



RESEARCH ARTICLE

Increasing Students' Scientific Self-Efficacy and Scientific Identity Through Community-Engaged Microbiology

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Abstract

Community-engaged (CE) microbiology courses allow students to apply microbiology concepts to real-world environmental challenges while contributing to community needs. Studies have demonstrated educational benefits of CE microbiology experiences, but less is known about their influence on psychosocial factors associated with STEM persistence. This study used the Tripartite Integration Model of Social Influence (TIMSI) to examine changes in students' scientific self-efficacy, scientific identity, and scientific value orientation in a CE undergraduate microbiology course at Bellarmine University. Students partnered with Kentucky Watershed Watch

(KyWW), a nonprofit organization focused on monitoring Kentucky waterways, to conduct water quality assessments and compare *E. coli* detection methods. Pre- and post-surveys revealed significant increases in students' scientific self-efficacy, scientific identity, and confidence in microbiology laboratory skills, while changes in scientific value orientation were not significant. These findings indicate that CE microbiology courses can not only support students' learning and integration into the scientific community but also contribute to community-based environmental efforts.

Introduction

Microbes play a critical role in many challenges that face modern society, including environmental health, infectious disease, and antimicrobial resistance. As a result, undergraduate microbiology courses increasingly prioritize helping students understand the connections between microbes and real-world issues. The American Society for Microbiology (ASM) Curriculum Guidelines encourage opportunities for students to develop conceptual understanding and scientific thinking, and for authentic application rather than the rote memorization of facts (Boury et al., 2024).

One approach to achieving these goals is community-engaged (CE) learning, a high-impact educational practice that combines students' learning with meaningful community partnerships, benefiting all parties. CE microbiology courses can provide students with opportunities to participate in real-world scientific practices that positively impact their communities. Research studies have demonstrated that CE or service-learning microbiology courses can deepen student understanding of microbiology concepts and enhance student civic responsibility and public health awareness (Webb, 2016; Webb, 2017). A CE course-based undergraduate research experience (CURE) in an undergraduate microbiology course increased students' scientific process skills, communication skills, and cultural competency (Malotky et al., 2020). A health professions microbiology course with student-driven service learning reported high student satisfaction and strong perceived relevance to population health (Lowrey, 2020).

Environmental microbiology is a subfield well suited to CE learning due to its connection to current environmental challenges and to the accessible nature of environmental samples. Students can often readily collect soil and water samples on or near their college campus, enabling the scientific investigation of microbial communities. Undergraduate students have contributed to environmental microbiology initiatives through CUREs and community partnerships focused on environmental monitoring (Adkins-Jablonsky et al., 2020; Fuhrmeister et al., 2021; Tawde & Williams, 2020).

We hypothesized that, in addition to increasing students' understanding of microbiology concepts, CE experiences may foster psychosocial factors associated with

student persistence and success in STEM disciplines. Scientific self-efficacy, defined as a person's confidence in their ability to perform scientific tasks and succeed in science, has been linked to academic achievement and satisfaction and is accomplished through participation in authentic scientific experiences (Syed et al., 2019; Nguyen et al., 2026). Scientific identity, the extent to which a person perceives themselves as a scientist and feels they belong in the scientific community, has been associated with higher persistence in STEM majors and careers, participation in undergraduate research experiences, and engagement in science despite academic challenges (Carlone & Johnson, 2007; Chemers et al., 2011; Hazari et al., 2010). Value orientation is the degree to which individuals believe science is useful, worthwhile, and important for their personal and professional lives, and research suggests it is a key motivational construct associated with persistence in STEM pathways (Guo et al., 2018; Perez et al., 2019). Together, scientific self-efficacy, scientific identity, and value orientation make up the core constructs of the Tripartite Integration Model of Social Influence (TIMSI), a framework used to explain students' integration into scientific communities and persistence in STEM pathways (Estrada et al., 2018).

While prior studies have investigated the educational benefits of CE microbiology experiences, relatively few have examined how these experiences influence students' scientific self-efficacy, scientific identity, and value orientation. To address this gap, we surveyed students before and after participation in a CE undergraduate microbiology course at Bellarmine University using the TIMSI. In the course, students partnered with the statewide nonprofit Kentucky Watershed Watch (KyWW) to conduct environmental microbiology studies focused on water quality monitoring. Students collected water quality data from two local creeks and conducted a comparative study testing two *E. coli* detection methods. Deliverables provided to KyWW included water quality assessment data and evidence supporting the comparability of the two detection methods, which informed KyWW's monitoring practices.

Through this work, the CE course provided students with an authentic opportunity to contribute to environmental stewardship efforts and apply microbiology

concepts in a real-world context. By examining the student outcomes of a CE microbiology course, this work contributes to the understanding of how CE learning supports student development and engagement in undergraduate STEM education.

Methods

Institutional Setting and Class Format

The institution is a liberal arts university located in the United States. It is a primarily undergraduate institution, with approximately 2,100 full-time undergraduate students and 570 full-time graduate students. Approximately 30% of students are from underrepresented racial or ethnic groups, 39% are first-generation college students, and 45% are Pell recipients. In 2025, the Carnegie Foundation and the American Council on Education designated Bellarmine as an Opportunity College and University.

To earn a Bachelor of Science in Biology, students are required to complete basic courses in biology and choose 12 credit hours from additional science courses, including microbiology. The four-credit-hour microbiology course is offered every fall semester and includes lecture and laboratory components. The course laboratory meets in person each week for three hours. Course learning objectives include an exploration of the functional, ecological, and evolutionary relationships among bacteria, fungi, viruses, and protozoa, focusing on microbial physiology, pathogenesis, and immunology.

Course Participants

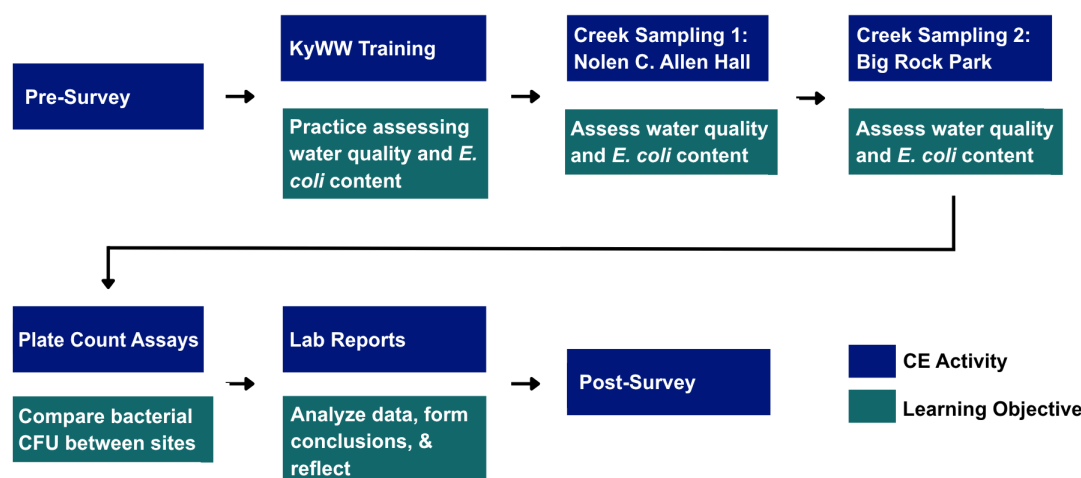
Twenty-one undergraduate students in the CE course completed both the pre- and post-surveys. Pre-surveys were administered during the course's first laboratory meeting, and post-surveys were administered during the course's last laboratory meeting, 12 weeks later. Approximately 86% of the students were white, and 71% were women. Students were either juniors (29%) or seniors (71%), and five students (24%) participated in faculty-mentored research outside of the CE course and during the same time period.

Community-Engaged Course Design

The instructor created a CE microbiology course through a partnership with KyWW, a statewide nonprofit organization formed to "support water quality monitoring that informs, connects, and empowers volunteers and their communities for the improvement and protection of Kentucky's water resources" (Kentucky Watershed Watch, n.d.). Course design reflected the goal to mutually benefit students and KyWW.

Most of the CE coursework occurred during course laboratory meetings, with some independent training, data analysis, and reflection outside of class time. Approximately 18 hours of laboratory course time over six three-hour laboratory meetings were dedicated to CE work. After taking pre-surveys, students ($N=21$) were trained in water quality sampling methods, including assessing water temperature, pH, conductivity, turbidity, stream flow, and bacterial contents (Figure 1). Following training,

FIGURE 1. Timeline of Course CE Activities. CE activities and learning objectives are shown in blue and green, respectively.



students completed two creek samplings of Beargrass Creek at sites near Bellarmine University's campus. Beargrass Creek is a watershed running through Louisville, Kentucky, covering about 60 square miles. Two Beargrass Creek sites were chosen, primarily for their proximity to campus. The first is part of the South Fork of Beargrass Creek and is on Bellarmine University's campus, running behind Nolen C. Allen Hall. The second creek sampling site is part of the Middle Fork of Beargrass Creek and is approximately two miles from the campus.

Students assessed water quality at both sites. They also measured creek water *E. coli* concentrations via two methods: R-cards and IDEXX Quanti-Tray tests. R-cards, produced by Roth Biosciences, are self-contained, rapid microbiological tests used to quantify *E. coli*. R-cards are cost effective, portable, and volunteer friendly, and KyWW uses them to monitor stream water quality. IDEXX Quanti-Trays are a U.S. Environmental Protection Agency-approved method that utilizes the most probable number (MPN) approach to determine the number of *E. coli* in a water sample. IDEXX Quanti-Trays are laboratory based and require more reagents, equipment, and skills than the R-card method. Students measured *E. coli* concentrations in the same creek water samples using both the R-card and IDEXX Quanti-Tray methods and completed subsequent analysis to compare the agreement between the two methodologies. KyWW representatives used this comparative study to inform their approach to monitoring water quality.

Students also completed plate count assays to assess and compare total bacterial colony-forming units (CFU) at the two creek sites. Upon completion of the laboratory experiments, students presented their work in a formal laboratory report, which was graded by the instructor. In the laboratory report, students also reflected on their experiences, including how they and the community partner benefited from the CE course, and whether they believed it was an effective way to learn environmental microbiology.

The course had three goals related to CE coursework: reflective learning, integrative learning, and collaborative action. These objectives were adapted by Bellarmine University's Center for Community Engagement from the Brown University Swearer Center for Public Service. Reflective learning involved the application of material learned through CE coursework to their lives and the

lives of those around them. Integrative learning involved students' connection of knowledge across fields of study and inquiry in relation to CE experiences. Collaborative action involved students' work with community partners to inform future actions and practices.

Community Partner Benefits

In a CE course, the community partner and students should benefit from the work. The laboratory component of the microbiology course was designed to ensure that student effort and work would produce meaningful information for KyWW. Student monitoring of water quality in Beargrass Creek contributed to the organization's mission to evaluate Kentucky waterways. Additionally, the comparison study of two methodologies for *E. coli* creek water concentrations provided valuable information regarding the validity of KyWW's current use of R-cards by citizen scientists across Kentucky. All data generated by students were shared promptly with KyWW.

Student Surveys

This research study was approved by Bellarmine University's Institutional Review Board. Surveys were administered on paper and matched using anonymous participant identifiers. Students were not required to participate, and results were not analyzed until after the course had closed.

Survey questions assessing students' perspectives on CE were adapted from the student survey (longer version) in *Assessing Service-Learning and Civic Engagement: Principles and Techniques* (Gelmon et al., 2018). The TIMSI model was used to assess students' scientific self-efficacy, scientific identity, and value orientation (Estrada et al., 2018). The researchers developed eight survey questions to assess students' confidence in performing microbiology laboratory tasks, including performing a four-quadrant streak plate to isolate bacterial colonies, using a compound microscope to observe bacteria, preparing and interpreting a Gram stain, measuring *E. coli* in environmental water samples, analyzing experimental data, designing a microbiology experiment, accurately interpreting laboratory observations and results, and following safety protocols. These items aligned with course learning objectives.

Likert response options for scientific self-efficacy and confidence performing microbiology laboratory tasks ranged from 1 (not at all confident) to 5 (absolutely confident). Response options for scientific identity and student perspectives on CE ranged from 1 (strongly disagree)

to 5 (strongly agree), whereas response options for value orientation ranged from 1 (not at all like me) to 5 (very much like me). Pre- and post-survey data were analyzed using IBM SPSS Statistics Version 29. Normality was assessed, and normally distributed variables were analyzed via paired samples t-tests. Non-normally distributed variables were evaluated using a Wilcoxon signed-rank test. Statistical significance was established at $p=0.05$. Internal consistency was assessed using Cronbach's α .

Student Assessments and Reflections

At the conclusion of the CE project, students presented their findings in formal laboratory reports. Laboratory reports included an abstract, introduction, materials and methods, results, and conclusion, and accounted for 5% of the final grade. Students also completed a 400-word written reflection. Reflections addressed three prompts: (1) How did you benefit from the work? (2) How did KyWW benefit from the work? and (3) Do you think this partnership is an effective way to learn environmental

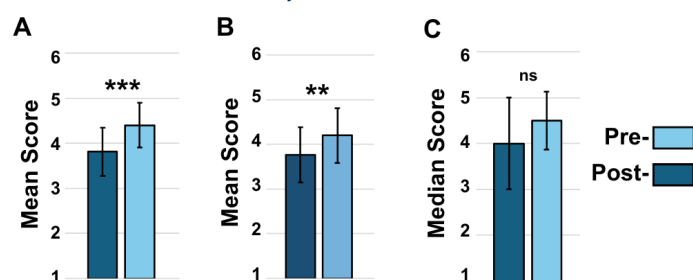
microbiology? Reflection responses were analyzed using an inductive thematic approach. All reflections were reviewed multiple times to identify recurring ideas, which were grouped into themes. The frequency of each theme was then recorded to characterize common student experiences.

Results

Scientific Self-Efficacy, Scientific Identity, and Value Orientation

The TIMSI framework was used to measure the effects of the CE course on students' scientific self-efficacy, scientific identity, and value orientation. Internal consistency of the constructs was assessed using Cronbach's α (Table 1), which ranged from .74–.86, indicating acceptable to good reliability and supporting the use of averaged item responses to create composite scores.

FIGURE 2. Composite pre- and post-assessment scores (N=21) for the TIMSI student survey measuring scientific self-efficacy (A), scientific identity (B), and value orientation (C)



Self-efficacy survey responses were ranked on the Likert scale from 1 (not at all confident) to 5 (absolutely confident), science identity survey responses were ranked on the Likert scale from 1 (strongly disagree) to 5 (strongly agree), and value orientation survey responses were ranked on the Likert scale from 1 (not at all like me) to 5 (very much like me). Paired sample t-tests were used to assess the statistical significance of scientific self-efficacy and scientific identity ($p<.01$ (**), $p<.001$ (***)). Value orientation scores were not normally distributed and were evaluated using a Wilcoxon signed-rank test ($p=0.54$). A and B represent mean scores (standard deviation), while C represents the median score (interquartile range).

TABLE 1. Cronbach's Alpha for Pre- and Post-Assessments (N=21)

CONSTRUCT	ITEMS	PRE-SURVEY	POST-SURVEY
Scientific Self-Efficacy	6	0.75	0.86
Scientific Identity	5	0.77	0.80
Value Orientation	4	0.81	0.74

TABLE 2. Pre- and Post-Assessment Means for Scientific Self-Efficacy and Scientific Identity (N=21)

	PRE- MEAN (SD)	POST-MEAN (SD)	MEAN DIFFERENCE	t	p VALUE	COHEN'S d
Scientific Self-Efficacy	3.81 (0.53)	4.40 (0.50)	0.59	4.55	<.001	0.99
Scientific Identity	3.76 (0.62)	4.20 (0.61)	0.44	3.58	.002	0.78

TABLE 3. Pre- and Post-Assessment Medians for Value Orientation (N=21)

	PRE-MEDIAN (IQR)	POST-MEDIAN (IQR)	Z	p VALUE	COHEN'S d
Value Orientation	4.0 (1.0)	4.5 (0.63)	-1.93	.054	0.99

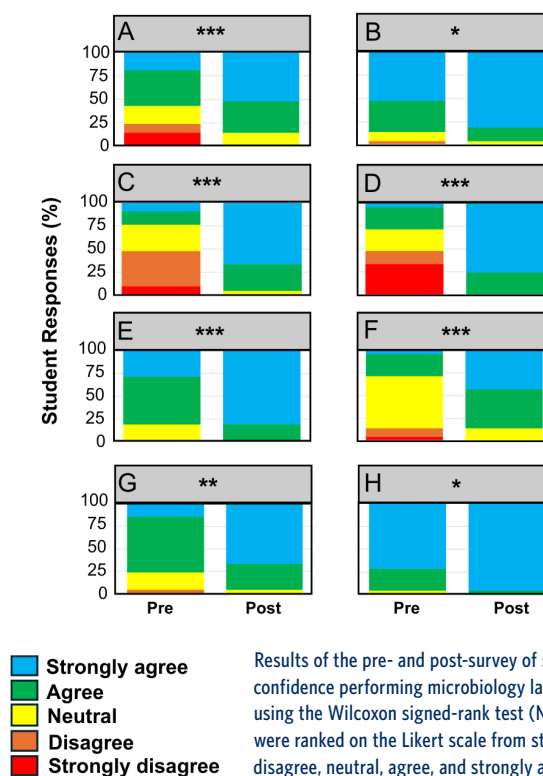
TABLE 4. Pre- and Post-Survey Assessment of Students' Confidence Performing Microbiology Laboratory Skills (N=21)

	Question	Z	P-value	Pre-Survey Median (IQR)	Post-Survey Median (IQR)	Effect size
A	Perform a four-quadrant streak plate to isolate bacterial colonies.	-3.08	0.002	4.0 (1.5)	5.0 (1.0)	0.67
B	Use a compound microscope to observe bacteria.	-2.309	0.021	5.0 (1.0)	5.0 (0.0)	0.50
C	Prepare and interpret a Gram stain of bacterial samples.	-3.764	<.001	3.0 (1.5)	5.0 (1.0)	0.82
D	Measure <i>E. coli</i> in environmental water samples using microbiological techniques.	-3.85	<.001	3.0 (3.0)	5.0 (0.5)	0.84
E	Analyze experimental data from lab experiments.	-3.419	<.001	4.0 (1.0)	5.0 (0.0)	0.75
F	Design an experiment to test a microbiology-related hypothesis.	-3.501	<.001	3.0 (1.0)	4.0 (1.0)	0.76
G	Accurately interpret lab observations and results.	-3.013	0.003	4.0 (0.5)	5.0 (1.0)	0.66
H	Follow safety protocols when working with bacterial cultures.	-2.121	0.034	5.0 (1.0)	5.0 (0.0)	0.46

Pre- and post-surveys measured scientific self-efficacy using six items designed to measure students' confidence in performing scientific activities. An example item is, "I can generate a research question to answer." Mean scientific self-efficacy scores significantly increased from 3.81 (SD=0.53) to 4.40 (SD=0.50), $t(20)=4.55$, $p<.001$, $d=0.99$ (Table 2; Figure 2A).

Scientific identity was measured using five items designed to evaluate the extent to which students identified as scientists. An example item is, "I feel like I belong in the field of science." Mean scientific identity scores increased from 3.76 (SD=0.62) to 4.20 (SD=0.61) (Table 2; Figure 2B). A paired-samples t -test indicated that this increase was statistically significant, $t(20)=3.58$, $p=.002$, with a large effect size ($d=0.78$).

The value orientation measure was evaluated using four items designed to assess how much students value scientific objectives, the specific, measurable goals that guide scientific research. An example item is "A person who feels discovering something new in the sciences is thrilling." Value orientation scores (Table 3, Figure 2C)

FIGURE 3. Microbiology Lab Skills

Results of the pre- and post-survey of students' confidence performing microbiology laboratory skills using the Wilcoxon signed-rank test (N=21). All questions were ranked on the Likert scale from strongly disagree, disagree, neutral, agree, and strongly agree from 1 to 5, respectively. Median and interquartile range values were rounded to the nearest tenth. $p<.05$ (*), $p<.01$ (**), and $p<.001$ (***).

TABLE 5. Likert-Scale Survey Items Used to Assess Students' Perspectives on Community-Based Learning Before and After the Course (N=21)

	Question	Z	P-value	Pre-Survey Median (IQR)	Post-Survey Median (IQR)	Effect Size
A	The community participation aspect of this course (will help/helped) me to see how microbiology can be used in everyday life and work.	-2.309	0.021	5.0 (1.0)	5.0 (0.0)	0.50
B	The community work I do through this course (will help/helped) me to better understand the lectures and readings in this course.	-2.814	0.005	4.0 (1.0)	5.0 (1.0)	0.61
C	The idea of combining work in the community with university coursework should be practiced in more classes at this university.	-2.443	0.015	4.0 (2.0)	5.0 (1.0)	0.53
D	I (am/was) responsible for the quantity and quality of the knowledge that I (obtain/obtained) from this course.	-1.613	0.107	4.0 (1.0)	5.0 (1.0)	0.35
E	The community work involved in this course (will help/helped) me to become more aware of the needs in my community.	0.0	1.0	4.0 (1.0)	4.0 (1.0)	0.00
F	I have a responsibility to serve my community.	-0.378	0.705	4.0 (1.0)	4.0 (1.0)	0.08
G	Most people can make a difference in their community.	0.0	1.0	5.0 (1.0)	5.0 (1.0)	0.00
H	The work I perform in the community (will enhance/enhanced) my ability to communicate my ideas in a real-world context.	-0.707	0.48	4.0 (1.0)	5.0 (1.0)	0.15

Note. Wording in pre- and post-surveys differed slightly, and both versions are presented in parentheses for each survey item, with pre-survey verbiage appearing before post-survey. Items A-H correspond to panels A-H in Figure 4.

were not normally distributed and were evaluated using a Wilcoxon signed-rank test. The median score increased from 4.0 (IQR=1.0) to 4.5 (IQR=0.63); this change was not statistically significant ($Z=-1.93$, $p=.054$), despite a moderate effect size ($d=.42$).

Confidence in Performing Microbiology Laboratory Skills

The course learning objectives included fundamental microbiology laboratory skills. Survey items asked students about their confidence performing a four-quadrant streak plate, using a microscope to observe bacteria, preparing and interpreting a Gram stain of bacteria, measuring *E. coli* in environmental samples, analyzing experimental

data, designing an experiment, interpreting observations and results, and following safety protocols while working with bacteria (Table 4). Pre- and post-surveys indicated significant increases in all eight measures of student confidence in the microbiology laboratory (Table 4; Figure 3).

Perspectives on Community-Engaged Work

Pre- and post-survey items assessed students' perspectives on this CE course, attitudes toward community involvement, and personal reflections (Table 5). Questions A, B, and C showed statistically significant increases. These items assessed students' views on the role of community participation in demonstrating the relevance of microbiology to everyday life and work, enhancing

TABLE 6. Selected Quotations from Student Reflections Upon Conclusion of the CE Project

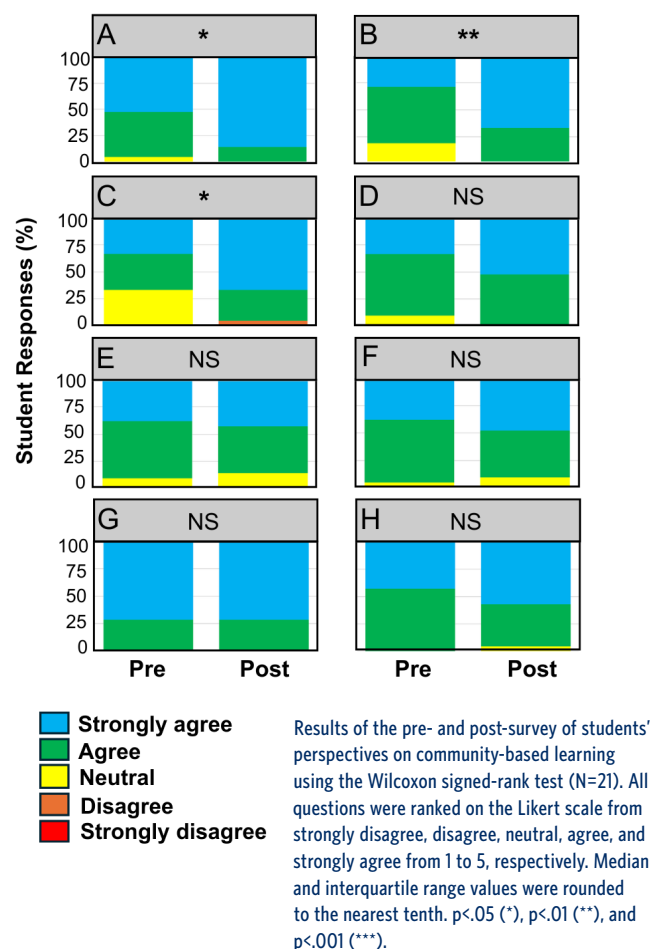
QUOTE
"I believe this partnership was an extremely effective way to learn environmental microbiology, proving that experiential learning strengthens understanding far more than classroom learning alone."
"Through this community engagement collaboration, we not only gained hands-on experience in a lab but also field experience that connected classroom learning to real-world application ... I also appreciated knowing that our testing served a larger purpose beyond the classroom."
"It's one thing to sit in class and learn about microbes and their effects, which is great, but getting to see it in action and actually being able to be part of something bigger than ourselves is such an eye-opening opportunity."
"The partnership with KyWW is a great way to learn, it changes things like serial dilution and <i>E. coli</i> calculations from abstract steps into tools for helping the community."
"While we have discussed <i>E. coli</i> in coursework, using the IDEXX protocol to quantify its actual presence in a campus creek made the public health implications feel immediate and eye-opening. It was exciting as a class to venture out of the lab setting and test waterways around campus and at nearby sites because it put a different meaning behind our time in the lab."

understanding of course lectures and readings, and combining university coursework with community-based experiences, respectively. No statistically significant changes were observed for the remaining items over the duration of the course.

Student Reflections

Following CE laboratory work, students were asked to present the collected data in a formal laboratory report and to write a 400-word reflection on their experience. Generally, students expressed enthusiasm for the CE project in their reflections. Three primary themes emerged from student reflections: reinforcement of course content (9/21), appreciation for authentic, real-world experience and skill development (12/21), and enthusiasm for laboratory work that served a meaningful purpose (15/21). Table 6 presents selected quotations from student reflections; each was written by a different student.

FIGURE 4. CE Perspectives



Discussion

In this study, students in a CE undergraduate microbiology course partnered with a nonprofit organization focused on water quality monitoring with the intention of mutually benefiting both parties. The course community partner, KyWW, benefited from gaining water quality data from 44 creek water samples to add to its database and data that informed its approach to measuring *E. coli* concentrations in water samples. Students generated comparable *E. coli* concentration data from the samples using R-cards and IDEXX Quanti-Trays, supporting KyWW's use of R-cards in their citizen scientist efforts across Kentucky. KyWW published a news article about the project on its website, highlighting its value to the organization. The article explained, "Kentucky Watershed Watch recently embraced the R-card method, which offers greater flexibility in sample logistics and helps cut costs. But how does it stack up against the tried-and-true lab techniques we've relied on for years? Enter Dr. Carroll and her dedicated team,

eager to put their skills to work in service of science and the local waterways" (Kentucky Watershed Watch, 2025).

Pre-/post-survey student assessments using the TIMSI framework showed significant increases in scientific self-efficacy and scientific identity following participation in the course, suggesting that a real-world, authentic environmental microbiology experience helped them feel more competent as scientists and see themselves as part of the scientific community. The CE coursework may have influenced scientific self-efficacy and scientific identity because students contributed real data, produced useful knowledge, and interacted with a community stakeholder. These findings align with previous reports that authentic research and CE experiences can strengthen students' scientific self-efficacy and scientific identity by allowing them to participate in meaningful scientific work (Borlee et al., 2024; Murphy & Kelp, 2023; Newell & Ulrich, 2022). Value orientation scores increased but did not reach significance. The one-semester course may not have been long enough to alter students' internalization of scientific values. Additionally, these 300-level students began the course with high scientific value orientation scores (pre-survey median=4.0), and that may have created a ceiling effect with minimal room for increases.

Because a significant portion of the microbiology laboratory class time was spent doing CE work, we felt it was important to assess students' confidence performing key microbiology laboratory tasks. Some items aligned closely with CE work (Table 4 D, E, G, and H), while others aligned with non-CE coursework. Students had laboratory class time dedicated to non-CE work, when they learned how to perform and interpret a Gram stain, run biochemical tests to identify an unknown bacterial sample, and perform enzyme-linked immunosorbent assays (ELISAs) to test for the presence of an antigen. Surveys indicated that students had increased confidence in their microbiology laboratory skills, including significant increases in students' confidence related to performing a four-quadrant streak plate, preparing and interpreting a Gram stain, and measuring *E. coli* in environmental water samples (Table 4 A, C, and D), skills that students likely hadn't acquired before taking this course, which may have contributed to the increases. Overall, students reported greater confidence performing a variety of microbiology laboratory tasks despite

spending a significant amount of course time on CE work. These findings suggest that incorporating CE activities into a microbiology laboratory curriculum does not need to come at the expense of skill development.

Assessments of students' perspectives on CE work showed significant increases in three items (Table 5 A-C), indicating that, after the CE course, students more strongly believed that the CE project helped them understand the traditional microbiology coursework and recognize the usefulness of microbiology in their lives and work. They also had higher levels of agreement with the idea that more university courses should have a CE component, indicating their support of community partnerships as a way to enhance learning more generally.

Student reflections were overall positive and enthusiastic about the project. It is possible that the reflections were somewhat performative, as students knew their instructor would read them. However, throughout the semester, students consistently showed positive attitudes and genuine effort when completing CE tasks. Student reflections frequently emphasized enthusiasm for laboratory work that served a meaningful purpose (15/21), suggesting that students viewed the work as meaningful beyond course completion requirements. Students also expressed appreciation for real-world experience (12/21), indicating that they valued opportunities to apply microbiology concepts outside of a traditional classroom context. Students' appreciation for purposeful, authentic scientific work may help explain the observed increases in scientific identity and self-efficacy. Participation in laboratory work that generated data for a community partner may have allowed students to view themselves as contributors to scientific and civic work with tangible impacts rather than solely as learners completing course requirements.

Because most students planned careers in health professions, it was uncertain whether they would perceive an environmental microbiology project as relevant and interesting. However, student reflections suggested strong engagement despite the indirect connection to the students' professional goals.

The study results have several limitations. The sample size is small ($N=21$), and there was no control group, as all students participated in the CE project. The one-semester time frame was also limited. The CE project will continue

in future semesters, and future iterations will strive to provide optimal outcomes for students and KyWW. Studies that replicate these findings across multiple semesters or compare the effects to traditional microbiology laboratory activities could build on the results. Additionally, analysis of the longitudinal effects on career development could paint a clearer picture of the project's long-term effects. Despite these limitations, the findings suggest that CE microbiology can simultaneously support student development and positive laboratory learning outcomes, while fostering meaningful community partnerships.

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