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Supplemental Materials

for

Students Who Analyze Their Own Data in a Course-Based Undergraduate Research Experience (CURE) Show Gains in Scientific Identity and Emotional Ownership of Research

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Appendix 1: Relevant measures and additional results

Supplemental online materials for

Students who analyze their own data in a course-based undergraduate research experience (CURE) show gains in scientific identity and emotional ownership of research

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This supplement contains the following:

DETAILED DESCRIPTION OF EACH MEASURE

Scientific self-efficacy. A six-item scale from Estrada et al., 2010 was used to measure students' scientific self-efficacy or their perceptions of their abilities to perform different research related tasks (e.g. to "figure out what data/observations to collect and how to collect them," "create explanations for the results of a study"). Students reported their perceptions of their abilities to perform certain tasks using a scale of 1 (not at all confident) to 5 (absolutely confident). Using the current data, the scientific self-efficacy scale was found to have acceptable internal consistency ($\alpha = 0.80$).

Scientific identity. Students' scientific identity was measured using a five-item scale from Estrada et al., (2010). The scale asked students to report the extent to which they agreed with statements such as "I have a strong sense of belonging to the community of scientists," and "I derive great personal satisfaction from working on a team that is doing important research, measured from 1 (strongly disagree) to 5 (strongly agree). Using the current data, the science identity scale was found to have acceptable internal consistency ($\alpha = 0.79$).

Scientific community values scale. Students' scientific community objective values or the extent to which students value objectives of the scientific community were measured using a four-item scale from Estrada et al., (2010). The scale asks students to rate four statements describing people who value objectives of the scientific community (e.g. "a person who feels discovering something new in science is thrilling," "a person who thinks discussing new theories and ideas between scientists is important") using response options from 1 (not like me at all) to 6 (very much like me). Using the current data, the scientific community objective values scale was found to have acceptable internal consistency ($\alpha = 0.77$).

Intent to pursue a scientific research career. Students' intent to pursue a scientific research career was measured using a single item from Estrada et al., (2010). Students were asked "To what extent do you intend to pursue a science-related research career?" which they answered on a Likert scale ranging from 1 (definitely will not) to 10 (definitely will).

The Laboratory Class Assessment Survey. The LCAS consists of three subscales to measure students' perceptions of the extent to which they engaged in three features of biology lab courses: collaboration, iteration, and discovery/relevance.

Collaboration*:* The LCAS collaboration subscale consists of six items that evaluate the frequency with which students engage in collaboration-related activities, such as discussing work with other students. Students report the frequency in which they engage in specific activities using four response options: 1 (never), 2 (one or two times), 3 (monthly), 4 (weekly). Using the current data, the collaboration subscale did not have acceptable internal consistency ($\alpha = 0.67$). As such, we removed item 5, "I was encouraged to provide constructive criticism to classmates and challenge each other's interpretations," yielding an acceptable reliability level ($\alpha = 0.70$). For all analyses, we used the five item adapted collaboration scale.

Iteration. The LCAS iteration subscale consists of six items about the extent to which students have time to experience iterative processes, such as repeating or revising their work. Students report the extent to which they have tie to experience iterative processes using six response options ranging from 1 (strongly disagree) to 6 (strongly agree). Using the current data, the iteration subscale was found to have acceptable internal consistency ($\alpha = 0.78$).

Discovery/Relevance. The LCAS discovery/relevance subscale uses five items to measure students' experiences of broadly relevant novel discoveries by asking students to rate the extent that they agree that their work in the lab could lead to new discoveries and whether their data are of interest to the scientific community. Students answer questions on a six-point scale ranging from strongly agree to strongly disagree. Using the current data, the discovery/relevance subscale was found to have acceptable internal consistency ($\alpha = 0.82$).

Perception of scientific research. We measured the extent to which students perceived they were engaging in scientific research in the context of the lab course using a previously developed question from Cooper et al., 2019. The question defines scientific research for the students as the type of research that is done in faculty members' labs and asked students to rate their agreement with the statement "I conducted scientific research in the Evolution course" on a 10-point scale from strongly disagree to strongly agree.

Project ownership. Students ownership of their research projects is measured using a 16-item survey developed by Hanauer and Dolan (2014). The project ownership scale contains two subscales measuring cognitive ownership or the degree to which students feel as though they have intellectual responsibility over their work and emotional ownership or the strength of the students' emotions toward their work (Hanauer and Dolan, 2014; Corwin et al., 2018).

***Cognitive ownership*:** Students' cognitive ownership was measured using 10 items that ask students to what extent they agree that they had intellectual ownership of or responsibility for their lab work (e.g., "I was responsible for the outcomes of the work I did [in my evolutionary lab course]) with a five-point response scale ranging from (1) strongly disagree to (5) strongly agree. Using the current data, the cognitive ownership subscale was found to have acceptable internal consistency ($\alpha = 0.89$).

***Emotional ownership**:* Students' emotional ownership was measured using six items that assess the strength of students' emotion toward their lab work (e.g. "To what extent does 'astonished' describe your experience of [your evolution laboratory course]?") with a five-point response scale ranging from (1) very slightly, to (5) very strongly. Using the current data, the emotional ownership subscale was found to have acceptable internal consistency ($\alpha = 0.88$).

Demographic questions. Students completed a set of demographic questions about their gender, race/ethnicity, major, year in college, and prior research experience. Students' demographics are reported in **Table 1.**

MEASURES

Scientific self-efficacy (Estrada et al., 2010)

Please indicate how confident you are in your ability	Not confident at all (1)	(2)	(3)	(4)	Absolutely confident (5)
1. to use technical science skills (use of tools, instruments, and/or techniques)					
2. to generate a research question to answer					
3. to figure out what data/observations to collect and how to collect them					
4. to create explanations for the results of the study					
5. to use scientific literature and/or reports to guide research					
6. develop theories (integrate and coordinate results from multiple studies)					

Science Identity (Estrada et al., 2010)

Please indicate the extent to which you agree with the statements below	Strongly disagree (1)	(2)	(3)	(4)	Strongly agree (5)
1. I have a strong sense of belonging to the community of scientists					
2. I derive great personal satisfaction from working on a team that is doing important research					
3. I have come to think of myself as a scientist					
4. I feel like I belong in the field of science					
5. The daily work of a scientist is appealing to me					

Science community values (Estrada et al., 2010)

Please rate how much the person in the description is like you.	Not like me at all (1)	Not like me (2)	A little like me (3)	Somewhat like me (4)	Like me (5)	Very much like me (6)
1. A person who thinks it is valuable to conduct research that builds on the world's scientific knowledge						
2. A person who feels discovering something new in the sciences is thrilling						
3. A person who thinks discussing new theories and ideas between scientists is important						
4. A person who thinks that science research can solve many of today's world challenges						

Plans to pursue a career in research

	Definitely will not 1	2	3	4	5	6	7	8	9	Definitely will 10
To what extent do you intend to pursue a science-related research career?										

The Laboratory Course Assessment Survey (Corwin et al., 2015)

Discovery/relevance scale

In this course I was expected to…	Strongly disagree (1)	Disagree (2)	Somewhat disagree (3)	Somewhat agree (4)	Agree (5)	Strongly agree (6)
1. generate novel results that are unknown to the instructor and that could be of interest to the broader scientific community or others outside of the class						
2. conduct an investigation to find something previously unknown to myself, other students, and the instructor						
3. formulate my own research question or hypothesis to guide an investigation						
4. develop new arguments based on data						
5. explain how my work has resulted in new scientific knowledge						

Iteration Scale

In this course…	Strongly disagree (1)	Disagree (2)	Somewhat disagree (3)	Somewhat agree (4)	Agree (5)	Strongly agree (6)
1. I had time to revisit or repeat work to account for errors or fix problems						
2. I had time to change the methods of the investigation if it was not unfolding as predicted						
3. I had time to share and compare data with other students						
4. I had time to collect and analyze additional data to address new questions or further test hypotheses						

that arose during the investigation				
5. I had time to revise or repeat analyses based on feedback				
6. I had time to revise drafts of papers or presentations about my investigation based on feedback				

Collaboration Scale

For this study, the full six-item collaboration subscale did not have acceptable internal consistency. Therefore, we dropped item 5 and used a five-item scale which did have acceptable internal consistency. The original scale is printed below.

In this course I was encouraged to…	Never (1)	One or two times (2)	Monthly (3)	Weekly (4)
1. discuss elements of my investigation with my classmates or instructors				
2. reflect on what I was learning				
3. contribute my ideas and suggestions during class discussions				
4. help other students collect or analyze data				
5. provide constructive criticism to classmates and challenge each other's interpretations				
6. share the problems I encountered during my investigation and seek input on how to address them				

Perception of scientific research (Cooper et al., 2019)

	Strongly disagree 1	2	3	4	5	6	7	8	9	Strongly agree 10
Scientific research is the type of research that is being done in faculty member research labs. Please indicate the extent you agree with the following statement: I conducted scientific research in the BIOL YYY Evolution course.										
Please explain your answer in 3-4 sentences.										

The Project Ownership Survey (Hanauer and Dolan, 2014

Cognitive ownership scale

	Strongly disagree (1)	Disagree (2)	Neither agree nor disagree (3)	Agree (4)	Strongly agree (5)
1. The work I did in the BIOL YYY Evolution course will help to solve a problem in the world.					
2. My findings in the BIOL YYY Evolution course were important to the scientific community.					
3. I faced challenges that I managed to overcome in completing the work I did in the BIOL YYY Evolution course.					
4. I was responsible for the outcomes of the work I did in the BIOL YYY Evolution course.					
5. The findings of the work I did in the BIOL YYY Evolution course gave me a sense of personal achievement.					
6. I had a personal reason for choosing what I worked on in the BIOL YYY Evolution course.					
7. The work I did in the BIOL YYY Evolution course was important to me.					
8. In conducting the work I did in the BIOL YYY Evolution course, I actively sought advice and assistance					
9. The work I did in the BIOL YYY Evolution course was interesting.					
10. The work I did in the BIOL YYY Evolution course was exciting.					

Emotional ownership scale

	Very slightly (1)	Slightly (2)	Moderate (3)	Considerably (4)	Very strongly (5)
1. To what extent does the word *delighted* describe your experience in the BIOL YYY Evolution course?					

2. To what extent does the word *happy* describe your experience in the BIOL YYY Evolution course?
3. To what extent does the word *joyful* describe your experience in the BIOL YYY Evolution course?
4. To what extent does the word *astonished* describe your experience in the BIOL YYY Evolution course?
5. To what extent does the word *surprised* describe your experience in the BIOL YYY Evolution course?
6. To what extent does the word *amazed* describe your experience in the BIOL YYY Evolution course?

Demographic questions

I most closely identify as

- Woman
- Man
- Other, please describe
- Decline to state

I most closely identify as

- American Indian or Alaska Native
- Asian or Pacific Islander
- Black or African American
- Hispanic, Latino, or Spanish Origin
- White/Caucasian
- Other, please describe
- Decline to state

I most closely identify as a

- First generation college student whose parents' highest level of education is a high school diploma or less
- Non-first generation college student (at least one parent has some college or a college degree)
- Decline to state

Do you have undergraduate research experience?

- Yes
- No

Table S2. Results of linear regression testing whether there were differences in students' perceptions of whether they conducted scientific research in the CURE between students who analyzed their own data and students who analyzed scientists' data.

	Students' perception of whether they conducted scientific research			
Variable	B	SE B	β	*p*
(Intercept)	8.2	0.4		<0.0001
Type of data analyzed (own)	0.4	0.5	0.1	0.33
Prior.research (yes)	0.5	0.5	0.1	0.31
Adjusted R^2	-0.00			

[a]B represents unstandardized coefficients and β represents standardized coefficients. Focus categories are indicated in parentheses.

Table S3. Summary of linear regression model exploring the relationship between the type of data students analyzed and their post CURE intent to pursue a science-related research career, controlling for student' pre CURE intent and demographics

	Pursue a career in science			
Variable	B	SE B	β	*p*
(Intercept)	2.5	1.0		0.01
Type of data analyzed (own)	0.7	0.5	0.1	0.20
Intention to pursue research career pre CURE	0.6	0.1	0.6	<0.001
Major (other)	0.6	0.9	0.1	0.52
Prior research (yes)	0.3	0.5	0.1	0.57
Gender (woman)	-0.4	0.6	-0.1	0.50
Race/ethnicity (Asian)	-0.3	0.7	-0.1	0.65
Race/ethnicity (BLPA)	-0.07	0.69	-0.0	0.92
Adjusted R^2	0.42			0.90

[a]B represents unstandardized coefficients and β represents standardized coefficients.
Focus categories are indicated in parentheses.

Table S4. Summary of linear regression model exploring the relationship between the type of data students analyzed and their emotional and cognitive ownership, controlling for students' major, prior research experience, gender, and race/ethnicty.[a]

	Model A: Emotional ownership				Model B: Cognitive ownership			
Variable	B	SE B	β	*p*	B	SE B	β	*p*
(Intercept)	20.7	1.5		<0.0001	41.6	2.0	0.2	<0.001
Type of data analyzed (own)	3.4	1.2	04	<0.01	2.2	1.6	-0.0	0.16
Major (other)	2.4	2.0	0.2	0.23	-0.1	2.6	0.0	0.98
Prior research (yes)	1.1	1.2	0.1	0.38	0.2	1.6	0.1	0.76
Gender (woman)	-0.0	1.2	-0.0	0.97	-0.5	1.6	-0.0	0.72
Race/ethnicity (Asian)	-1.3	1.4	-0.1	0.36	-0.7	1.8	-0.1	0.72
Race/ethnicity (BLPA)	0.97	1.5	0.1	0.52	0.3	2.0	0.0	0.86
Adjusted R^2	0.10				-0.06			

[a]B represents unstandardized coefficients and β represents standardized coefficients.
Focus categories are indicated in parentheses.

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