Enhancing STEM Pathways for Diverse Student Success: Insights from the 2022 STEM Transfer Pathways Conference

Alex R. Paine
Sabrina M. Solanki
Brian K. Sato

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Alex R. Paine, Sabrina M. Solanki, and Brian K. Sato
University of California – Irvine

INTRODUCTION

A primary goal shared by numerous federal agencies, institutions of higher learning, and industry leaders is the diversification of the nation's science, technology, engineering, and mathematics (STEM) workforce. To accomplish this objective, one essential approach involves increasing the number of STEM degrees awarded to historically minoritized populations. This can be achieved by fostering efforts that enhance success in higher education transitions, encompassing transitions from high school to college, from two-year to four-year institutions, and from undergraduate to graduate programs. Such initiatives also play a crucial role in expanding our understanding of the barriers to broadening participation in STEM fields.

In the context of this endeavor, the authors of this work delve into the National Science Foundation-funded initiative, which sought to assemble teams, referred to as campus research communities (RCRs). These communities brought together complementary stakeholders from neighboring two-year and four-year institutions to collaboratively explore how to measure transfer student success in STEM disciplines. The STEM Transfer Pathways conference took place from July 27 to July 29, 2022. In the following sections, the authors discuss the rationale behind the conference's inception as well as its noteworthy impacts.

Community College: A Viable STEM Transfer Pathway. Community colleges play an integral role in the attainment of STEM degrees (Hagedorn & Purnamasari, 2012; Hoffman, Starobin, Laanan, & Rivera, 2010; Wang, 2015), with nearly half of STEM bachelor's degree holders and one-third of STEM master's degree holders having been enrolled in a community college at some point in their educational journey (National Science Board, 2016; Tsapogas, 2004). According to a national survey, three-quarters of STEM students at community college cited their primary motivation as earning credits for a bachelor's degree (Mooney & Foley, 2011). These institutions also contribute significantly to the diversification of STEM field, as they enroll proportionately more students from underrepresented demographic groups (Cohen, Brawer, & Kisker, 2014; Hagedorn, 2010). In the 2018 academic year, 37% of low-income students began their college careers at community colleges (compared to 18% of high-income students), as did 55% of Hispanic students and 44% of African American students (compared to 28% of Caucasian students), and 35% of first-generation college students (compared to 20% of continuing-generation students).[1]

Challenges with the STEM Transfer Pathway. Even though community colleges serve as a viable STEM transfer pathway, community college students who wish to transfer to a four-year college face a number of documented challenges, both at their home institution and at the institutions to which they hope to transfer. These challenges include informational gaps about the transfer process (Baker, 2016; Hull, 2018; Jaggars & Fletcher, 2014), transfer shock, the drastic difference in cultural and/or academic expectations between the community college and the four-year college (Hills, 1965; Lakin and Elliott, 2016), and the concern among transfer students that they lack the research experience to be competitive in STEM disciplines (Hirst, Bolduc, Liotta, and Packard, 2014).

These challenges lead to low transfer and degree completion rates. Even though 81% of community college students would like to earn bachelor's degrees, only 33% transfer to four-year institutions. Of these students, only 42% complete their degrees within six years of entering higher education (Jenkins and Fink, 2016). It is important to note that recent empirical studies using national and state-level data (e.g., New York and California) have found striking differences between two- and four-year institutions' abilities to prepare students to transfer and complete a four-year degree (e.g., Carrell and Kurlaender, 2016; Ehrenberg and Smith, 2002; Jenkins and Fink, 2016), illustrating the context dependent-nature of transfer student success. For example, using data from the California higher education system, Carrell and Kurlaender (2016) show considerable variability in key academic outcomes by each community college/California State University (CSU) pair. Focusing on a single CSU and its four main feeder community colleges, four-year graduation rates among transfer students range from 40% to 80%. Furthermore, results suggest that community colleges that are closer in proximity to a CSU are associated with better student transfer outcomes, as compared to community colleges that reside farther away. This may be why transfer partnerships between individual two- and four-year institutions play a critical role in facilitating successful transfer student preparedness (Kisker, 2007; Xu, Ran, Fink, Jenkins & Dundar, 2017), as these leverage local opportunities for their specific student populations.

Transfer student success is even more of an issue in the STEM fields. The Missouri Department of Higher Education finds that degree completion rates for transfer students in STEM are lower compared to non-STEM and non-transfer peers, a difference of roughly forty percentage points. And time-to-degree is higher for transfer students in STEM (Kramer & Walston, 2015). To compound the issues facing STEM transfer students, there is a documented underrepresentation of community college and transfer students as study populations in STEM education research literature (Handel & Williams, 2012; Lo et al., 2019). This potentially leaves the unique experiences of these populations out of many transfer policy discussions.

Establishing Effective STEM Transfer Pathways: Two- and Four-Year Collaborations. Given that the transfer process requires support from *both* the two-year community college a student is attending and the four-year college that they intend to transfer to, a major barrier to the success of transfer students is often a lack of meaningful collaboration between two- and four-year institutions. Two-year and four-year institutions tend to work in silos. This is mainly due to the difference in mission between these two institution types. With the greater focus on student success and degree completion today, it's more critical than ever for two- and four-year institutions to work collaboratively. Collaborations can help both types of institutions better understand the issues faced by their prospective STEM transfer students and identify effective support structures that can improve academic outcomes (Kisker, 2007; Xu et al., 2017).

The STEP Project (De Leone et al., 2016) is an example of an effective two- and four-year partnership that has resulted in improved outcomes for STEM transfer students. The STEP Project is a joint endeavor led by faculty and administrators from California State University San Marcos (CSUSM) and Palomar College aimed at lowering institutional barriers for transfer students, particularly in Physics, by creating more coherent STEM transfer pathways. To reach these goals, the project components included intercampus faculty learning communities that trained faculty in implementing evidence-based instructional practices in gateway math and chemistry courses at both campuses (e.g., active learning). The project also expanded the existing CSUSM Learning Assistant (LA) program to Palomar College. And, lastly, the project included activities to increase community between Palomar and CSUSM Physics students. As a result of

these efforts, pass rates in introductory courses improved and the number of transfer students increased, including within the Physics major. Data suggest that faculty benefitted from the intercampus learning community, specifically because it focused on pedagogy training and exposed faculty to curriculum and practices on the partner campus. The increased awareness allowed faculty to better understand the needs and experiences of prospective and successful transfer students.

In another example, Hirst et al. (2014) describes an innovative initiative pairing community college faculty and students with four-year faculty in collaborative summer research at the four-year institution. The initiative aimed to build a STEM transfer pathway and increase capacity for research at the community college. Similar to the STEP project described above, the two- and four-year partnership resulted in promising outcomes for STEM students. Specifically, 75% of the total participants transferred to a four-year institution and majored in a STEM discipline with ninety percent of these individuals graduating with a STEM degree. Furthermore, data suggests that students experienced a sense of belonging to the broader scientific community and increased confidence to transfer. The initiative was also valuable to two- and four-year faculty because it allowed them to have a space to discuss curriculum improvement. Given the importance of establishing support and networks at both students' home and destination institution to STEM transfer success and degree completion, our conference aims to facilitate these types of collaborations so that they happen more frequently and broadly.

EXAMINING STEM TRANSFER PATHWAYS CONFERENCE

Conference description. The STEM Transfer Pathways Conference was held at the University of California Irvine in Summer 2022. It intentionally brought together neighboring two- and four-year institutions with the goal of broadening participation in STEM through the establishment of novel campus research communities to examine transfer student success. The conference design and goals were motivated by the academic model for transfer proposed by Eaton (1990) that stresses a close relationship between two and four-year institutions as the means to improve the success of transfer students. To improve transfer success, the model requires (1) faculty involvement from both the two- and four-year campuses, (2) institutional commitment to establishing benchmarks of transfer effectiveness, evaluating transfer success, and examining institutional culture and its impact on opportunities for transfer, and (3) the development of faculty/student relationships. To facilitate cross-institution relationship building, the conference design and goals were further informed by theories on research collaboration (Kezar, 2005, Mohrman et al. 1995) that outline how institutions move from a culture that supports individual work to facilitating collaborative work. Part of the process involves clarifying values and key outcomes; these are important for establishing a strong foundation for collaboration. Sustaining collaboration requires the development of structures and networks to support the collaborations.

The conference aimed to convene and support campus research communities (CRCs) to consider STEM transfer success at their home campuses, identifying and evaluating relevant transfer support pathways and structures. Specifically, the conference goals included:

1. Opening lines of communication and expanding networks amongst stakeholders within and across institutions.
2. Expanding the definition of transfer pathway success by (A) leveraging institutional data and (B)

identifying a set of student socialization outcomes.

3. Initiating an evaluation plan to examine the effectiveness of a transfer support structure at each participating campus through academic and/or student socialization outcomes.

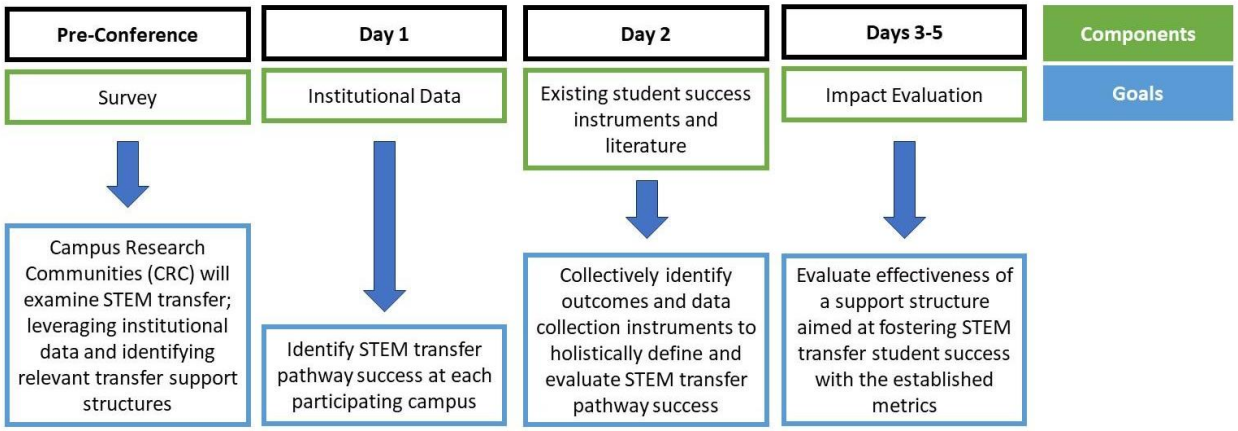

Figure 1. Examining STEM Transfer Pathway Conference Components and Goals. Figure 1 highlights the components and goals of the conference. A major theme connecting these goals is the empowerment of CRCs to implement research designs that permit a more comprehensive and synergistic use of data that sheds light on mechanisms that allow for successful STEM transfer across both institution types. To reach this goal, CRCs are provided space to discuss transfer issues from the perspective of their institution, engage in a broader discussion about evaluating outcomes of transfer students, and develop instruments to measure the impact of existing interventions designed to promote transfer student success at their institution.

METHODS

Participants. Ten institutions from across the California Public Higher Education System - including University of California (UC), California State University (CSU), and California Community College (CCC) campuses were invited to participate. The selection of these institutions was based on the following criteria:

1. The institution is designated a Hispanic-Serving Institution within the California Public Higher Education System,
2. The institution has made a commitment to improving transfer pathways by formalizing a transfer partnership and/or
3. The institution has at least one program on campus that aims to facilitate STEM transfer.

The STEM Transfer Pathways conference focused on the California Public Higher Education System because of its intentionally interconnected nature, which may help to facilitate cross-campus collaborative efforts. Within this system, the conference specifically concentrated on Hispanic-Serving Institutions (HSIs) as the Latinx undergraduate population is the largest minority group in the country,

doubling in the past fifteen years (McFarland et al., 2017; Pew Hispanic Center, 2009), yet the percentage of Latinx students earning STEM bachelor's degrees and participating in the STEM workforce trails that of their White and Asian counterparts (James and Singer, 2016). Latinx students are a key demographic in California higher education, representing 25.0%[1], 45,0%[2], and 46.7%[3] in UC, CSU, and CCC systems respectively. As such, these institutions were ideal targets for studying strategies to improve STEM transfer student success as a means to broaden participation in STEM fields.

Half of the invitees represented two-year institutions with the other half from four-year institutions. The organizers intentionally recruited pairs of institutions that serve as transfer feeders and recipients with a goal of strengthening ties between institutions who share a common pool of students.

The CRC from each institution consisted of four individuals: a campus administrator, a STEM faculty member, an institutional research staff member, and a staff or faculty member involved with transfer student success. The organizers strongly encouraged participating campuses to assemble teams that were also demographically diverse in terms of both race/ethnicity and gender. This diverse CRC composition ensured that each institution had a profound understanding of their campus's STEM and transfer success culture, as well as access to institutional data, and genuine willingness to undertake the research plan developed during the conference.

Conference Agenda. Each day of the conference commenced with an interactive presentation by an invited speaker with expertise relevant to that day's agenda. This seminar enabled the speaker to present their work and contextualize it within the conference goals. Prior to the conference, attendees read On My Own, a book by Dr. Xueli Wang, to better understand the STEM transfer student experience and in their CRCs, identified the answers to the following questions leveraging their campus' institutional data:

1. For two-year attendees: What percent of STEM students, broken down by various demographics, at your institution transfer to a four-year institution?
2. For four-year attendees: How does the academic success of your STEM transfer students, broken down by various demographics, compare to that of non-transfer students?
3. For both institutions, examine the performance of various student demographics in your foundational STEM courses.
4. What programs, policies, or other mechanisms does your institution employ to support successful transfer in STEM?

Day 1 "Getting to Know Our Participating Institutions"
Objective. Use institutional data and identify the degree to which institutions prioritize STEM transfer.

Participants discussed STEM transfer success issues within the context of their specific institutions. To aid in this discussion, they examined their institutional data and reviewed key academic momentum markers, comparing outcomes across institutions. Guided by Dr. Wang, participants learned about ways to measure opportunity gaps (differences in academic outcomes between minoritized and non-minoritized groups), discussed interpretation of these data and identified limitations of institutional data to measure transfer student success.

Day 2 “Moving Beyond Institutional Data”

Objective. Learn about measures beyond those captured through institutional data that can characterize students’ disciplinary socialization as STEM majors (e.g., sense of belonging and science-identity) and their perceptions of diversity and inclusion in STEM programs.

Participants learned about common approaches to collecting non-academic outcomes data via research instruments, such as surveys and interviews. Within their CRC, participants collaboratively identified outcomes that they felt best captured STEM student transfer success at their institution.

Day 3 “Impact Evaluation”

Objective. Develop an impact evaluation plan for a STEM transfer student success program within their institution or between their institution and their partner campus.

Leveraging the institutional data analysis (Day 1) and other non-academic outcomes (Day 2), participants discussed ways to assess the quality of an identified program known to promote STEM pathway success for underrepresented populations. CRCs developed an impact evaluation plan including identifying program outcomes, relevant data to collect, barriers to data collection, a preliminary analysis plan, and key stakeholders to include in the evaluation plan as well as in a dissemination plan.

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[1] Data retrieved from https://www.universityofcalifornia.edu/infocenter

[2] Data retrieved from https://www2.calstate.edu/data-center/institutional-research-analyses/Pages/enrollment.aspx

[3] Data retrieved from https://datamart.cccco.edu/datamart.aspx

Data Collection

Following the conference, attendees were asked to complete a Qualtrics survey examining the potential of the STEM Transfer Pathway Conference to foster the establishment and activities of Campus Research Communities (questions from the survey can be found in Supplemental Figure 1). Surveys were distributed to all 40 participants via email. The response rate for the survey was 43% (17 respondents). All data was collected in accordance with the University of California Irvine’s Institutional Review Board (UCI IRB Protocol #1066). The survey covered the following topics:

Expectations and experience. Participants were asked to rate their overall experience as well as report aspects of the STEM Transfer Pathway they felt went well and what could be improved upon.

Networks. Attendees were asked to identify which conference attendees they knew or collaborated with prior to the conference and which became part of their professional network as a direct result of participating in the conference.

Post-conference steps. Attendees were asked to indicate what steps they intended to take towards implementing their program/policy evaluation as well as any barriers they perceived for this implementation. Furthermore, attendees were prompted to report their interest in a follow-up

conference as well as elaborate on what they believed the purpose of this follow-up conference should be.

Data Analysis

For this survey, questions took the form of either multiple choice response options, likert scale response options, or open-ended responses. For those multiple choice and likert-scale questions, the percentage of each response are reported. For open-ended responses, qualitative coding was used for analysis. Through an iterative coding process, emergent codes were identified and categorized to determine the frequency of each response type.

RESULTS

One week after the conference, a survey was distributed to all conference participants using Qualtrics. The purpose of this survey was to obtain a more comprehensive understanding of their conference experience.

Overall experience. Participants were requested to offer feedback about their experience through the survey. Specifically, the survey aimed at identifying parts of the conference that went well and parts that did not go well. In general, all participants reported that the conference matched (11.8%) or exceeded (88.2%) their expectations. The participants appreciated the organization of the conference (i.e., bringing together two- and four-year partner institutions and folks from different departments on campus) and the structure (e.g., the balance of time devoted to activities and networking). One participant stated, “The structure of the conference really facilitated interactions with nearby CC, and also gave time for internal conversations that really should be happening more frequently.” Most participants stated they valued the chance to collaborate with partner institutions to navigate STEM transfer success (58.8%). The following response is an example of the common sentiment shared by the respondents,

> “I thought the guest speakers were really well chosen and inspired a lot of great conversation. The concept of working directly between JC and University was really innovative, particularly as it relates to transfer. Most institutions think only of the students when they are at their campus, not before or after. The thought of how to serve the students before transfer or after transfer was inspiring.”

The most common suggestions for improvement of the conference centered around interaction with partner institutions (41.2%). Many respondents suggested more time with their partner institution, earlier contact to establish a relationship prior to the conference, facilitated follow-up interactions with partners, or opportunities to interact with more institutions during the conference.

Other considerations that may be of interest were around participant selection with one individual indicating that they would have benefitted from a different partnership "We should have been more intentional about who was attending. [University] brought an engineering-based team, and we [Community College] don't have engineering majors so some of their activities and focus didn't apply to our students." Additionally, one respondent mentioned including the voices of transfer students in their considerations for developing methods to increase STEM transfer rates: "Incorporating student voices into the process. Having actual transfer students talk to us about their perspectives, issues, and needs.

Network expansion. The finding revealed that the majority of respondents (87.5%) agreed with the statement that the conference expanded their professional network. The remaining respondents neither agreed nor disagreed with this statement. In order to conduct a more in-depth analysis of the expansion of participants' networks, respondents were prompted to identify conference attendees who they considered part of their professional network both before and after the conference. The analysis unveiled a notable increase (paired t-test, $p<0.001$) in the number of professional contacts. Prior to the start of the conference, survey respondents identified an average of 2.8 (± 1.3) conference attendees that were part of their professional network. For the most part (60%), these respondents identified other individuals from their own institution. Following the conference, there was a noticeable rise in the number of individuals and institutions within each participant's network. Respondents reported an average of 8.1 (± 3.8) attendees from an average of 3.3 (± 1.5) institutions as part of their professional network at the conclusion of the conference. Below are a few examples of pre and post professional networks for three survey respondents.

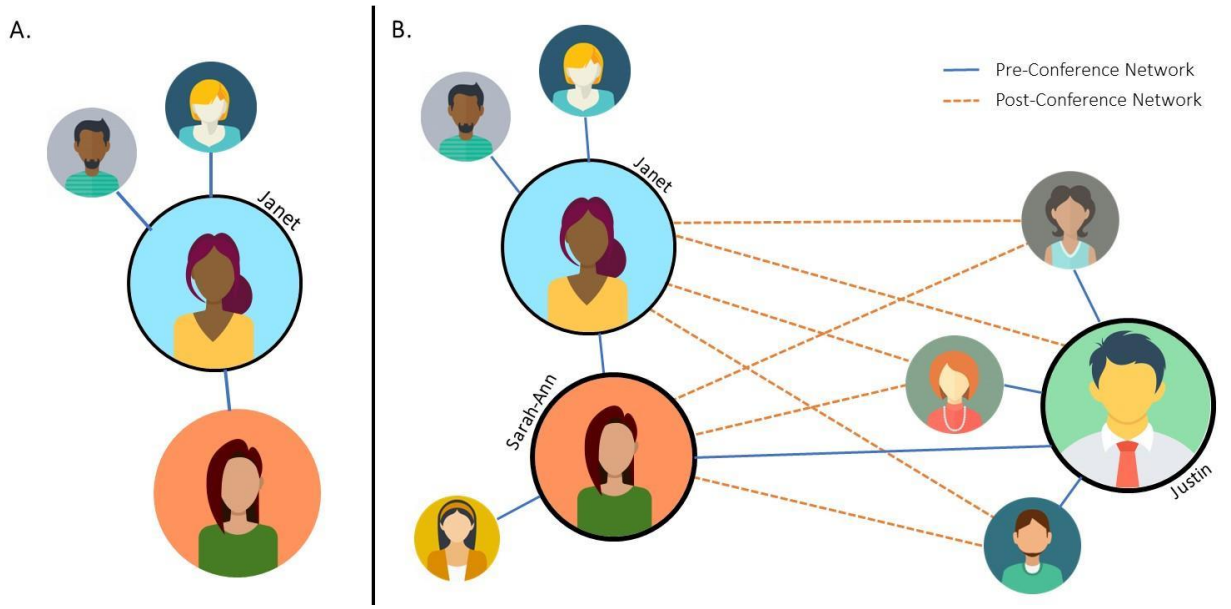

Figure 2. Professional Network Expansion. Figure 2A shows the initial network connections for "Janet." Here pre-conference connections are indicated by solid blue lines. Figure 2B shows the connections for "Janet", "Sarah-Ann", and "Justin" at the conclusion of the conference. All initial connections are indicated by solid blue lines while new connections made over the course of the conference are indicated by the orange dashed lines.

Post-conference. Attendees were asked about their interest in a follow-up conference on STEM transfer pathways as well as what they felt this conference should include. Of those that responded, 70.6% reported being interested in attending a follow-up conference. When prompted to elaborate, many respondents indicated that they believed that a follow-up conference would be beneficial to share results from their proposed projects. Most discussed sharing results, but others also mentioned discussing areas of success or challenges they were facing. One example that captured these concepts was the following: "Yes, I think it will be helpful to bring the group together to share updates and exchange ideas/problem solve if we run into any roadblocks."

Furthermore, some suggested using the time provided through a follow-up conference to continue to develop their current proposals or even create new proposals. For example: "Would love more time with my collaborators to further develop the proposed project and share ideas with other institutions."
Finally, attendees were asked about how they planned to move forward after the conference to implement their evaluation program as well as any perceived barriers to accomplishing this. When promoted to indicate post-conference actions, the majority (57.1%) reported setting up follow-up meetings with their conference team members. This was followed by gathering resources (33.3%) and contacting relevant stakeholders (23.8%).

Post Conference Action	**Count**	**Percentage**
Set up a follow-up meeting with my conference team members	12	57.1%
Set up a meeting with someone **on campus** (outside of my team members)	4	19.0%
Set up a meeting with someone **off campus** (outside of my team members)	4	19.0%
Emailed relevant stakeholders on or off campus for reasons other than to set up a meeting	5	23.8%
Gathered additional information (e.g. relevant literature or online resources) to inform the program evaluation plan	7	33.3%
Other	6	28.6%
When asked to specify “other” post conference actions, survey respondents replied with either “Emailing with conference team members” or “No Post Conference Action.”		

For most respondents, when considering areas in which they still felt they needed support, stakeholder buy-in was the most significant factor (41.1%). This was followed by resources such as staffing (29.4%), time (29.4%), and funding (23.5%). These needs were captured by the following response: "We will need to get leadership buy-in in order to be allowed the time and resources to move forward."

DISCUSSION

Valuing Collaboration. The overarching objective of the conference was to facilitate and nurture the success of collaborative campus research communities (CRC) dedicated to examining and evaluating the effectiveness of strategies for supporting STEM transfer pathways. The organizers harnessed the power of collaboration as a tool to promote the development of this shared responsibility, drawing inspiration from theories on research collaboration, notably those articulated by Kezar (2005) and Mohrman et al. (1995). These theories offered insights into the transformation of institutional cultures from a focus on individual work to a culture that fosters collaborative endeavors.

An analysis of survey results and feedback from participants clearly indicated that the structure of the conference agenda and activities had laid strong foundations for collaboration, both within and across institutions. A crucial element in building these collaborative networks was the process of two- and four-year institutions jointly defining key terms, such as "transfer success," and identifying common obstacles and support structures at each institution to enhance student success. It also involved two-year institutions openly expressing the type of support they required from their four-year counterparts, and vice versa. This conference stands as an exemplary model for constructing collaborative partnerships between two-year and four-year institutions, a template that other disciplines and institutions can

leverage to build collaborative networks focused on areas such as transfer success or other institutional concerns.

Establishing Professional Networks. The diversification of STEM fields has been a well-recognized goal for the past few decades on a national scale. It is well-established that more diverse teams tend to be more productive and creative. In order to maintain its position as a global leader in STEM, the United States must prioritize expanding opportunities for participation. Community colleges are a key source for future STEM graduates, especially among minoritized populations. However, the rates of successful transfer to four-year colleges or universities by those seeking bachelor's degrees in STEM remain incredibly low.

Improving these outcomes requires effective communication between faculty and staff at two-year and four-year campuses. Unfortunately, numerous barriers often hinder this necessary collaboration. Nevertheless, the results obtained from the survey conducted after the STEM Transfer Pathways Conference revealed a significant increase in the number of professional networking connections between these two-year and four-year institutions. This shift indicates that the conference served as a platform for stakeholders to overcome some of the barriers impeding effective communication and collaboration in the pursuit of STEM diversification and broadened participation opportunities.

Moving forward. While many positive outcomes stemmed from the interactions within the conference itself, there remains a significant amount of work to be done beyond this context. As per the responses received from attendees, several barriers must be addressed to ensure the successful implementation of their evaluation programs. These challenges encompass aspects such as securing stakeholder buy-in, addressing staffing needs, managing time constraints, securing adequate funding, and accessing necessary resources.

One potential strategy to tackle some of these barriers is the organization of a follow-up conference. The survey results indicated a high level of interest among participants, with many suggesting the inclusion of such a conference to facilitate the sharing of results, the discussion of successes and challenges, and the continuation of effective collaboration with their partner institutions.

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[1] Data retrieved from: https://ccrc.tc.columbia.edu/Community-College-FAQs.html and https://nces.ed.gov/datalab/

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