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Gains in Scientific Identity, Scientific Self-Efficacy, and Career Intent Distinguish Upper-Level CUREs from Traditional Experiences in the Classroom

MiKayla J. Newell[a] and Paul N. Ulrich[b]

[a]*Department of Learning Sciences, Georgia State University, Atlanta, Georgia, USA*
[b]*Department of Biology, Georgia State University, Atlanta, Georgia, USA*

Attrition from the science, technology, engineering, and math (STEM) pipeline limits the number of graduates needed to meet STEM workforce demand and impedes efforts to diversify the workforce. Identifying factors that underlie academic success and STEM persistence is an important component to increasing the number of STEM graduates. The current study utilizes the social influence process indicators of the Tripartite Integration Model of Social Influence to investigate effects of course-based undergraduate research experience (CURE) participation and to predict career intent in a diverse population. CURE participants experienced significant gains in scientific self-efficacy, scientific identity, and career intent, while students in control courses did not. Between-groups analysis showed that scientific self-efficacy and scientific identity increased significantly more for CURE participants than for non-CURE participants. Regression analysis revealed that scientific identity was the only significant predictor of a student's career intent. This work underscores the central importance of prioritizing scientific identity in STEM curricula to improve throughput in the STEM pipeline and illustrates the usefulness of CUREs as viable interventions to positively influence factors that promote STEM career intent.

KEYWORDS CUREs, scientific identity, scientific self-efficacy, career, TIMSI

INTRODUCTION

The science, technology, engineering, and math (STEM) academic "pipeline" has garnered increasing attention over the past 3 decades, with its emphasis on racial disparities and establishing a robust workforce. The STEM pipeline is particularly leaky for underrepresented minority students (URMs). Completion of STEM degrees for white students is nearly 60%, compared to 34 to 43% for Latinx and Black students (1). Continuation of this trend will result in STEM careers and academic pipelines reflecting historic patterns of underrepresentation. There is also a substantial concern that the supply of STEM graduates is continuously outpaced by growth in STEM workforce needs. In 2012, the Presidential Council of Advisors on Science and Technology stressed that higher education in the United States would need to produce 1 million more STEM graduates by 2022 to meet workforce demand (2).

Consequently, efforts have been executed by governmental agencies and researchers to address these issues. The *Vision and Change in Undergraduate Biology Education* report (3) encouraged the integration of authentic research experiences in curricula and a pedagogical shift to a student-centered approach. Student-centered learning approaches, such as undergraduate research experiences (UREs), provide opportunities to investigate factors that impact retention, an important element of a national strategy to increase the pool of STEM graduates (2, 4, 5).

Because the pipeline continues to leak students and workforce demand is expected to exceed supply, researchers must identify factors critical to STEM persistence, inform retention-related interventions, and address loss of talent from the STEM pipeline. Studies investigating course-based undergraduate research experiences (CUREs) suggest that CUREs provide a viable mechanism to foster the development of factors related to a student's academic success and retention in STEM (6–10). While various methods have been utilized to examine the effects of CUREs, few studies have used the Tripartite Integration Model of Social Influence (TIMSI) (11, 12).

Estrada and colleagues (11, 12) used UREs to develop the TIMSI to assess factors that influence persistence of URMs into STEM careers. The measures in the model, which are referred to as social influence process indicators (e.g., scientific self-efficacy, scientific identity, value orientation, mentorship, and career intent), were developed in an exclusively URM sample. Few studies have applied these measures in more diverse populations or investigated the effects of CUREs. Of these few studies, Shuster et al. (13) applied TIMSI to a CURE population comprised of 70% URM at a

Hispanic-serving institution and observed positive gains in TIMSI process indicators that were linked to graduation (13). Another study used TIMSI to guide the coding process in a qualitative analysis of a CURE but did not utilize the TIMSI measures directly (14). The current study addresses this gap by exploring the utility of the TIMSI measures in a diverse sample and investigates the effects of CURE participation. To begin, we review the benefits of CURE participation and how TIMSI provides a unique theoretical framework for investigating factors that influence STEM persistence.

CUREs

There are a growing number of opportunities for undergraduates to participate in research experiences. CUREs are gaining popularity and students perceive them as positive experiences and prefer them over traditional "cookbook" labs (8, 15). CUREs are designed to engage students in authentic research (13, 16) and can broaden opportunities at scales not feasible for traditional approaches. CUREs also encourage intellectual development by providing students a route to improve scientific skills. Students experience cognitive gains, including analyzing data, interpreting results, and increased content knowledge (6–10, 17, 18). In a robust study with propensity-matched participants, graduation with a STEM major and completion of a degree within 6 years was significantly linked to CURE participation (5). Thus, CUREs present opportunities to identify and investigate factors that are critical to students' academic success and persistence in STEM. The current study uses the TIMSI model to investigate learning gains associated with CUREs.

TIMSI framework

The TIMSI model was designed to predict URM persistence in STEM career pathways by examining integration into the scientific community. The model was derived from Kelman's social influence framework (19–21), which includes three social influence processes (i.e., compliance, identification, and internalization) that describe how an individual's interactions within a social system predict their behavior and persistence of responses over time. Analysis of the persistence of STEM students through a lens of social influence can reveal influencing agents that intentionally and unintentionally affect persistence and motivation in academic environments (11). Estrada et al. (12) applied this model to academia by creating social influence process indicators to measure students' scientific self-efficacy, scientific identity, and value orientation. The scientific self-efficacy, scientific identity, and value orientation scales operationalize the compliance, identification, and internalization processes of Kelman's model, respectively. A mentorship scale that assesses the relationship quality between students and their mentors is also included in the TIMSI. Mentorship is described as a relationship between individuals with different levels of experience in which a mentor provides professional guidance, offers career support, and influences student engagement (11). Quality mentorship can provide students with instrumental and psychosocial support and relationship satisfaction (22–24), which is positively related to science self-efficacy,

scientific identity, and value orientation in URE participants (12). Previous work using TIMSI suggested that scientific self-efficacy, scientific identity, and value orientation are predictive of scientific integration (career intent); however, scientific identity and value orientation contributed stronger, unique, and significant predictive values over scientific self-efficacy (12). A longitudinal study of URMs indicated that scientific identity uniquely predicts STEM employment (11). The theoretical framework presented by TIMSI provides valuable information concerning the relationships of the social process indicators and suggests that these factors are predictive of students' integration into the scientific community. Our work highlights factors that influence persistence and can inform institutional efforts to increase retention in STEM. Thus, further investigation of TIMSI is warranted.

Current study

This study was conducted at a research-intensive, urban institution in the southeastern United States. We explored the utility of the TIMSI in a diverse population and investigated differences between CURE and non-CURE samples. Furthermore, the social process indicators were examined as predictors of students' intent to pursue a science-related research career. The current study is designed to investigate the following research questions (RQs):

RQ1: What are the relations among students' scientific self-efficacy, scientific identity, value orientation, and mentorship?
RQ2: How does participating in CUREs affect students' scientific self-efficacy, scientific identity, value orientation, and career intent compared to a non-CURE sample?
RQ3: To what extent are students' scientific self-efficacy, scientific identity, value orientation, and mentorship predictive of students' intent to pursue a science-related research career?

Consistent with the work of Estrada and colleagues (11, 12), we expected scientific self-efficacy, scientific identity, value orientation, and mentorship would positively correlate with each other (RQ1). RQ2 is exploratory, because we were unsure how the measures related to each other due to the limited number of studies that have used the TIMSI measures. However, we expected CURE participants to experience larger gains from pre-test to post-test compared to non-CURE participants. For the regression analysis (RQ3), we expected all predictor variables would contribute; however, previous work had suggested that scientific identity would significantly predict students' intent to pursue a science-related research career more than scientific self-efficacy, value orientation, and mentorship (11, 12, 25).

METHODS

Participants

Participants ($n = 182$) were recruited from a large, urban university. Students registered in CUREs (Table 1) were included

TABLE 1
CURE titles and participants

CURE title	No. of participants
Behavioral Endocrinology	29
Microbial Ecology	9
International Genetically Engineered Machines Competition	8
Metagenomics and Microbes	5
Vertebrate Development	14
Molecular Parasitology	10
Total	75

TABLE 2
Control and experimental group demographic characteristics

Variable	Control group	Experimental group
Age[a]	22.2 ± 2.5 yrs	23.7 ± 6.0 yrs
Gender		
Female	71%	74%
Male	29%	25%
Race		
Asian	28%	26%
Black or African American	41%	36%
Hispanic or Latinx	5%	3%
Multiracial	3%	3%
White	17%	22%
Other	7%	8%
Classification		
Freshman	19%	15%
Sophomore	25%	35%
Junior	17%	11%
Senior	40%	38%
Major		
Biology	94%	90%
Chemistry	1%	1%
Neuroscience	4%	4%
Other	1%	4%

[a]Reported values are means ± SD.

in the experimental group ($n = 75$), while students enrolled in a standard biology course were included in the control group ($n = 107$). Students coenrolled in both types of courses were excluded from the analysis. Over a period of 3 semesters, we recruited from a pool of 701 students from the non-CURE zoology course. A total of 15% participated in the study. We recruited from a total of 183 students enrolled in the CURE courses, and 41% participated in the study. Participant ages ranged from 18 to 49 years (22.6 ± 4.0 years, mean ± standard deviation [SD]). Thirty-nine percent self-identified as African American or Black, 27% Asian, 19% white, 4% Hispanic or Latinx, 3% as multiracial, and 7% identified as other. Females comprised 72% of the sample, while 27% identified as male. In addition, 17% identified as freshmen, 29% as sophomores, 15% as juniors, and 39% as seniors. The majority identified as a Biology major (93%), but 4% identified as a Neuroscience major, 1% identified as a Chemistry major, and 2% identified as having another major. Table 2 provides information regarding the demographics of each group.

Description of the participating courses

Control group. A standard, 3000-level zoology course was selected as a comparison group because it is required of all biology majors and thus was expected to be representative of all biology majors. The course is a traditional survey of animal phyla delivered in a lecture-based format. No research or laboratory element is included in these course sections. Direct engagement of students with primary literature is rare or absent completely. Class sections meet two to three times per week for 50 to 75 min, and instructors rely heavily on summative assessments to gauge student learning. Students participating in this study were all enrolled in sections taught by experienced faculty instructors.

Experimental group. The CURE courses in this study (Table 1) were organized around the five criteria for CUREs defined by Auchincloss et al. (26) and were characterized by close instructor engagement coupled with student independence in designing and executing experiments and a goal of equipping students with competencies representative of STEM careers. The CUREs were oriented around topical areas ranging from microbiology to animal behavior. All CUREs were upper

division offerings taught by faculty instructors with at least 4 years of experience teaching CUREs. Hypothesis formation and testing, analysis, literature searches, and interpretation of results (use of scientific practice) were integrated throughout the semester to interrogate questions to create new knowledge (discovery) with the aim to ultimately produce publishable results of interest beyond the classroom or products to solve problems to industrial or medical applications (broad relevance). Per Auchincloss et al. (26), the broader relevance component distinguished all CUREs in this study from inquiry-based labs. Each CURE was organized around a research area (e.g., hormonal regulation of social behavior in a specific fish model) that focused attention of the course yet provided freedom and autonomy with respect to specific questions asked by students. Extensive teamwork characterized these courses (collaboration) in group meetings, reports, and presentations. Iteration is an important part of the scientific process, and students experienced this over the term as they moved through the cyclical process of experimental design, hypothesis testing, and refinement. Each CURE met in person twice per week for 2 to 3 h to learn techniques, explore primary literature through journal club activities, and train in experimental design. Instead of examinations to assess students, writing assignments, presentations, laboratory notes, and oral presentations were utilized. Most experimental work was performed by students

throughout the week at times that fit their personal schedules, and students were provided unsupervised access to science buildings and the laboratory. Student researchers typically invested 10 to 15 h of time outside of class hours per week to complete assignments and experiments.

Measures

Scientific self-efficacy. The scientific self-efficacy measure was a 6-item scale designed to assess confidence to perform scientific tasks. Participants responded using a 5-point Likert scale ranging from 1 (not at all confident) to 5 (absolutely confident). An example item is, "I am confident that I can create explanations for the results of a study." The measure demonstrated good reliability ($\alpha = 0.90$).

Scientific identity. The scientific identity measure was a 5-item scale that assessed the extent to which participants identified as scientists. Participants completed the scale using a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). An example item is, "I feel like I belong in the field of science." The scale demonstrated good reliability ($\alpha = 0.87$).

Value orientation. The value orientation measure was a 4-item scale that measured students' values of scientific objectives. The scale required participants to rate how much a description aligned with them personally. Participants responded using a 6-point Likert scale ranging from 1 (not like me at all) to 6 (very much like me). An example item is, "A person who thinks discussing new theories and ideas between scientists is important." Reliability of this measure was good ($\alpha = 0.87$).

Mentorship. The mentorship measure was a 9-item scale that examined the extent to which faculty members contributed to development in students' science careers and provided psychosocial, instrumental, and networking support. Participants responded using a 5-point Likert scale ranging from 1 (not at all) to 5 (to a very large extent). An example item is, "To what extent has your mentor given you challenging assignments that present opportunities to learn new skills?" The mentorship scale demonstrated good reliability ($\alpha = 0.93$).

Career intent. The career intent scale was a single-item scale to measure the extent to which students intended to pursue a science-related research career. Participants were asked, "To what extent do you intend to pursue a science related research career?" Participants answered using a slider scale from 0 (definitely will not) to 10 (definitely will).

Procedures

A total of six CUREs and a standard biology course were selected for inclusion in this study. Participants were recruited via information shared by faculty teaching these courses and by e-mails to students from the study team. At the beginning of the semester, a survey link for the pre-test was emailed to students and instructors for a total of 3 semesters. Links to the post-test were distributed at the end of each term. Students were not provided compensation from the principal investigator. Pre-test measures included scientific self-efficacy, scientific identity, and value

orientation, along with demographic information. The post-test measures were the same but also included a mentorship measure.

Ethics statement

All research protocols were approved by the Georgia State University Institutional Review Board (IRB H19618) and were performed in accordance with institutional and federal policies.

Analytic summary

The analysis proceeded in several stages. First, we performed a factor analysis to assess factor loadings of each item. The preliminary factor analysis yielded positive results. All items loaded appropriately on the corresponding scale (Table 3). We then calculated bivariate correlations to evaluate the relations among the measures (RQ1). Next, we conducted dependent t tests ($\alpha = 0.05$) to investigate within-group differences. Composite scores were calculated to decrease the number of tests. For each scale on the pre-test and post-test, composite scores were generated by averaging the items on each scale. Because the career intent scale contained a single item, an average was not necessary. Thus, participants had a total of eight scores representing scientific self-efficacy, scientific identity, value orientation, and career intent: four from the pre-test and four from the post-test. After that, we conducted independent t tests to investigate between-group differences (RQ2). We used students' composite scores to create difference scores for independent t tests. Difference scores for each variable were computed by subtracting students' pre-test composite score from their post-test composite score. Multiple linear regression analysis was performed to explore the extent to which students' scientific self-efficacy, scientific identity, value orientation, and mentorship were predictive of intent to pursue a science-related, research career (RQ3).

RESULTS

Correlations

Bivariate correlations were calculated for all of the main study variables. All of the variables were positively correlated, and the majority were significantly related for each group. Because our main interest was to investigate differences between the CURE and non-CURE group, we have only reported on the differences that emerged. However, all correlations are reported in Table 4. Interestingly, the correlation strength from pre-test to post-test increased for most of the variables for the CURE group, while most correlations in the control group weakened.

Career intent and value orientation were not related for the CURE sample ($r = 0.16$) but were positively and significantly related for the non-CURE group ($r = 0.44$, $P < 0.01$). However,

TABLE 3
Results of factor analysis for TIMSI scales

Factor	Factor loadings	
	Pre	Post
Scientific self-efficacy ($\alpha = 0.90$; 22% of variance)		
1. Use technical science skills (use of tools, instruments, and/or techniques)	0.67	0.72
2. Generate a research question to answer	0.75	0.78
3. Figure out what data or observations to collect and how to collect them	0.84	0.83
4. Create explanations for the results of the study	0.85	0.81
5. Use scientific literature and/or reports to guide research	0.80	0.75
6. Develop theories (integrate and coordinate results from multiple studies)	0.84	0.82
Scientific identity ($\alpha = 0.83$; 5% of variance)		
1. I have a strong sense of belonging to the community of scientists	0.77	0.81
2. I derive great personal satisfaction from working on a team that is doing important research	0.62	0.80
3. I have come to think of myself as a "scientist"	0.66	0.86
4. I feel like I belong in the field of science	0.78	0.71
5. The daily work of a scientist is appealing to me	0.59	0.70
Value orientation ($\alpha = 0.88$) (10% of variance)		
1. A person who thinks discussing new theories and ideas between scientists is important	0.77	0.77
2. A person who thinks it is valuable to conduct research that builds the world's scientific knowledge	0.87	0.85
3. A person who thinks scientific research can solve many of today's world challenges	0.81	0.77
4. A person who feels discovering something new in the sciences is thrilling	0.74	0.73
Mentorship ($\alpha = 0.93$; 30% of variance)		
1. To what extent has your mentor discussed your questions or concerns regarding feelings of competence, commitment to advancement or relationships with peers?		0.81
2. To what extent has your mentor conveyed empathy for concerns or feelings you have discussed with him or her?		0.83
3. To what extent has your mentor encouraged you to talk openly about anxieties and fears?		0.80
4. To what extent has your mentor shared personal experiences with you?		0.76
5. To what extent has your mentor helped you finish assignments/tasks or meet deadlines that otherwise would have been difficult to complete?		0.79
6. To what extent has your mentor helped you improve your writing skills?		0.86
7. To what extent has your mentor helped you meet people elsewhere?		0.76
8. To what extent has your mentor helped you meet other people in your field at the university?		0.79
9. To what extent has your mentor given you challenging assignments that present opportunities to learn new skills?		0.73

these correlations were positively and significantly related in the post-test (CURE: $r = 0.26$, $P < 0.01$; non-CURE: $r = 0.37$, $P < 0.01$). Mentorship and value orientation were unrelated for each group but significantly related for the non-CURE sample ($r = 0.19$, $P < 0.05$). Similarly, mentorship and career intent were unrelated for the non-CURE sample but positively and significantly related in the CURE sample ($r = 0.32$, $P < 0.01$).

Dependent t test

Paired-sample t tests were conducted to compare students' pre-test and post-test scientific self-efficacy, scientific identity, value orientation, and career intent scores for each sample.

Control group (non-CURE). There were no significant differences within the control group's pre-test and post-test scores on any of the scales. The average scientific self-efficacy score slightly increased from pre-test (3.97 ± 0.65 [mean ± SD]) to post-test (4.04 ± 0.73), and career intent score increased from pre-test (6.51 ± 2.86) to post-test (6.68 ± 2.65). However, these gains were not significant. The average scientific identity score decreased from pre-test (3.85 ± 0.75) to post-test (3.78 ± 0.92), and students' value orientation decreased from pre-test (5.23 ± 0.82) to post-test (5.15 ± 0.76), but these changes were not significant. Similarly, students' average value orientation score decreased from pre-test (5.23 ± 0.82) to post-test (5.15 ± = 0.76), but again these changes were not significant.

TABLE 4
Correlation analysis results

Group and scale	Pre-test					Post-test					
Experimental group	Category score (mean ± SD)	Correlation[a]				Category score (mean ± SD)	Correlation[a]				
		1	2	3	4		1	2	3	4	5
1. Scientific self-efficacy	3.50 ± 0.83					4.26 ± 0.60					
2. Scientific identity	3.94 ± 0.72	0.45**				4.23 ± 0.71	0.56**				
3. Value orientation	5.49 ± 0.72	0.37**	0.56**			5.52 ± 0.82	0.46**	0.34**			
4. Career intent	6.91 ± 2.52	0.10	0.29**	0.16		7.51 ± 2.37	0.30**	0.50**	0.26**		
5. Mentorship						3.92 ± 0.79	0.31**	0.42**	0.17	0.32**	
Control group											
1. Scientific self-efficacy	3.96 ± 0.65					4.03 ± 0.73					
2. Scientific identity	3.85 ± 0.75	0.50**				3.79 ± 0.92	0.37**				
3. Value orientation	5.23 ± 0.82	0.44**	0.58**			5.16 ± 0.76	0.43**	0.50**			
4. Career intent	6.52 ± 2.85	0.18	0.48**	0.44**		6.71 ± 2.66	0.21**	0.57**	0.37**		
5. Mentorship						3.28 ± 1.10	0.25**	0.34**	0.19*	0.18	

[a]The strength of a correlation was determined using Pearson's r. **, $P < 0.01$; *, $P < 0.05$.

Experimental group (CURE). In contrast to the pattern observed in the control group, students in CUREs experienced significant gains. The average scientific self-efficacy significantly increased from pre-test (3.50 ± 0.83) to post-test (4.26 ± 0.61) [$t(72) = -7.77$, $P < 0.001$, $d = 0.82$]. Furthermore, students' scientific identity significantly increased from pre-test (3.95 ± 0.73) to post-test (4.23 ± 0.72) [$t(72) = -2.99$, $P < 0.05$, $d = 0.79$]. Although the average value orientation score increased from pre-test (5.47 ± 0.73) to post-test (5.51 ± 0.83), the differences were not significant. Students' career intent increased significantly from pre-test (6.94 ± 2.56) to post-test (7.51 ± 2.40) [$t(72) = -2.09$, $P < 0.05$, $d = 2.31$].

Independent t test

Independent sample t tests were conducted to investigate differences between the CURE and non-CURE groups in terms of scientific self-efficacy, scientific identity, value orientation, and career intent scores. The CURE group's scientific self-efficacy scores (0.75 ± 0.83) were significantly higher than the non-CURE scores (0.06 ± 0.70) [$t(177) = -5.91$, $P < 0.001$]. In addition, students enrolled in CUREs had significantly higher scientific identity scores (0.27 ± 0.79) than students in the control group (−0.07 ± 0.76) [$t(177) = -2.97$, $P < 0.05$]. Although CURE students had higher value orientation scores (0.03 ± 1.03) than students in the control group (−0.07 ± 0.65), the difference was not statistically significant [$t(177) = -0.87$, $P = 0.38$]. Similarly, students in CURE courses had higher career intent scores (0.49 ± 2.38) than the control group (0.16 ± 2.96), but these differences were not significant.

Regression analysis

Multiple linear regression analysis was used to explore the extent to which students' self-reported scientific self-efficacy, scientific identity, value orientation, and mentorship predicted their intent to pursue a science-related research career (Table 5). We performed two multiple linear regression analyses to determine whether the models differed between the groups. With respect to the CURE group, regression analysis resulted in a four-predictor model that accounted for 27% of the variance in students' intent to pursue a science-related research career [$F_{(4, 67)} = 6.45$, $P < 0.001$, $R^2 = 0.27$]. Scientific identity significantly predicted students career intent ($\beta = 0.42$, $P < 0.05$), while scientific self-efficacy ($\beta = 0.01$, $P = 0.93$), value orientation ($\beta = 0.01$, $P = 0.88$), and mentorship ($\beta = 0.14$, $P = 0.21$) did not significantly contribute to the model. For the control group, regression analysis resulted in a four-predictor model that accounted for 33% of variance in students' intent to pursue a science-related research career [$F_{(4, 101)} = 12.47$, $P < 0.001$, $R^2 = 0.33$]. Similar to the CURE group, scientific identity ($\beta = 0.52$, $P < 0.001$) predicted students' career intent significantly, while scientific self-efficacy ($\beta = -0.03$, $P = 0.71$), value orientation ($\beta = 0.11$, $P = 0.23$), and mentorship ($\beta = -0.01$ $P = 0.89$) did not significantly contribute to the model. Overall, scientific identity played a significant role in predicting students' intent to pursue a science-related research career.

DISCUSSION

To staunch leakage from the STEM pipeline and address concerns of STEM workforce shortages, it is imperative that we further elucidate how certain factors influence STEM students' academic success. TIMSI provides a theoretical framework that helps contribute to our understanding of how scientific self-efficacy, scientific identity, and value orientation influence integration into the scientific community. To our knowledge, no studies have used TIMSI measures to assess effects of CURE participation, and so exploratory analysis guided our

TABLE 5
Multiple linear regression results

Source	B	B SE	β	t	P
Experimental group					
Scientific self-efficacy	0.04	0.52	0.01	0.07	0.93
Scientific identity	1.40	0.46	0.42	3.04	0.00
Value orientation	0.08	0.55	0.01	0.14	0.88
Mentorship	0.42	0.34	0.14	1.24	0.21
Control group					
Scientific self-efficacy	−0.12	0.33	−0.03	−0.36	0.71
Scientific identity	1.52	0.28	0.52	5.33	0.00
Value orientation	0.40	0.34	0.11	1.19	0.23
Mentorship	−0.02	0.20	−0.01	−0.12	0.89

work. Thus, the overarching goal of the current study was to use the TIMSI measures to investigate how CURE participation affected students' scientific self-efficacy, scientific identity, value orientation, mentorship, and career intent compared to a non-CURE control sample.

The current study contributes to the literature by quantifying the gains associated with CURE participation compared to a non-CURE sample. Results from the factor analysis demonstrated that all items on each TIMSI scale loaded appropriately on the corresponding constructs, suggesting use of the TIMSI measures can be expanded beyond URMs to racially diverse populations. Bivariate correlations among students' scientific self-efficacy, scientific identity, career intent, value orientation, and mentorship were positively related, and the majority of the relationships were significant. Though overall patterns in correlations were similar between the CURE and the non-CURE groups, strengths of the correlations weakened for the control group from pre-test to post-test while they were strengthened for the CURE group. These trends suggest that CUREs are particularly effective in strengthening the relationships among these variables, which could be the result of CUREs integrating different aspects of science within a single experience (e.g., learning how to "be" a scientist while "doing" coupled with shared responsibility of instructors and students for generating new scientific knowledge; refer to descriptions of courses regarding characteristics of CUREs) rather than lecture-based courses that focus on knowledge acquisition. For instance, lecture-based courses may be less likely to positively influence the relationship between students' scientific self-efficacy and other variables due to a "sage-on-the-stage" instructional format. "Sage-on-the-stage" pedagogy conveys to students that the value of science training is primarily knowledge acquisition, at the loss of greater understanding how perspectives of self and one's efficacy are interconnected.

Furthermore, non-CURE students did not experience significant gains from pre-test to post-test. However, CURE students experienced significant gains in their scientific self-efficacy, scientific identity, and career intent. These results were further supported when investigating between-group differences. CURE students reported significantly higher scientific self-efficacy, scientific identity, and career intent scores than the non-CURE sample students. In comparison to non-CURE courses at the study site, CUREs were intentionally designed to promote collaboration among students and student-instructor interaction, utilize collective troubleshooting and iterative refinement of experimental processes, and foster independence in learning laboratory techniques.

Olimpo et al. (18) conducted a similar study comparing CURE and non-CURE courses in a diverse population. However, the results differed from those in the current study. Olimpo et al. (18) observed that students participating in the *Tigriopus* CURE declined in terms of intrinsic motivation, self-determination, self-efficacy, and grade motivation, based on use of the CLASS-Bio and BMQ instruments. It is interesting to note that CURE students declined in these measures but that traditional laboratory students experienced a greater decrease in each. CURE participants in the current study, in contrast, experienced gains in scientific self-efficacy, STEM career intent, and scientific identity. Population characteristics, such as percentages of first-year students (>55% first-year students in the Olimpo et al. study versus <20% in the current study) may account for these differences, but we stress that a student's background, educational experiences, and instructors also may influence a student's academic experiences while in CUREs.

Value orientation and mentorship scores did not significantly differ between the groups, suggesting that students generally valued research and advancing scientific knowledge regardless of the type of course. We anticipated that CUREs would significantly impact students' mentorship experiences compared to a non-CURE sample. Faculty in traditional, non-CURE courses primarily serve instructional roles, while CUREs prioritize mentorship (16). Therefore, we were surprised to find that mentorship was not affected by the type of course. However, the CURE sample included several different CUREs, each

taught by a different instructor. It is possible that variation of mentorship experiences in the CUREs obscured differences between groups. Because mentoring relationships are complex and outcomes range widely (24), future studies of CURE outcomes should consider which mentoring interactions contribute most strongly to positive outcomes while avoiding negative mentoring interactions that can occur in UREs (26). In general, our findings suggest that CUREs have a greater impact on students' scientific self-efficacy, scientific identity, and career intent compared to a standard course. These findings underscore prior findings that CUREs offer a student experience distinct from traditional learning opportunities (16), and they lend support to efforts to expand CUREs as a means to positively impact factors related to STEM persistence. We are not suggesting that standard courses be replaced by CUREs, but we highlight the benefits of participating in CUREs and encourage their implementation.

Additionally, regression analyses were used to investigate the extent to which scientific self-efficacy, scientific identity, value orientation, and mentorship predicted students' intent to pursue a science-related research career. Regression analyses revealed that scientific identity was the only significant predictor of career intent, consistent with Estrada et al. (11). These findings suggest that it is important to prioritize practices like CUREs to positively impact students' scientific identity. Although scientific identity is a recurrent theme in the literature, factors that affect scientific identity are not as well known. As institutions exert efforts to maintain and increase retention rates, additional research is necessary to elucidate factors that directly and indirectly impact students' scientific identity to combat loss of talent from the STEM pipeline.

Although this work demonstrates gains associated with CURE participation, there are limitations that should be noted. Data in this study were collected via survey methods, which can introduce inaccurate and incomplete responses (27, 28). Confirmatory factor analysis yielded results similar to existing studies, and incomplete questionnaires were excluded from analysis. Thus, we believe the survey methods were not problematic for the current study. In addition, students were not randomly assigned to conditions. Students were able to enroll in CURE courses, which may have introduced self-selection bias. That is, students who enrolled in the CURE courses may have been different from students who did not enroll in a CURE. It may be beneficial for future studies comparing the effects of CURE and non-CURE participation to consider random assignment or matching procedures.

The results of this study indicate that CUREs are a promising route to positively impact student success in STEM. While additional studies are necessary to fully understand the factors that contribute to scientific identity, retention-related programs can leverage CUREs as a means to maximize likelihood that students of all backgrounds progress through the STEM pipeline.

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