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Equity and Retention: Strategies to Increase Engineering Enrollment, Retention, and Success of Underprepared Students

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INTRODUCTION

For the US to increase diversity in engineering, Community Colleges (CC) are positioned to play a crucial and substantial role. Nationally for the Fall 2015 cohort, the overall transfer rate from Community Colleges to baccalaureate institutions is only 31.6% and a mere 15.5% of all students who start at a Community Colleges complete a bachelor's degree within six years.[1] The demographic profile of Community Colleges reveals a large percent of underrepresented minorities are enrolled (40%, 50%, and 53% of Black, Hispanic, and Native American students, respectively) [2]. With current CC demographics and student remediation needs [3], CCs must develop a strategy to increase engineering enrollment, retention, and transfer, for the diversity in the engineering profession to increase.

Moreover, since most CC students require math remediation, this poses additional challenges to engineering enrollment. [3] First-time college students taking remedial mathematics are less likely to complete an engineering degree at a 4-year institution, or even pursue the discipline in the first place. [3] Much of the engineering transfer research since the 2000s is focused on the 4-year receiving institutions, rather than on initial CC enrollment, retention, and preparing minorities for successful transfer and engineering degree completion. Summer Bridge Programs are increasingly common for addressing students' academic readiness regardless of discipline, to support the high school to college transition and establish belonging. Much of the research on the topic is from PhD granting institutions with limited and conflicting data on retention correlated with participation in these programs. [4-11] One decade-old study on a community college summer bridge program found improved retention for STEM students. [12] As such, further and more current research is needed to determine how this type of intervention can improve retention, transfer, and graduation for underrepresented minority students.

Attaining academic equity in engineering and computer science through contextualized strategies and intentional support can decrease remediation and increase retention of underprepared and underrepresented students. [13-16] To test this hypothesis, Wright College, an urban open-access Community College and a federally recognized Hispanic-Serving Institution (HSI), created frameworks through the National Science Foundation (NSF) funded research streamlining two transitions: 1) High School to CCs and 2) CCs to 4-year transfer institutions. [14] Subsequently, the program has expanded to include current Wright College degree seeking students, Wright College Adult Education students (English language and GED), and reverse transfer students (students who started at other colleges and universities and transferred to Wright College) (Figure 1). Curriculum and support structures were created to incorporate college and engineering readiness through contextualized Summer Bridge Program, programmatic transfer agreements, dual advising, holistic support, and Community of Practice (CoP). Methods focus on students who are STEM and Near-STEM ready (prior to calculus) pursuing a degree in engineering or computer science. Students' progress is monitored during their time at Wright College, after they transfer to a 4-year institution, and when available, after bachelor's degree completion.

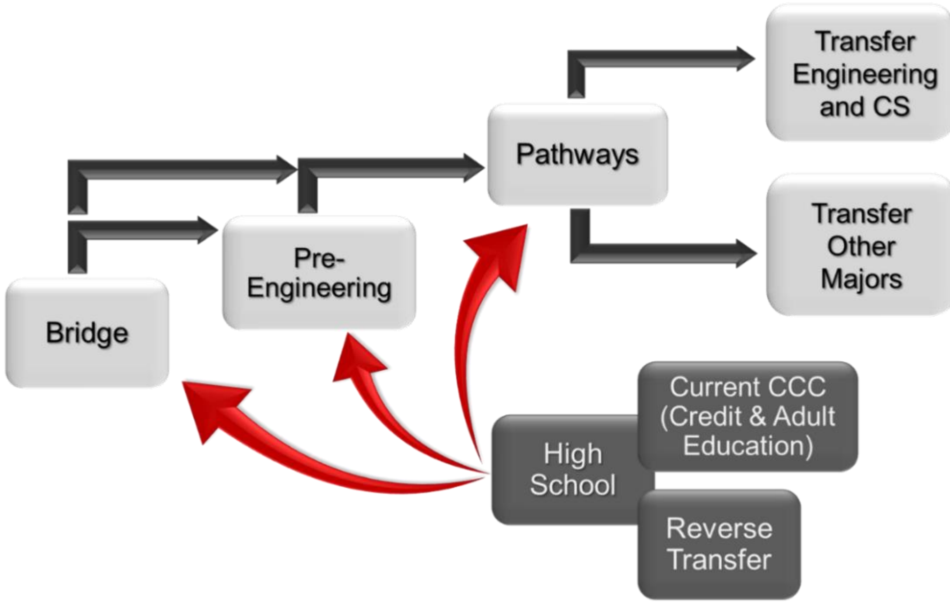

Figure 1. Diagram of Wright's Engineering and Computer Science pathways entry and exit points

To promote equity and retention, Wright College created contextualized approach strategies which are continuously improved based on qualitative and quantitative data, and the Appreciate Inquiry based case study interviews. Frameworks and methods developed to support this approach have been introduced by Espiritu et.al. [15, 16]. In addition, recognizing that each student has a different academic background and needs, authors introduced the HPAT model that assesses these needs and designs an individualized pathway for each student. [15] It presents a strategic plan emphasizing the importance of early identification of the major aligned to student's initial interest with flexibility for modification within specified length of time; the alignment of the curriculum and its contents between CCs and transfer institutions; and methods to eliminate curricular barrier ensuring seamless junior standing after transfer by identifying gaps in alignment [15]. In this publication, authors analyze the efforts to streamline the transition from high school to CCs through Contextualized Bridge approach [14], the outcomes from the first Bridge cohort, and interventions which were the basis of the contextualization.

METHODS

The Contextualize Bridge is one of the strategies that address academic inequities resulting in increased enrollment, retention and student success in engineering or computer science. It is designed to deliver a specific curriculum in a condensed period (6 weeks), emphasizing the mastery of student's deficiencies before entering a rigorous engineering or computer science curriculum. Bridge participants are mostly low-income, underprepared, and underrepresented students, some originally requiring up to two years of math remediation. As such, the main goals of the Contextualized Bridge are to develop, implement, and assess on-ramp strategies for high school students into engineering pathways at CCs; decrease remediation; increase engineering enrollment; and increase retention and belonging to the engineering profession.

The Contextualized Bridge strategies include:

- addressing low self-efficacy in the profession due to gaps in math or science skills

- developing professional identity by creating a cohort system and promoting socialization activities
- alleviating financial barriers by providing a stipend
- strengthening connections to Wright College and the profession
- building awareness of engineering fields and career opportunities.

Enrollment

The Contextualized Bridge methodology, initially targeting only high schools, was expanded to include students who completed their GED and to the current Wright College students who require math remediation. Due to the limitation of seats, priority for admission is given to Near-STEM ready students (not Calculus ready) who are interested in Engineering or Computer Science majors. Students' math proficiency is assessed using the ALEKS platform.

Logistics

The Contextualized Bridge is equivalent to 100 hours of class time (4 days a week, 4.5 hours a day for 6 weeks). It is designed to mimic the workplace environment where students are tasked to learn math and chemistry and are held accountable for their attendance and participation. No examinations are administered, other than the Baseline Assessment on the first day of the Bridge and the ALEKS Math Placement on the last day of instruction.

Bridge instruction utilizes Math and Chemistry modules developed contextually for the needs of the participants. Chemistry modules were first implemented in the second Bridge iteration. Results on students' chemistry performance after the Bridge will be shared in a future report. In addition to modules, participants are required to supplement lectures with adaptive Online Prep for Calculus course contextualized to students' preparation. The course initially customized with 350 topics was expanded to 411 topics for the second Bridge iteration. The course topics are aligned with Math modules, with participants navigating the learning paths based on their readiness level. The online Prep for Calculus licenses for Bridge participants are NSF funded. In the first Bridge iteration, two (2) hours per day were designated for Online Prep for Calculus course with an instructor and tutors available for consultations; followed by two (2) hours of lectures and practice problems; and 30 minutes of activities aimed at developing participants professional identity and sense of belonging. These activities included social interaction with students, an instructor, mentors, and academic advisors. Students are encouraged to dedicate additional study time outside the classroom, which is monitored through the ALEKS Online Calculus Prep.

Instruction Modality

The Bridge was originally developed for face-to-face delivery, incorporating, and evaluating activities believed to develop sense of belonging and the Community of Practice (CoP). The modality of Bridge implementation varied throughout the years, due to COVID pandemic (Table 1). The first Bridge was delivered in-person, second and third were remote, while the fourth Bridge was offered in hybrid modality (remote and in-person), with most students opting to attend in person.

Year	Modality
2019	In-person
2020	Remote
2021	Remote
2022	Hybrid

Table 1. Modality of the Contextualized Bridge instruction

Peer Tutors and Mentors

Current Wright College Engineering and Computer Science Program students are hired as Bridge tutors and mentors. Having successfully completed their first- or second-year Math and Chemistry courses, they are in a unique position to show current Bridge participants the outcomes achievable based on their effort. For the third and fourth Bridge iteration, these positions were mostly occupied by former Bridge participants. Tutors are tasked to proactively reach out to participants during class time, and to assist with examples and with ALEKS self-study. For the duration of the Bridge, participants are also given an option to schedule additional tutoring sessions both in person and remotely.

Cohorts

Students entering the Bridge self-identify as interested in Engineering or Computer Science majors. Participants are made aware they are learning alongside peers and future college classmates, thus initiating a Community of Practice (CoP) [17]. During the years of in-person instruction, lunch was brought in once a week providing students with an opportunity to interact and get to know each other, their tutors, and program staff. During remote instruction, limited in-person social engagement was possible due to COVID restrictions. However, an opportunity to develop CoP prior to the start of the semester was provided on the last day of Bridge. Students were invited to take the in-person final math and chemistry placement exam followed by Bridge completion celebration.

Financial Incentive and Professional Development

Through the NSF grant, students are provided a stipend for their time spent during the scheduled lecture and ALEKS work time. The stipend is offered to support students who would otherwise not be able to participate due to the need to work full-time during the summer. Participants' stipend, received upon Bridge completion, is based on the attendance during the live instruction and scheduled online preparations. Correspondingly, students' professional skills are affected due to expectations of on-time attendance and accountability for their performance.

Belonging and Self-Efficacy Surveys

"Self-Efficacy and Professional Identity" surveys were administered to all participants at the beginning and end of the Bridge, and after the completion of their first subsequent semester. Throughout the school year, external evaluators conducted surveys and case study interviews with Bridge participants, utilizing the Appreciative Inquiry approach [18]. "Belongingness" within

Lave and Wenger's Communities of Practice and Bandura's self-efficacy concepts [17, 19, 20] are used to explore the success of the Program. Participants' feedback is utilized to continuously improve the practices through further contextualization. With IRB approval, a Belonging and Self-efficacy Survey was enhanced using the "Retrospective Survey" during the COVID pandemic. It was adjusted to include the General Self-Efficacy Scale (NGSE) [21] was administered at the end of each semester during the fully remote instruction era. It captured students' immediate needs, and offered feedback on their financial security, self-efficacy, self-related competencies, and sense of belonging related to community of practice (CoP). Subsequently, additional sections were added containing Retrospective Pre-Test (RPT) questions [22, 23].

RESULTS

Overall Enrollment and Demographics

The Contextualized Bridge was first implemented in 2019. After four (4) iterations, 202 diverse participants attended the Bridge. The demographic makeup of Bridge participants (Tables 2 and 3) is representative of Wright College's student body. The main discrepancy is observed in gender demographics, as Wright College enrollment consists of more than 50% women. This underrepresentation of females is consistent with national engineering enrollment trends [24].

Contextualized Bridge (Number of participants)	Hispanic (%)	Black (%)	Asian (%)	White (%)	Multi (%)
1st (32)	72	3	9	16	0
2nd (50)	72	12	12	4	0
3rd (53)	58	12	15	13	2
4th (67)	70	4.5	7.5	16.5	1.5

Table 2. Contextualized Bridge participants' demographics by race and ethnicity

Contextualized Bridge (Number of participants)	Gender			Low Income
	Male (%)	Female (%)	Other (%)	
1st (32)	75	25	0	72
2nd (50)	76	24	0	64
3rd (53)	85	13	2	79
4th (67)	70	28.5	1.5	TBA

Table 3. Contextualized Bridge participants' demographics by gender and income

One-hundred-ninety (190) out of two-hundred-two (202) initially enrolled participants have successfully completed the Contextualized Bridge (Table 4). All completers were subsequently enrolled in Engineering and Computer Science programs. Additionally, each student eliminated at least one semester of Math remediation. Fifty percent (50%) of participants attained Calculus I placement (ALEKS score of 76 or higher), entering the guaranteed transfer pathways, including the highly selective engineering programs. Subsequently, students excelling in Calculus were hired as tutors throughout the academic year and for the next Bridge iterations. A more detailed analysis of the 2019 Bridge cohort's placement, retention and transfer follows, with participants having reached their fourth year of college.

Year	Participants		Transfer within 2 years (Transfer to date)	On track for Bachelor's degree completion in 4 years
	Started	Completed		
2019	32	31	11 (24)	11
2020	50	46	12 (26)	---
2021	53	50	---	---
2022	67	63	---	---

Table 4. Contextualized Bridge participants' current completion and transfer data

First Contextualized Bridge Outcomes

Thirty-two (32) students officially participated, and thirty-one (31) students completed the first Contextualized Bridge. Participants Pre- and Post-Bridge academic profile and subsequent placement in Engineering and Computer Science pathways at Wright College is analyzed by placing participants in three categories of Initial ALEKS scores (Table 5).

(1) **76 or above (Calculus ready).** Six (6) out of eight (8) participants scored significantly lower in their Post-Bridge ALEKS placement. Upon further investigation, the researchers found that the first attempt for taking the ALEKS Math Placement at Wright college is an online, un-proctored, and no-time limit test. This observation prompted the modification of the admission requirements and assessment, that went into effect for the second Bridge iteration.

(2) **Below 76.** Eleven (11) out of twenty (20) participants eliminated up to three (3) semesters of remedial Math and were subsequently placed in Calculus I after achieving an ALEKS score of 76 or higher. All Category 2 participants scored at least a twenty-five percent (25%) increase in ALEKS and eliminated at least one (1) semester of remedial Math.

(3) **Below 76 and requiring up to two (2) semesters of remedial math prior to the Bridge.** No significant difference in Pre- and Post-Bridge ALEKS scores was observed for the three (3) participants.

Categories	Participants		GPA Average (Range)	Math SAT Average (Range)	ALEKS Math Placement Scores		Fall 2019 (Post-Bridge) Math Placement	
	Started	Completed			Pre-Bridge Average (Range)	Post-Bridge Average (Range)	Calculus I	Pre-Calculus
1	8	8	3.21 (2.9-4.0)	524 (450-590)	80 (77-83)	60 (33-94)	6	2
2	21	20	3.03 (2.4-3.06)	528 (350-680)	43 (8-63)	69 (30-95)	11	8 (1)*
3	3	3	2.48 (2.1-2.9)	NA	41 (40-43)	45 (40-50)	2	1

Table 5. Pre- and Post-Bridge academic profile for the first Contextualized Bridge. *One student increased placement from Foundational Math to Developmental Math, which is one semester before Pre-Calculus.

To normalize the categories, a Baseline Assessment was obtained on the first day of the Bridge (results not shown) and compared to the Post-Bridge ALEKS scores. All participants who successfully completed the Bridge improved their math skills by 20-70%. The magnitude of growth was measured as a function of the Prep for Calculus completion rate at the end of the Bridge. Students who immensely improved their Post-Bridge ALEKS score (by at least 50%) dedicated on average an additional 100 hours of studying outside of classroom during the 6-week period.

Thirty (30) Bridge participants were subsequently placed in cohorts and enrolled in Engineering or Computer Science pathways at Wright College, with nineteen (19) becoming eligible for selective guaranteed transfer programs (Table 5). Eleven (11) participants transferred to top engineering programs within two (2) years from the Bridge and are on track for bachelor's degree completion within four years (Table 4). To date, thirteen (13) additional participants have transferred and two (2) are still on track to graduate and transfer. Only five (5) students from the first Bridge were not retained in the Program.

IMPACTS

The results indicate that the implementation of the contextualized practices provides underprepared and underrepresented students with means to attain academic equity and self-efficacy needed to complete a bachelor's degree in a shorter timeframe. As shown in Table 4, twenty-three (23) participants from the first and second Bridge iterations transferred to top engineering programs within two (2) years. More importantly, eleven (11) First Bridge participants are on track for bachelor's degree completion within four (4) years. Without the Contextualized Bridge strategies, it is unlikely that these students could have successfully navigated the rigor and expectations of the demanding engineering curriculum, especially within the four-year timeframe. Without receiving equity minded academic interventions through Bridge participation, their low initial math placement would most likely have prevented them from accessing selective engineering schools upon transfer, and they would not be completing their degrees in the same timeframe as students entering college with higher levels of academic readiness.

A significant positive impact of the Contextualized Bridge can be observed in Wright's Fall 2019 initial admission and final enrollment data of students originally placed in Foundational Studies or Developmental Education (remedial) math based on their ALEKS score (Table 6). A comparative analysis between the Bridge participants and general student body shows that while the percentage of students who were initially tested and admitted with Foundational or Developmental Math placement was comparable (22.3% and 19.6%), the final first-semester enrollment was significantly different. Even though all incoming students are allowed multiple attempts at the ALEKS math assessment, none of the non-Bridge students attained higher math placements. In addition, only 18.2% of out of this group who first placed into Foundational or remedial math attended Wright in Fall 2019.

In comparison, almost all students who were initially placed in Foundational or Developmental Math and attended the Contextualized Bridge drastically improved their math skills, eliminated up to two years of foundational, developmental, precalculus preparation, and were enrolled in Calculus I in Fall 2019. Most importantly, all students who completed the Bridge enrolled in the engineering program at Wright College in Fall 2019. In the most striking contrast, while none of these non-Bridge students transferred after two years, 52% of all Bridge students did so. Eleven

(11) Fall 2019 Bridge students completed their associate degree and transferred within two-years from Bridge participation and are on track to completing their bachelor's degrees in four years, including some who transferred to highly selective engineering schools.

Fall 2019 Admission – Foundational Studies (FS) and Developmental Education (DevEd) Math based on the ALEKS score	Wright College (%)	Contextualized Bridge (%)
Tested and admitted	22.3	19.6
Outcomes for Students Tested and Admitted in FS or DevEd Math		
Enrolled in FS/Dev Math in Fall 2019	18.2	1.3
Enrolled in Calculus I in Fall 2019	0	18.3
Associate degree completion and transfer in 2 years	0	52.0

Table 6. 2019 Wright College general (overall) and Contextualized Bridge admission and Fall 2019 placements for students initially placed in Foundational Studies and Developmental Math based on ALEKS scores.

The Contextualized Bridge also contributed to racial and ethnic diversity in engineering, as most of the participants' demographics are underrepresented in the profession [24] (Table 1 and 2). In addition, most are from low-income households. The ability to complete the degree in a shorter timeframe is imperative, since spending one-to-two years in remedial math has been found to be a deterrent to persistence [25]. As such, shortening time to graduation by reducing math remediation enables Bridge participants, many who are underrepresented in engineering, to improve their socioeconomic status by providing a more attainable path to this profession with high earning potential. To qualitatively demonstrate the impact of the Contextualized Bridge, two case studies are presented.

Case Study 1. Student A received her GED seven (7) years after leaving high school. After enrolling at Wright College, she initially placed in Pre-Calculus. After participating in the first Contextualized Bridge, she placed into Calculus I, eliminating one (1) semester of remedial math, and accessing the guaranteed transfer pathway. While at Wright College, she was hired by the Engineering program as an ambassador to support recruiting efforts. She also served as an elected officer in Wright's student chapter of the Society of Women Engineers (SWE). She completed an associate degree in two years and is on track to graduate in her fourth year of college. Upon transferring, she received merit scholarships and obtained an internship in her major of computer engineering.

Case Study 2. Student B joined Wright College and was placed into Developmental Math. After participating in the first Contextualized Bridge, he placed into Calculus I, eliminating one (1) year of remedial math. This placement granted him access to a guaranteed transfer pathway at a highly selective engineering university. While at Wright College, he was hired by the Engineering Program as a tutor for the Contextualized Bridge, and throughout the academic year. He also served as an elected officer in Wright's student chapter of the Society of Hispanic Professional Engineers (SHPE). Within two (2) years, he completed an associate degree in engineering, transferred, and is on track to graduate. Without the Contextualized Bridge, student B would not be currently completing his bachelor's degree in mechanical engineering from one of the top engineering schools in the country.

Self-Efficacy as Contributing Factor to Retention

Most students attribute their success to the structure of the Contextualized Bridge including its cohort system, and benefits gained such as increased self-efficacy as well as a sense of belonging to college and the engineering profession. The systemic pursuit of equity, particularly with a focus on self-efficacy, belonging and creating an environment committed to inclusive excellence, resulted in very strong outcomes regardless of students' diverse academic, economic and racial backgrounds.

Students who met with evaluators reported how their involvement in the Contextualized Bridge contributed to their persistence in engineering. The first evaluation was conducted in 2020 and correlated with early data from the first Bridge iteration [16]. In the more recent 2022 evaluation, the respondents having all attended the Bridge remotely, still found the experience transformational. In a case study interview conducted by Ruxton Consulting, one student attributed their success to the Bridge saying, "I really think I wouldn't be here. I wouldn't be studying engineering without the creation of the Bridge program." (Ruxton Consulting Evaluation Report presented to the PI, 2022).

Students also reflected on how their effort, within the structure of the Bridge, contributed to their improved self-efficacy in math. As one student shared, "It's not a test of your finances, or your brains. It's a test of how hard you can work, and I think that's a great factor to measure someone by." Another student acknowledged how much work was ultimately needed in order to be ready for a rigorous engineering program, even when their ACT score led them to believe they were prepared. They remarked, "I could have gotten in [to the selective guaranteed transfer program] because of my past qualifications... I think my ACT was above a certain range. But the ALEKS test was so difficult, and if I had not taken the summer Bridge and studied as hard as I did, I may not have passed it."

Students' improvements during the Bridge are not limited to higher math placement. They carry these skills into their overall college studies and their professional development, as quite frequently these students are seen giving back to the community of learners. One student expressed, "As a Bridge tutor, I appreciated being able to help students who are in the same position I once was, a Bridge participant!" These transformations show it is possible to advance equity in engineering and computer science by removing barriers for underprepared and underrepresented students pursuing these majors.

FUTURE WORK

Regardless of the Contextualized Bridge success, the researchers aim to continuously improve the project, and introduce methods to minimize the need for math remediation. Additional research will be conducted on how bridge students perform in math and chemistry courses compared to non-participants. The first iteration of the Winter Bridge was held in 2022, with the goal of helping continuing students improve their math preparation. Although not as impactful as the Summer Bridge, researchers have identified methods to appropriately contextualize the next iteration. Additionally, through partnership with local high schools, Wright College is piloting a Model

Engineering Pathway for students who express interest in engineering. The Model Engineering Pathway will integrate the Contextualized Bridge strategies into current Dual Enrollment curriculum (students enrolled in college level classes as high school students). Through this program, students will be in cohorts comparable to the Bridge, increase their chance for guaranteed admission to top engineering programs, and preclude the need for summer Bridge intervention.

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