Instructor Conceptions and Implementation of Course-based Undergraduate Research Experience (CURE) Features

Ruth Kaggwa, Lisa Walsh, and Kristine Callis-Duehl;
Donald Danforth Plant Science Center, St. Louis, MO

Abstract

Course-based undergraduate research experiences (CUREs) defined by five features/attributes; use of scientific practices/process, iteration, collaboration, broad relevance and discovery, are a unique form of pedagogy that incorporates authentic research into classroom teaching. Despite their contributions to improving student outcomes, CUREs are not wide spread. Insights into the conceptions of instructors that implement CUREs might inform efforts towards increased adoption and improved student outcomes.The goal of our study was therefore to investigate instructor conceptions of the CURE features and their influence on implementation. We developed a survey informed by research goals targeting biology undergraduate instructors and shared it on the online platform Qualtrics to professional scientific organization directories. Our respondents comprised 53 instructors with CUREs experience including faculty and graduate students. Of the five CURE features, the highest proportions of misaligned conceptions were in the discovery and broad relevance aspects. Furthermore, fewer respondents reported including broad relevance and iteration in implementation of their CUREs relative to the other three. Our findings suggest the need for greater professional development efforts focused on the framework of CUREs to improve fidelity of implementation and consequently student outcomes; and a revision of the current framework to incorporate new instructor suggested aspects such as student centered-communication.

Subject/Problem:

Course-based undergraduate research experiences (CUREs), that involve embedding of authentic research into classroom teaching have been adopted by instructors of undergraduate classrooms to improve student outcomes. Despite numerous benefits to students including stimulated interest in STEM fields and careers, increased knowledge and learning of STEM content, and STEM degree completion, the adoption of CUREs is still not widespread (Siritunga et al., 2011; Shaffer et al., 2014; Wolkow et al., 2019; Rodenbusch et al., 2016; Kerr et al., 2016; Provost et al. 2019). CUREs are uniquely defined by five features/aspects/dimensions/attributes that include; use of scientific practices/process, iteration, collaboration, broad relevance, and discovery (Auchincloss et al. 2014), but hardly any information exists on instructor conception and implementation of these features, yet instructor understanding of concepts will impact implementation and thus might impact dissemination, adoption and student outcomes. Research studies on instructor experiences with CUREs have so far mostly examined benefits and challenges of implementing CUREs (Shortlidge et al., 2016 & 2017; Spell et al. 2014). Insights into instructor conceptions and experiences of the five core CURE features should inform efforts to disseminate and increase adoption of CUREs towards improving student outcomes. The aim of our study was therefore to investigate how much instructors know about CUREs to identify how that knowledge and understanding influences implementation of CUREs through the following research questions:

1. *Fidelity and alignment of terminology* – Do instructor definitions of the 5 CURE aspects align with the CURE foundational literature? How are these CURE aspects defined by

CURE instructors? How are CUREs defined based on how well instructor conceptions align with the foundational literature?

2. *Fidelity and alignment of implementation* – Do instructors try to implement the 5 CURE aspects, and does their implementation align with the CURE foundational literature?
3. *Additions to foundational literature* – Are there critical aspects to a CURE that are missing from the foundational literature?

Design or Procedure:

We utilized a mixed methods approach and outlined research goals to inform our development of the survey questions and mapped each survey question to our research goals. We refined the survey questions through a cycle of soliciting feedback from biology education research experts and CURE experts and revising the survey. After six rounds of revision, the survey was finalized in Qualtrics and distributed to over 15 professional scientific organization listservs, directories, and biology departments. The survey was open from February to March 2020. The final survey consisted of five academic background questions, three CURE experience questions, and 16 CURE qualitative questions. For each of the five CURE aspects, survey participants were asked to describe the aspect, if they implement the aspect in their CURE, and if so, how do they implement the aspect? Additionally, we asked participants if they could think of any additional aspects important to their CURE.

Analyses and Findings:

Two researchers independently coded the five CURE aspects descriptions to determine how closely aligned (aligned, semi-aligned, or misaligned) the responses were to their definitions found in Auchincloss et al. (2014). After initial coding, inter-rater reliability, measured using Cohen's Kappa coefficient, was 0.488. This low inter-rater reliability was primarily due to differences in "semi-aligned" coding between the two researchers. A mediated discussion between the two researchers was implemented to reconcile conflicting coding, resulting in a Cohen's Kappa coefficient of 0.915. To evaluate variation in definition alignment between instructors running network CUREs and instructors running home grown CUREs, we ran a binary logistic regression in SPSS (IBM version 27) using the forward likelihood ratio, which adds categorical or continuous variables to the model if they significantly improve the model's performance.

To identify common themes in the qualitative survey descriptions of each of the CURE aspects, we used MonkeyLearn software to build word clouds for each of the three different groups (aligned, semi-aligned, and misaligned) that had at least 7 responses. This software removes non-informative words (e.g., "the", "you", "is"), collapses words to their shared stem word (i.e., collecting or collected become collect), compiles synonyms, and uses artificial intelligence to automatically identify and group co-occurring words (i.e., phrases) (https://monkeylearn.com/word-clouds/ accessed June 10). For each CURE aspect, the researchers used the most frequent words within each word cloud to compile one-sentence definition, as well as an overall definition for CUREs.

CURE Implementation Analysis: Two researchers independently coded the participants survey data on the five CURE aspects implementations to determine if each aspect aligned (aligned, semi-aligned, or misaligned) with the definitions found in Auchincloss et al. (2014). For respondents who indicated that they did not implement a given CURE aspect, their remaining implementation answers and their overall CURE description were reviewed by researchers to determine if there was evidence that they actually implemented the given CURE aspect. After initial coding, inter-rater reliability, measured using Cohen's Kappa, was 0.737. For responses with conflicting codes, a third researcher independently coded the responses to reach a final consensus.

To evaluate variation in implementation alignment between instructors running network CUREs and instructors running home grown CUREs, we ran a binary logistic regression in SPSS (IBM version 27) using the forward likelihood ratio, which adds categorical or continuous variables to the model if they significantly improve the model's performance. We also evaluated the correlation between the respondent's CURE description and how their implementation was coded (i.e., are their definitions more likely to align with literature if they are correctly implementing the aspect in their course). This was done in R by measuring Cramér's V, a statistical extension of the Chi-Squared statistic (Cramer 1946), available in the 'rcompanion' package (Mangiafico, 2021).

There were 53 respondents who had experience with CUREs including 21 tenured faculty, 14 tenure track faculty, 12 non-tenure track faculty, three graduate students, two lab managers, and one department chair. Most respondents taught both lecture and lab (N = 48), but three exclusively taught lab and two exclusively taught lecture, majority at R1 institutions and primarily undergraduate institutions. The most frequent CURE activity respondents had participated in was implementing a CURE (98%), followed by designing a CURE (72%). Most respondents (81%) had participated in running a CURE within the last year, and the remaining participants had participated in the last five years.

CURE Definition Analysis: The CURE feature, discovery had the highest percentage of misaligned responses (46.3%), to the Auchincloss et al. (2014) CURE framework, followed by broad relevance (35%). While most responses for iteration and scientific process were aligned with CURE literature, 68.3% of collaboration descriptions were only vague enough to be coded as semi-aligned to the literature. When the five word-cloud generated CURE aspects are combined, the "crowd-sourced" CURE definition from survey responses that aligns with Discipline Based Education research (DBER) literature reads:

"*Student groups using their diverse skills to generate and analyze data for novel scientific questions, reflecting on their results to improve and repeat their experiments leading to new knowledge that connects to societal topics or scientific problems within the field of study*."

The compiled CURE definition that is misaligned from DBER literature reads:
"*Students learn new knowledge through answering inquiry science questions that interest them, while developing useful science skills*."

CURE Implementation Analysis: When instructors were asked if they implement each of the five CURE components (Auchincloss *et al.*, 2014), a smaller percentage of instructors' CURE included broad relevance and iteration than the scientific process, discover, and collaboration. Of the respondents who included a description of their CURE but indicated they did not include at least one of the CURE aspects, 10 ran home grown CUREs while two ran network CUREs.

The binary logistic regression revealed a significant relationship between type of CURE (home-grown vs. network) and whether broad relevance was implemented according to the foundational literature's definition (p = 0.046). While 80% of respondents who used network CUREs implemented broad relevance, only 61% of respondents who used home-grown CUREs implemented broad relevance. Based on Cramér's V coefficients (>0.5 high association, 0.3-0.5 moderate association, 0.1-0.3 low association), there was a moderate association between definition alignment and implementation alignment for iteration, discovery, and collaboration (Cramér, 1946). There was a low association between definition alignment and implementation alignment for scientific practice and broad relevance.

Additional CURE Aspects Analysis: We received 16 responses from survey participants (13 faculty, two lab managers, and one graduate student) suggesting additional CURE aspects to the 5 outlined in Auchincloss et al. (2014). We identified two overarching themes: CUREs as a learning experience opportunity (N = 14) for students and the need for outside support (N = 3) such as faculty support, department support, or broader community support. Five subthemes emerged within Learning Experience: student communication skills, student-centered inquiry, and design to improve student engagement and ownership of the project, resilience, research techniques, and teamwork.

Conclusion: Our studies have shown that, of the five CURE dimensions/features proposed by Auchincloss et al. (2014) higher proportions of misaligned conceptions of the CURE features discovery and broad relevance prevail among biology instructors implementing CUREs, relative to the other three. Additionally, only a few of our sample of instructors include broad relevance and iteration in implementation of their CUREs relative to the scientific process, discovery, and collaboration. Furthermore, implementation of CURE features such as broad relevance is greater among instructors implementing network relative to home-grown CUREs. Our respondent instructors suggest an expansion of the current framework of five features Auchincloss et al. (2014) to include student-centered aspects such as communication skills, inquiry and design, resilience, research techniques, and teamwork.

Contribution:

To understand student experience and outcomes from CUREs, gauging conceptions of CURE features and fidelity of implementation are a key component that is currently missing in the assessment of CUREs. We are adding to this definition of a CURE by collecting instructor conceptions of each of these dimensions. Our results indicate that even among biology instructors that implement CUREs, in their classroom teaching, misconceptions about the CURE features and framework still prevail, this is likely to impact fidelity of implementation and consequently student outcomes. These findings suggest the need for professional development by instructors that implement CUREs to improve understanding and to ensure fidelity of implementation, which could impact student outcomes.

General Interest:

Education reform efforts by the AAAS have advocated for integration of research into classroom teaching to improve STEM learning. While CUREs have addressed this call, gaps prevail in instructors' understanding of the CURE framework that are likely to impact dissemination to peers, classroom implementation and student outcomes. Our findings suggest the need for greater professional development efforts focused on the framework of CUREs and a revision and expansion of the current framework to incorporate new instructor suggested aspects that contribute to student outcomes.

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