Urban STEM Collaboratory After Two Years: A Multi-institutional Approach to the Success of Financially Disadvantaged Students

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Abstract

The *Urban STEM Collaboratory* is a five-year project sponsored by the National Science Foundation (NSF) that addresses challenges to student success in STEM disciplines through a multi-institutional collaboration via the University of Memphis (UofM), University of Colorado Denver (CU Denver), and Indiana University--Purdue University Indianapolis (IUPUI). Study groups, tutoring, peer and faculty mentoring, and career exploration programs are being used across the three campuses to increase the participants' commitment to a STEM field. Innovative features from *CourseNetworking* (CN) software are being deployed to provide scholars with evidence of their learning journey while expanding a meaningful academic cloud-based social network. This paper extends a previous introductory ASEE conference paper titled: "Launching the Urban STEM Collaboratory," (Goodman et al., 2020), which outlined the initial efforts of the tri-campus collaboration. The purpose of the present paper is to summarize the impact of the project, including data analysis of effectiveness, for Year 1: 2019-2020 and Year 2: 2020-2021. Although still in progress, with the longitudinal efficacy of several of the project's components undetermined, the project's organizational structure, activities, and findings to date should be of value to others conducting or proposing projects with similar goals.

Keywords: STEM identity, engineering education

Collaboratory Model

The model for the Urban STEM Collaboratory (hereafter Collaboratory) project was developed collectively across three institutions: University of Memphis (UofM), University of Colorado Denver (CU Denver), and Indiana University--Purdue University Indianapolis (IUPUI). While each campus has unique attributes, these large, public, urban campuses share similarities in student demographics and challenges faced in both recruitment and retention of STEM majors. The project team identified key aspects critical to student success and developed a strategy informed by literature as well as the experience of the project team. As summarized by Goodman et al. (2020), the Collaboratory goals are as follows:

1. Increase at each institution the recruitment, retention, student success, and graduation rates of mathematical sciences and engineering majors who are academically talented and have documented unmet financial aid need;
2. Implement ambitious but feasible strategies contributing to student academic success, development of STEM identity, and workforce readiness;
3. Implement mechanisms to ensure substantial student participation in project activities through a special Badge and Seed system, incentivizing participation;
4. Implement activities for mathematics and engineering classes leading to a high probability of student success; and conduct formative and summative evaluations with special focus on determining effectiveness and impact of the project activities, strategies, and adjustments.
5. Conduct a research study that focuses on developing an evidence-based understanding of factors influencing development of STEM identity and the resulting impact on student success, attitudes, workforce readiness, and STEM self-efficacy, with particular attention to impact on first-generation and underrepresented students.
6. Conduct formative and summative evaluations of the project that explore the extent to which each objective is being met. A particular emphasis is placed on determining effectiveness and impact of the project activities, strategies, and adjustments made throughout the project.

The Collaboratory is a five-year, NSF-funded project that includes scholarships for student participants (scholars), who are academically talented and with documented unmet financial need, in conjunction with activities and programs designed to achieve the project goals. A crucial consideration in developing the project model was the opportunity to leverage individual strengths at each campus to determine how successful programs might be translated to other institutions. The purpose of this paper is to describe in depth the Collaboratory structure and components and report findings from the first two years of the program. Some aspects of the project beyond the first two years appear in the introductory ASEE conference paper titled: "Three Years of the Urban STEM Collaboratory" (Darbeheshti et al., 2022).

First, we discuss the overarching needs the Collaboratory is designed to address. We then outline the overarching structure of the program and describe the scholars who are participating at each campus. Next, we provide an overview of the common program elements across the campuses, followed by descriptions of program elements that are unique to each campus. Finally, we present evaluation data on student success and program satisfaction through year two.

Need for the Collaboratory

The need to recruit and train a broad workforce in STEM is one of the most pressing challenges facing the U.S. in the coming decades (Stine & Matthews, 2009). Nearly half of all economic growth during the last half-century was a result of scientific innovation (Greenstone & Looney, 2011). Growth of STEM occupations was double that for non-STEM occupations with median wages well above those for most non-STEM (U.S. Bureau of Labor Statistics, 2021), and these trends are expected to continue for STEM through 2024 (Fayer et al., 2017). Undergraduate STEM education is a key component in training a STEM workforce, but undergraduate STEM students face many barriers to success, including the following: financial need (Dusselier et al., 2005); off-campus working hours (Bozic, 2008); and commuting (Marth, 2017). These barriers affect one's ability to leverage academic and other available resources. Other challenges include difficult transitions (e.g., high school to college, precalculus to calculus, general education to major courses); few role models for first-generation students (Lohfink & Paulsen, 2005; Bozic, 2007; Brost & Payne, 2011); class absence due to other responsibilities; and insufficient background in mathematics and science (Gandhi-Lee et al., 2015; Hoffman, 2016). Many of these challenges contribute to an underdeveloped STEM identity.

Carlone and Johnson (2007) define STEM Identity as one's recognition by self and others as a STEM person and propose a STEM identity framework comprising: (1) competence, or one's knowledge and understanding of STEM; (2) performance, or one's ability to engage in various STEM practices; and (3) recognition, or being seen by others and seeing one's self as a STEM person. Developing STEM identity is associated with greater persistence in STEM majors (Chang et al., 2011; Perez et al., 2014), but is not always a straightforward process. STEM students may resist or find such an identity undesirable (Brooks, 2017). STEM students from underrepresented groups face additional challenges to developing STEM identities because of their race or gender (e.g., negative racial experiences, stereotype threat, lack of recognition as scientists; Carlone & Johnson, 2007; Chang et al., 2011).

As STEM identity is multifaceted, the Collaboratory involves interventions that focus on academic, social, community, workforce, and networking-related activities. Academic success and satisfaction with one's major, feeling part of a STEM community, participating in STEM activities, interacting with role models, collaborating and "STEM communicating," understanding career opportunities, and developing STEM self-efficacy all potentially play a role in developing a STEM identity. Each component of the Collaboratory was crafted with developing STEM identity and increasing student success at the forefront.

Description of the Urban STEM Collaboratory

Scholar Cohorts

The number of cohorts recruited at each campus and the number of years scholars are eligible to receive scholarships while in the Collaboratory program vary (Figure 1). The range of individual scholarships ($2.5K-$10K per student per year) is consistent across the three institutions and is based on unmet financial need as determined by the Free Application for Federal Student Aid (FAFSA). Although the differences are based in part on team members' prior experiences with NSF Scholarships for STEM (S-STEM) (Alfrey et al., 2014), NSF STEM Talent Expansion Programs (STEP) (Best et al., 2010; Russomanno et al., 2010; Windsor et al., 2015) and similar initiatives, the project team is examining the different scholar cohort formats to investigate best practices for a variety of scenarios.

The UofM team has recruited from high schools and first-year students for cohorts 1 and 2 and from second-year students for cohort 3. This approach was designed such that students can receive scholarship funding through their fourth year of study. To be eligible, high school students were required to have a minimum 3.0 high school gpa and first-year students a 2.8 college gpa,

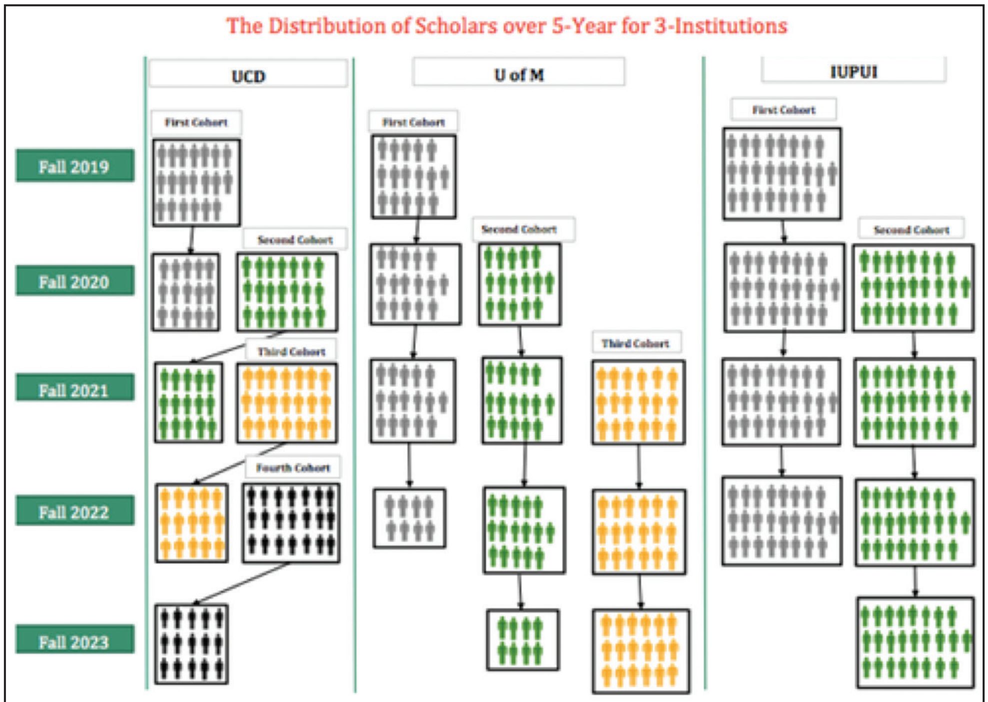

Figure 1. Scholar Cohorts at CU Denver, UofM, and IUPUI

and a minimum ACT composite of 26.

The CU Denver team will have recruited four cohorts from high schools and first-year students. This approach allows first-time first-year students to enter the program each year for the duration of the project. Each student will be financially supported through the Collaboratory for the first two years of their studies at CU Denver. The students are offered opportunities to receive financial aid for their remaining two years through participating in various initiatives at CU Denver, including a Learning Assistant program, tutoring, and mentoring the new incoming first-year students. For the first two cohorts, high school students were required to have a minimum 3.5 gpa, 25/1260 composite ACT/SAT, and 27/650 math ACT/SAT. After the onset of the COVID-19 pandemic, minimum ACT/SAT scores were removed as an eligibility requirement because many high school students did not take the ACT or SAT.

IUPUI's two cohorts comprise both first-time first-year students who were directly admitted to their program of study and returning students who were not directly admitted as first-year students into their major but who were accepted into IUPUI's University College (UC). Each cohort at IUPUI took Calculus 1 together either having satisfactory math placement scores or standardized test scores (for first-year students) or successful completion of prerequisite courses(s) (for UC students). IUPUI adopted a holistic admission process and is ACT/SAT test optional. However, for direct admission to engineering programs and to be selected as a scholar, high school students must have attained at least a 3.0 gpa and be evaluated as Calculus 1 ready.

Scholars were recruited through announcements through campus portals, emails to eligible students, flyer distributions at recruiting events, and personal outreach through both staff and faculty advisors. Each campus reviewed applications from potential scholars, and selected awardees based on project team members' review and recommendation. In all cases, selection teams strived to achieve diversity of major, gender, and ethnicity in forming scholar cohorts. As the amount of unmet need that can be awarded to a student can be difficult to determine because of the timing of awards of other scholarships and aid, in most cases scholars were not confirmed on each campus until the summer prior to the start of each academic year.

Student cohort data and demographics for each campus are provided for Cohort 1 in Table 1 and Figure 2, and for Cohort 2 in Table 2 and Figure 3. Scholars at CU Denver were recruited from two main sources: regular outreach programs at high schools, which serve underrepresented students, and admitted students to CU Denver with diverse backgrounds. At UofM, a more diverse cohort was recruited in the second year, with more targeted outreach through several organizations serving underrepresented students. At IUPUI, there was a decline in the number of students in cohort 2 from the UC and resulted in decreased diversity. Although more investigation is needed to determine factors that may have led to the disappointing number of students in cohort 2 from UC, as well as a decrease in diversity as compared to cohort 1, the impact of COVID-19 appears to have had a disproportionate impact on UC students (continuing) versus first-time, full-time new students. For cohort 1, efforts to include UC students increased the overall diversity of the cohort along the other axes,

	CU Denver		UofM		IUPUI	
	First-Years	Sophomores	First-Years	Sophomores	First-Years	Returning Students
Total	12	5	9	8	14	11
Gender						
Male	7	5	4	6	11	6
Female	5	-	5	2	3	5
Race/ethnicity						
White	5	-	5	6	10	2
Hispanic	2	2	-	1	1	3
Asian	3	1	-	-	1	3
Black	-	2	2	1	1	2
2 or more	2	-	2	-	1	1
Major						
Biomedical Engineering	2	-	5	3	6	2
Civil Engineering	1	-	2	-	-	-
Computer Engineering	-	-	1	2	1	5
Computer Science	4	1	-	-	1	1
Electrical Engineering	-	-	1	-	-	-
Mathematics	-	-	-	-	-	1
Mechanical Engineering	5	3	-	3	-	1
Motorsports Engineering	-	-	-	-	1	-
Mechanical & Motorsports Eng.	-	-	-	-	5	1
Pre-Engineering	-	1	-	-	-	-

Table 1. Collaboratory Cohort #1

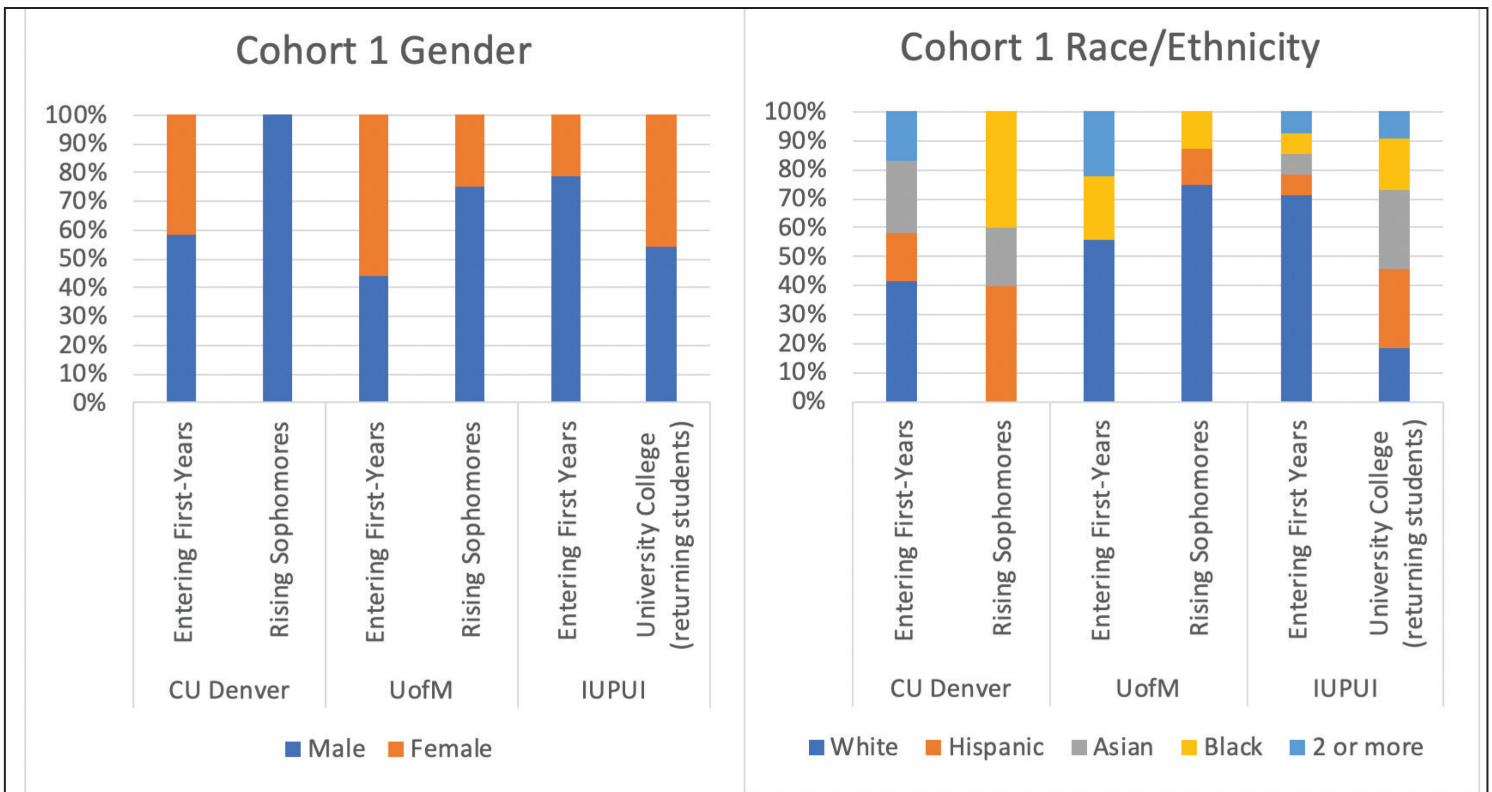

Figure 2. Cohort 1 by Gender and Race/Ethnicity

	CU Denver		UofM		IUPUI	
	First-Years	Sophomores	First-Years	Sophomores	First-Years	Returning Students
Total	11	2	12	9	16	4
Gender						
Male	9	1	6	2	12	4
Female	2	1	6	7	4	-
Race/ethnicity						
White	5	2	2	4	11	3
Hispanic	1	-	2	-	-	1
Asian	2	-	-	1	3	-
Black	2	-	7	4	2	-
2 or more	1	-	1	-	-	-
Major						
Biomedical Engineering	2	-	6	5	5	1
Civil Engineering	2	-	5	1	-	-
Computer Engineering	-	-	1	1	1	1
Computer Science	3	1	-	-	2	-
Electrical Engineering	-	-	-	-	2	-
Mathematics	-	-	-	2	3	1
Mechanical Engineering	4	1	-	-	3	-
Motorsports Engineering	-	-	-	-	-	-
Mechanical & Motorsports Eng.	-	-	-	-	-	1
Pre-Engineering	-	-	-	-	-	-

Table 2. Collaboratory Cohort #2

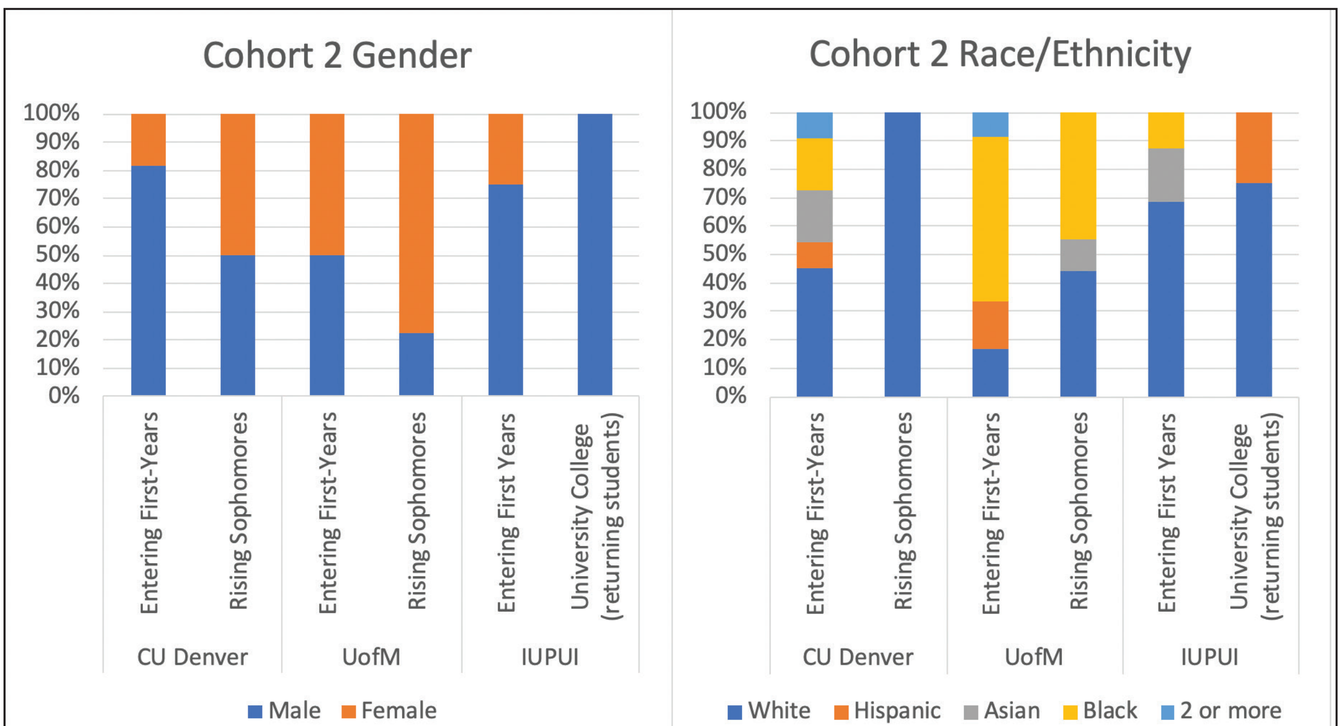

Figure 3. Cohort 2 by Gender and Race/Ethnicity

Badge	Criteria
Collaboratory Bridge Scholar	Successfully complete the summer bridge STEM Collaboratory as a student or a mentor, including building an initial e-Portfolio within CN.
Collaboratory Participant– *Semester*	Earn 250 seeds for posting to the STEM Collaboratory Network or one of the affiliated group networks (networks on CN).
Collaboratory Influencer– *Year*	Members selected for *Post of the Week* receive an additional 25 seeds. Students selected for 3 *Posts of the Week* in the STEM Collaboratory Network for any academic year receive the STEM Collaboratory Influencer badge.
STEM Professional Member – *Year*	Join a professional organization related to major field of study. One badge will be awarded for active participation in each membership per year. Active participation requires attending at least 2 organization events each semester. Examples include, but are not limited to: ACM, ASCE, ASEE, ASME, BMES, IEEE, MAA, SHPE, SIAM, SWE, etc.
STEM Professional Leader – *Year*	Be elected as an officer within a student chapter of a professional organization related to major field of study. Award of badge will require supporting evidence of satisfactory participation as a leader of the society such as a *Showcase* on their CN e-Portfolio.
Peer Led Team Mentor – *Semester*	Successfully complete an experience as a Peer Led Team Mentor over a semester.
Peer Led Team Leader – *Semester*	Successfully complete an experience as a Peer Led Team Leader over a semester.
"Sector" Industry Intern – *Semester*	Awarded for each successful completion of an industry internship or significant experience related to a given industrial sector (with documentation via a showcase on your CN e-Portfolio): Aerospace, Automotive, Defense, Logistics, Manufacturing, Pharma, etc. [a]
Community Service Scholar – *Semester*	Document significant, meaningful experiences in the community, via a showcase on your CN e-Portfolio [a]
Research Scholar – *Semester*	Document significant research experience such as a member of Diversity Scholars Research Program (DSRP), REU participant, research assistant for a faculty member, etc., via a showcase on your CN e-Portfolio.*
Diversity Scholar – *Semester*	Document a significant diversity experience via a showcase on your CN e-Portfolio. For example, attending an implicit bias seminar and reflecting on the experience. [a]
Global Engagement – *Semester*	Completion of a study abroad experience or other experience documenting significant global engagement (with documentation via a showcase on your CN e-Portfolio).[a]
STEM Outreach – *Semester*	Significant effort devoted to K-12 STEM outreach, recruiting new Urban STEM Collaboratory Scholars, etc. (with documentation via a showcase on your CN e-Portfolio).[a]
e-Portfolio Master – one time	Fully developed e-Portfolio as described in Urban STEM Collaboratory guidelines.[b]
STEM Tutor – *Semester*	Document significant STEM tutoring experience (requires submission of service hours or timesheets, 40 hours per semester) and create a showcase on your CN e-Portfolio.
Urban STEM Research Contributor – *Year*	Contribute your responses to the intro and exit surveys and at least one other research activity of the Urban STEM Collaboratory each year (such as interviews, focus groups, or additional surveys).
Student Defined Badge(s) – *Semester or Year*	Student defined criteria. Requires review and approval of STEM Collaboratory Project Team.

[a] All badges requiring "significant experience" must be approved by the project leadership team for the badge to be awarded. [b] The e-Portfolio Master is intended as a one-time award for a comprehensive e-Portfolio that has been developed over multiple years.

Table 3. STEM Collaboratory Badges

as the pool of calculus-ready entering first-year students tended to skew white, male, and intending to pursue a major in Biomedical Engineering or the Mechanical Engineering/Motorsports Engineering dual program. Recruiting scholars at all three campuses was impacted by the COVID-19 pandemic, which altered both normal recruitment practices, such as campus visits and college fairs, and potential students' decisions about attending college. Also, each campus made concerted efforts to reach out to cohort members who were less active in Collaboratory activities and/or who were experiencing other difficulties in their studies. For example, at UofM, the Collaboratory PI was added as a "success coach" for each Scholar and reached out to those who received "early intervention" reports to help connect them to help and resources.

Common Program Elements

Summer Bridge

The summer bridge programs at each campus were designed to engage the scholars in icebreaker activities to acquaint themselves with each other, students from partnering campuses, and Collaboratory faculty. Other activities were designed to help transition from summer break into impending coursework through mathematics review, special-interest presentations (such as biomedical engineering), and communication and growth mindset workshops. Students were also introduced to CourseNetworking (the CN), which is being used for students and project investigators to interact and implement the seed and badge systems that track students' participation in the project and attainment of certain knowledge, abilities, skills, or other characteristics associated with STEM identity.

The Collaboratory programs also introduced students to academic and other resources available to support students in their transition to their universities. Although some of the students in cohorts 1 and 2 were returning students and not new to campus, they indicated they enjoyed helping the first-time first-year students with some of the activities focused on transition to college, which further strengthened the collegiality among the members of each cohort. Program lengths varied by campus. CU Denver's program was four days, with an extended day to observe the campus-wide convocation ceremony for all first-year students. The IUPUI program was one week. UofM's program was three days to avoid conflict with another (required) first-year camp. After the summer bridge, the scholars continued to meet on a regular basis throughout the fall semester. At CU Denver, those meetings occurred through the Engineering Learning Community (ELC) and the mentorship program. IUPUI had a common seminar course. UofM hosted monthly meetings with the scholars focused on study skills, campus academic resources, and career preparation.

The CourseNetworking (CN) Model

The CN software platform, provided by CourseNetworking, LLC, is an important infrastructure component of the project. The CN affords scholars opportunities to become part of an academic and professional network and leverage the collective services and partnerships of the universities. The CN platform is designed to enhance student communication and collaboration during project activities and events, allowing scholars to enact STEM identities, and unites several components of the project.

Although the CN is a stable commercial product, adopted by several universities as a comprehensive Learning Management System, it continues to incorporate new methods and emerging technology. The CyberLab in the Purdue School of Engineering and Technology at IUPUI provides research and instructional design support for the interface and technical development of the CN and incorporates feedback from the project team and scholars to continuously improve the software. CourseNetworking, LLC has given permission to use the CN software and study its impacts in support of this project. CN features being employed include e-Portfolio, which serves as a digital collection of each student's academic work and accomplishments accompanied by micro-certification badges that provide validation of a student's participation, knowledge, behaviors, and skill sets. The e-Portfolio provides scholars with evidence of their learning journey while expanding a meaningful academic social network and building STEM identity. CN posting and reflection tools promote student self-reflection and student-student and student-faculty interactions. A reward system provides 'seeds' to reward online engagement and 'badges' to reward participation in various project programming and incorporates social learning, knowledge sharing, peer assessments, and collaboration. Such techniques often are engaging for students (Kapp, 2012). The role of the CN in the Collaboratory is to enhance the potential student success and to develop and maintain a broader STEM community across the campuses.

The project provides incentives for recognizing scholars' participation and attainment of knowledge, skills, and abilities through earning 'badges' via CN. Badges are micro-credentials that help reward and celebrate participation and achievement in Collaboratory programming and provide a mechanism for the scholar and project investigators to monitor participation in various activities. Low participation in activities promoted to scholars are a focus for continuous improvement, potentially for both the project and the student, including identifying barriers the scholar might be experiencing that prevent at least a minimum expected level of participation.

Badges incentivize participation and recognize accomplishments both within and outside of the Collaboratory in the following areas: (a) academic success; (b) professional society participation or leadership; (c) peer-led mentoring; (d) peer-led team leadership; (e) career exploration and development (e.g., internship); (f) research; (g) engagement with community service, diversity and inclusion, or study abroad; (h) STEM tutoring and outreach; (g) e-Portfolio mastery; and (h) a self-designed badge. Table 3 provides a summary of the badges available to scholars. As a point of pride, recipients may display earned badges on their CN e-Portfolio or push them to social media sites like Facebook and Twitter. In terms of the total number of badges each scholar received in the 2019-2020 academic year, we had two scholars who each earned six program badges; three scholars who each earned five program badges, and 23 scholars who each earned four program badges. We recognized the top badge winners by writing each a recommendation on their CN e-Portfolio and via a press release (Purdue School of Engineering and Technology News and Research, 2020).

To incentivize engagement on the CN, Scholars are encouraged to earn 250 participation seeds through the CN platform to earn the Collaboratory Participant Badge. Seeds are earned by making posts, commenting on posts from others in the Collaboratory, and engaging in other activities within the Urban STEM network on CN. We began with faculty-led/initiated activities on CN in the fall of year one but moved to student-led activities by the second semester. Two students were identified at each campus to work in a Collaboratory-wide student leadership team to develop prompts to engage the rest of the scholars in community-building discussions. A campus competition was instituted to further encourage participation. The winning campus, selected based on the highest average number of posts per scholar, won the right to choose the design of the Urban STEM Collaboratory tee-shirt, which is provided to all students across the Collaboratory. During the 2019-2020 academic year, based on the posts per member in the Urban STEM Collaboratory, IUPUI had 8.2 posts/person, CU-Denver had 7.7 posts/person, and UofM had 5.4 posts/person. However, UofM had the highest average number of reflections, post ratings, and seeds, as shown in Table 4.

Campus		Number of Posts	Number of Reflections	Number of Post Ratings	Network Seeds
IUPUI	Total	221	600	4083	12371
	Average	8.2	22.2	151.2	458.2
CU Denver	Total	146	358	2026	7145
	Average	7.7	18.8	106.6	376.1
U of M	Total	97	584	2829	8498
	Average	5.4	32.4	157.2	472.1

Table 4. CN Engagement Metrics 2019-2020

	Fall 2019 ELC Cohort	Fall 2020 ELC Cohort
Enrollment	26	25
Eligible Majors	Pre-engineering Mechanical Engineering Civil Engineering Mathematics Electrical Engineering Bioengineering Computer Science	Pre-engineering Mechanical Engineering Civil Engineering Mathematics Electrical Engineering Bioengineering Computer Science
Fall Semester Course Bundle	First-Year Design Precalculus *or* Calculus I Core Composition I	First-Year Design Precalculus *or* Calculus I Core Composition I
Spring Semester Course Bundle	Computer-Aided Drafting Calculus I *or* Calculus II Core Composition II	Fundamentals of Computation Calculus I *or* Calculus II Core Composition II
Near-Peer Involvement	TA (Teaching Assistant) PAL (Peer Advocate Leader) Group Mentorship	TA PAL Individual Peer Mentorship

Table 5. Summary of CU Denver Engineering Learning Community (ELC) Components

	Spring 2020 Course Completion Rate
Fall 2019 ELC Students	91.97%
Fall 2019 Non-ELC Students	87.63%

Table 6. Spring 2020 Course Completion Rates by Fall 2019 ELC Participation, CU Denver

	No Participation in the LMP	Some Participation in the LMP (1 or 2 Semesters)
Fall 2019 Starting Population	123	23
Total 2019 - 2020 Attrition	38	4
Total 2019 - 2020 Retention	85	19
Retention Rate	69%	83%

Table 7. Comparing the Retention Rates of Students with No Mentoring to Students with Some Mentoring

	All students in all sections	Urban STEM Collaboratory Cohort Recitation
A	91	7
B	101	11
C	83	7
D	27	0
F	49	0
W	29	0
Total	380	25

Table 8. MATH 16500 Calculus I Final Grades, Fall 2019

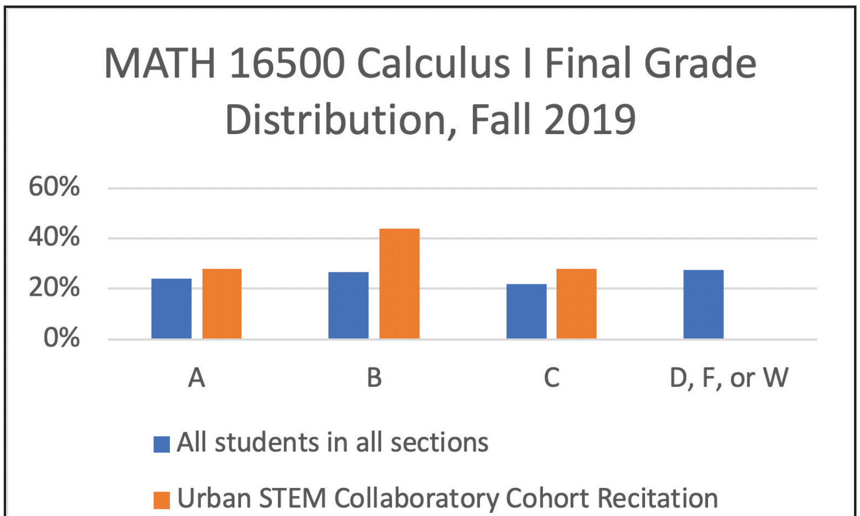

Figure 4. Calculus I Final Grade Distribution, Fall 2019

Individual Campus Activities

CU Denver: Engineering Learning Community

The Engineering Learning Community (ELC) at CU Denver is a cohort of first-year students with a commonly declared interest in pursuing a degree in engineering. One feature of the CU Denver ELC program is to provide the students with an early hands-on engineering experience through a first-year design course. In addition, the students in the ELC enroll in a common section of a math course (Precalculus, Calculus I, or Calculus II) and a common section of an English course (Core Composition I or Core Composition II). Having the students share their experience through the ELC is intended to create a supportive cohort of engineering students ultimately leading to an increased probability of success. In fall 2019 (Year 1), a total of 26 students joined the ELC, 17 of whom were awarded a Collaboratory scholarship. In fall 2020 (Year 2) a total of 25 students joined the ELC, 13 of whom were awarded the scholarship.

The ELC was first implemented in fall 2016 using high-impact practices with the goal of increased success and retention of undergraduate engineering students. Each year following, the format of the ELC was revised based on student feedback and best practices, and evidence has demonstrated increased success and academic resilience through participating in the ELC (Howland Cummings et al., 2021).

Table 5 shows the summary of components of the ELC for the last two years. Table 6 compares the first-year completion rate of ELC students to the first-year completion rate of non-ELC students, both for the same period of fall 2019 entering students.

CU Denver: Layered Mentorship Program

The Layered Mentorship Program (LMP) is a unique program at CU Denver that was established as one of the main components of the ELC for first-year engineering students. Each ELC student is assigned a peer mentor upon joining the program. Peer mentors are sophomore- through senior-level undergraduate engineering students in the college who hold loosely structured meetings with the mentee students. The peer mentors are in turn supported by multiple "layers," including senior mentors, graduate students, and faculty.

A quantitative study examined how participation in the LMP was associated with student academic success and retention in the engineering program. The study compared retention rates and GPAs of engineering students who participated in the LMP in the fall 2019 semester only (n= 8), in both the fall 2019 and spring 2020 semesters (n = 15), and engineering students who did not participate in the LMP during either of these semesters (n = 123). Table 7 compares the retention rate of students who participated in LMP to those who did not participate in LMP (Simon et al., 2021).

IUPUI: Calculus I with PLTL

One significant reason STEM students are not retained after the first year is poor performance in calculus. There have been numerous studies concerning strategies that help students clear this hurdle. However, the barrier still persists as a national problem (Rasmussen & Ellis, 2013). Poor performance in calculus often is a result of failing to inculcate the big ideas of the course. At the same time, being able to communicate mathematics well is an important part of doing mathematics; it helps clarify and structure the students' cognitive ways of knowing and understanding. Oral as well as written communication in a calculus course can promote the construction of conceptual understandings, new knowledge, and lead to increased problem-solving ability (Beidleman, 1995). With this as an evidence-based guide, a special focus is on communication while applying the Peer-Led Team Learning (PLTL) model (Gosser et al., 1998).

	All students in all sections	Urban STEM Collaboratory Cohort Recitation
A	111	8
B	99	6
C	31	7
D	17	0
F	19	1
W	16	0
Total	293	25

Table 9. MATH 16600 Calculus II Final Grades, Spring 2020

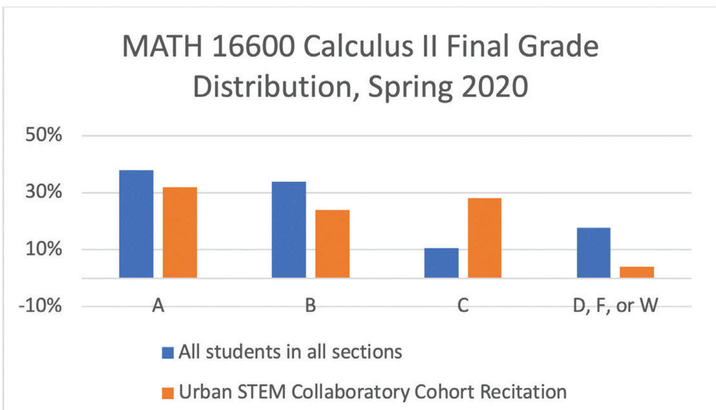

Figure 5. Calculus II Final Grade Distribution, Spring 2020

To foster both comfort with applying mathematics concepts and a deeper sense of STEM identity, the PLTL framework was deployed to recruit and train undergraduate students who have previously been successful in Calculus I to serve as facilitators for small group activities that reinforce and apply concepts from lecture to thought-provoking applied problems explored in a recitation section. Perhaps the most significant effects of the PLTL experience are on the peer leaders themselves, who in other projects, demonstrated increased content knowledge and better success in higher-level classes as well as increased confidence to pursue science-related careers (Varma-Nelson et al., 2004). For this reason, scholars who perform well in their first semester Calculus I courses are actively recruited as PLTL peer leaders in subsequent semesters, thus strengthening their connection to the STEM community both as mentors (to their PLTL students) and mentees (to the faculty mentoring the peer leaders) and potentially enhancing their sense of STEM identity.

At IUPUI, cohort 1 consists of 25 scholar students who were in a single designated calculus recitation in fall 2019 focused in part to build community among the cohort members. This designated recitation was one of five recitation sections (up to 30 students each) of a large lecture course of 140 students. The course has a required common departmental final exam across all sections of the course, and a student must pass the common final exam to receive a course grade of C or better.

The results of IUPUI cohort 1 in the fall 2019 semester MATH 16500, Calculus I, are summarized in Table 8 and Figure 4.

In the spring 2020 semester, the COVID-19 pandemic resulted in all sections of Calculus II going online, and there was no common department final across all sections of the course. In addition, the IUPUI campus allowed students the option to convert any passing final course grade to S or P to avoid GPA implications because of the pandemic; the grades (Table 9; Figure 5) were captured before any student requested conversion to S/P grading.

The DFW rate for all calculus courses in the spring semester fell by 10-15%, due possibly to the pandemic forcing all courses at IUPUI to go online with testing being non-proctored. The recitation sections for cohort 1 were led by peer mentors who had taken courses from other departments using PLTL mentoring in recitations, so there was familiarity with the concept. During the summer of 2019, the peer mentors were coached by the course instructor on how to implement the activities and focus on building conceptual understandings in calculus. These activities were designed to promote critical calculus concepts via verbal, geometric, numerical, and algebraic perspectives. In the spring semester, the PLTL activities were stopped after the first six weeks because of moving the course online. The remaining recitations for this cohort in the spring semester became Zoom help sessions.

Cohort 1 started with 25 scholar students, all passing Calculus I. Of these students, 22 continued as a cohort into Calculus II, where all but one student passed the course. Of these students, eight took Multivariate Calculus during the summer 2020 semester, where all eight passed the course with a grade of C or better.

UofM: STEM Ambassadors

The UofM STEM Ambassador program supports K-12 STEM teaching and learning through a variety of in-person and virtual (due to COVID-19) activities such as tutoring, STEM competition coaching, and STEM activity leadership. The Ambassadors are undergraduate STEM majors who not only make a positive impact with K-12 students through providing this support, but also learn essential professionalism, communication, and leadership skills through a structured training program. Ambassadors are paid for their roles, and many students in the program are able to quit non-STEM part-time employment and work solely as Ambassadors because of the relatively high pay (competitive with local job market), flexibility around class schedules, and convenience. Ambassadors are able to select the number of hours and location of assignments they take on.

Previous studies have shown positive impacts on the students that Ambassadors serve as well as the Ambassadors themselves. In one study, K-12 students working with Ambassadors achieved math performance goals at rates of 12% (middle school) and 30% (elementary) higher than that of their peers, as demonstrated through analysis of standardized assessments. Surveys with Ambassadors also reveal increased confidence in communication and leadership abilities and STEM self-efficacy ratings of the Ambassadors (Ivey et al., 2015; Aguayo, 2018).

UofM scholars are encouraged and given opportunities to become STEM Ambassadors. In year 1, only 3 of the 17 scholars took advantage of this opportunity. These three scholars finished the year with strong GPAs (top of the cohort) while also engaging in numerous other activities, such as research positions and leadership in student chapters of professional organizations. The cohort size was too small to be able to determine any statistically significant findings. For cohort 2, there were an additional eight students serving as STEM Ambassadors, so more detailed studies are now underway.

Assessment of Scholars' Performance and Satisfaction

Overall Scholars' Performance

Total full-time undergraduate student populations of the three universities in 2019 were 12,646 at UofM; 11,531 at CU Denver; and 17,540 at IUPUI. Table 10 summarizes the UofM, CU Denver, and IUPUI numbers and

	CU Denver			UofM			IUPUI		
	Univ.	Eligible	Scholars	Univ.	Eligible	Scholars	Univ.	Eligible	Scholars
Full-time Enrollment	11531	287	21	12646	1139	17	17540	755	25
First-Year	1442	59	21	2643	249	8	3674	245	13
First-Year Pell Eligible	591	36	9	1372	105	5	1469	39	3
Unmet need > $6k	4381	230	7	7761	526	2	5788	460	13
Underrepresented	4266	132	6	7777	452	5	3858	211	9
First-Generation	5535	178	12	5312	353	8	4385	219	5
Female	6227	83	5	10431	292	8	9998	121	8
Disability	-	-	-	908	79	1	-	-	-

Table 10. 2019 Demographics: University, Program Eligible, and Scholars

percentages of full-time first-year students, Pell eligible first-year students, unmet financial need >$6,000, underrepresented, first generation, female, and students with a disability.

The evaluation team measured scholars' academic performance as compared to the students who were eligible to apply to the program but were not selected as scholars, as summarized in Table 11. Scholars at UofM had higher average GPAs than their counterparts in terms of overall GPA, math GPA, and calculus 1 GPA; they also earned more course credits. However, their major GPA was lower than the overall pool of scholarship-eligible students. At CU Denver and IUPUI, the same trends are reflected in the data except the scholars outperformed their counterparts for every collected measure while at the same time completing more course credits on average.

	CU Denver		UofM		IUPUI	
	Eligible	Scholars	Eligible	Scholars	Eligible	Scholars
n	287	21	1405	17	755	25
Overall GPA	3.03	3.45	2.9	3.09	2.87	2.93
Major GPA	3.05	3.54	2.18	1.93	2.21	2.95
Math GPA	2.42	3.33	2.06	2.52	2.27	2.92
Calculus I GPA	2.23	3.26	2.61	2.81	2.17	2.94
Credits earned	11.42	13.29	12.76	13	12.9	15.2

Note. Math GPA is for Calculus I or higher.

Table 11. 2019 Scholars' Performance Compared to Overall STEM Population

Scholars' Satisfaction

The evaluation team also implemented surveys and interviews to learn about the scholars' perceptions. The surveys focused on scholars' engineering identity (Godwin, 2016); engineering self-efficacy (Mamaril et al., 2016); intrinsic value (Li et al., 2007); and sense of belonging to place (NSSE, 2016). There was a total of 44 survey items (11 for engineering identity, 17 for engineering self-efficacy, 12 for intrinsic value, and 4 for sense of belonging to place).

To determine the mean differences of students' academic performance before and after project participation, descriptive statistics including Hedge's g effect sizes are presented in Table 12. The mean reported rating for students' engineering identity increased after their participation in the project (g=1.488). Students' sense of belonging to place was slightly decreased, but the difference was small (g=0.112). Effect sizes of both engineering self-efficacy and intrinsic value showed that the means decreased after students' participation. Further investigation is needed to understand this finding, and the implementation of post-survey activities are ongoing.

The evaluation team decided to implement student interviews at one university in each subsequent year (IUPUI in 2020, CU Denver in 2021, and UofM in 2022). For the first year, seven scholars from IUPUI were interviewed. The interviews focused scholars' experiences with respect to resources/mentors, changes in career interests, and identity development. All interviewees considered themselves to be engineers/scientists and indicated interests towards STEM career choices and satisfaction with the project to keep their interests and motivation in STEM fields. In particular, scholars cited that interacting with peer leaders and the other scholars encouraged them to keep focusing on their academic goals, as exemplified in the interview excerpts below.

> ***Student A:*** *They [Peer leaders] are always there if you had questions about anything and they answer the questions well and taught well.*

> ***Student B:*** *With this program, I ended up making a lot of friends because I kind of just like it was inevitable. I'm with these people all the time, the same major. So that was pretty nice, we still study all the time, but we just like kind of do it together.*

> ***Student C:*** *That [PLTL] has a better opportunity to, for us to communicate because like it's about the time that we all have to be together anyway. . . I think it's better when the room person just because you see them struggle with the same thing. Like, oh, I'm not the only*

		Pre-Survey	Post-Survey	Hedge's g
Engineering Identity	**N**	35	17	1.488
	M	63.171	69.647	
	SD	3.884	5.037	
Engineering Self-Efficacy	**N**	35	17	0.736
	M	92.943	86.647	
	SD	8.967	7.132	
Intrinsic Value	**N**	35	17	0.722
	M	75.771	70.824	
	SD	5.699	8.553	
Sense of Belonging to Place	**N**	35	17	0.112
	M	25.371	25.118	
	SD	2.353	1.900	

Table 12.. Mean, Standard Deviation, and Effect Sizes of Pre- & Post- Surveys

one. I'm not the only one having a tough time with this class and you kind of get a sense of companionship in that way. . . And then you can support each other.

These findings are consistent with those of a broader analysis of semi-structured interviews conducted with scholars across all three campuses, focusing more specifically on STEM identity. This study further substantiated that peer relationships were a key factor in scholars' STEM identities (Stewart, 2022).

However, some students (3 out of 7) pointed out the difficulty of getting badges in CN. These difficulties related both to the timeliness of receiving earned badges on the CN and to challenges to participation in activities that could lead to earning badges, some of which were exacerbated by the pandemic. The evaluation team provided these students' feedback to PIs, and the PIs brainstormed opportunities to earn more badges, as exemplified in the excerpts below.

Student D: *We're kind of like talking about the badges and try to add more that are a little bit more accessible. Because like, there's research badges and internship badges, but like, not everyone gets an internship, they are in first or second year, and get chosen to be part of our research as much as we want to.*

Student E: *I do like the website [CN]. Getting a lot of our badges and earning different things from our campus. That's kind of tough and that's hard to keep up with. But the overall course networking experience is really cool for me and I do enjoy it.*

One potential explanation for impacts on both academic performance and satisfaction numbers is the impact of COVID-19 on the experience of these first-year scholars. The pandemic has impacted all three of the participating universities in drastic ways over the 2019-2020 academic year. All student outcome data and changes therein must be analyzed in light of the external impact of the pandemic. For example, the immediate use of online instructional measures may not have been implemented in a way that reached every student the same way that in-person courses would. Further, if students or their families were adversely affected by the pandemic or subsequent shutdown, their self-efficacy, confidence, motivation, identity, or otherwise satisfaction may be impacted from that fact alone.

Discussion

While it may not be explicit from the data presented, the programs described here are available to more than the scholars. For example, the Engineering Learning Community (ELC) at CU Denver contains about half scholars and half without the scholarship. At UofM, the STEM Ambassador program is ongoing outreach that engages mostly non-scholars. At IUPUI, PLTL is being expanded beyond the Calculus 1 course for scholars. Therefore, these programs go far beyond the numbers stated here to support student success across our institutions. The scholars are more directly engaged in some ways. They are more heavily encouraged or even required to participate, but it bears repeating that many of these supports have ripple effects that improve the experience of many more students than the ones accounted for here.

Another common component across the three institutions that may not be explicit is mentorship. Mentoring takes place in different formats, with different names, and yet all the student-scholars are mentored, whether by near-peers, faculty, or advisors, these students have regular check-ins. These mentoring sessions touch on issues directly related to academic success, and also more casually on issues that they sometimes call "adulting" – simply coping with life in general. These mentoring relationships became more important during the pandemic (Stewart et al., 2021).

Also, we cannot overstate the impact of the pandemic on this work. March 2020 was the first year for Cohort 1. We do not have a "normal" year to compare to directly. Shifting to remote or hybrid activities has made recruiting Cohort 2 and subsequent cohorts much more difficult, not only because events that would have been held in person were canceled, but also because the increased uncertainty students are dealing with has also caused them to delay college and college-related decisions. The pandemic is also having an unspecified effect on retention. Families have more precarious economic situations, which may be causing students to focus more on jobs. The modifications to instruction – to all remote and hybrid – may be changing student outcomes and motivation.

Conclusions

Our primary focus for the project is delivering a seamless program experience for our cohort of Urban STEM Collaboratory scholars across all three campuses and increasing cross-campus connections. It is anticipated that this will promote development of STEM identity and will increase student success and persistence in STEM majors. While limited results are available thus far, findings are promising in terms of academic performance and engineering identity. Additionally, positive impacts were seen with each of the campus-specific interventions (PLTL, the Engineering Learning Community, and STEM Ambassadors). More study is needed to determine specific impacts of each model and the potential for scale and replication at other institutions. As COVID-19 has resulted in significant challenges for students at all campuses, further study will be conducted to determine the ultimate implications for the scholars and the Collaboratory as a whole.

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