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Board 411: Training Socially Responsible and Engaged Data Scientists: Lessons from Four Student Cohorts

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Replicating the Community-Engaged Educational Ecosystem – differences in outcomes across students

Introduction

With the ongoing transition to the knowledge-based, mobile economy, cities in the United States recognize the importance of a STEM-literate workforce. In the depopulated, legacy industrial areas in the Midwest, cities fight to attract and retain an educated workforce – particularly workers with STEM skills. STEM-related jobs, which generally have higher wages and growth [2] are important to stabilizing and rebuilding their communities in the Digital Age. Yet, these areas also tend to have higher percentages of those underrepresented in STEM, including low socio-economic status (LSES) and underrepresented minorities (URM). Engagement and retention in STEM disciplines is of national importance, but for these regions it is critical to competing in the knowledge economy and revitalizing these cities.

The Center for Civic Innovation at the University of Notre Dame (UND) piloted a program leveraging what we know about STEM engagement, project-based learning (PBL), academic community engagement, and asset-based community development [3-12] with federal support (NSF *IUSE Exploration and Design Tier for Engaged Student Learning & Institution and Community Transformation)*. Through examination and refinement, researchers developed the *Community-Engaged Educational Ecosystem Model (C-EEEM, pronounced 'seam')* [1, 4, 13]. The C-EEEM pilot contributed to our understanding of how to build learning environments that support 1) improvements in student motivation and retention in STEM; 2) changes in place attachment for participants; and 3) community impacts from project implementation. [4-6, 13, 14]. Through support of an *NSF IUSE Development and Implementation Tier* grant, the C-EEEM is now in its second year for replication in two cities, Youngstown, Ohio and Louisville, Kentucky.

By operating in the complexity of a real-world context and providing more personalized learning and professional skill building supporting personalized learning and professional skill building, the C-EEEM represents and example of the future of engineering education [15]. Nonetheless, the C-EEEM learning environment also supports a range of STEM and STEM-adjacent disciplines. Through a careful curriculum that centers on community-driven, strategically developed projects in critical areas for these communities (e.g., affordable housing, sustainability and resilience, health equity, and government efficiency) high school and college students work in interdisciplinary teams with a high degree of autonomy. In doing so, it also produces as range of broader impacts – from neighborhood development and industry partnership to developing greater attraction to the region in the participants.

The C-EEEM has shown outcomes across all of the primary areas of interest. This paper examines the first two years of replication data on the Community-Engaged Educational

Ecosystem model (C-EEEM) in the three different Midwestern states. In doing so, we pay particular attention to underrepresented subgroups in STEM.

Replication of the C-EEEM

Although there is a long-term aim to replicate more broadly, researchers and partners are focusing on replicating the C-EEEM only in the Midwest for this study and current efforts. Partners chose the location of replication sites for their similarities to the pilot site region, such as depopulation, disinvested neighborhoods, and a high percentage of those underrepresented in STEM fields [1]. Nonetheless, these regions that have lost population over that last 50 years, have corresponding opportunities [16].

Participating institutions besides UND include the University of Louisville (UofL) and Youngstown State University (YSU). Each institution has different strengths for hosting the C-EEEM, but all are within the college/school of engineering at the anchor university. The demographics for underrepresented groups vary at each institution and within engineering, with some having higher representation from women and others for URM [1]. The cities themselves all have poverty rates higher than the official national rate (11.5%) – ranging from over 15% to over 33%.

Replicating the C-EEEM

Elements of the Community-Engaged Educational Ecosystem Model.

Researchers have described the Community-Engaged Educational Ecosystem Model in previous work [1, 4-6, 13]. However, it is best described as a hierarchy of nested layers (see Figure) that together support the internship and contrasts typical project-based learning approaches. The **collaborative infrastructure** in which the projects are developed and delivered involves network-building and sustained collaborations; this is not only between and within educational institutions, but also between and across community organizations [1, 17].

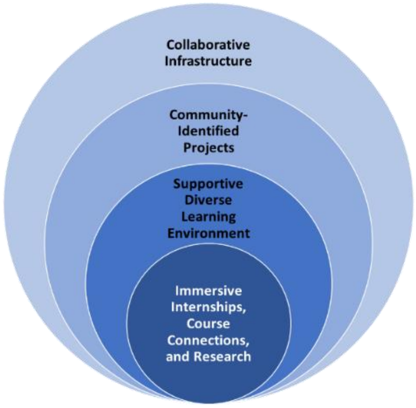


Figure 1 C-EEEM Hierarchy [1]

Community-identified projects are developed inside of this framework and the ongoing collaboration fosters contribution toward larger, complex community issues – broader impacts. By working to develop a faculty and professional network of diverse mentors and leveraging this for targeted recruitment, institutions build a **supportive and diverse learning environment** to deliver an **immersive internship** that provided connection to the community while contributing to important change.

Replication in the Second Year

In the first year of replication, the University of Notre Dame shared their orientation materials, and project planning strategies. Despite this aspect to facilitate the launch and alignment of the different sites, each site was recognized as having a unique approach. Differences in the programming delivered to students included team building, project refinement, and approaches to introducing interns to the local environment [1]. Further, the institutional supports for delivering the program varied at each site – with YSU partnering with a community nonprofit involved in redevelopment activities in Youngstown. Many of these implementation differences were captured in the first-year findings [1].

In the second year, the focus was on routinizing certain activities at each site on a general schedule. The pilot site had staff transitions, which meant that there were opportunities for co-learning across all of the locations, pilot and replication sites. Site managers held regular meetings prior to, during, and following the internship. This allowed for coordinating planning and troubleshooting, as well as the opportunity for a closure conversation. Recent conversations amongst PIs and site managers across the universities indicated that a longer debriefing would be valuable soon after the internship end. This would allow each site to share 'lessons learned' that may be helpful across sites, while the observations are still fresh.

Methods

This paper aggregates two years of implementation data from the replication of the Community-Engaged Educational Ecosystem (C-EEEM). Working with two summers (2022, 2023) of data enabled researchers to examine the impacts of the C-EEEM on smaller subgroups by aggregating the two cohorts, thereby increasing statistical power.

In the first year of the C-EEEM replication (2022), researchers began with data collection protocols and instruments developed in the original pilot at the University of Notre Dame, which were then modified slightly [1, 4, 5, 18-21]. Instruments included weekly check-in surveys for team feedback, prompts to encourage reflection on the experiences, and the main post-internship survey instrument. The original instruments reflected researchers' consistent interest of the impact of the C-EEEM on STEM-learning experiences for students generally and underrepresented groups in particular; these integrated considerations informed by research on high impact practices for STEM motivation and retention, as well as those for facilitating innovation ecosystems and place attachment [3-12, 22, 23].

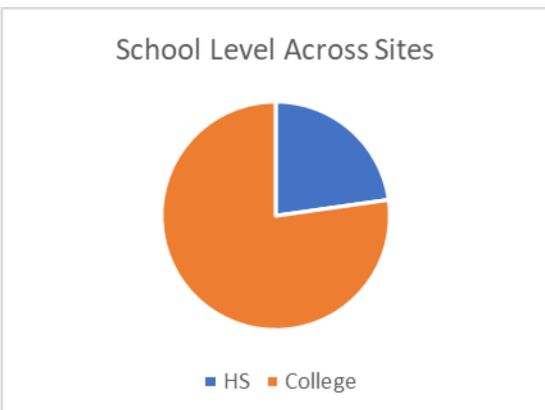
Researchers modified the post-internship survey from the pilot by augmenting it with items to examine the C-EEEM internships' outcomes in relation to Self Determination Theory (SDT) [24-26]. Since the original survey instrument had many overlapping items relevant to SDT, the amendments were few. The post-internship survey instrument was digitally delivered (Qualtrics platform) as a retrospective-pre/post using Likert-type scaling, with an emphasis on measuring dispositional shifts. In the pilot, researchers found that for estimating dispositional shifts in unfamiliar settings, the retrospective-pre/post is more sensitive than pre-post approaches [4, 19, 21, 27]. The University of Notre Dame's Institutional Review Board (IRB) provided review and approval for the sites of all three different universities.

The two summers of data (2022, 2023) for all three sites was aggregated and cleaned, with incomplete cases removed. Data was then sorted by subgroups of interest, including gender, race, socio-economic status, and education level and analyzed across the key constructs of interest. Researchers also analyzed each site separately to understand contextual and programmatic differences. Researchers used SPSS and Microsoft Excel for quantitative data analysis, which included running Paired-Samples T Tests for statistical significance for estimated impacts on the internship participants. Researchers also used Cohen's D to estimate the effect size of the internship (see Tables) and descriptive statistics.

Findings and Discussion

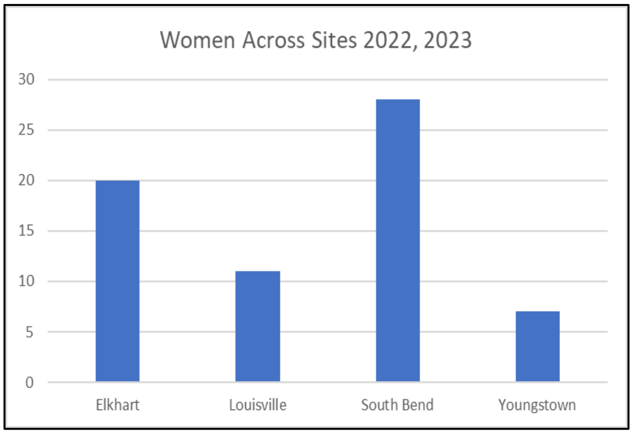
Demographics Across Sites

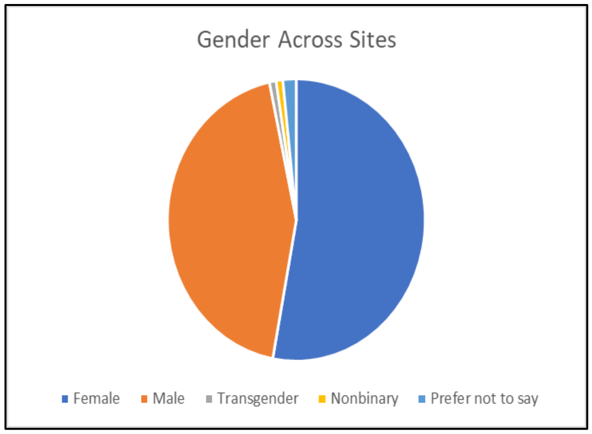
This describes the demographics over the first two years of replication. The data is aggregated across the original pilot site (South Bend-Elkhart) and the replications sites of Louisville and Youngstown. Many of the demographics across the sites reflected the long-term aims of the grant – which includes engagement of underrepresented groups.



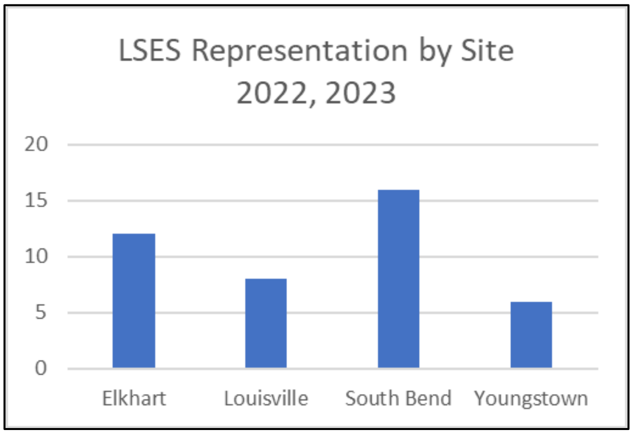
In the first year of the grant, replication sites were not expected to have high school students represented in their C-EEEM internships. Replication sites had committed to recruiting high school students in the second year. The mature pilot has well-developed programming with high schools, so continued to represent the majority of pre-college students.

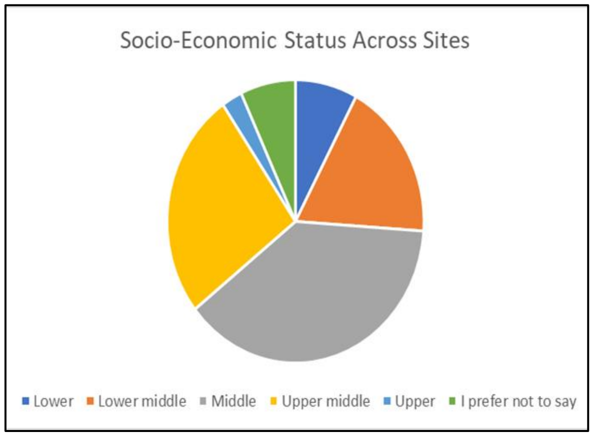
Across sites, there were slightly more female participants than male (See figure). In this two-year aggregation, as with the first year, the South Bend/Elkhart pilot disproportionately influenced the numbers. The original pilot site (with Elkhart and South Bend) had higher rates of female participation than the replication sites; however, both replication sites, especially Louisville, substantially improved their recruitment of women to their programs.



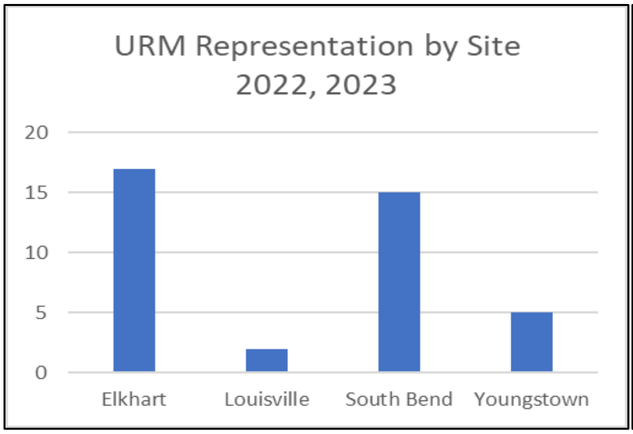


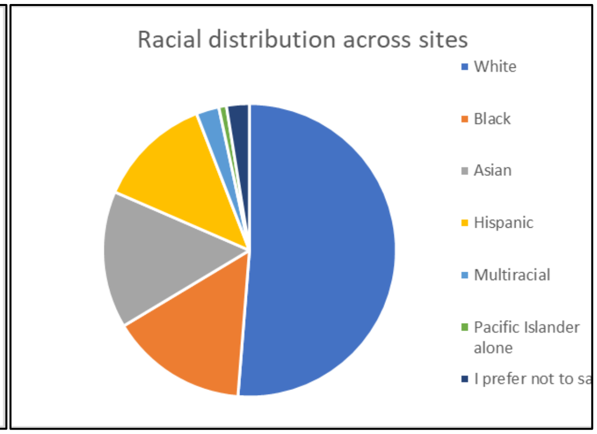
Socio-economic status (SES) was self-described, with more than 25% across the three sites identifying as Lower Middle income to Lower income (See figure). Over the first two years of implementation, the South Bend/Elkhart site had the largest number of lower SES (LSES), but the proportion was higher at the Youngstown site. A fair proportion of the participants chose not to disclose their SES.





Underrepresented minorities (URM) self-identified as well, with Hispanic ethnicity expressed separately (e.g., "Black alone, non-Hispanic). Across sites, approximately half of the participants were white, with the remainder primarily Asian, Black, and Hispanic ethnicity. The pilot site again impacted the overall numbers, but the proportion of URM (Black or African American alone, non-Hispanic, Multiracial, Pacific Islander alone, Hispanic) at the Youngstown site was similar. See the figures below for distributions.





Student Outcomes Across Sites

To extend the first-year findings, this paper focuses on student outcomes across the same key constructs as examined in year one. These outcomes are related to the grant aims and the original findings from the pilot, which were grouped into the areas of interest –*confidence and experience in STEM*, *problem-solving and teamwork skills*, and *contribution and attachment to the region*. [1] Data presented includes analysis of the two years of aggregated data across all three sites, as well as analysis of the subgroups and individual site data. This allows for examining the differences – strengths and weaknesses of the program for particular subgroups or of the implementation at a particular site. In keeping with the findings from the pilot [1, 4, 5, 18], the C-EEEM has a greater impact on underrepresented groups (women, URM, LSES) despite showing statistically significant differences across the whole of the two years of interns.

Outcomes across All Sites for the Two Years

Across the three sites for the two years of data, researchers saw highly statistically significant changes in all of the construct areas (*confidence and experience in STEM*, *problem-solving and teamwork skills*, and *contribution and attachment to the region*). The effect size for most of the items was medium (.5 to .8). These outcomes were generally consistent across sites.

STEM Confidence and Experience

Question	TTEST	df	pvalue	Cohen's D	Effect Size
I have identified, accessed, cleaned and/or analyzed data in addressing a real-world issue	8.65	121	<0.001**	0.783	Medium
I am comfortable collecting information and analyzing it.	9.33	122	<0.001**	0.707	Medium
I would do well in a field that uses technical skills.	6.41	121	<0.001**	.508	Medium
I feel confident that I could take things I learn and apply them to challenges in real-world situations.	11.1	122	<0.001**	1.002	Large

Problem Solving and Teamwork Skills

Question	TTEST	df	pvalue	Cohen's D	Effect Size
I am comfortable speaking in front of groups about my work.	8.58	115	<0.001**	0.796	Medium
I enjoy solving open-ended problems that do not have a single solution.	7.09	116	<0.001**	0.655	Medium
I am confident that I can manage conflict or tensions when working on a team.	4.52	120	<0.001**	0.411	Small
I know how to apply design thinking to problem-solving in the real world.	9.34	122	<0.001**	.842	Large
I enjoy problem-solving with people with different perspectives.	6.04	122	<0.001**	0.544	Medium

Contribution and Attachment to the Region

Question	TTEST	df	pvalue	Cohen's D	Effect Size
I feel a connection to the (PLACE) region.	7.97	107	<0.001**	.766	Medium
I can make meaningful contributions to society through STEM skills.	5.01	118	<0.001**	0.459	Small
I can imagine myself living in this region at some point after I graduate.	6.07	117	<0.001**	0.559	Medium
I understand how positive change happens in communities	9.42	121	<0.001**	0.853	Large
My work will impact others	7.00	122	<0.001**	0.631	Medium

Outcomes for Women across All Sites for the Two Years

As noted, the C-EEEM has a greater impact on women. Although all of the main constructs showed statistical significance across populations, the effect size for many was larger for women. This is true on several of the critical factors that are related to professional identity and retention in STEM long term (e.g., "I am comfortable collecting information and analyzing it").

Women: STEM Confidence and Experience

Question	TTEST	df	pvalue	Cohen's D	Effect Size
I have identified, accessed, cleaned and/or analyzed data in addressing a real-world issue	6.88	65	<0.001**	0.847	Large
I am comfortable collecting information and analyzing it.	6.64	66	<0.001**	0.811	Large
I would do well in a field that uses technical skills.	5.79	65	<0.001**	0.713	Medium
I feel confident that I could take things I learn and apply them to challenges in real-world situations.	8.99	66	<0.001**	1.10	Large

Women: Problem Solving and Teamwork Skills

Question	TTEST	df	pvalue	Cohen's D	Effect Size
I am comfortable speaking in front of groups about my work.	7.94	60	<0.001**	1.02	Large
I enjoy solving open-ended problems that do not have a single solution.	5.92	62	<0.001**	0.745	Medium
I am confident that I can manage conflict or tensions when working on a team.	4.10	64	<0.001**	0.509	Medium
I know how to apply design thinking to problem-solving in the real world.	7.81	66	<0.001**	.955	Large
I enjoy problem-solving with people with different perspectives.	4.33	66	<0.001**	0.529	Medium

Women: Contribution and Attachment to the Region

Question	TTEST	df	pvalue	Cohen's D	Effect Size
I feel a connection to the (PLACE) region.	5.52	59	<0.001**	.712	Medium
I can make meaningful contributions to society through STEM skills.	3.82	63	<0.001**	0.477	Small
I can imagine myself living in this region at some point after I graduate.	5.73	62	<0.001**	0.722	Medium
I understand how positive change happens in communities	6.82	66	<0.001**	0.833	Medium
My work will impact others	5.77	66	<0.001**	0.750	Medium

Outcomes for Underrepresented Minorities (URM) across All Sites for the Two Years

Similarly, other subgroups of interest, such as interns that are URM also showed larger effect sizes for several of the factors of interest. Not only was this true on factors related to STEM identity and confidence, but also on factors related to place attraction. While the change for "I can imagine myself living in this region at some point after I graduate" is statistically significant for the overall data, the effect size for the URM subgroup is larger.

URM: STEM Confidence and Experience

Question	TTEST	df	pvalue	Cohen's D	Effect Size
I have identified, accessed, cleaned and/or analyzed data in addressing a real-world issue	5.634	38	<0.001**	0.902	Large
I am comfortable collecting information and analyzing it.	5.03	38	<0.001**	0.805	Large
I would do well in a field that uses technical skills.	4.78	38	<0.001**	.766	Medium
I feel confident that I could take things I learn and apply them to challenges in real-world situations.	6.90	38	<0.001**	1.11	Large

URM: Problem Solving and Teamwork Skills

Question	TTEST	df	pvalue	Cohen's D	Effect Size
I am comfortable speaking in front of groups about my work.	6.26	36	<0.001**	1.03	Large
I enjoy solving open-ended problems that do not have a single solution.	3.75	38	<0.001**	0.600	Medium
I am confident that I can manage conflict or tensions when working on a team.	3.95	38	<0.001**	0.633	Medium
I know how to apply design thinking to problem-solving in the real world.	6.02	38	<0.001**	0.963	Large
I enjoy problem-solving with people with different perspectives.	3.1	38	0.002*	0.496	Small

URM: Contribution and Attachment to the Region

Question	TTEST	df	pvalue	Cohen's D	Effect Size
I feel a connection to the (PLACE) region.	5.30	36	<0.001**	.871	Large
I can make meaningful contributions to society through STEM skills.	3.20	37	0.001*	0.519	Medium
I can imagine myself living in this region at some point after I graduate.	4.84	37	<0.001**	0.786	Medium
I understand how positive change happens in communities	5.56	38	<0.001**	0.890	Large
My work will impact others	4.56	38	<0.001**	0.730	Medium

Outcomes for Low Socio-Economic Status (LSES) across All Sites for the Two Years

Interns from a LSES background showed changes in outcome areas of interest as well, but effect sizes were both lower ("I can imagine myself living in this region at some point after I graduate.") and higher than the general population of interns (I am comfortable collecting information and analyzing it; I would do well in a field that uses technical skills; My work will impact others).

LSES: STEM Confidence and Experience

Question	TTEST	df	pvalue	Cohen's D	Effect Size
I have identified, accessed, cleaned and/or analyzed data in addressing a real-world issue	5.86	41	<0.001**	0.903	Large
I am comfortable collecting information and analyzing it.	3.82	41	<0.001**	0.590	Medium
I would do well in a field that uses technical skills.	4.43	41	<0.001**	0.683	Medium
I feel confident that I could take things I learn and apply them to challenges in real-world situations.	6.18	41	<0.001**	0.954	Large

LSES: Problem Solving and Teamwork Skills

Question	TTEST	df	pvalue	Cohen's D	Effect Size
I am comfortable speaking in front of groups about my work.	6.27	40	<0.001**	0.979	Large
I enjoy solving open-ended problems that do not have a single solution.	3.71	40	<0.001**	0.58	Medium
I am confident that I can manage conflict or tensions when working on a team.	2.80	41	0.004*	0.432	Small
I know how to apply design thinking to problem-solving in the real world.	6.07	41	<0.001**	.937	Large
I enjoy problem-solving with people with different perspectives.	3.41	41	<0.001**	0.525	Medium

LSES: Contribution and Attachment to the Region

Question	TTEST	df	pvalue	Cohen's D	Effect Size
I feel a connection to the (PLACE) region.	4.58	38	<0.001**	.733	Medium
I can make meaningful contributions to society through STEM skills.	3.03	39	0.002*	0.475	Small
I can imagine myself living in this region at some point after I graduate.	2.17	40	0.018*	0.339	Small
I understand how positive change happens in communities	5.89	41	<0.001**	0.909	Large
My work will impact others	5.28	41	<0.001**	0.815	Medium

Outcomes for High School students across All Sites for the Two Years

Within the subgroups examined, High School aged interns showed the greatest effect sizes across the three sites. This is in keeping with findings from the pilot, but also aligns with researchers' understanding of this work as a 'gateway' experience. By this, we mean that impacts have shown to be higher with participants from late high school to early college [1]. Our previous work examined Self Determination Theory (SDT) as a theoretical underpinning [24] to understand the impacts of the C-EEEM; as a first or early internship experience, the C-EEEM, for many, satisfies the requirements of autonomy, relatedness, and competence opportunities.

High School: STEM Confidence and Experience

Question	TTEST	df	pvalue	Cohen's D	Effect Size
I have identified, accessed, cleaned and/or analyzed data in addressing a real-world issue	6.08	27	<0.001**	1.148	Large
I am comfortable collecting information and analyzing it.	4.54	27	<0.001**	0.859	Large
I would do well in a field that uses technical skills.	3.68	27	<0.001**	0.696	Medium
I feel confident that I could take things I learn and apply them to challenges in real-world situations.	6.32	27	<0.001**	1.19	Large

High School: Problem Solving and Teamwork Skills

Question	TTEST	df	pvalue	Cohen's D	Effect Size
I am comfortable speaking in front of groups about my work.	5.79	25	<0.001**	1.136	Large
I enjoy solving open-ended problems that do not have a single solution.	3.79	25	<0.001**	0.744	Medium
I am confident that I can manage conflict or tensions when working on a team.	3.05	27	0.003*	0.576	Medium
I know how to apply design thinking to problem-solving in the real world.	5.88	27	<0.001**	1.111	Large
I enjoy problem-solving with people with different perspectives.	3.79	25	0.001**	0.636	Medium

High School: Contribution and Attachment to the Region

Question	TTEST	df	pvalue	Cohen's D	Effect Size
I feel a connection to the (PLACE) region.	4.44	24	<0.001**	.888	Large
I can make meaningful contributions to society through STEM skills.	3.01	26	0.003*	0.563	Medium
I can imagine myself living in this region at some point after I graduate.	1.98	27	0.029*	0.374	Small
I understand how positive change happens in communities	6.81	27	<0.001**	1.287	Large
My work will impact others	5.39	27	<0.001**	1.018	Large

Moving Forward

In year two of this replication grant for the Community-Engaged Educational Ecosystem model approach, pilot and replication sites continue to have important outcomes that support STEM confidence, identity, and retention – as well as place attachment for these Midwestern regions. Despite the community and institutional contextual differences [1], these experiences inside the core elements of the model produce similar types of impacts on participating students. Ideally, each region will begin to build an educational culture whereby project-based learning and community-identified challenges are woven together and broader impacts as part of learning becomes the norm. If they are to fulfill this vision, each of the sites will need to continue to refine their work and strengthen their partnerships for designing and implementing projects.

Next steps for the sites include projects that are implemented across all three sites. This requires identifying common topics across the cities that community-partners all have an interest in – such as walkability and tree canopy measurement and development. In doing so, the sites functionally hold part of the 'curriculum' of the C-EEEM constant, allowing for an understanding of the influences of differences in programmatic implementation and the contextual setting (culture, institutional assets, etc.) on student outcomes. This may help researchers to understand the different approaches to developing a C-EEEM within a particular community or institutional setting for future replications.

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