Supplemental Material

CBE—Life Sciences Education

Cooper *et al.*

Supplemental online materials for

The impact of broadly relevant novel discoveries on student project ownership in a traditional lab course turned CURE

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This supplement contains the following:

Table S1. Results of chi square tests of independence. There were no significant demographic differences between students in the traditional lab course and students in the CURE courses.

Demographics[a]	Traditional lab course students n = 32	CURE students n = 72	Results of chi square tests
	n (%)	n (%)	
Gender			
Female	17 (53%)	42 (58%)	$\chi^2 = 0.10$, $p = 0.76$
Male	13 (41%)	28 (39%)	
Race/ethnicity[b]			
Non-URM	21 (66%)	46 (64%)	$\chi^2 = 0.14$, $p = 0.71$
URM	8 (25%)	21 (29%)	
College generation status			
First generation	11 (34%)	29 (40%)	$\chi^2 = 0.39$, $p = 0.53$
Non-first generation	21 (66%)	42 (58%)	
Previous research experience			
No	15 (47%)	27 (38%)	$\chi^2 = 0.81$, $p = 0.37$
Yes	17 (53%)	45 (63%)	

[a]We did not compare the proportions of students who were reported "other" for their gender or race/ethnicity or of students who declined to state a demographic variable because of the small number of students in each category. Thus, the percentages in each demographic group may not add up to 100%.[b]Students who identified as Black or African American, Hispanic, Latino/a, or of Spanish Origin were classified as underrepresented racial minorities (URM). Students who identified as Asian/Pacific Islander and White were classified as Non-URM.

MEASURES

The Laboratory Course Assessment Survey (Corwin et al., 2015)
Discovery/relevance scale (original Chronbach's alpha = 0.76)

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(original Chronbach's alpha = 0.75)

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 (original Chronbach's alpha = 0.76)

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

	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 MIC YYY: Experimental Immunology.										
Please explain your answer in 3-4 sentences.										

The Project Ownership Survey (Hanauer and Dolan, 2014

(original Chronbach's alpha = 0.92)

The original survey was adapted slightly for our study by replacing the words "research question" or "research project" with "the work I did in MIC YYY: Experimental Immunology." "YYY" is used in place of the course number.

Cognitive ownership scale

	Strongly disagree (1)	Disagree (2)	Neither agree nor disagree (3)	Agree (4)	Strongly agree (5)
1. The work I did in MIC YYY: Experimental Immunology will help to solve a problem in the world.					
2.My findings in MIC YYY: Experimental Immunology were important to the scientific community.					
3. I faced challenges that I managed to overcome in completing the work I did in MIC YYY: Experimental Immunology.					
4. I was responsible for the outcomes of the work I did in MIC YYY: Experimental Immunology.					
5. The findings of the work I did in MIC YYY gave me a sense of personal achievement.					
6. I had a personal reason for choosing what I worked on in MIC YYY: Experimental Immunology.					
7. The work I did in MIC YYY: Experimental Immunology was					

important to me.					
8. In conducting the work I did in MIC YYY: Experimental Immunology, I actively sought advice and assistance					
9. The work I did in MIC YYY: Experimental Immunology was interesting.					
10. The work I did in MIC YYY Experimental Immunology 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 MIC YYY: Experimental Immunology?					
2. To what extent does the word *happy*describe your experience in MIC YYY: Experimental Immunology?					
3. To what extent does the word *joyful*describe your experience in MIC YYY: Experimental Immunology?					
4. To what extent does the word *astonished*describe your experience in MIC YYY: Experimental Immunology?					
5. To what extent does the word *surprised*describe your experience in MIC YYY: Experimental Immunology?					
6. To what extent does the word *amazed*describe your experience in MIC YYY: Experimental Immunology?					

Demographic questions

I most closely identify as

- Female
- Male
- 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. Coding rubric for students' explanation of their agreement with the statement that they conducted scientific research in their immunology lab course**.**

Topic	Description
Research was novel or broadly relevant	Student must describe that they engagedwith a novel or broadly relevant research question or that they were doing real research with an unknown answer. The student canacknowledge that their work will lead to new information. Further, the student can acknowledge that the work they're doing is contributing to a faculty member's research. If a student simply lists the research question that they were answering, this is not sufficient to be coded as this category.
Research was not novel or broadly relevant	Student must describe that the research question they were answering had already been investigated, understood, or reproduced. Student can also describe that the research that they did was not real or not relevant.
Engaged in scientific practices	Student must describe engaging in a scientific practice including following the scientific method, making hypotheses, designing experiments, following protocols, learning or using techniques, analyzing data or interpreting data.
Lack of autonomy when engaging in scientific practices	Student must describe a lack of autonomy when engaging in a specific scientific process. For example, describing that they did not develop their own research question, set up their own experiments, or decide which experiments to perform.

Table S3. Student scores on the LCAS collaboration, iteration, and discovery/relevance subscales.[a]

	Traditional lab students		CURE Students						
	Mean	SD	Mean	SD	Welch *df*	t	*p*	Hedge's *g*	Possible range of scores
Collaboration scale	20.84	2.73	21.15	3.04	NA	0.49	0.62	0.11	6-24
Iteration scale	20.50	5.11	21.54	6.18	NA	0.83	0.41	0.18	6-36
Discovery scale	18.06	5.09	26.54	3.18	42.12	8.70	<0.0001	2.18	5-30

[a]Students in the CURE had significantly higher ratings than students in the traditional lab course on the discovery/relevance scale, but there were no significant differences between student ratings on the collaboration scale or iteration scale. The collaboration scale measures how often students engage in collaborative activities in lab ranging from never (1) to weekly (4). The iteration and discovery/relevance scales measure the extent to which students agree that they experience these dimensions with six response options ranging from strongly disagree (1) to strongly agree (6). The assumption of homogeneity was met for the collaboration and iteration subscales as well as the LCAS total score. However, it was not met for the discovery/relevance scale and thus Welch's *df* adjustment was made for the discovery scale only.

Table S4. Student agreement with the statement "I conducted scientific research in [the immunology lab course][a]."

	Traditional lab students		CURE Students						
	Mean	SD	Mean	SD	Welch *df*	t	*p*	Hedges' *g*	Possible range of scores
Agreement student was conducting real research	6.71	2.66	8.57	1.69	40.75	3.59	<0.001	0.91	1-10

[a] Students in the CURE were more likely to agree that they had conducted real research in their immunology lab course than students in the traditional lab course. Students rated their agreement from (1) strongly disagree to (10) strongly agree. The assumption of homogeneity was not met forthis question and thus Welch's *df* adjustment was made.

Table S5. Results of chi square tests of independence comparing proportions of coded student responses to the question about why they do or do not perceive they are participating in scientific research.

Category	Traditional lab course students n = 27	CURE students n = 57	Results of chi square tests of independence
	n (%)	n (%)	
Research was novel or broadly relevant	0 (0%)	31 (54.4%)	$\chi^2 = 17.6$, $p < 0.0001$
Research was not novel	17 (63.0%)	0 (0%)	$\chi^2 = 41.9$, $p < 0.0001$
Engaged in scientific processes	16 (59.3%)	32 (56.1%)	$\chi^2 = 0.10$, $p = 0.76$
Lack of autonomy when engaging in scientific processes	2 (7.4%)	11 (19.3%)	$\chi^2 = 0.93$, $p = 0.33$

Table S6. Comparison of traditional lab student and CURE student mean cognitive ownership and emotional ownership scores.

	Traditional lab students		CURE Students					
	Mean	SD	Mean	SD	t	*p*	Hedges' *g*	Possible range of scores
Cognitive ownership	36.72	5.24	40.71	5.89	3.29	0.001	0.69	10-50
Emotional ownership	17.84	4.15	20.60	5.19	2.65	<0.01	0.56	6-30

Table S7. Summary of linear regression model exploring the relationship between lab course design features and students' cognitive and emotional ownership controlling for student demographics.[a]

	Model A: Cognitive Ownership				Model B: Emotional Ownership			
Variable	B	SE B	β	*p*	B	SE B	β	*p*
(Intercept)	11.06	3.36		<0.01	0.61	3.43		0.86
Course type: (CURE)	-2.74	1.45	-0.21	0.06	-0.66	1.48	-0.06	0.66
Collaboration	0.45	0.18	0.22	<0.05	0.37	0.18	0.22	<0.05
Iteration	0.07	0.10	0.07	0.49	0.05	0.10	0.07	0.58
Discovery/relevance	0.80	0.14	0.72	<0.0001	0.45	0.14	0.48	<0.01
Gender (female)	-0.39	0.91	-0.03	0.67	-1.01	0.93	-0.10	0.28
Race/ethnicity (URM)	0.23	0.98	0.02	0.82	0.35	1.00	0.03	0.73
College gen. status (first-gen)	0.75	0.97	0.06	0.44	0.19	0.99	0.02	0.85
Prior research experience (no)	-0.34	0.89	-0.03	-0.70	0.20	0.91	0.02	0.83
Adjusted R^2	0.54				0.32			

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

REFERENCES

Corwin, L. A., Runyon, C., Robinson, A., & Dolan, E. L. (2015). The laboratory course assessment survey: a tool to measure three dimensions of research-course design. *CBE-Life Sciences Education*, *14*(4), ar37.

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