Building Bridges into Engineering and Computer Science: Outcomes, Impacts and Lessons Learned

Espiritu, D, Todorovic, R, O'connell, B
Center of Excellence for Engineering and Computer Science
Wilbur Wright College, One of the City Colleges of Chicago
Chicago, Il, 60634

ABSTRACT

Wright College, an urban open-access community college, independently accredited within a larger community college system, is a federally recognized Hispanic-Serving Institution (HSI) with the largest community college enrollment of Hispanic students in its state. In 2018, Wright College received an inaugural National Science Foundation-Hispanic Serving Institution (NSF:HSI) research project grant "Building Capacity: Building Bridges into Engineering and Computer Science".

The project's overall goals are to increase underrepresented students pursuing an associate degree (AES) in engineering and computer science and streamline two transitions: high school to community college and 2-year to 4-year institutions. Through the grant, Wright College created a holistic and programmatic framework that examines and correlates engineering students' self-efficacy (the belief that students will succeed as engineers) and a sense of belonging with student success. The project focuses on Near-STEM ready students (students who need up to four semesters of math remediation before moving into Calculus 1). The project assesses qualitative and quantitative outcomes through surveys and case study interviews supplemented with retention, persistence, transfer, associate and bachelor's degree completion rates, and time for degree completion. The key research approach is to correlate student success data with self-efficacy and belonging measures.

Outcomes and Impacts

Three years into the project, Wright College Engineering and Computer Science Program was able to:

- Develop and implement the Contextualized Summer Bridge with a total of 132 Near-STEM participants. One hundred twenty-seven (127) completed; 100% who completed the Bridge eliminated up to two years of math remediation, and 54% were directly placed in Calculus 1. All successful participants were placed in different engineering pathways, and 11 students completed Associate in Engineering Science (AES) and transferred after two years from the Bridge.
- Increase enrollment by 940% (25 to 235 students)
- Retain 93% of first-year students (Fall to fall retention). Seventy-five percent (75%) transferred after two years from initial enrollment.
- Develop a holistic and programmatic approach for transfer model, thus increasing partnerships with 4-year transfer institutions resulting in the expansion of guaranteed/dual admissions programs with scholarships, paid research experience, dual advising, and students transferring as juniors.
- Increase diversity at Wright College by bridging the academic gap for Near-STEM ready students.
- Increase self-efficacy and belonging among all Program participants.
- Increase institutionalized collaborations responsible for Wright College's new designation as the Center of Excellence for Engineering and Computer Science.
- Increase enrollment, retention, and transfer of Hispanic students instrumental for Wright College Seal of Excelencia recognition.

Lessons Learned

The framework established during the first year of the grant overwhelmingly increased belonging and self-efficacy correlated with robust outcomes. However, the COVID-19 pandemic provided new

challenges and opportunities in the second and third years of the grant. While adaptations were made to compensate for the negative impact of the pandemic, the face-to-face interactions were critical to support students' entry into pathways and persistence within the Program.

1. INTRODUCTION

Several factors have been identified to contribute to the uneven pursuit and completion of engineering and computer science degrees based on race and ethnicity: (a) the lack of exposure to engineering or computer science as fields of study or as career opportunities [1], (b) the lack of professional identity (inability to see oneself as a professional) [2], (c) an impaired sense of belonging [3, 4], and (d) the lack of self-efficacy (how well one can execute a course of action to deal with a prospective situation) [5]. The demands of an engineering and computer science curriculum contribute to high dropout rates [6], even higher for underrepresented students [3, 7, 8]. Early failure in math and science courses pose a barrier to persisting in these fields [9]. Compounding these challenges, when engineering and computer science students begin their higher education at a community college, they take longer to complete their degree, and are less likely to graduate [10].

Research has shown how retention of and completion for underrepresented minorities in engineering and computer science can be increased by (a) improving math proficiency through summer bridges, (b) providing extensive faculty mentoring, (c) research experiences, and (d) student support designed to break down barriers to inclusiveness, and (e) fostering a local Community of Practice (CoP) [11-16]. To enable a CoP, programmatic frameworks such as one-stop intentional advising; tutoring; near-peer, faculty, and professional mentoring; and access to professional organizations can all play a role.

1.1. Wilbur Wright College

Wright College, an urban open-access community college, independently accredited within a larger City Colleges of Chicago community college system, is a federally recognized Hispanic-Serving Institution (HSI) with the largest community college enrollment of Hispanic students in its state. In 2015, Wright College piloted Engineering Pathways (EP), a selective guaranteed admission program to one of the top engineering schools in the country. The Engineering Pathways Program is a 2+2 cohort model with prescriptive and rigorous curriculum aligned to the transfer institution. Wilbur Wright College built programmatic frameworks to support the EP students (Figure 1). In 2018, Wright College received an inaugural National Science Foundation-Hispanic Serving Institution (NSF-HSI) research project grant for "Building Capacity: Building Bridges into Engineering and Computer Science". The project's overall goals are to increase underrepresented students pursuing an associate degree (AES) in engineering and computer science, and to streamline two transitions: high school to community college and 2-year to 4-year institutions.

Wright College hypothesizes that the lack of professional identity and preparation are two of the contributing factors for why underrepresented students are not completing engineering and computer science degrees at equitable rates [17-19]. Through the grant, Wright College created holistic and programmatic frameworks to examine and correlate engineering and computer science students' self-efficacy (the belief that students will succeed as engineers), and a sense of belonging with student success. The project assesses qualitative and quantitative outcomes through surveys and case study interviews supplemented with retention; persistence; transfer; associate and bachelor's degree completion rates; and time for degree completion. This paper highlights the methods developed in the first three years of the project, adaptations due to COVID-19, results from the first year, and lessons learned.

1.2. The NSF:HSI Grant Structure

NSF:HSI grant "Building Bridges into Engineering and Computer Science" initially (first year of implementation) recruited only STEM-ready (Calculus 1 ready) and Near-STEM ready (non-Calculus ready) students from high schools into the Program. Subsequently, the project begun admitting post-traditional (adult education, veterans, transfers from another institution) students into the Program. Near-STEM ready students were admitted to the Contextualized Summer Bridge while STEM-ready students were directly placed into multiple structured engineering pathways (cohorts). It is integral to address multiple challenges found throughout the community college student's life cycle, from the Bridge, into multiple structured pathways, socialization activities, mentoring, networking, and leadership opportunities. Wright College, through the "Building Bridges into Engineering and Computer Science" project, has developed the holistic and programmatic approach that supports underprepared students to succeed in a demanding engineering curriculum, including beyond the associate degree (Figure 1) [20, 21]. Cohorts consist of engineering and computer science students both in guaranteed admission transfer pathways, as well as pursuing other transfer institutions. Guaranteed admission transfer pathways are based on well-thought-out articulation agreements, facilitating successful transfer by completely aligning Wright's curriculum to that of 4-year institutions. It provides students with an ideal preparation, decreases financial obligations, and allows students to transfer as rising juniors while obtaining an associate degree.

In addition, Wright College offers work opportunities and memberships in professional societies to provide students with different avenues for developing leadership skills and a sense of belonging in the profession. Such activities are reported to enhance levels of engagement among students [22, 23]. Integral to all project's activities is a development of participants' sense of belonging within the Program, college and profession, which has shown to ultimately translate to a sense of belonging to the more global CoP. Similarly, as one of the main components of the project, these activities increase participants' self-efficacy.

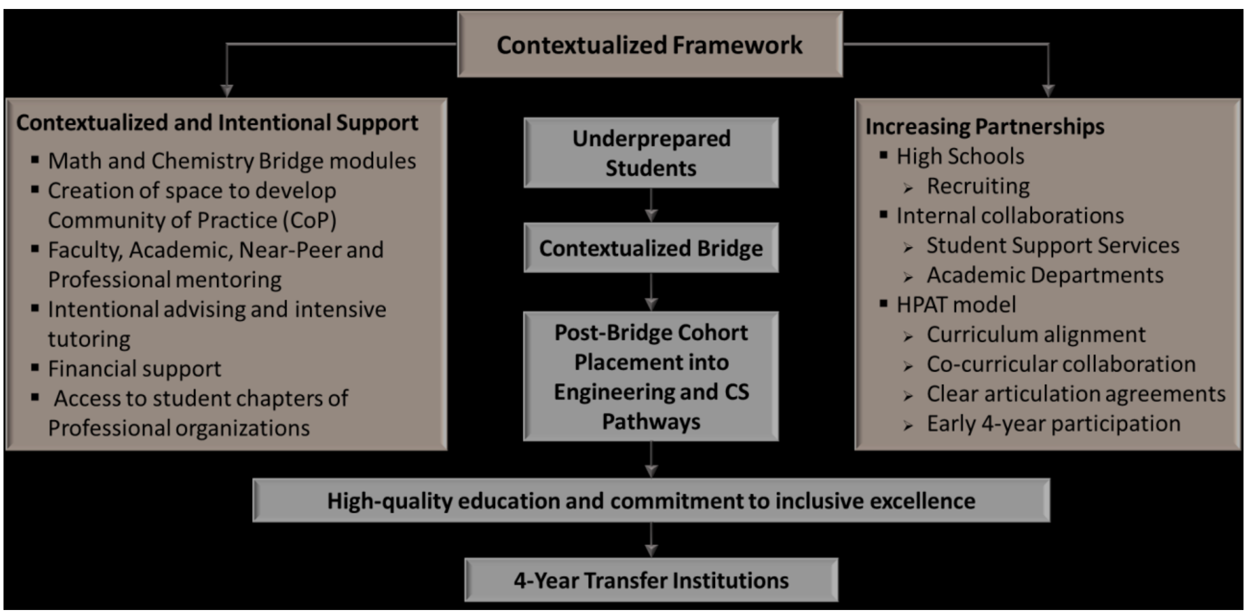


Figure 1. Programmatic frameworks for Engineering and Computer Science Program at Wright College

2. METHODS

With support of the NSF:HSI grant, Wright College explored barriers and developed a programmatic framework (Figure 1) to support underrepresented students. Among others, known practices such as the Bridge, Guided Pathways, tutoring, advising and mentoring were contextualized and improved to provide a more holistic and programmatic approach to supporting students. Transfer institutions were engaged early on into a Holistic and Programmatic Approach for Transfer (HPAT) [21]. These practices were contextualized based on students' needs for increased belonging and self-efficacy. In the first year of the project, prior to COVID-19 pandemic, all activities were done in-person. The Program pivoted to remote in year 2 and 3 (during the pandemic). All interventions are currently offered in hybrid modality (remote and in-person).

2.1. The Contextualized Summer Bridge

The contextualized Bridge approach was first described by Espiritu et.al. [20]. Due to the limitation of seats, priorities for admission were given to Near-STEM ready students interested in engineering or computer science. The Bridge was originally developed for face-to-face delivery, incorporating, and evaluating activities believed to develop belonging and CoP. The first implementation of the Bridge was in-person, while the second and the third Bridge iterations were done remotely.

2.2. Recruitment and Enrollment

To support recruiting efforts, the Program created relationships with local high school counselors, teachers, and leaders. Utilizing co-branding with partner institutions, staff visited and hosted high school students, informing them about the Program and application process. Within Wright College, introductions were made to students attending STEM courses, who either had not learned about the Engineering and Computer Science Program prior to enrolling, or chose not to initially join the Program.

2.3. Robust Support and Retention Efforts

The HPAT model [21] incorporates practices that eliminates barriers to student success.

1. ***Cohort Model:*** *S*tudents are intentionally grouped with carefully chosen faculty who champion the Program efforts.
2. ***Intentional Advising*** is integral to student's overall development. Student's curriculum is personalized according to their field of interest; transfer institution; and student's academic preparation, financial, cultural, social, and professional aspects.
3. ***Intensive Tutoring:*** Students have access to tutors dedicated to cohorts, and are required to attend intensive tutoring throughout their participation in the Program. Talented students are trained to assist their peers in math, chemistry, physics, and computer science courses, while promoting independent learning and self-reliance.
4. ***Near-peer mentoring*** addresses students' overall well-being including social identities, providing crucial support especially for underrepresented students who face uncertainty about belonging in a group. [24] Developing the mentor-mentee relationship before transferring is expected to minimize, if not eliminate, the difficulties students face acquiring a sense of community at the transfer institution. Mentors and mentees follow a structure, submitting a mentor plan and outcomes. A near-peer mentoring model was developed wherein second year students mentored first-year students, and recent transfer students mentored second year students, typically of the same major. Ongoing research is being conducted to determine the most effective way to match mentors and mentees.
5. ***Leaderships Opportunities:*** Since the start of the grant, four (4) new chapters of national engineering organizations have been founded. Currently, Engineering and Computer Science students at Wright College comprise most of the officers and active members of seven organizations: Society of Hispanic Professional Engineers (SHPE), American Chemical Society (ACS), Society of Women Engineers (SWE), Society for Asian Scientists and Engineers (SASE), Association of Computing Machinery (ACM), National Society of Black Engineers (NSBE), and American Society of Mechanical Engineers (ASME). These chapters provide students an

opportunity to develop CoP, build leadership skills, gain access to mentors and employers, and win awards at the national level.

6. ***First Year Experience:*** An Engineering Success Seminar course was developed during the first year of the grant. The course involves three dimensions (orientation of engineering professions, professional development, and college success) designed to develop professional-identity and self-efficacy. The course is now offered across the City Colleges of Chicago system.
7. ***Financial Incentives:*** Students are offered financial incentives for their participation in many of the Program's practices. Students supporting tutoring, mentoring, recruiting, and the Bridge receive a stipend. Future guaranteed scholarships are offered to students, depending on their successful transfer to certain institutions. Additionally, some students have received financial incentives for participation in engineering and computer science organizations.

2.4. Developing Community of Practice (CoP) – Engineering Center

The Engineering and Computer Science Program acquired dedicated space on Wright College campus (The Engineering Center) for tutoring, group study and social interaction. The Engineering Center is a physical space for students with shared domain of interest, with a purpose of creating a community of future engineers and computer scientists. Students interact and engage in shared activities, help each other, share information with each other, and build relationships that enable them to learn from each other. They develop a shared repertoire of resources which can include helpful tools, experiences, stories, ways of handling typical problems, among others. During the COVID-19 pandemic, a "Virtual Engineering Center" was made available with office hours hosted by the Program staff.

2.5. Belonging and Self-Efficacy

"Belongingness" within Lave and Wenger's Communities of Practice and Bandura's self-efficacy [25-27] concepts were used to explore the success of the Program. Appreciative Inquiry method [28] is used for case-study interviews, as a strengths-based interviewing protocol that helps students accept educational responsibility. Participants' feedback is utilized to continuously improve the practices. A belonging and self-efficacy survey was enhanced by using "retrospective survey" during the COVID-19 pandemic. With IRB approval, the standard survey was adjusted to include the General Self-Efficacy Scale (NGSE) [29], and administered at the end of each semester during the fully remote instruction era. It captured students' immediate needs, and offered feedback about their financial security, self-efficacy, self-related competencies, and sense of belonging related to CoP. Subsequently, additional sections were added containing Retrospective Pre-Test (RPT) questions. A "Self-efficacy and Professional Identity" survey was administered to all participants who completed the Contextualized Summer Bridge, before Bridge and at the end of their first Fall semester. Additionally, all students who held a professional development position (tutors, mentors, ambassadors and research assistants) were required to take the survey at the beginning and end of each semester.

2.6. Quantitative and Qualitative Assessment

The key performance indicators commonly used to quantitatively assess the transfer pathways include retention rate at all levels, associate and bachelor's graduation, and transfer rate. In addition to these common indicators, the project reviews admission data (high school GPA, Math and English placement, and student demographics), transfer GPA, time to degree completion, and graduation rate for determining longitudinal outcomes. These metrics provide a relatively simple, and comprehensive, set of leading indicators of success that can be measured for each cohort and compared year-to-year. The project assessment is done in collaboration with an external evaluator. For students admitted to the Bridge, math proficiency was captured before and after Bridge participation. Results will be correlated with the ongoing collection of qualitative and quantitative data from surveys and case study interviews. Data on transfer, rates of associate and bachelor's degree completion, and time to degree completion will also be correlated with the survey and case study results for longitudinal study.

3. OUTCOMES

Three years into the NSF:HSI grant "Building Bridges into Engineering and Computer Science", the Program has developed frameworks that increase enrollment, retention, transfer, belonging, self-efficacy as well as decrease time to degree completion. The most important outcomes are the development and implementation of Contextualized Summer Bridge and the Holistic and Programmatic Approach for Transfer (HPAT) [20, 21]. Combined, these frameworks show robust outcomes. The Program is continuously improving through development, implementation, assessment, and piloting of other high impact educational practices. This paper summarizes current high-level outcomes and impacts of the project, and an overview of self-efficacy and belonging research and outcomes. Details on the initial Program development have been published [20, 21, 30] and longitudinal research on the first four years of the Program is forthcoming.

3.1. Enrollment and Retention

Since the initiation of the project, Engineering and Computer Science Program enrollment has been on a continuous rise. The Program has grown from 25 to 235 students, a 940% increase in enrollment (Table 1). It retained 93% of first-year students based on the Fall-to-Fall data. The initial cohort transferred seventy-five percent (75%) of its students in only two years from initial enrollment. Supporting the goals of the project, in addition to an increase in enrollment, representation of traditionally underrepresented minorities has increased as well. This has directly benefited an increased enrollment, retention, and transfer of Hispanic students, which was instrumental for Wright College's Seal of Excelencia recognition [31]. By bridging the academic gap, and streamlining high school to college transition, Near-STEM ready students are successfully navigating the challenging engineering curriculum. The project increased diversity in engineering and computer science at Wright college through diverse Bridge population and their subsequent success (Figure 2).

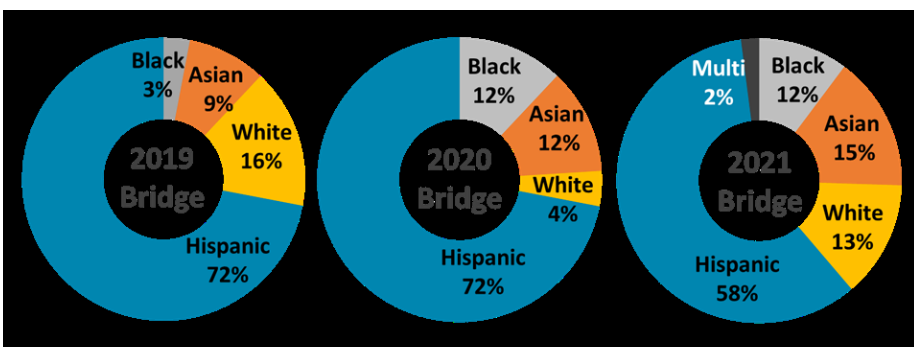


Figure 2. Contextualized Summer Bridge participants demographics

Since the start of the NSF:HSI funded research project, Wright College developed and implemented three iterations of the Contextualized Summer Bridges with a total of 132 near-STEM ready participants. One hundred twenty-seven (127) participants completed the Bridge. All participants (100%) who completed the Bridge eliminated up to two years of math remediation, and 54% were directly placed in Calculus 1. All successful participants were placed in appropriate engineering and computer science pathways. The most significant result of first year Bridge is that the eleven (11) students who completely eliminated remediation earned As and Bs in Calculus 1, successfully completed AES degree, transferred after two years from the Bridge, and are thriving at their transfer institutions. First year results also indicated a need to further develop support for students who showed improvement but, after Bridge were still placed in remedial math, as only five (5) out of these ten (10) participants were retained (50% Fall-to-Fall retention). It is also important to note a less reported outcome of the Bridge participants: five (5) out of 132 students changed their academic and career goals to a non-engineering or computer science discipline. One of the requirements for Bridge admission is the initial interest in engineering or computer science. The Bridge not only prepared students in math but also provided information about these careers. This intentional recruiting and enrollment approach, as well as design of the Bridge content, can be a significant contribution to students' success, even if they choose another discipline. Since the students who changed their goals did so prior to starting college credit courses, they had the opportunity to spend less time toward their degree due to a more appropriately curriculum alignment than if they had made that realization later.

		Pre-NSF	NSF		
		Fall 2018	Fall 2019	Fall 2020	Fall 2021
Total Program Enrollment		25	79	156	235
Contextualized Bridge	Enrollment	---	32	50	53
	Completion	---	31	46	50

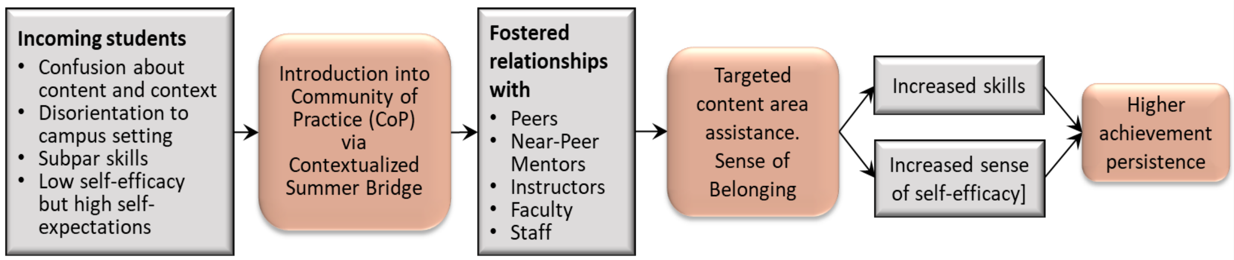
Table 1. Program Enrollment. The NSF:HSI Building Bridges into Engineering and Computer Science project is instrumental for Wilbur Wright College Engineering Program enrollment growth.

A positive impact of participation in the Contextualized Summer Bridge was observed whether the Program was held face-to-face with the social interaction component, or held remotely. However, the number of Bridge participants who completely eliminated remedial math was significantly higher when the Bridge was held in person (55%) as compared when the course was held remotely (29%). Interestingly, the low Bridge success rate during the first year of virtual modality (onset of COVID-19 pandemic), was remedied back to 54% through face-to-face exit conversation and continuous one-on-one virtual support. This was not observed during the second iteration of virtual Contextualized Summer Bridge (third overall Bridge iteration). More students who participated in the third iteration of the Bridge, two years through pandemic were less engaged and opted out of face-to-face exit conversations. The researchers are currently collecting more data about the longitudinal impact of pandemic on student engagement and will be reported separately.

3.2. Increased Self-Efficacy, Community of Practice (CoP), and Belonging Among Program Participants

Due to the complexity and variability of modalities for implementation, and the socio-economic impact of the pandemic on Bridge participants, only the first iteration of the Contextualized Summer Bridge was included in current analysis. More data will be gathered to understand the impact of COVID-19 pandemic and the need for additional intentional interventions.

The Contextualized Bridge and the HPAT model were designed to increase self-efficacy for Near-STEM-ready students by minimizing financial barriers and incorporating practices that make participants feel they belong in the college and in the profession. The first iteration of the Contextualized Summer Bridge combined with the HPAT model show strong correlations among increased self-efficacy, belonging and higher achievement. Quantitative survey outcomes show an increase in self-efficacy and belonging for all students in the first Bridge (results not shown), and a qualitative model was generated based on the survey and case study interview narratives (Student narrative-generated model), Figure 3.



Incoming students with subpar skills are confused and disoriented in campus settings. Although students expressed high expectations, they experienced low self-efficacy. Introduction to Community of Practice through the Contextualized Summer Bridge fostered relationships with peers, mentors, faculty and staff that developed a sense of belonging to college and to the profession. The academic preparation increases students' math skills and develops self-efficacy which is correlated to elimination of remedial Math and subsequent success in Calculus 1 and beyond.

Figure 3. Student narrative-generated model

3.3. First Year Case Studies and Survey Results

While the Appreciative Inquiry approach is a strengths-based query that explores students' best experiences, the evaluators did not overlook the "weaknesses". Participants were asked to share their thoughts on changes, additions or subtraction to the Program, based on their personal narratives. For a more meaningful assessment of professional identity, the Brinkerhoff Success Case Method [32] was utilized to randomly select interview participants during their time in the Program and upon exit from the community college. The researchers explored roles of supportive community, belonging, and knowing self that fostered personal transformation with formal learning that last outside the classroom.

For the first Engineering Cohort, thirteen (13) case study interviews were done using an Appreciative Inquiry approach. Eighty-three percent (10 of 12, 83%) of the Bridge participant case study interviewees self-identified as under-represented individuals in at least one area: Ethnic identity, or Gender identity (females and non-binary/LGBTQ+). For example, based on first year case study interviews, and subsequent research on predictors of STEM persistence [33], in year two, chemistry preparation was added to the Bridge curriculum. Hearing students' voices and implementing students' suggestions in continuous improvement of the Program is essential to increasing students' sense of belonging to the college. A very important outcome of the project is the transformation of student perception of self which is attributed to their positive experience. In one particular example, a case study participant altered negative perspectives about education that has harmed them since childhood. Anchored from their unique positive face-to-face experiences; they changed their perspectives, transformed approaches, and adapted to remote interactions.

3.4. Overall Observations and Correlation with Quantitative Results

A strong correlation between the qualitative and quantitative assessment for first year cohort was observed. Students were actively engaged; leading Wright College chapters of national organizations, study groups, engineering tutoring sessions; and eight (8) participants were Engineering ambassadors actively involved in advocating for the Bridge. Table 2 summarizes overall findings of the first-year case study interviews and surveys and Figure 3 is a model generated based on the findings.

Table 2. First year case studies and surveys - Overall summary

Participants' "origin stories" about how they came to Wright's Contextualized Summer Bridge indicate that personal connections to faculty and/or other students are important.
Incidences of self-efficacy growth and Community of Practice (CoP) belongingness emerge organically from participants' narratives about the highlights of their experiences.
Participants value the Contextualized Summer Bridge, which allows them to be better able to calibrate their abilities within a fixed norm (ALEKS test) so that they have a better sense of their ability to succeed more widely.
The Contextualized Summer Bridge cohort becomes a close-knit, inclusive CoP in which all participants recognize personal strengths and next steps that work synergistically with the strengths and next steps of other participants.
Surrounding faculty and staff successfully foster this functional and supportive CoP.

4. IMPACTS

4.1 Practices Implemented as a Result of Continuous Improvement

The project develops, implements, and assesses frameworks for continuous improvement. The HPAT model was developed as an outcome of the project's first year implementation, while the sudden pivot to remote learning provided more opportunities to develop and implement high impact practices. These practices as well as additional opportunities were piloted in Year-3 of the project.

4.1.1. Research Opportunities

The NSF:HSI Building Bridges into Engineering and Computer Science is a research grant. This is an opportunity to engage participants to learn STEM education research and assess the impact of student research participation on belonging and self-efficacy. Six (6) sophomores (Bridge participants) joined the initial research group in Fall 2020. Two (2) participants published and presented their project in 2021 ASEE Virtual Conference [34]. In Fall 2021, the research opportunities were expanded to include freshman Bridge participants as Junior Research Assistants. Students work alongside the Principal Investigator and sophomores (Research Assistants), identifying research topics, learning the research process, contributing to published research and presenting at local as well as national forums.

4.1.2. External Partnerships and Professional Development

Starting in Year-2 of the grant, Wright College fostered relationships with additional engineering and computer science organizations. It facilitated an "Employer Showcase" and an "Engineering Internship Fair" virtually. Through the Engineering Success course, professional development opportunities, collaborations with industry partners, and individual coaching, Wright College facilitated hiring of community college students for industry internships and research programs following the completion of their freshman and sophomore years. Twenty-three students (23) were offered these opportunities in second and third year of the project. The Program also engaged industry and academic organizations, locally and nationally, to create professional development opportunities which aligned with the goal of the project.

4.2. Institutional and Broader Impacts

The Contextualized Bridge and the HPAT model are now extensively implemented at Wright College. The HPAT model is also adopted by Wright's transfer institution partners. The outcomes of the NSF:HSI project are recognized by the 50K Coalition and its partner institutions. Due to the frameworks developed by the grant, Wright College was designated as the City Colleges of Chicago's Center of Excellence for Engineering and Computer Science in Spring of 2020, and was recognized by Insights in Diversity Magazine as one of the 2021 STEM Inspiring Programs. The Contextualized Summer Bridge framework prepares near-STEM ready students (especially Latinx students) to succeed. The frameworks developed by the project including the activities of the Society of Hispanic Professional Engineers (SHPE) contributed to Wright College Seal of Excelencia designation.

5. LESSONS LEARNED

The framework established during the first year of the grant overwhelmingly increased belonging and self-efficacy correlated with robust outcomes. However, the COVID-19 pandemic provided new challenges and opportunities during second and third year of the grant. While adaptations were made to compensate for the negative impact of the pandemic, the face-to-face interactions were critical to support students' entry into pathways and persistence within the Program. Understanding barriers (socio-economic, emotional, financial and cultural) will continue to be considered, further creating practices and interventions. Appreciative Inquiry and data-driven approach to continuously improve enabled and will enable program development for broader impacts.

6. FUTURE WORK

Some of the practices implemented out of necessity due to the COVID-19 pandemic will be adopted as future research methods. The fourth year of the bridge will be offered in a hybrid format, allowing participants to choose their modality. This will further enable the study and compare remote versus in-person learning for the Bridge. Longitudinal analysis will be conducted based on five years of data obtained during the NSF-HSI grant, assessing students that complete their bachelor's degree four years after the Bridge and two years after transferring. Belonging and Self-efficacy survey data especially during the pandemic will be carefully analyzed and correlated with students' performance longitudinally. Practices that generated results will be expanded and disseminated for replication.

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