, A. (2012). The path to pedagogical reform in the sciences. *Liberal Education*, 40-45.
- Kezar, A., and Eckel, P.D. (2002). The effect of institutional culture on change strategies in higher education: Universal principles or culturally responsive concepts? *Journal of Higher Education*, 73(4), 436-460.
- Kienzl, G.S., Wesaw, A.J., and Kumar, A. (2011). *Understanding the transfer process*. Washington, DC: Institute for Higher Education Policy.
- Kirst, M. (2007, Winter). Who needs it?: Identifying the proportion of students who require postsecondary remedial education is virtually impossible. *National CrossTalk*, 15, 11-12.
- Laanan, F.S. (1996). Making the transition: Understanding the adjustment process of community college transfer students. *Community College Review*, 23(4), 69-84.
- Laanan, F.S. (2003). Degree aspirations of two-year college students. *Community College Journal of Research and Practice*, 27, 495-518.
- Lee, J.M., and Ranson, T. (2011). *The educational experience of young men of color: A review of research, pathways, and progress*. New York: The College Board.
- Lester, J. (2010). Women in male-dominated career and technical education programs at community colleges: Barriers to participation and success. *Journal of Women and Minorities in Science and Engineering*, 16(1), 51-66.
- Levin, H.M., and Calcagno, J.C. (2008). Remediation in the community college: An evaluator's perspective. CCR Working Paper. *Community College Review*, 35, 181-207.
- Malcom, L.E. (2008a). *Accumulating (dis)advantage? Institutional and financial aid pathways of Latino STEM baccalaureates*. Unpublished dissertation, University of Southern California, Los Angeles.
- Malcom, L.E. (2008b). *Multiple pathways to STEM: Examining state differences in community college attendance among Latino STEM bachelor's degree holders*. Presented at the Association for the Study of Higher Education, November, Jacksonville, FL.
- Malcom, L.E., and Dowd, A.C. (2012). The impact of undergraduate debt on the graduate school enrollment of STEM baccalaureates. *Review of Higher Education*, 35(2), 265-305.
- Malcom, L.E., Dowd, A.C., and Yu, T. (2010). *Tapping HSI-STEM funds to improve Latina and Latino access to STEM professions*. Los Angeles: Center for Urban Education, University of Southern California.
- Martin, D.B. (2009). Researching race in mathematics. *Teachers College Record*, 111(2), 295-338.
- McGee, E., and Martin, D.B. (2011). "You would not believe what I have to go through to prove my intellectual value!" Stereotype management among academically successful black mathematics and engineering students. *American Educational Research Journal*, 48(6), 1,347-1,389.
- Melguizo, T., and Dowd, A.C. (2009). Baccalaureate success of transfers and rising four-year college juniors. *Teachers College Record*, 111(1), 55-89.
- Melguizo, T., Hagedorn, L.S., and Cypers, S. (2008). Remedial/developmental education and the cost of community college transfer: A Los Angeles County sample. *Review of Higher Education*, 31(4), 401-431.
- Mullin, C.M. (2011). *The road ahead: A look at trends in the educational attainment of community college students*. Washington, DC: American Association of Community Colleges.

- National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. (2011). *Expanding underrepresented minority participation: America's science and technology talent at the crossroads*. Committee on Underrepresented Groups and the Expansion of the Science and Engineering Workforce Pipeline; Committee on Science, Engineering, and Public Policy; Policy and Global Affairs. Washington, DC: The National Academies Press.
- National Center for Education Statistics. (2011). *Students attending for-profit postsecondary institutions: Demographics, enrollment characteristics, and 6-year outcomes*. Washington, DC: U.S. Department of Education, National Center for Education Statistics, Institute of Education Sciences.
- National Center for Education Statistics. (n.d.-a). *Table A-40-1: Number of associate's and bachelor's degrees awarded by degree-granting institutions, percentage of total, number and percentage awarded to females, and percent change, by selected fields of study: Academic years 1998-99 and 2008-09*. Available: <http://nces.ed.gov/surveys/ctes/tables/index.asp?LEVEL=COLLEGE> [January 25, 2012].
- National Center for Education Statistics. (n.d.-b). *Table P45: Percentage distribution of credential-seeking undergraduates, by sex, race/ethnicity, age, credential goal, and curriculum area: 2007-08*. Available: <http://nces.ed.gov/surveys/ctes/tables/index.asp?LEVEL=COLLEGE> [January 25, 2012].
- National Center for Education Statistics. (n.d.-c). *Table P46: Percentage distribution of credential-seeking undergraduates in career education, by sex, race/ethnicity, age, credential goal, and career field of study: 2007-08*. Available: <http://nces.ed.gov/surveys/ctes/tables/index.asp?LEVEL=COLLEGE> [January 25, 2012].
- National Science Board. (2010). *Preparing the next generation of STEM innovators: Identifying and developing our national human capital*. Arlington, VA: Author.
- National Science Foundation. (2011). *Women, minorities, and persons with disabilities in science and engineering: 2011* (No. NSF 04-317.) Arlington, VA: Author.
- Ornelas, A., and Solorzano, D.G. (2004). Transfer conditions of Latina/o community college students: A single institution case study. *Community College Journal of Research and Practice*, 28(3), 233-248.
- Packard, B.W.-L. (2011). *Effective outreach, recruitment, and mentoring into STEM pathways: Strengthening partnerships with community colleges*. Paper presented at the Community Colleges in the Evolving STEM Education Landscape, Washington, DC.
- Packard, B.W.-L., Gagnon, J.L., LaBelle, O., Jeffers, K., and Lynn, E. (2011). **Women's experiences in the STEM community college transfer pathway**. *Journal of Women and Minorities in Science and Engineering*, 17(2), 129-147.
- Pak, J., Bensimon, E.M., Malcom, L.E., Marquez, A., and Park, D. (2006). *The life histories of ten individuals who crossed the border between community colleges and selective four-year colleges*. Los Angeles: University of Southern California.
- Parsad, B., Lewis, L., and Greene, B. (2003). *Remedial education at degree-granting postsecondary institutions in Fall 2000*. (No. NCES 2004-010.) Washington, DC: U.S. Department of Education, National Center for Education Statistics.
- Pascarella, E.T., Whitt, E.J., Edison, M.I., Nora, A., Hagedorn, L.S., Yeager, P.M., et al. (1997). Women's perceptions of a "chilly climate" and their cognitive outcomes during the first year of college. *Journal of College Student Development*, 38(2), 109-124.
- Penuel, W.R., Fishman, B.J., Cheng, B.H., and Sabelli, N. (2011). Organizing research and development at the intersection of learning, implementation, and design. *Educational Researcher*, 40(7), 331-337.
- Polkinghorne, D.E. (2004). *Practice and the human sciences: The case for a judgment-based practice of care*. Albany: State University of New York Press.
- Reyes, M.-E. (2011). Unique challenges for women of color in STEM transferring from community college to universities. *Harvard Educational Review*, 81(2), 241-263.

- Rutschow, E.Z., and Schneider, E. (2011). *Unlocking the gate: What we know about improving developmental evaluation*. New York: MDRC.
- Ruud, C.M., and Bragg, D.D. (2011). *The applied baccalaureate: What we know, what we learned, and what we need to know*. Champaign: Office of Community College Research and Leadership, University of Illinois at Urbana-Champaign.
- Santiago, D. (2006). *Inventing Hispanic-Serving Institutions (HSIs): The basics*. Washington, DC: Excelencia in Education.
- Schein, E.H. (1985). Understanding culture change in the context of organizational change. *Organizational Culture and Leadership*, 244-310.
- Seo, M.G., and Creed, W.E.D. (2002). Institutional contradictions, praxis, and institutional change: A dialectical perspective. *Academy of Management Review*, 27(2), 222-247.
- Sevo, R. (2009). *The talent crisis in science and engineering*. Available: <http://www.engr.psu.edu/AWE/ARPRResources.aspx> [February 1, 2009].
- Seymour, E., and Hewitt, N.C. (1997). *Talking about leaving: Why undergraduates leave the sciences*. Boulder, CO: Westview Press.
- Snyder, T.D., Tan, A.G., and Hoffman, C.M. (2006). *Digest of education statistics, 2005*. Washington, DC: National Center for Education Statistics.
- Stanton-Salazar, R.D. (2010). A social capital framework for the study of institutional agents and their role in the empowerment of low-status youth. *Youth and Society*, 42(2), 1-44.
- Stanton-Salazar, R.D., Macias, R.M., Bensimon, E.M., and Dowd, A.C. (2010). *The role of institutional agents in providing institutional support to Latino students in STEM*. Paper presented at the Association for the Study of Higher Education.
- Starobin, S., and Laanan, F.S. (2008). Broadening female participation in science, technology, engineering, and mathematics: Experiences at community colleges. In J. Leaster (Ed.), *Gendered perspectives on community college* (pp. 37-46). Wilmington, DE: Wiley Periodicals.
- Steinecke, A., and Terrell, C. (2010). Progress for the future? The impact of the Flexner Report on medical education for racial and ethnic minority physicians in the United States. *Academic Medicine*, 85(2), 236-245.
- Strenta, A.C., Elliott, R., Adair, R., Matier, M., and Scott, J.W. (1994). Choosing and leaving science in highly selective institutions. *Research in Higher Education*, 35(5), 513-547.
- Townsend, B.K., and Wilson, K. (2006). "A hand hold for a little bit": Factors facilitating the success of community college transfer students to a large research university. *Journal of College Student Development*, 47(4), 439.
- Vanasupa, L., Stolk, J., and Herter, R.J. (2009). The four-domain development diagram: A guide for holistic design of effective learning experiences for the twenty-first century engineer. *Journal of Engineering Education*, 98(1), 667-680.
- Wang, X. (2011). *Modeling student entrance into STEM fields of study at community colleges and four-year institutions: Towards a theoretical framework of motivation, high school learning, and postsecondary context of support*. Proposal submitted to Association for Institutional Research.
- Weissman, E., Butcher, K., Schneider, E., Teres, J.J., Collado, H., and Greenberg, D. (2011). *Learning communities for students in developmental math: Impact studies at Queensborough and Houston Community Colleges*. New York: National Center for Postsecondary Research.
- Zinser, R., and Hanssen, C. (2006). Improving access to the baccalaureate: Articulation agreements and the National Science Foundation's Advanced Technological Education program. *Community College Review* 34(1), 27-43.