

Expanding Pathways for Hispanic Students to Enter and Succeed in Computing Graduate Studies

Jessica Rivera
Computing Alliance of Hispanic-
Serving Institutions
University of Texas at El Paso
El Paso, TX USA
jrivera63@utep.edu

Ann Q. Gates
Office of the Provost
University of Texas at El Paso
El Paso, TX USA
agates@utep.edu

Elsa Villa
Center of Excellence for K-12
Computer Science Education
University of Texas at El Paso
El Paso, TX USA
evilla@utep.edu

Patricia Morreale
Department of Computer Science
and Technology
Kean University
Union, NJ USA
pmorreale@kean.edu

Abstract—Involving diverse individuals who bring different perspectives, experiences, and disciplinary knowledge in solving problems is critical in our nation's ability to innovate and compete in a global economy. Unfortunately, the trends in the number of graduates with advanced degrees, in particular ethnically and racially diverse citizens and permanent residents, are insufficient to meet current and future national needs. This is exacerbated in computing, which is one of the least diverse fields. Despite the growth in numbers of Hispanics nationally and their representation in undergraduate studies, the number of Hispanic citizens and permanent residents who enter and complete graduate computing studies is disturbingly low. Studies report that Hispanic graduate students across all fields of study feel isolated and alienated, face lack of support, experience low expectations from faculty, and a negative racial/ethnic climate. Students often encounter a STEM culture centered on competition and selectivity, and this must be addressed to increase pathways to the doctorate to support our nation's economic and national security goals. This paper describes a collective effort of institutions with high enrollments of Hispanic students that have built partnerships among non-doctoral-granting and doctoral-granting institutions to increase representation of Hispanics in graduate studies. Led by NSF's Eddie Bernice Johnson Computing Alliance of Hispanic-Serving Institutions (CAHSI), the collective employs evidence-based practices grounded in the Hispanic-servingness literature to address the root causes.

Keywords— *research experiences of undergraduates, Affinity Research Group Model, graduate studies, computing, Hispanic servingness.*

I. INTRODUCTION

Diversifying the technical workforce and the academy is critical to our nation's ability to innovate and compete in a global economy. Unfortunately, the trends in the number of graduates with advanced degrees who enter the computing workforce and academia are insufficient to meet current and future national needs. Computing, which is ubiquitous in almost all research endeavors, is the least diverse field of all STEM disciplines. The National Academies of Science, Engineering, and Medicine (NASEM) [1] report, *Minority-Serving Institutions: America's Underutilized Resource for Strengthening the STEM Workforce*, stresses the importance of minority-serving institutions (MSIs) in addressing these shortages. Hispanic-Serving Institutions (HSIs) enroll 25% or

more full-time undergraduate Hispanic/Latinx students (we use the term Latinx interchangeably with Hispanic as a gender-neutral and inclusive term) and constitute the majority (70%) of MSIs [1]. HSIs compose 18% of all higher education institutions but enroll two-thirds of all Hispanic students in higher education [2]. HSIs also graduate a disproportionately high share of Hispanic undergraduates in computing. One recent analysis found that, while just 11.8% of computing bachelor's degree earners from all postsecondary institutions were Hispanic, 42% of Hispanic computing bachelor's degree earners graduated from HSIs [3]. Hispanics are also the largest population of color in higher education (at about 1 in 5 students overall), and the number of Hispanics enrolled in higher education is growing.

Hispanic representation in graduate programs is the lowest in fields like computer science. Enrollment data from 2021 found that Hispanics represented 11% of master's students and 9% of doctoral students [7]. Yet, the most recent available data of the number of Hispanics who completed graduate programs in computing fields in 2018 comprised a mere 3% in master's and 2% in doctoral programs [3]. While the national numbers are alarmingly low, HSIs are important in preparing students for doctoral degrees. As reported in NCSES [3], 37.8% of Hispanic students who received science and engineering doctorates between 2015 and 2019 had received their bachelor's degree from an HSI. In 2018-2019, HSIs represented only 17% of all higher education institutions in the United States [8]. It is important to note that not all HSIs offer graduate programs; HSIs that offered master's or doctoral programs in 2018-2019 represented only 6.8% of all higher education institutions [8]. However, this small fraction of HSIs enrolled more than a quarter (25.8%) of all Latinx graduate students in computer science [3]. These data demonstrate the critical role HSIs play in diversifying STEM fields.

Additionally, it is important to note that while HSIs have been recognized for their efforts in contributing to the success of Hispanic students in higher education, these institutions are often tasked to do this work with fewer resources while at the same time disproportionately serving larger numbers of students who are first-generation, low-income, and from racial/ethnic minoritized communities [9], [10]. Federal funding is often allocated at higher rates to selective higher education institutions

that graduate lower numbers of minoritized students in STEM disciplines [11], [1], [12].

Diversifying computing will not only fill the need for more technology workers but also has several implications for benefiting our larger society. With Hispanics overrepresented among the U.S. population in poverty, promoting the educational and occupational success of Latinx graduate students in computing is especially essential because their success can result in achieving high-status/high-paying professional careers that have the potential to interrupt intergenerational poverty [13], [14]. Moreover, as a nation, we can reach new levels of inquiry and scientific discovery by encouraging innovative thinking made possible by broadening the diversity of thought that comes with a diverse computing research workforce. Research has shown that better science is developed when groups of diverse people work together [15].

The NSF Eddie Bernice Johnson Computing Alliance of Hispanic-Serving Institutions (CAHSI) [16], [17], [18] is uniquely positioned to increase the number of Hispanic students who earn graduate degrees by leveraging and extending its NSF-funded effort to advance a research-based framework for attracting, preparing, and supporting Hispanics and women students in their trajectory toward completion of graduate degrees in computing areas. This paper provides a background of CAHSI and its approach to making collective change. It then summarizes the literature that informs practices it adopted to institute change.

II. BACKGROUND

A. Computing Alliance of Hispanic-Serving Institutions

CAHSI was originally formed in 2006 with funding from the NSF Broadening Participation in Computing program to address the low representation of Hispanics in computing and became an NSF National INCLUDES (Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science) Alliance in 2018. NSF INCLUDES is a comprehensive national initiative designed to enhance U.S. leadership in STEM discoveries and innovations by focusing on broadening participation in STEM fields at scale.

CAHSI serves students at all levels, in particular first-generation students. In 2020, Hispanics accounted for 62.3M of the U.S. population, or 19%, and by 2060, Hispanics are expected to account for 28% of the population [19]. CAHSI aims to reach parity in the number of Hispanics in the computing workforce relative to the country's demographics; thus, its 2030 vision is: By 2030, 20% of Hispanics will earn credentials in computing. CAHSI's mission is to grow and sustain a networked community committed to recruiting, retaining, and accelerating the progress of Hispanics in computing. Its efforts align with NASEM's call for an urgent national need to develop strategies to substantially increase the postsecondary and STEM degree attainment rates of Hispanics in graduate studies.

CAHSI is organized by geographic hubs representing areas of the country with the largest population of Hispanics. Each region has a CAHSI Regional Lead, supported by a staff member called a Connector, and one or more co-leads, depending on the region's size, who a part-time Coordinator supports. The West region covers California; and the Southwest

region covers Arizona, New Mexico, and Texas. The Southeast region covers Florida and Puerto Rico; and finally, the North region covers New Jersey, New York, Virginia, Connecticut, and Illinois.

CAHSI focuses on collaborative work to transfer high-impact practices, partnerships with private and public sectors focused on retention and workforce development, and research capacity building. Its goals are to:

- challenge students' knowledge, skills, and abilities so that they are positioned to thrive in the workforce and academia;
- support pedagogical and professional growth for those who can impact Hispanics, which includes faculty, professional staff, and others who work with our students;
- expand meaningful partnerships that align with strategic regional and national efforts and support the success of our students; and
- inform policy through evidence.

Through research efforts, CAHSI contributes to evidence-based literature on organizational structures and pedagogy that lead to Hispanic student success [20], [21], [22]. What sets CAHSI apart from other organizations are its high-impact practices and strategic actions embedded in each academic institution. Intentionality in this context translates to creating tailored initiatives, policies, and practices that meet students where they are in their college careers academically, financially, and socially while doing so with cultural mindfulness that moves students toward higher levels of academic achievement and self-confidence.

B. Collective Impact

CAHSI formally adopted a **collective impact model** [23] to coordinate the scaling and spreading of its effective strategies to promote equity in computing. Collective impact consists of the following five elements [23]: (1) common agenda, (2) common measures, (3) mutually reinforcing activities, (4) continuous communication, and (5) an organization that serves as centralized support to facilitate all these activities.

CAHSI's common agenda is centered on the 20-30 vision stated above, which partners in the network jointly established. Continuous communication provides opportunities to share data/knowledge, adopt/adapt effective practices, build research capacity, and establish communities that allow members to learn from each other. Mutually reinforcing activities are those focused on increasing Hispanic representation, preparing students for competitive computing positions, and increasing Latinx representation in graduate studies, which led to changes in organizational practices and other support systems focused on Latinx student success [24], [25]. In CAHSI's application of collective impact, the CAHSI Backbone provides the centralized structure to facilitate the network's activities at the national level. At the regional level, the Regional Leads and Co-Leads, along with their Connectors and Coordinators, support the mutually reinforcing activities and continuous communication

among the institutions to achieve the common metrics in the shared agenda.

C. Hispanic Servingness Research

While HSIs serve large numbers of diverse students, these institutions were historically Predominately White Institutions (PWIs). Given their historical context, researchers argue that the policies and practices at HSIs often reflect those of their historical contexts [26]. This has led to HSIs being critiqued for not living up to their “serving” title, and as a response to these critiques, researchers have recommended a servingness framework [27]. Servingness is focused on engaging institutions to think of ways to promote student success beyond traditional measures. Specifically, a servingness framework [27] examines academic outcomes (i.e., graduation rates), non-academic outcomes (i.e., sense of belonging) and the structural components (i.e., equity-minded efforts) in higher education institutions that contribute to student success. The proposed project’s success has several critical implications from the perspective of a Hispanic-Servingness approach.

First, increasing the number of Latinx graduate students introduces a multiplier effect through in-class and out-of-class validation of Latinx undergraduate and graduate students [28] that then contributes to their overall academic success and persistence [29], [30] and emboldens them to become future role models. Second, Latinx graduate students who serve as teaching and graduate assistants play an essential role as role models for undergraduate and other graduate students. Thus, they can influence the experiences of undergraduate students and their ability to see themselves as graduate students [31], [32] and are likely to have a deeper understanding of Latinx cultural and linguistic backgrounds [33], [31], [34]. Third, through their multiple roles, Latinx graduate students also benefit from improving their teaching, coaching, and mentoring skills, making them more marketable [35]. Finally, the increase of Latinx graduate students in computing benefits not only individuals but also higher education institutions because Ph.D. degree recipients of diverse backgrounds and experiences increase the pool of diverse faculty members, and diverse faculty members are resources for achieving diverse campus climates. A scant 4% of all full-time faculty in degree-granting postsecondary institutions were Latinx in 2015, 2016, and 2017. More alarmingly, Latina faculty accounted for only 3% of all full-time faculty *in all disciplines* in the fall of 2020 [36]. A survey of 161 computing departments from the Computing Research Association found that only 2.6% of computing faculty participating in the study were Latinx [37]. Accordingly, the underrepresentation of Latinx graduate students in computing subsequently influences the representation of Latinx in professions requiring graduate degrees and in the professoriate in computing fields. While Latinx faculty are more well-represented in HSIs than non-HSIs [1], the share of Latinx faculty falls short of being at parity with the Latinx student population at HSIs [38], [39].

Latinx students face several obstacles as they navigate educational contexts, and ultimately these barriers impact their entry into graduate programs. First-generation college students

are less familiar with the process of going to college and far less familiar with pathways to graduate school than other students; such students can benefit from more structured knowledge about graduate academic and research career pathways. Engaging Latinx students to experience a *sense of belonging* early in their college careers is crucial for promoting persistence [41] and *cultivating social capital* through supportive relationships is an essential component of promoting Latinx STEM success in computing and engineering fields [42], [43].

Studies report that Latinx graduate students across all fields of study feel isolated and alienated, face a lack of support, experience low expectations from faculty, and encounter a negative racial/ethnic climate [44]. These hostile environments contribute to lower retention and graduation rates for students from minoritized backgrounds, and this is even more pronounced in STEM fields [45]. A study on Black and Latinx doctoral students at a Predominately White Institution (PWI) found that common challenges faced by the participants in this study included issues with the program structure and climate, negligent or unsupportive advisors, difficulties adjusting to a PWI, gaps in education, limited social support, having a unique research focus, psychological and emotional factors, and overcoming failures and financial issues [46]. Students in that study described having difficulty navigating competitive academic environments and the issues of dealing with the politics of academia. Another student explained their difficulty transitioning from working with an advisor that was constantly on them to an advisor who was never there. Students often have to figure out how to navigate the program on their own. Additional concerns surfaced for these students as they struggled to adapt to institutional environments that lacked diversity. As a result of the limited diversity, more than half of the participants indicated that they experienced racism and hostility, resulting in feeling alone and not feeling like they fit in or belonged in their programs. One student was told they were probably only admitted to the institution to meet a diversity quota. These hostile and unsupportive environments contribute to the lack of diversity in doctoral programs, especially in STEM, as such environments are often perceived as valuing competition, grounded in ideas of survival of the fittest, meritocracy, individualism, which reinforces white privilege and the marginalization of minoritized populations [47]. To address many of the issues contributing to the lack of diversity of Hispanics in graduate education, CAHSI has developed pathways for expanding the participation of Hispanics.

III. EXPANDING GRADUATE PATHWAYS FOR HISPANICS THROUGH EVIDENCE

CAHSI aims to advance more Hispanic students into and through computing graduate programs through strategic actions centered on three main pillars: expanding knowledge about research in first- and second-year students; preparing and involving third- and fourth-year students in research; and providing support structures for graduate student success (Fig.

- 1). Underpinning the strategic actions is a research-focused network focused on building research capacity at HSIs and integrating elements of Hispanic-Servingness across the alliance's efforts. This paper focuses on the following strategies:
 - a. building research capacity for students to pursue graduate pathways;
 - b. building research capacity at HSIs; and
 - c. creating multi-dimensional graduate support structures and networks.

A. Building Students' Research Capacities

Description. A Local Research Experience for Undergraduates (LREU) initiative funds research experiences at the home institution for CAHSI students, emphasizing first-generation students and those with financial needs. The initiative focuses on matching students based on their areas of interest and developing their domain knowledge in areas aligned with CAHSI research institutions. The LREU builds upon the virtual REU (vREU) model [48] and is facilitated through the CAHSI Collaborate Learning Community (CCLC). The CCLC provides professional development for faculty mentors in short weekly increments to provide just-in-time adoption of effective practices that build students' research, communication, and professional skills needed to thrive in research. LREU faculty mentors co-create a Research Plan with their mentees, and students are required to maintain a Research Journal in which they record what they have learned and identify areas for their growth and development as researchers. At the end of the program, students create and refine their research poster based on constructive critique received through a collaboration board. The intent of the LREU initiative is to establish a network of faculty at HSIs and Hispanic scholars who cultivate a growth mindset through deliberate practice and reflection from personal, professional, social, and academic perspectives.

The Backbone provides workshops to students across the CAHSI network, assists students in finding external research opportunities, supports submission of competitive applications for such opportunities, and provides guidance on how to submit competitive scholarships and fellowships and how to apply to graduate school. CAHSI views *student fellowships and scholarships* as a powerful resource in attracting students into graduate studies toward a doctorate. The Fellow-Net signature practice engages students early in their academic career in research activities. Fellow-Net guides students on preparing competitive applications through hands-on activities and critical review of successful and unsuccessful fellowship packets. Early exposure to navigating the graduate application process is

critical to creating pathways for Latinx first-generation college students at HSIs to pursue doctoral degrees [49].

As noted earlier, the LREU initiative also promotes student involvement in an external REU initiative by facilitating student placement in summer research experiences at external sites, e.g., NSF REU programs, Computing Research Association (CRA) Distributed Research Experiences for Undergraduates (DREU) [50], and research internships at national labs and PhD-granting institutions. DREU aligns with CAHSI's model of matching research experiences based on interests, mentoring, and role models.

Research Basis and Supporting Evidence. A UnidosUS study [40] found 70% of Latinx postsecondary students are first in their families to go to college. This is not surprising, given that only 10.3% of people in the U.S who are over 18 years old and have earned a bachelor's degree are Hispanic while Whites make up 78.8% of that total. Of all the people over 18 years of age with master's degrees, Hispanics make up 7.2% of that group while Whites make up 76%, and out of the people over 18 years old with doctorates, Hispanics represent only 5.8% of the total while Whites make up 78.8% of that group [51].

Because first-generation college students are less familiar with the process of going to college and far less familiar with pathways to graduate school than other students, they can benefit from more structured knowledge about graduate academic and research career pathways. Latinx students exhibit a particularly relational and social orientation compared to other groups [52]. As stated earlier, engaging Latinx students to experience a *sense of belonging* early in their college careers is crucial for promoting persistence [53], [54], [41]. Moreover, the *cultivation of social capital* through supportive relationships is an essential component of promoting Latinx STEM success in computing and engineering fields [55], [56], [57, [42], [43].

Undergraduate research experiences strengthen students' scientific identities, bolster their aspirations to STEM research careers and sharpen their understanding of tools and practice of scientific research [58], [18], especially for minoritized students in STEM fields [59], [60]. Research experiences at MSIs can promote student success and entry into STEM professions [59], [1] and into graduate programs. Recruiting and retaining students from diverse backgrounds is a noted focus of undergraduate research programs, such as the NSF REU and CRA DREU programs mentioned earlier. These efforts show positive outcomes, such as gains in technical skills, professional identity, and self-efficacy [61], [62].

Developing a foundation in research is also critical as students transition into graduate programs. Research on CAHSI students found that a lack of research exposure prior to beginning a doctoral program created difficulties for doctoral students [63]. A doctoral student from that study explained that his lack of research experience made it difficult for him to develop a research topic for his dissertation studies. The student explained that the biggest challenge in his doctoral program “was coming up with a research topic.” He noted that his master’s program focused on “programming-based and project-based [assignments]” which was a stark contrast from the expectations in his Ph.D. program where he described “Now you have to do research...but you don't have the ability.” Prior

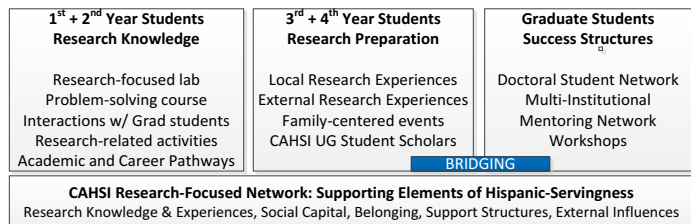


Fig. 1. CAHSI strategic actions for expanding Hispanic students' graduate pathways.

experiences conducting research, he explained, could have “become like a steppingstone and the idea for a Ph.D. dissertation.” However, because this student did not have prior research experiences to build on, it became challenging to develop a dissertation topic.

According to a study of CAHSI students, undergraduate research experiences offer more than just academic preparation: They also equip students with essential professional and technical skills necessary for successful careers in computer science [63]. This study highlighted research experiences’ significant role in fostering persistence within the major, shaping a strong computer science identity, and facilitating job placements in industry. For example, a first-generation Latinx student in that study described how his participation in an undergraduate research experience led to an internship at his dream company. Despite lacking professional experience in the computing field, recruiters at a conference expressed interest in interviewing him based on his research background. The student explained, “Even though I was scared, ... I went to talk to some of the recruiters...and they talked to me...they were interested in my research. They asked me about it, and they’re like, “Do you have any interviews with us?”. This example emphasizes the value of research experiences in enhancing students’ appeal to industry recruiters and creating career opportunities.

CAHSI’s Affinity Research Group (ARG) signature practice has had a positive impact on student experiences in computing [17], [64] and serves as a model to prepare students for research. The ARG model is a set of practices built on a cooperative team framework to support the creation and maintenance of dynamic and inclusive research groups in which students learn and apply the knowledge and skills required for research and cooperative work in a deliberate and intentional manner. Research experiences raise students’ preparation to enter graduate programs. Longitudinal research on former participants in CAHSI’s ARG program has demonstrated that participation in a supportive research group environment is associated with more successful transitions into the STEM workforce [64].

CAHSI’s virtual REU (vREU) pilot, which was launched in 2020, provided a foundation for the LREU initiative. What was learned from the vREU program guides the development of research experiences for students participating in the LREU. CAHSI’s successful vREU pilot ensured that students had opportunities to engage in research, gain critical skills to advance their knowledge, and prepare them for advanced study while providing financial resources.

Student responses (n=51) at the end of the vREU reported growth in research skills (89%), communication skills (66%), technical knowledge (64%), and personal growth, including confidence (57%). Students planned to attend professional meetings (93%), prepare posters (50%), and evenly split on authoring a journal article (32%) and authoring a conference paper (32%). Students indicated greater confidence and interest in computer science research (>90% agree/strongly agree). Students were asked about graduate school, and 68% of the responding students reported that their research experience had influenced their decision, and 55% of the students credited their research mentors. Students participating in the vREU were

primarily juniors and seniors, with Hispanic students in the majority (79%) [65], [66].

Practice Evaluation. In 2022, CAHSI launched the LREU initiative. The initiative has had a two-fold benefit for CAHSI institutions: creating research opportunities for students at CAHSI institutions and providing professional development opportunities for faculty at CAHSI institutions. Fig. 2 shows the participation in the program across CAHSI regions. As shown in the figure, CAHSI is on track to reach its projected number of students participating in the LREU.

As described in the CAHSI External Evaluation report (2022), faculty mentors received virtual training in the Affinity Research Group (ARG) model. Mentors displayed significant growth from pre- to post survey in their knowledge of effective research mentoring practices ($t=-2.259$, $df=38$, $p=.030$) and their understanding of the ARG model ($t=-3.639$, $df=37$, $p<.001$). Likewise, the percentage of mentors who were knowledgeable or had extensive knowledge of effective mentoring practices for underrepresented students rose from 39% before the REU to 83% at the end of the experience. Mentors reported that students’ strongest learning gains were in understanding the research process, developing independence, and understanding the research literature. Student pre- to post-survey results show great growth in research skills ($t=2.38$, $df=34$, $p.023$), ARG development ($t=4.39$, $df=32$, $p.0001$), computing interest and confidence ($t= 3.99$, $df= 34$, $p.0003$), and problem-solving skills ($t= 3.28$, $df=34$, $p.0024$).

In the past year, CAHSI added an online collaborative learning community for LREU mentors. All (100%) LREU mentors reported that they benefited from the learning community, namely gaining effective strategies for interacting with and mentoring underrepresented students, resources, and materials to support their students, and building their own professional network. While CAHSI faculty have benefited from the LREU, there is room to expand this opportunity to more faculty and to involve more departments.

B. Building Research Capacity at HSIs

Description. CAHSI has focused on increasing competitive research efforts at HSIs through several efforts:

- A 2019 CAHSI Community Workshop brought together

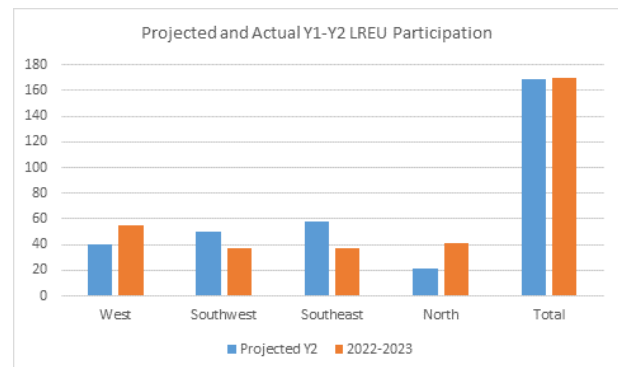


Fig. 2. Student participation in the LREU program 2022-23.

researchers, particularly Hispanic researchers, from HSIs to make recommendations on increasing representation of Hispanic researchers and HSIs in the NSF Computer and Information Science & Engineering (CISE) directorate's portfolio. The 2019 workshop informed the establishment of the NSF CISE MSI Research Expansion program.

- b. Two CAHSI members served on the American Society of Engineering Education (ASEE) Advisory and Programming Committee for the Capacity Building for Research at Minority-Serving Institutions: Infrastructure Research Readiness (CyBR-MSI: IRR) program. They facilitated sessions for the 2020, 2021 and 2022 workshops to support submissions from faculty at HBCUs, Tribal Colleges and Universities (TCUs), and HSIs to the NSF MSI CISE MSI Research Expansion program. The workshops centered on research capacity building.
- c. CAHSI hosted an ideation workshop in 2020 to propose research projects that seek solutions to challenging problems that align with NSF's key research areas.
- d. CAHSI received funding from Google to create the CAHSI-Google Institutional Research program. The partnership initiatives to promote graduate studies through research exposure, experiences, and career pathways (*research inclusion*); and allocation of project seed funds and Google Cloud Platform credits to support competitive research projects aligned with Google's research interests (*research collaboration*). The collaborative research effort pairs faculty at doctoral-granting HSIs with those from non-doctoral-granting HSIs.

A key component of efforts *c* and *d* has been virtual ideation workshops that provide opportunities to pitch research ideas, seek constructive feedback from the collective, refine and extend research ideas, and build collaborations. The outcomes are concept papers on potential research projects that can be developed into proposals for the CAHSI-Google Institutional Research program, the NSF CISE Research Expansion program, and other funding opportunities.

Research Basis and Supporting Evidence. Building the research-focused network requires a systems perspective that transcends the competitive ethos between individuals and institutions common in academia. A case study revealed that CAHSI enacts interdependent values across its institutional partners [20]. CAHSI ideation convenings have demonstrated the ability of CAHSI to build research-focused networks with support for faculty professional development. Building a community of HSIs committed to improving research capacity and building infrastructure translates into more opportunities for faculty to gain knowledge of how best to collaborate and seek funding opportunities, especially for faculty who are not actively engaged in research.

This is especially critical for faculty at HSIs given that these institutions often receive less funds to conduct research. For example, studies have shown that a few select universities receive the majority of federal research funds that are awarded each year [66]. These institutions overall serve less students

from underrepresented minority groups and less Pell Grant recipients. The lack of funding across institutions, especially institutions like HSIs that serve large numbers of first-generation, low-income and students from minoritized backgrounds [10], restricts students' opportunities to gain research experiences [67]. Students who attend institutions with fewer researchers often have less opportunities to engage in or be exposed to cutting-edge research.

Practice Evaluation. In 2021, CAHSI implemented a mini-IDEAS workshop to bring faculty together and build their capacity to develop and submit research proposals. Faculty reported that they had gained expertise in writing proposals, ideating on problem solutions, targeting a grant solicitation, and expanding their collaborative network of researchers. In follow-up surveys, 92% of participants reported the workshop had facilitated cross-institutional research collaborations. Additionally, 85% of attendees reported that they had generated research ideas. The majority (61%) improved their ability to write competitive proposals. Generally, each year since the Ideation workshop, about half of CAHSI-engaged faculty have submitted a cross-institutional collaborative grant proposal that advances CAHSI's vision. However, these collaborations could be expanded within CAHSI departments to involve even more faculty as few faculty report they have cross-institutional research collaborations.

The involvement of CAHSI in the ASEE workshops and submissions to the NSF CISE MSI Expansion program resulted in six proposals being funded in 2021 and 2022. In the latest survey of participant activity in CAHSI, 59% of CAHSI-engaged faculty reported involvement in developing or managing cross-sector partnerships to advance CAHSI's vision. Recent efforts to engage CAHSI faculty in cross-institution research experienced a large boost in 2023 through the Google initiative to fund CAHSI faculty collaborative projects. The CAHSI-Google ideation workshop resulted in 88 research ideas for ten slots, demonstrating the interest in such opportunities. In spring 2023, the qualitative responses in interviews with 20 CAHSI departmental teams indicate the effort was valuable for exciting faculty about research questions and topics, and for engaging previously unengaged faculty, as well as faculty from a wide range of CAHSI institutional types. The CAHSI Expertise Connector, a webpage that presents the research profiles of CAHSI faculty engaged in CAHSI initiatives, rose to 174 profiles in spring 2023, which indicates greater interest in networking across CAHSI institutions.

C. Building Graduate Support Structures

Description. The CAHSI Doctoral Scholars Network (DSN) is a community of doctoral students who connect across CAHSI institutions to develop students' research capacity, empower leaders, and provide a safe space for Black, Native American, and Hispanic doctoral students to connect. The network aims to cultivate cultural support and belonging by affirming students' values as assets in developing community and belonging in computing through dedicated professional development.

The lead of the DSN ensures that the network remains vibrant and engaged in activities that create a strong sense of

community. The intent is to cultivate a talent development mindset [20] through deliberate practice and reflection. An important activity is the delivery of workshops focused on the deliberate development of research and professional skills, e.g., setting clear goals and objectives, writing research questions, writing technical papers, and preparing for the professoriate. The lead coordinates the workshops with partner institutions for delivery through the GMIS-CAHSI Summit, virtual webinars, and in-person workshops at the home institution. In coordination with the CAHSI data manager and the institutional graduate coordinators, the lead ensures that the network members remain current on its activities.

Research Basis and Supporting Evidence. Hispanics represent a very small number of doctoral degree recipients, and an even smaller number in fields like computer science. For example, Hispanics only earned 1.9% of all the doctoral degrees awarded in computer science in 2020 [6]. There are various factors that contribute to these low numbers, and the lack of representation also perpetuates a lack of participation. For example, faculty mentors and role models play an important part in the recruitment and retention of graduate students from minoritized communities; however, the lack of diverse faculty impacts who goes and who stays in graduate school. A survey from the Computing Research Association that received responses from 161 computing departments, found that only 2.6% of computing faculty that participated in the study were Hispanic [37]. A survey that examined the experiences of STEM undergraduate, graduate, and postdoctoral scholars of color found that those who had a same-race or same-gender research mentor reported receiving more support from their mentors [68].

While no research exists on the specific experiences of Hispanic doctoral students in computer science, limited research exists on Hispanic students in STEM doctoral programs and minoritized student experiences in STEM graduate programs [69], [70]. Additionally, the majority of research on Hispanic students in STEM has focused on students' experiences at the undergraduate level [68].

Practice Evaluation. The DSN is a more recent initiative. The first meeting of the network took place in late November 2022, and formal evaluation of this program will take place a year after the program has been in effect. The majority of students in the DSN have expressed an interest in participating in the network to build a community among other students from shared identities. Some students expressed a lack of mentorship or opportunities to connect with experts in their specific areas of research as they prepared for their dissertation. However, participants in the program have participated in the following workshops/events: Building Atomic Habits based on the book by James Clear [71], writing workshops, and a presentation from a professor who shared his journey of being an undergraduate student at a CAHSI institution and moving into a faculty position after completing his doctoral program. The CAHSI DSN lead has an upcoming workshop for students on writing research and teaching statements. These workshops

have been developed in response to participant requests. Additionally, one student in the network created a Discord channel for students to communicate with each other outside of meeting contexts. The lead of the network will be meeting with students over the summer to develop the fall programming. Additionally, DSN participants are invited to attend the Great Minds in STEM conference in fall 2023 for professional development and an opportunity for participants to network and meet in person.

Summary. Hurtado and colleagues' *framework of inclusive science* [72] is based on an integrative review of empirical research on evidence-based efforts to diversify science in less well-resourced higher education institutions, including many MSIs and HSIs. The *framework of inclusive science* offers one way of conceptualizing a student success infrastructure in STEM fields. In this model, six *dimensions of inclusive science* are embedded in four *functional areas of practice*. The four functional areas of practice are (a) faculty development, (b) research enrichment or curriculum innovation, (c) student training, and (d) partnerships/networks. The six dimensions embedded in these areas of practice include (1) participation of diverse researchers, (2) diversity innovations in science (including learning and research grounded in societally relevant problems), (3) climate for diversity, (4) connections with diverse communities, (5) culturally responsive practice, and (6) integrated race/gender and science identities.

The approach being undertaken by the DSN lead is congruent with an inclusive science approach to build an infrastructure of support for Latinx students to pursue pathways to the professoriate and advanced levels of industry. CAHSI's culturally responsive norms and practices support Hispanic students through the ARG workshops, problem-solving communities of practice, and the Learning Collaborative Community faculty meetings. CAHSI Student Advocates, CAHSI Student Scholars, the Allyship program, the Fellow-Net program, and other programs have laid the foundation for student growth and success. CAHSI's *partnerships* focused on diversifying computing have been developed over a decade and a half and build and expand networks that build students' CS identities.

IV. CONCLUSION

HSIs play a vital role in fostering the growth and success of Latinx students pursuing undergraduate and graduate degrees, especially in computer science, one of the least diverse fields in the nation. A challenge often faced by HSIs is accomplishing more with fewer resources compared to institutions that serve large numbers of students from privileged backgrounds. In response to this and other underlying issues in higher education that hinder recruitment to and persistence in graduate studies, CAHSI, an organization promoting diversity in computer science, has defined signature practices and adopted strategic actions focused on research capacity building. Increasing the number of Latinx students who pursue graduate degrees in computing will have economic benefits for our society and will

provide opportunities to advance inquiry and scientific discovery through broadened diversity of thought.

ACKNOWLEDGMENT

The authors would like to express their appreciation for the CAHSI Backbone, regional leads and co-leads, regional connectors and coordinators, and faculty mentors for their contributions to increasing Hispanic representation in graduate studies. This material is based upon work supported by the National Science Foundation under Grant No. CNS 2137791 and HRD 1834620, the Sloan Foundation #G-2022-19463, and Google. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the NSF.

REFERENCES

- [1] National Academies of Sciences, Engineering, and Medicine, "Minority Serving Institutions: America's Underutilized resource for strengthening the STEM workforce," 2019.
- [2] Excelencia in Education, "Hispanic-Serving Institutions (HSIs): 2021-22 Fact Sheet," 2023.
- [3] National Center for Science and Engineering Statistics, "Women, minorities, and persons with disabilities in science and engineering," 2021. [Online], Available: <https://nces.nsf.gov/pubs/nsf21321/>
- [4] G. C. Mora, R. Perez and N. Vargas, "Who identifies as 'Latinx'? The generational politics of ethnoracial labels. Soc. Forces., 100.3, pp.1170-1194, 2022.
- [5] National Center for Education Statistics. "College Enrollment Rates. The Condition of Education 2020," 2020.
- [6] U.S. Census Bureau. School Enrollment in the United States: 2018, September, 2020, Available: <https://www.census.gov/content/dam/Census/library/publications/2020/demo/p20-584.pdf>
- [7] National Center for Science and Engineering Statistics, "Women, minorities, and persons with disabilities in science and engineering," 2023. [Online], Available: <https://nces.nsf.gov/pubs/nsf23315/>
- [8] Excelencia in Education, "Hispanic-Serving Institutions (HSIs): 2018-19 Fact Sheet," 2020.
- [9] W. C. Bolland, A. C. Samayoa, M. Gasman, A. W. Lockett, C. Jimenez and P., "National campaign on the return on investment of minority serving institutions. Penn Center for Minority Serving Institutions," 2017. [Online] Available: <https://cmsi.gse.upenn.edu/publications/research-reports>.
- [10] A. M. Núñez, S. Hurtado and E. Calderón Galdeano, "Why study Hispanic-serving institutions?," in *Hispanic-serving institutions: Advancing research and transformative practice*. New York, NY: Routledge, 2015, ch. 1, pp. 1-22.
- [11] C. Armitage, "Less prestigious institutions deliver better value for grant money," *Nature*, 2018.
- [12] M. A. Taffe and N. W. Gilpin, "Racial inequity in grant funding from the US National Institutes of Health, 2021. [Online] Available: [Elife.doi: 10.7554/eLife.65697](https://doi.org/10.7554/eLife.65697).
- [13] D. J. Harding, C. Jencks, L. M. Lopoo and S. E. Mayer, "The changing effect of family background on the incomes of American adults. In *Unequal chances: Family background and economic success*, pp. 100-144. Princeton U. Press and Russell Sage, 2004.
- [14] S. E. Seay, D. E. Lifton, K. L. Wuensch, L. K. Bradshaw and J. O. McDowelle, "First-generation graduate students and attrition risks," *J. Contin. High. Educ.*, vol. 56, no. 3, pp. 11-25, 2008.
- [15] R. B. Freeman and W. Huang, "Collaborating with people like me: Ethnic coauthorship within the United States," *J. Labor. Econ.*, vol. 33, no. (S1), pp. S289-S318, 2015.
- [16] A. Q. Gates, S. Hug, H. Thiry, R. Aló, M. Beheshti, J. Fernandez, ... and M. Adjouadi, "The computing alliance of Hispanic-serving institutions: Supporting Hispanics at critical transition points." *ACM Transactions on Computing Education (TOCE)*, vol. 11, no. 3, pp. 1-21, 2011.
- [17] A. Q. Gates, H. Thiry and S. Hug, "Reflections: The computing alliance of Hispanic-serving institutions," *ACM Inroads*, vol. 7, no. 4, pp. 69-73, 2016.
- [18] H. Thiry, S. L. Laursen and A. B. Hunter, "What experiences help students become scientists? A comparative study of research and other sources of personal and professional gains for STEM undergraduates," *J. Higher Educ.*, vol. 82, no. 4, pp. 357-388, 2011.
- [19] U. S. Census Bureau (2018, October 9). Hispanic population to reach 111 million by 2060.
- [20] A.-M. Núñez, J. Rivera, J. Valdez and V.B. Olivo, "Centering Hispanic-Serving Institutions' strategies to develop talent in computing fields. *Tapuya: Lat. Am. Sci. Technol. Soc.*, pp. 1-20, 2021.
- [21] A.-M. Núñez, "Creating cultures of student success: Insights from Hispanic-Serving Institution computer science departments. *Change*, 2022.
- [22] A. -M. Núñez, "Examining organizational behavior of Hispanic-Serving Institution computer science departments: Toward servingness and equity in the field.," *J. Women Minor. Sci. Eng.*, vol. 29, no. 2, pp. , 2023.
- [23] F. Hanleybrown, J. Kania and M. Kramer, "Channeling change: Making collective impact work," *Stanf. Soc. Innov. Rev.*, pp. 1-8, 2012.
- [24] E. Q. Villa, S. Hug, H. Thiry, D. S. Knight, E. F. Hall and A. Tirres, "Broadening Participation of Hispanics in Computing: The CAHSI Includes Alliance, 2019. In Annual Collaborative Network for Engineering and Computing (CoNECD) at the American Society for Engineering Education, Washington, DC. <https://www.asee.org/public/conferences/148/papers/24674/view>
- [25] S. Hug, and A. S. Jurow, "Learning together or going it alone: How community contexts shape the identity development of minority women in computing," *J. Women Minor. Sci. Eng.*, vol. 19, no. 4, pp. 273-292, 2013.
- [26] G. A. Garcia, "Decolonizing Hispanic-serving institutions: A framework for organizing," *J. Hispanic High. Educ.*, vol. 17, no. 2, pp. 132-147, 2018.
- [27] G. A. Garcia, A.-M. Núñez and V. A. Sansone, "Toward a multidimensional conceptual framework for understanding 'servingness' in Hispanic-serving institutions: A synthesis of the research," *Rev. Educ. Res.*, vol. 89 no. 5, 745-784, 2019.
- [28] C. M. Alcantar and E. Hernandez, "Here the professors are your guide, tus guías": Latina/o student validating experiences with faculty at a Hispanic-serving community college. *J. Hisp. High. Educ.*, 19(1), 3-18, 2020.
- [29] L. Hagedorn, Y. Chi, R. M. Cepeda and M. McLain, "An investigation of critical mass: The role of Latino representation in the success of urban community college students," *Res.High. Educ.*, 48(1), 73-91, 2007.
- [30] V. Torres, "A mixed method study testing data-model fit of a retention model for Latino/a students at urban universities," *J. Coll. Stud. Dev.*, vol. 47, no. 3, pp. 299-318, 2006.
- [31] P. Marin and P. Pereschica, "Becoming an Hispanic-serving research institution: Involving graduate students in organizational change," *Assoc. Mex. Am. Educ. J.*, vol. 11, no. 3, pp. 154-177, 2017.
- [32] M. Cuellar, "The impact of Hispanic-Serving Institutions (HSIs), emerging HSIs, and non-HSIs on Latina/o academic self-concept," *Rev. High. Ed.*, vol. 37 no. 4, pp. 499-530, 2014.
- [33] G. A. Garcia and A. Guzman-Alvarez, "Descriptive analysis of graduate enrollment trends at Hispanic-serving institutions: 2005-2015. *J. Hisp. High. Educ.*, vol. 20, no. 2, pp. 196-212, 2021.
- [34] R. Reddick, K. Griffin, R. Cherwitz, A. Cérda-Pražák and N. Bunch, "What you get when you give: How graduate students benefit from serving as mentors," *J. Fac. Dev.*, vol. 26, no. 1, pp. 37-49, 2012.
- [35] E. Dolan and D. Johnson, "Toward a holistic view of undergraduate research experiences: An exploratory study of impact on graduate/postdoctoral mentors," *J. Sci. Educ. Technol.*, 18, pp. 487-500, 2009.

- [36] National Center for Education Statistics. "Characteristics of Postsecondary Faculty," *Condition of Education*, 2022.
- [37] S. Zweben and B. Bizot, "Taulbee Survey: CS Enrollment Grows at All Degree Levels With Increased Gender Diversity," *Computing Research News*, pp. 1-82, 2021.
- [38] F. Contreras, "Latino faculty in Hispanic-Serving Institutions: Where is the diversity?," *Assoc. Mex. Am. Educ. J.*, vol. 11, no. 3, pp. 223-250, 2017.
- [39] L. D. Gonzales, "The horizon of possibilities: How faculty in Hispanic-serving institutions can reshape the production and legitimization of knowledge within academia." In *Hispanic-Serving Institutions*, pp. 121-135, Routledge, 2015.
- [40] UnidosUS, "Latinos in higher education: Enrollment and completion," March, 2019.
- [41] A. -M. Nuñez, "A critical paradox? Predictors of Latino students' sense of belonging in college," *J. Divers. High. Educ.*, vol. 2, no. 1, pp. 46-61, 2009.
- [42] A. -M. Nuñez, R. E. Hoover, K. Pickett, A. C. Stuart-Carruthers and M. Vázquez, *Latinos in higher education and Hispanic-serving institutions: Creating conditions for success*. Wiley/Jossey-Bass, 2013.
- [43] S. L. Rodriguez and K. Lehman, "Developing the next generation of diverse computer scientists: the need for enhanced, intersectional computing identity theory. *Comput. Sci. Educ.*, vol. 27, no. 3-4, pp. 229-247, 2018.
- [44] R. E. Gildersleeve, N. N. Croom and P. L. Vasquez, "Am I going crazy?!!: A critical race analysis of doctoral education," *Equity Excell. Educ.*, vol. 44, no. 1, pp. 93-114, 2011.
- [45] S. K. Gardner, "The challenges of first-generation doctoral students," *New Dir. Teach. Learn.*, vol. 2013, no. 163, pp. 43-54, 2013.
- [46] T. Pumacahua and M. R. Rogers, "Academic warriors: Community cultural wealth among Latinx and Black STEM doctoral students at predominately White institutions. *J. Lat. Educ.*, pp.1-15, 2022.
- [47] E. O. McGee, "Devalued Black and Latino racial identities: A by-product of STEM college culture?," *Am. Educ. Res. J.*, vol. 53, no. 6, pp. 1626-1662, 2016.
- [48] P. Morreale, E. Villa and A. Gates, "Expanding the pipeline – CAHSI introduces national virtual research experience for undergraduates," *Computing Research Association (CRA) News*, 32(9), 2020.
- [49] A. Martinez, "Pathways to the professoriate: The experiences of first-generation Latino undergraduate students at Hispanic serving institutions applying to doctoral programs" *Educ. Sci.*, vol. 8, no. 1, pp. 1-14, 2018.
- [50] J. D. Burge and N. M. Amato, "CREU & DREU: Expanding the Impact of the Traditional REU," *ACM Inroads*, vol. 7, no. 4, pp. 81-83, 2016.
- [51] U.S. Census Bureau (2023). Educational attainment in the United States: 2022.
- [52] M. Martinez and E. Fernández, "Latinos at community colleges," *New Dir. Stud. Serv.*, vol. 2004, no. 105, pp. 51-62, 2004.
- [53] S. Hurtado and D. F. Carter, "Effects of College Transition and Perceptions of the Campus Racial Climate on Latino College Students' Sense of Belonging," *Sociol. Educ.*, vol. 70, no. 4, pp. 324-345, 1997.
- [54] A. M. Locks, S. Hurtado, N. A. Bowman and L. Oseguera, "Extending notions of campus climate and diversity to students' transition to college," *Rev High Ed*, vol. 31, no. 3, pp. 257-285, 2008.
- [55] E. M. Bensimon, A. C. Dowd, R. Stanton-Salazar and B. A. Dávila, "The role of institutional agents in providing institutional support to Latinx students in STEM," *Rev High Ed*, vol. 42, no. 4, pp. 1689-1721, 2019.
- [56] E. J. López, V. Basile, M. Landa-Posas, K. Ortega and A. Ramírez, "Latinx students' sense of familismo in undergraduate science and engineering," *Rev High Ed*, vol. 43, no. 1, pp. 85-111, 2019.
- [57] S. D. Museus, R. T. Palmer, R. J. Davis and D. C. Maramba, "Racial and ethnic minority students' success in STEM education." *ASHE higher education report*, vol. 36, no. 6, pp. 1-140, 2011.
- [58] National Academies of Sciences, Engineering, and Medicine. "Undergraduate research experiences for STEM students: Successes, challenges, and opportunities," 2017.
- [59] A. Carpi, D. M. Ronan, H. M. Falconer and N. H. Lents, "Cultivating minority scientists: Undergraduate research increases self-efficacy and career ambitions for underrepresented students in STEM," *J. Res. Sci. Teach.*, vol. 54, no. 2, pp. 169-194, 2017.
- [60] M. Estrada, P. R. Hernandez and P. W. Schultz, "A longitudinal study of how quality mentorship and research experience integrate underrepresented minorities into STEM careers." *CBE Life Sci. Educ.*, vol. 17, no. 1, ar9, 2018.
- [61] A. Nyame-Mensah, N. B. Tamer, and J. G. Stout, "Understanding how summer research experiences can foster diversity in computing research," In 2015 Research in Equity and Sustained Participation in Engineering, Computing, and Technology (RESPECT) (pp. 1-7). IEEE, 2015.
- [62] A. S. Rorrer, J. Allen and H. Zuo, "A national study of undergraduate research experiences in computing: Implications for culturally relevant pedagogy, " In Proceedings of the 49th ACM Technical Symposium on Computer Science Education, pp. 604-609, Feb, 2018.
- [63] J. Rivera, *Rewriting the Code to Success: Examining the Experiences of Latinx Students in Computer Science at Hispanic-Serving Institutions*. The Ohio State University, 2021.
- [64] E. Q. Villa, K. Kephart, A. Q. Gates, H. Thiry and S. Hug, "Affinity research groups in practice: Apprenticing students in research. *J. Eng. Educ.*, vol. 102, no. 3, pp. 444-466, 2013.
- [65] S. Hug, vREU Survey Results Summer/Fall 2020: Evaluation Report, Correspondence, Colorado Evaluation and Research Consulting, 2021
- [66] P. Morreale, E. Villa, A. Gates, S. Hug, "Faculty Development for Research Inclusion: Virtual Research Experiences for Undergraduates", Proceedings of the 2021 ASEE Annual Conference and Exposition (ASEE '21), virtual, 2021. <https://peer.asee.org/37179>
- [67] M. Quider and G. C. Blazey, "How to keep emerging research institutions from slipping through the cracks. *Issues Sci. Technol.* pp. 50-53, 2023.
- [68] S. Blake-Beard, M. L. Bayne, F. J. Crosby and C. B. Muller, "Matching by race and gender in mentoring relationships: Keeping our eyes on the prize," *J. Soc. Issues*, vol. 67, no. 3, pp. 622-643, 2011.
- [69] D. Horton and I. Torres-Catanach, "Critical Incidents for Hispanic Students on the Path to the STEM Doctorate.," *Front. Psychol.*, 13, 2022.
- [70] G. C. Fleming, A. D. Patrick, D. Grote, M. Denton, D. Knight, W. Lee, ... and H. Murzi, "The fallacy of "there are no candidates": Institutional pathways of Black/African American and Hispanic/Latino doctorate earners," *J. Eng. Educ.*, vol. 112, no. 1, pp. 170-194, 2023.
- [71] J. Clear, *Atomic habits: An easy & proven way to build good habits & break bad ones*. Penguin, 2018.
- [72] S. Hurtado, D. White-Lewis and K. Norris, "Advancing inclusive science and systemic change: the convergence of national aims and institutional goals in implementing and assessing biomedical science training." In BMC proceedings, vol. 11, no. 12, pp. 1-13). BioMed Central, December 2017.