A Boost for the CURE: Improving Learning Outcomes with Curriculum-Based Undergraduate Research

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In a recent survey of geoscience employers, more than 75% of respondents indicated that the particular courses a job candidate had taken were less important predictors of workforce success than the development of problem-solving skills, competencies, and conceptual understanding (Summa et al., 2017). An effective pathway to develop these attributes is through participation in undergraduate research experiences (UREs), which are known to catalyze increases in conceptual understanding, confidence, and skills through the practice of scientific investigation (NASEM, 2017). Since many traditional UREs follow an apprentice-style approach via one-on-one mentoring, they are faculty intensive, often selective, and open to fewer students. Course-based UREs (CUREs) provide a mechanism to scale up participation and increase access by bringing collaborative research that generates new knowledge with broad relevance into the classroom (Auchincloss et al., 2014). However, the short-term nature of a CURE (NASEM, 2017) leaves little time for students to reflect upon alternative interpretations or revise hypotheses—two fundamental components of the process of science.

Time is a critical factor in the development of science skills and professional attitudes, because novice researchers become proficient at technical tasks through iterative data collection relatively rapidly, but it can take more than a year in a URE to develop confidence, perseverance, and a more holistic understanding of the nature of science (Thiry et al., 2012). How can a URE provide the benefit of time, while also increasing student access to research? In this contribution, we propose that it is possible to resolve this by extending a CURE across multiple required courses in a curriculum. This gives students the positive impact of a commitment that is sustained over time, reduces the bottleneck associated with apprentice-style UREs, and broadens academic and social inclusion by opening the doors of research to everyone.

A CURRICULUM-BASED UNDERGRADUATE RESEARCH EXPERIENCE

Our novel, multi-semester, curriculum-based undergraduate research experience (MS-CURE) is embedded in five semester-length courses across the core geology curriculum. The two-year sequence begins with a sophomore-level course in environmental and applied geology and continues through earth materials and minerals, structural geology, petrology, and our summer geology field camp. Research is spread across each course as: (1) writing assignments integrating traditional course topics with the URE; (2) components of endemic laboratory activities; and (3) short discussions (specific activities and learning goals are presented in Fig. S1[1]). Importantly, each student retains the same research project through the sequence so he/she/they can incrementally build a complex data set while progressively writing and revising a journal-style research paper at the same time as others in the class. The writing spans four courses, providing students space for metacognitive reflection from one course to another and time to mature in their understanding of the process of science. In order to scaffold the learning experience, students incrementally present results at a campus-wide poster forum during the second and fourth semesters.

The student research topics are multidisciplinary and focus on the petrology, geochemistry, and structural geology of a system of mid-crustal fault rocks in the Colorado Rockies. Although the research foci are based upon our departmental capabilities and research interests, the MS-CURE model is transferable to other research themes, course sequences, and durations. For example, an MS-CURE could be distributed across two or more courses with or without gaps and lead to senior independent research or a capstone course. Further, an MS-CURE could capitalize on local geologic, hydrologic, or environmental problems amenable to collaborative, long-term investigation.

In our MS-CURE, participants prepare thin sections from the field area and analyze them using petrographic methods and electron probe microanalysis across four consecutive campus-based courses. The URE concludes with original mapping at the field site during the summer field camp, in which the lab work is placed in a field context and samples for future cohorts are collected. This fosters continuity and establishes scientific communication and data sharing between past and future cohorts. Students are assigned samples from the same field site, but each student feels ownership of a unique set of data.

LEARNING GAINS

In order to evaluate learning gains and the effectiveness of the MS-CURE, two cohorts of students anonymously responded to a set of questions from the Undergraduate Research Student Self-Assessment (URSSA; Weston and Laursen, 2015) at the end of the five-course sequence. Both cohorts were taught by the same instructors (JLA and SCK), and an external evaluator (EGC) prompted students to respond to the URSSA on the basis of the embedded URE. We then compared pub-

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[1]Supplemental Material: MS-CURE research activities, learning goals, and rubric for student assessment. Please visit https://doi.org/10.1130/GSAT.S.12290381 to access the supplemental material, and contact editing@geosociety.org with any questions.

lished data (Thiry et al., 2012) from novice (≤1 year) and experienced (>1 year) undergraduate researchers to the MS-CURE students. Students in the comparison groups participated in apprentice-style UREs predominated by bioscience disciplines at two research-intensive universities. Those participants were competitively selected, received stipends, and had access to supplemental enrichment activities as part of their experience. Therefore, the comparison groups likely reflect best-case URE outcomes. In contrast, our MS-CURE reached a broad cross section of students who completed their research as part of graded, required courses that included other topics and exams and a higher student-faculty ratio, which can discourage interest in research (Auchincloss et al., 2014).

The comparative results show that the MS-CURE students experienced gains comparable to the experienced, apprentice-style URE students (Table 1). In the category of personal and professional gains, four of five items and the mean for the category show statistically significant gains between the novice URE comparison group and the MS-CURE group. This suggests that extended time helped the MS-CURE students to develop self-confidence in their ability to function as scientists. Alternatively, other factors, such as group interaction among the MS-CURE students, as well as with the instructors, fostered increased personal and professional gains. In the category of thinking and working like a scientist, the MS-CURE group showed high Likert scores that are similar to those of experienced students, although statistically indistinguishable from novice students. The highest gains were in perceived improvements in problem solving and probably reflect the real-world nature of the research project.

SYNERGISTIC BENEFITS

Students of lower socioeconomic status, first-generation students, and underrepresented groups often are unaware of the benefits of research and thus may not apply for competitive research opportunities (NASEM, 2017). Extending the traditional CURE into a curriculum-embedded experience provides an opportunity for all students in an academic major to have access to a more authentic research experience that can foster gains in confidence, comfort in working with others, and problem solving. These are examples of the types of changes to student learning that promote workforce preparedness (Summa et al., 2017). For students, the MS-CURE model supports enhancement of social diversity and thus levels the playing field for research access. For academic departments, student-focused research provides a central organizing theme for the curriculum and allows undergraduates and faculty to operate within a connected learning community.

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REFERENCES CITED

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., Trautmann, N.M., Varma-Nelson, P., Weston, T.J., and Dolan, E.L., 2014, Assessment of course-based undergraduate research experiences: A meeting report: CBE Life Sciences Education, v. 13, p. 29–40, https://doi.org/10.1187/cbe.14-01-0004.

National Academies of Science, Engineering, and Medicine (NASEM), 2017, Undergraduate Research Experiences for STEM Students: Successes, Challenges, and Opportunities: Washington, D.C., National Academies Press, 279 p., https://doi.org/10.17226/24622.

Summa, L., Keane, C., and Mosher, S., 2017, Meeting changing workforce needs in geoscience with new thinking about undergraduate education: GSA Today, v. 27, no. 9, p. 60–61, https://doi.org/10.1130/GSATG342GW.1.

Thiry, H., Weston, T.J., Laursen, S.L., and Hunter, A.-B., 2012, The benefits of multi-year research experiences: Differences in novice and experienced students' reported gains from undergraduate research: CBE Life Sciences Education, v. 11, p. 260–272, https://doi.org/10.1187/cbe.11-11-0098.

Weston, T.J., and Laursen, S.L., 2015, The Undergraduate Research Student Self-Assessment (URSSA): Validation for use in program evaluation: CBE Life Sciences Education, v. 14, p. 1–10, https://doi.org/10.1187/cbe.14-11-0206.

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TABLE 1. MEANS FOR SURVEY ITEMS

URSSA survey items and category means. How much did you gain in the following areas as a result of your URE?*	**Novice** student comparison group† (*n* = 29)		**Experienced** comparison group† (*n* = 44)		**MS-CURE** students# (this study; *n* = 14)	
	Mean	(SD)	Mean	(SD)	Mean	(SD)
Personal/Professional Gains Category						
Confidence in my ability to do research	2.82	(1.10)	3.38	(0.68)	3.43§	(0.62)
Confidence in my ability to contribute to science	2.75	(1.00)	3.32	(0.78)	3.29§	(0.70)
Comfort discussing scientific concepts with my research mentor	3.18	(0.60)	3.40	(0.82)	3.36	(0.61)
Comfort discussing scientific concepts with other research students	2.85	(0.84)	3.45	(0.69)	3.64§	(0.48)
Comfort in working collaboratively with others	3.09	(0.70)	3.64	(0.57)	3.57§	(0.50)
Category Mean	**2.94**	**(0.85)**	**3.44**	**(0.71)**	**3.46§**	**(0.58)**
Thinking and Working Like a Scientist Category						
Understanding how to collect scientific data	3.40	(0.64)	3.61	(0.65)	3.57	(0.49)
Understanding how scientific research is done	3.43	(0.79)	3.71	(0.55)	3.71	(0.45)
Analyzing data for patterns	3.10	(0.76)	3.35	(0.79)	3.29	(0.59)
Interpreting results from analyzing scientific data	3.09	(0.86)	3.40	(0.74)	3.43	(0.49)
Problem solving in general	3.15	(0.77)	3.44	(0.76)	3.64§	(0.48)
Formulating a research question that can be answered with data	3.26	(0.75)	3.21	(0.93)	3.29	(0.70)
Identifying flaws in the interpretation of data	3.09	(0.76)	3.35	(0.83)	3.29	(0.70)
Figuring out the next steps in a research project	3.17	(0.79)	3.24	(0.88)	3.07	(0.70)
Category Mean	**3.21**	**(0.77)**	**3.41**	**(0.77)**	**3.41**	**(0.58)**

* Likert scale: 1 = no gain; 2 = a little gain; 3 = good gain; 4 = great gain.
† Comparison group data from Thiry et al. (2012).
# Demographics: 43% female, 14% minority, 36% 1st generation, 43% Pell, $\bar{x}$ GPA 3.03 (RGE 2.1–3.7), $\bar{x}$ GPA major 2.64 (RGE 2.0–3.6).
§ $P \leq 0.05$ determined from unequal variances *t*-test of novice student comparison group mean vs. MS-CURE mean.
SD—standard deviation; RGE—range; URE—undergraduate research experiences; URSSA—Undergraduate Research Student Self-Assessment.