Investigating Student Attitudinal Outcomes of a First-Year, Two-Semester Biology Course-based Undergraduate Research Experience (CURE)

Emma Throneburg, Natalie Christian, Connor Morozumi, Mikus Abolins-Abols, Jeffery Masters, and Rachel Pigg, University of Louisville, Louisville, KY

Subject/Problem

Undergraduate participation in research experiences can improve student attitudinal outcomes and retention in STEM.[1] However, most institutions lack the resources to include broad student populations in research.[1,2] Students also face many barriers that may limit their participation, such as hesitancy to approach faculty, financial barriers, and a lack of awareness of research opportunities or their benefits.[3] Furthermore, these barriers may be amplified for students with identities that are underrepresented in science.[4] Course-based Undergraduate Research Experiences (CUREs) have emerged as a means to lower participation barriers and include diverse populations of students in research, particularly if these CUREs are incorporated into introductory courses.[5] Such CUREs maximize research accessibility to all students early in their academic career and may increase retention by supporting the development of student scientific self-efficacy, science identity, and sense of belonging in both research and academic communities.[3,6,7] However, despite their potential student benefits, CUREs in introductory courses are uncommon.[3]

Self-efficacy, or the belief of one's ability to complete tasks, predicts academic perseverance[8] and has been positively linked to science identity, or the perception of oneself and recognition by others as a science person.[9,10] Science identity influences students' academic success and career trajectories.[11] Internalization of the values of the scientific community, such as feeling that conducting scientific research is important, has also been positively related to the intention to pursue a scientific career.[9] However, students that see themselves as underrepresented or marginalized in science may face difficulties developing their science identity and sense of belonging in the scientific community.[12]

Demographic Variable	% (n) of students in dataset
Minority in science	
No	62.2 (112)
Yes	33.3 (60)
Prefer not to respond	4.4 (8)
Gender	
Woman	69.4 (125)
Man	25.5 (46)
Non-binary	2.7 (5)
Transgender	0.5 (1)
Prefer not to respond:	1.1(2)
First Generation	
No	75 (135)
Yes	25 (45)
Working	
No	58.3 (105)
Yes, part-time	28.9 (52)
Yes, full-time	8.3 (15)
Prefer not to respond	4.4 (8)

In this study, we implemented a two-semester CURE across an introductory biology laboratory sequence for STEM majors. This CURE was implemented in all sections of the sequence, ensuring broad student participation rather than selective opt-in. Using attitudinal surveys, we asked how students' scientific self-efficacy, science identity, and science community values change throughout a first-year, two-semester CURE. Moreover, given

that students face different barriers to their development of science identity, self-efficacy, and sense of belonging in the scientific community, we asked how student attitudes may vary across demographic groups before, during, and after CURE participation.

Design/Procedure

This project took place at a large, public research institution in the southeastern United States, and was conducted in two first-year/introductory-level biology laboratory courses (Institutional IRB no 21.0170). These courses teach fundamental principles of biology while guiding students through a research experience investigating soil microbiomes. The first semester of the CURE focuses on molecular biology techniques and concepts, during which students locally collect soil samples and associated metadata. Students then analyze their individual soil sample's chemistry and microbiome in the lab. In the second semester of the CURE, students analyze data collected across all student groups from the first semester and form hypotheses related to the principles of community ecology. Students perform statistical analyses and report their findings through a collaborative writing project.

Table 1. Demographic composition of student population.

Surveys

From Fall 2021–Spring 2024, we measured scientific self-efficacy, science identity and scientific community values using a quantitative attitudinal survey.[9] Students could elect to complete the attitudinal survey for extra credit at three timepoints: beginning of semester one, end of semester one, and end of semester two. Students could also complete a demographic survey for extra credit. Table 1 summarizes our demographic survey data.

Our survey contained Likert-scaled questions from Estrada et al., 2011 that assessed scientific self-efficacy (n=6 questions), science identity (including sense of belonging; n=5), and scientific community values (n=4) (Table 2). Although we used a previously published instrument, we conducted a confirmatory factor analysis to verify that survey items loaded significantly on their respective scales (standardized factor loadings range: 0.67-0.86).

Construct	Example Survey Questions
Scientific self-efficacy	"Please indicate how confident you are in your ability… to create explanations for the results of the study."
Science identity	"Please indicate the extent to which you agree with the statements below… I have a strong sense of belonging to the community of scientists; …I have come to think of myself as a scientist"
Science community values	"Please rate how much the person in the description is like you… a person who thinks it is valuable to conduct research that builds on the world's scientific knowledge"

Table 2. Example survey questions

Data Analysis Methods

Students (n = 180) were included in the analysis if they were 18 years of age or older, completed the attitudinal survey at all three timepoints, and remained in the dataset after filtering for response patterns that indicated lack on engagement with the survey. Due to small sample size, students identifying as non-binary or transgender were omitted from the analysis, and we combined students who were working full-time and part-time into a single category. Consequently, each analysis compared two demographic groups: self-reported minority in science (yes/no), gender (women/men), first generation (yes/no), and working (yes/no) (Table 1).

Questions under each of the three constructs (scientific self-efficacy, science identity, and science community values) were averaged together to create mean scores for each construct for each student at each of the three survey timepoints. To compare each construct's mean across timepoints while accounting for non-normality and repeated measures, we used a Wilcox signed-rank test. To compare the mean of each construct between demographic groups at each of the three timepoints separately, a Wilcoxon rank-sum test (Mann-Whitney U test) was used. We selected this non-parametric test due to the non-normal data distribution and independent nature of the samples from demographic groups at single time points. All statistical analyses were conducted using R v4.3.2.[13]

Analyses and findings

How does students' science identity, scientific self-efficacy, and science community values change throughout the two-semester CURE?

Across all students, scientific self-efficacy increased substantially after one semester of the CURE (Wilcox $p < 0.001$), and again, slightly, after a second semester (Wilcox $p = 0.0019$, Figure 1A). Similarly, students experienced improvement in science identity after one semester of the CURE (Wilcox $p < 0.001$) and sustained these gains after a second semester (Wilcox $p = 0.27$, Figure 1B). Students' scientific community values started high before CURE participation and were maintained throughout; although the means for scientific community values were statistically different after one (Wilcox $p = 0.017$, Figure 1C) and two semesters (Wilcox $p = 0.026$), the actual difference in means was negligible.

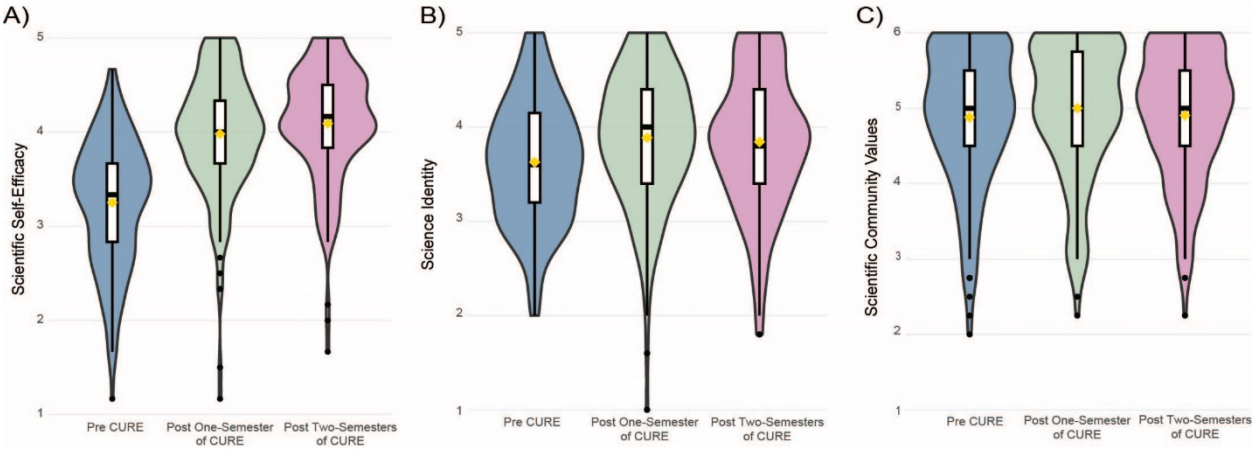
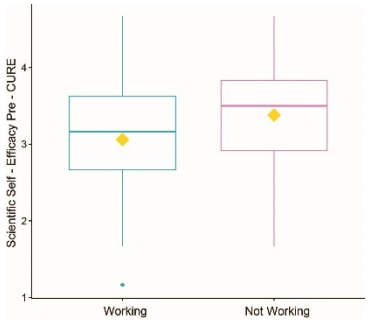


Figure 1A-C. Distributions of scientific self-efficacy, science identity, and science community values across three survey timepoints (pre-CURE, post one semester of a CURE, and post two semesters of a CURE. Means at each time period are indicated by a gold diamond.

Do attitude changes in CURE vary by demographic group?

Prior to starting the CURE, students who were not working had a slightly but significantly higher scientific self-efficacy than those who were working (Wilcoxon $p = 0.004$, Figure 2). After one semester of the CURE, that difference in self-efficacy is no longer seen. However, by the end of the second semester, non-working students again had a marginally higher scientific self-efficacy than working students ($p = 0.056$).



Interestingly, prior to starting the CURE, students who self-identified as minorities in science had a slightly but significantly higher science identity than students who did not identify as minorities in science (Wilcoxon p = 0.03, Figure 3), but after one and two semesters of the CURE, there is no difference in science identity between students that do and do not identify as minorities in science.

Figure 2. Scientific self-efficacy scores for students who are working (blue, left) and not working (pink, right) before entering CURE. Means for each group are indicated by a gold diamond.

Scientific self-efficacy, science identity, and science community values did not differ significantly across gender or first-generation status demographics at any time point.

Contribution

Our results align with previous work on upper-level CURE participation, which found increased student scientific self-efficacy and science identity, but no change in scientific community values.[14] Our work demonstrates that these patterns hold true for an introductory-level CURE as well. We also found that an extended CURE may strengthen gains seen in a single semester CURE, as scientific self-efficacy and science identity gains were maintained despite students' facing new challenges in data analysis and scientific writing in the second semester of our CURE.

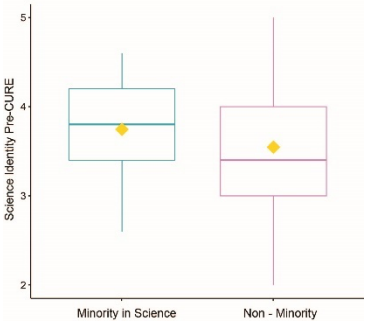


Figure 3. Science identity scores for students who identify as a minority in science (blue, left) and students with non-minority status (pink, right) before entering CURE. Means for each group are indicated by a gold diamond.

Our work contributes to the gap in our understanding of how student outcomes from CURE participation may differ by demographics. Specifically, we found that scientific self-efficacy, science identity, and science community values were overall consistent, regardless of first-generation status, gender, current employment situation, or whether students self-identified as a minority in science. This is remarkable given previous research suggesting that different students may obtain different outcomes through research participation.[4] We chose to analyze students' self-selection of 'minority in science,' because not all marginalized identities are visible and individual student's perceptions vary. However, because of this, it is not apparent which aspects of these students' identities are driving their selection. We acknowledge that these students likely have different experiences relative to their marginalized identity and encourage further work in this area, including consideration of intersectionality, to more deeply explore the nuances of student experiences in CUREs.

In this study, we observed notable ceiling effects (i.e., student responses are capped at a maximum value on our surveys) for scientific self-efficacy, science identity, and particularly scientific community values. It is logical that STEM majors enter CUREs with high scientific community values, as their prior passion about science may be what led them to this course. It is encouraging that students' scientific community values are maintained throughout an introductory CURE, despite experiencing the challenges of conducting scientific research while adjusting to life as a college student. For scientific self-efficacy and science identity, no or few students (respectively) are reaching the ceiling pre-CURE, but after one or two semesters of the CURE, students are reaching the upper limit of the surveys' scales. Moreover, students that report very weak feelings of scientific self-efficacy and science identity are less common particularly after two semesters of the CURE, represented by the shortening of the tails across our data distributions (Figure 1). This suggests that students with both high and low scientific self-efficacy and science identity are seeing gains in these areas.

Finally, we emphasize that qualitative research (e.g., interviewing students) may uncover aspects of student experiences that were not captured by our quantitative analyses. The next steps of this research will use student interviews to study how different CURE components, such as mentorship, peer collaboration, and a student's own sociocultural identity, shape their science identity.

General interest

Engaging diverse populations of students in meaningful science experiences should be of interest to all NABT members. We demonstrate the effectiveness of a two-semester introductory biology CURE in promoting student attitudes in science and suggest that this approach could be adapted to benefit introductory-level biology students across diverse institutions, including high school, two-year colleges, and four-year colleges. Additionally, though this study is situated within an undergraduate-level biology CURE, the findings may be applied to other STEM disciplines or environments featuring mentorship and collaboration.

Acknowledgements

This study was supported by a REDACTED. Further support was provided by a REDACTED.

References

[1] Harrison, M., Dunbar, D., Ratmansky, L., Boyd, K., & Lopatto, D. (2011). Classroom-based science research at the introductory level: changes in career choices and attitude. *CBE Life Sci. Educ.*, 10(3), 279-286. **[2]** Desai, K.V., Gatson, S.N., Stiles, T.W., Stewart, R.H., Laine, G.A., & Quick, C.M. (2008). Integrating research and education at research-extensive universities with research-intensive communities. *Adv. Physiol. Educ*. 32,136–141. **[3]** Bangera, G., & Brownell, S. E. (2014). Course-based undergraduate research experiences can make scientific research more inclusive. *CBE Life Sci. Educ*., 13(4), 602–606. **[4]** Jones, M. T., Barlow, A. E. L., & Villarejo, M. (2010). Importance of undergraduate research for minority persistence and achievement in biology. *J. High. Educ.*, 81(1), 82–115. **[5]** Auchincloss, L.C., Laursen, S.L., Branchaw, J.L., Eagan, K., Graham, M., Hanauer, D.I., Lawrie, G., McLinn, C.M., Pelaez, N., Rowland, S., & Towns, M. (2014) Assessment of course-based undergraduate research experiences: a meeting report. *CBE Life Sci. Educ.,*13, 29–40. **[6]** Esparza, D., Wagler, A. E., & Olimpo, J. T. (2020). Characterization of instructor and student behaviors in CURE and non-CURE learning environments: Impacts on student motivation, science identity development, and perceptions of the laboratory experience. *CBE Life Sci. Educ.*, 19(1). **[7]** Brownell, S. E., Kloser, M. J., Fukami, T., & Shavelson, R. (2012). Undergraduate biology lab courses: comparing the impact of traditionally based "cookbook" and authentic research-based courses on student lab experiences. *J. Coll. Sci. Teach*., 41(4). **[8]** Chemers, M. M., Hu, L., & Garcia, B. (2001). Academic self-efficacy and first-year college student performance and adjustment. *J. Educ. Psychol*., 93, 55–64. **[9]** Estrada, M., Woodcock, A., Hernandez, P. R., & Schultz, P. W. (2011). Toward a model of social influence that explains minority student integration into the scientific community. *J. Educ. Psychol.*, *103*(1), 206–222. **[10]** Carlone, H. B., & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *J. Res. Sci. Teach*., 44(8), 1187–1218. **[11]** Chemers, M. M., Zurbriggen, E. L., Syed, M., Goza, B. K., & Bearman, S. (2011). The role of efficacy and identity in science career commitment among underrepresented minority students. *J. Soc. Issues*, 67(3), 469–491. **[12]** Rainey, K., Dancy, M., Mickelson, R., Stearns, E., & Moller, S. (2018). Race and gender differences in how sense of belonging influences decisions to major in STEM. *Int. J. STEM Educ*., 5(1), 10. **[13]** R Core Team (2023). R: A language

and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/. **[14]** Cooper, K. M., Knope, M. L., Munstermann, M. J., & Brownell, S. E. (2020). Students who analyze their own data in a course-based undergraduate research experience (cure) show gains in scientific identity and emotional ownership of research. *JMBE*, 21(3), 10-1128.