Perspective

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Can We Quantify If It's a CURE?

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Course-based undergraduate research experiences (CUREs) rapidly have become more common in biology laboratory courses. The effort to implement CUREs has stimulated attempts to differentiate CUREs from other types of laboratory teaching. The Laboratory Course Assessment Survey (LCAS) was developed to measure students' perceptions of how frequently they participate in activities related to iteration, discovery, broader relevance, and collaboration in their laboratory courses. The LCAS has been proposed as an instrument that can be used to define whether a laboratory course fits the criteria for a CURE or not. However, the threshold LCAS scores needed to define a course as a CURE are unclear. As a result, we examined variation in published LCAS scores among different laboratory course types. In addition, we examined the distribution of LCAS scores for students enrolled in our research-for-credit course. Overall, we found substantial variation in scores among CUREs and broad overlap among course types in scores related to all three scales measured by the LCAS. Furthermore, the mean LCAS scores for all course types fell within the main part of the distribution of scores for our mentored research students. These results suggest that the LCAS cannot be used to easily quantify whether a course is a CURE or not. We propose that the biology education community needs to move beyond trying to quantitatively identify whether a course is a CURE. Instead, we should use tools like the LCAS to investigate what students are actually doing in their laboratory courses and how those activities impact student outcomes.

KEYWORDS course-based undergraduate research experience, CURE, CRE, Laboratory Course Assessment Survey, LCAS, mentored research, authentic research, discovery, broad relevance, iteration, collaboration

PERSPECTIVE

Over a decade ago, the Vision and Change report (1) called for research experiences for all undergraduate students. Because providing traditional mentored research experiences for all students is not feasible, reforms in science laboratory education have pushed replacing traditional laboratory courses with research courses to meet this goal (2). Course-based undergraduate research experiences (CUREs) first appeared in science education literature in the early 2000s, along with an acronym for an assessment instrument on classroom undergraduate research experiences (3). However, the pedagogical concept is much older (4). A survey conducted soon after the release of the Vision and Change report found that laboratory courses in biology rarely incorporated authentic research experiences (5). Yet, the number of publications on CUREs has increased rapidly in recent years (Fig. 1).

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Along with the development and implementation of CUREs, there has been substantial discussion of how CUREs differ from other forms of laboratory teaching (5–8). Most commonly, discipline-based education researchers and laboratory instructors have used the framework proposed by Auchincloss et al. (8), in which CUREs are distinguished from traditional laboratory courses by (i) collaboration, (ii) discovery, (iii) broad relevance, (iv) iteration, and (v) use of science practices. Based on this framework, Corwin et al. (9) developed the Laboratory Course Assessment Survey (LCAS), a 17-item survey instrument to measure students' perceptions of how frequently they participate in activities related to iteration, discovery and relevance, and collaboration in their courses. An original version of the LCAS included items related to the use of science practices. However, those items did not group together in their factor analysis and were removed from the final version of the survey (9). Six items ask students about iteration, five items ask students about aspects of discovery and relevance that combine the criteria of discovery and broad relevance, and six items ask about aspects of collaboration. These three sets of items then establish a score on each of three scales related to these types of course activities. In their original study, Corwin et al. (9) found that perceptions of students in CURE courses differed significantly from those of students in "traditional" laboratory courses in terms of iteration and in terms of discovery and relevance, though not in relation to collaboration. As a result, the LCAS was proposed as an instrument that could be used to

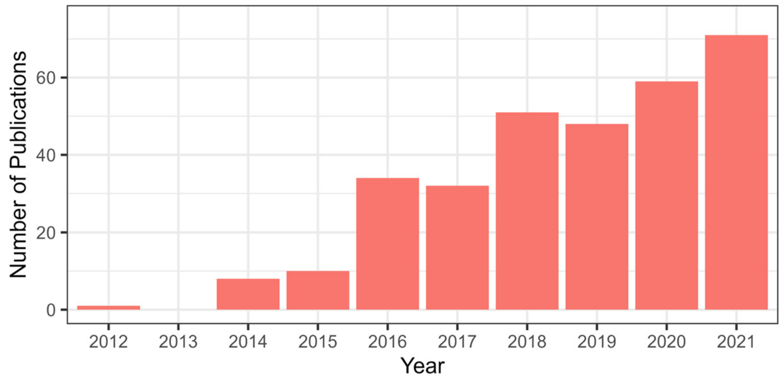

FIG 1. Number of publications on course-based undergraduate research experiences over time. Data are from a Web of Science search of all fields using the terms "course-based undergraduate research experience," "course-based undergraduate research experiences," "course-based research experience," and "course-based research experiences." These publications included papers on development and implementation of specific CURE curricula as well as papers on studies of CUREs as a pedagogical approach.

determine whether a laboratory course fits the criteria for a CURE or not (9, 10). However, the thresholds on the LCAS scales for a course to be considered a CURE were not defined.

As a result, we were interested in the variation in mean scores of the LCAS scales reported in previous studies and whether these data could be used to quantify a threshold for whether a course should be considered a CURE. In addition, we examined the distribution of LCAS scores for students enrolled in our research-for-credit course, in which students conduct independent research under the mentorship of a faculty member, postdoctoral fellow, or advanced graduate student. Typically, students take the course as a part of a two-semester sequence, although students can take it for more than two semesters. Students in our sample included those enrolled for the first semester and those who are continuing. Corwin et al. (9) suggested using the LCAS in the context of mentored research experiences. Because the LCAS was designed for CUREs, we modified the prompts slightly to make them more appropriate for mentored research students (see Table S1 in the supplemental material). As CUREs are intended to replicate mentored research experiences in a course setting, we suggest that a laboratory course with LCAS scores that fall within the distribution of LCAS scores for students in mentored research experiences could be considered a CURE. Alternatively, if the LCAS scores for a range of laboratory courses found in the literature largely overlap the distribution of LCAS scores for students in mentored research experiences, this would suggest that the LCAS might not be able to clearly distinguish among the range of student research experiences.

Variation in LCAS scores

To determine the variation in LCAS scores in the literature, we conducted a cited reference search for the Corwin et al. article (9) in Web of Science and Google Scholar. The resulting papers were searched to determine if they cited Corwin et al. (9) and if they collected LCAS data rather than just citing Corwin et al. (9). Our search resulted in 24 papers that collected LCAS data (9, 11–33). Papers were excluded from our analysis when LCAS scores or summary statistics were not presented (13, 19, 20, 30, 32) or the LCAS scores were not in forms that were directly comparable (17). Because some studies modified the LCAS survey by either changing the number of items or altering the Likert scale, we normalized the data by presenting scores as a percentage of the maximum possible score. The majority of the studies examined curricula that extended across an entire semester. However, some laboratory modules were as short as 2 weeks (28) or as long as several semesters (26).

Of the three scales in the LCAS (discovery and relevance, iteration, and collaboration), perceptions of discovery and relevance varied most based on course type (Fig. 2; Fig. S1). Most "traditional" laboratory classes had lower scores than other types of courses. Similarly, Corwin et al. (9) found the largest difference between the traditional and CURE courses in relation to discovery and relevance. However, other traditional laboratory classes and those described as "inquiry" fell within the range for scores reported for courses identified as CUREs (Fig. 2; Fig. S1). Although Corwin et al. (9) found a significant difference between traditional lab classes and CUREs in relation to iteration, our data set indicated that LCAS iteration scores showed broad overlap across course types (Fig. 2; Fig. S2). In addition, values on the collaboration scale did not vary based on course type (Fig. S3).

While CUREs are not clearly differentiated from other laboratory course types on single dimensions of the LCAS, CUREs might be unique on combinations of the scales. To test this hypothesis, we created bivariate plots to visualize differences among laboratory course types in two dimensions (Fig. 2; Fig. S4 and S5). Again, scores for CUREs and other laboratory course types were similar, with the exception of two traditional laboratory courses that were low on both the discovery and relevance and iteration scales (Fig. 2). Interestingly, these plots also did not show a relationship between the scales. For example, courses with a greater emphasis on discovery and relevance

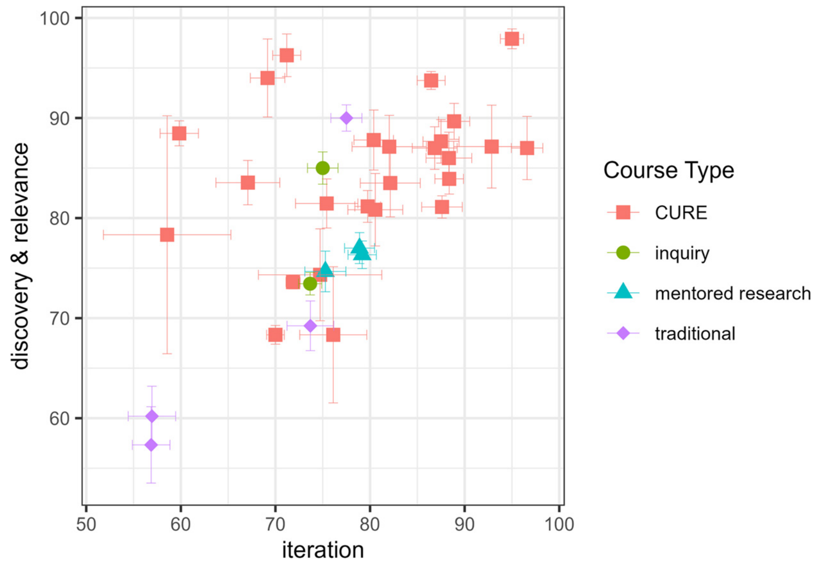

FIG 2. Bivariate plot of "iteration" and "discovery and relevance" scores based on laboratory course type, as defined by the studies' authors. The construct scores were scaled to a percentage of the total possible score. Values represent means and standard errors.

did not necessarily also have a greater (or lesser) emphasis on iteration or collaboration.

When we examined the LCAS scores of students in our research-for-credit course, we found that mean scores for all three constructs were within the range found for different laboratory course types (Fig. S1 to S3). In addition, the values did not differ based on whether students were at the initial stages of a research project, either during the first semester of the course or in subsequent semesters. For all three LCAS scales, the distribution of scores for mentored research-for-credit students was quite variable but tended to be skewed toward the higher end of the scales (Fig. 3). This was especially true for collaboration. Notably, whereas we hypothesized that traditional laboratory class scores might fall below the range of research-for-credit and CURE scores, most of the LCAS scores, regardless of associated course type, fell within the main part of the distribution for our mentored research students (Fig. 3).

Ethics statement

Survey data collection from mentored research students for this study was approved by the Emory University IRB (00106478).

Conclusions and future directions

Although discovery and relevance, iteration, and collaboration are considered to distinguish traditional and inquiry-based laboratory courses from CUREs (8, 9), based on the LCAS, CUREs vary considerably along these scales. The substantial variation among CUREs for these scales might indicate that CURE developers emphasize different aspects of CUREs depending on their institutional and course context and their learning goals for the CURE (7). Because of the variation among CUREs, their LCAS scores largely overlap with other types of laboratory courses. One possible explanation for this finding is that many approaches to teaching laboratory courses incorporate collaboration and have the potential to incorporate iteration, even if the work being done in a course will not lead to novel findings. Indeed, courses that faculty consider to include authentic research might emphasize science process skills over discovery and relevance (i.e., novel research questions) (5). An alternative explanation is that student perceptions of their CURE might not align with faculty perceptions of the CURE (34). For example, faculty might perceive that their course fits the criteria for a CURE and label it as such, but students in the course do not perceive that they are involved in collaboration, iteration, or discovery and relevance to as great a degree. Corwin et al. (9) suggested examining this possible disconnect as an area of future research. This might include addition of scales that incorporate other aspects of CUREs, such as scientific practices, as suggested by Corwin et al. (9), or measures that students relate to authentic research experiences, like failure (22).

In addition to the overlap between CUREs and other types of laboratory courses for the scales of the LCAS, we found substantial variation among the perceptions of students participating in our mentored research program that also overlapped with all laboratory course types for these same scales. As CUREs are intended to emulate mentored research experiences in a course context, our data from mentored research students suggest that CUREs could be quite variable on the LCAS scales while still paralleling the experiences that students have in a mentored research setting.

In short, based on LCAS data from published studies, we suggest that there is no clear threshold or range of values for the LCAS scales that can be used to define whether a course is a CURE or not. Further, LCAS scores do not distinguish whether different laboratory course types are different from a mentored research experience. Together, this evidence suggests that we

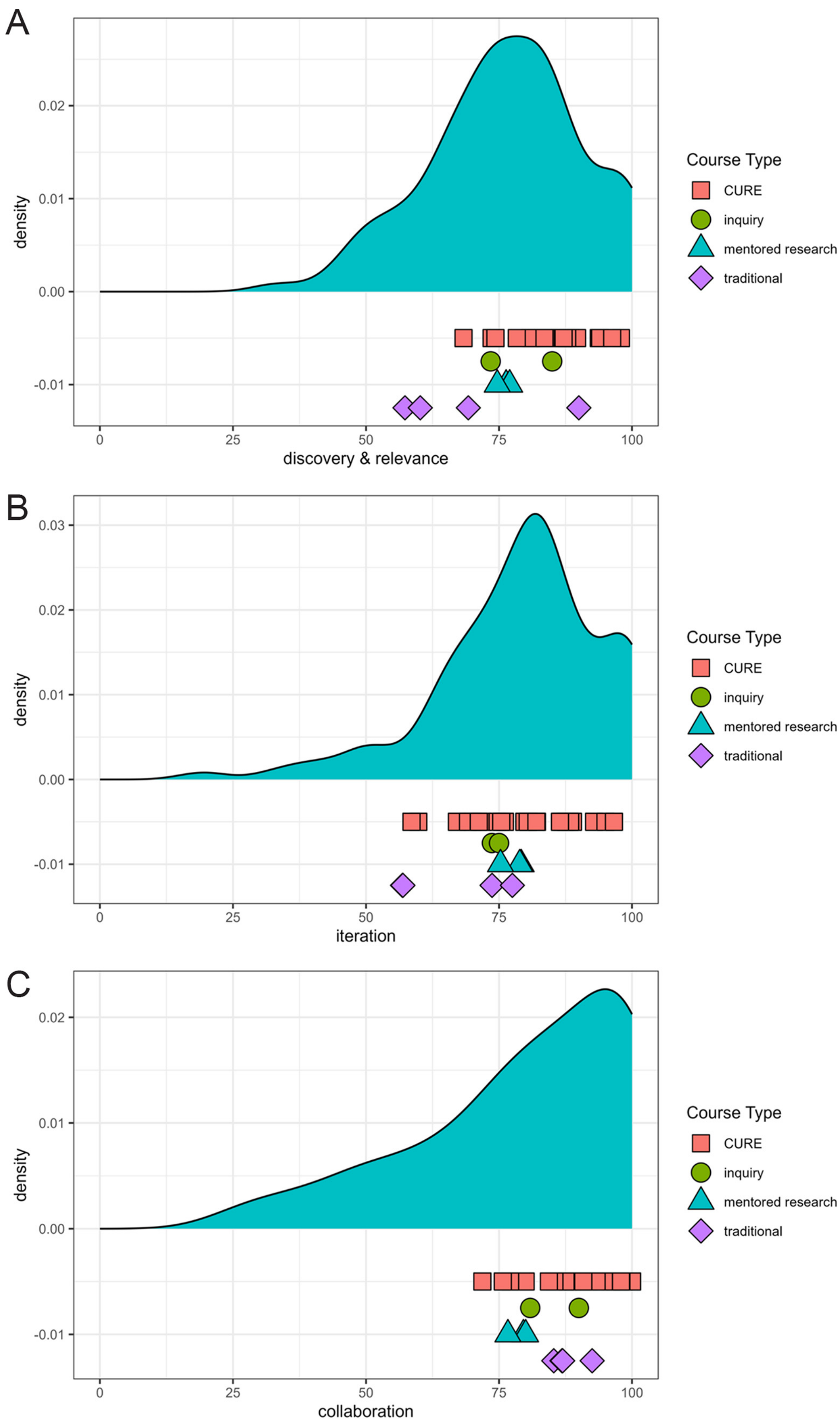

FIG 3. Estimated distributions (probability density functions) based on actual measured distributions for discovery and relevance (A), iteration (B), and collaboration (C) for students enrolled in our research-for-credit course. Symbols below represent means from the literature (see Fig. S1 to S3 in the supplemental material).

need to move beyond trying to use metrics to label courses as CUREs (or not CUREs). Instead, tools like the LCAS should be used to investigate what students are actually doing in their laboratory courses and whether that influences student outcomes (9). For example, Corwin et al. (17) found that student perceptions of discovery, iteration, and collaboration across a range of laboratory course types were associated with student ownership of their work in their laboratory course, which in turn was associated with students' career intentions. Similarly, Beck and Blumer (35) showed that individual student perceptions, rather than instructor perceptions, of instructional practices in laboratory courses were associated with student self-efficacy related to science literacy.

SUPPLEMENTAL MATERIAL

Supplemental material is available online only.

SUPPLEMENTAL FILE 1, PDF file, 1.1 MB.

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