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Research

Each to Their Own CURE: Faculty Who Teach Course-Based Undergraduate Research Experiences Report Why You Too Should Teach a CURE †

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Course-based undergraduate research experiences (CUREs) meet national recommendations for integrating research experiences into life science curricula. As such, CUREs have grown in popularity and many research studies have focused on student outcomes from CUREs. Institutional change literature highlights that understanding faculty is also key to new pedagogies succeeding. To begin to understand faculty perspectives on CUREs, we conducted semi-structured interviews with 61 faculty who teach CUREs regarding why they teach CUREs, what the outcomes are, and how they would discuss a CURE with a colleague. Using grounded theory, participant responses were coded and categorized as tangible or intangible, related to both student and faculty-centered themes. We found that intangible themes were prevalent, and that there were significant differences in the emphasis on tangible themes for faculty who have developed their own independent CUREs when compared with faculty who implement pre-developed, national CUREs. We focus our results on the similarities and differences among the perspectives of faculty who teach these two different CURE types and explore trends among all participants. The results of this work highlight the need for considering a multi-dimensional framework to understand, promote, and successfully implement CUREs.

INTRODUCTION

Course-based undergraduate research experiences (CUREs) are research experiences embedded into a formal laboratory course (3), providing a way for students to experience the process of conducting scientific research. The hallmark of a CURE is that students work on research problems with unknown answers that are broadly relevant to stakeholders outside of the classroom and, as such, participate in "authentic research" (1–5). Traditional undergraduate research experiences have been shown to produce an array of benefits for involved students (6,7), but these experiences are only available to a small subset of undergraduates due to the limited number of positions available in faculty labs. In contrast, CUREs can expose a much larger number of students to research, including many who would not otherwise have such an opportunity (8,9). CUREs can lead to positive student outcomes, many of which are akin to outcomes from traditional undergraduate research experiences (e.g., 10–17).

Two different models of CUREs are currently being used: 1) independent CUREs, developed and taught by individual faculty members, and 2) network CUREs, developed by a faculty member and then packaged to be implemented by different faculty members at multiple institutions. In an independent CURE, the course research topic is often aligned with the faculty member's own personal research interests and/or existing research programs, as they are the one developing the CURE (3,17). In contrast, the network CURE model is typically characterized as a single faculty member's individual CURE that is expanded and replicated so that many faculty members implement the same CURE in classrooms at different institutions around the country (5). By implementing a previously developed network CURE instead of developing and teaching their own CURE, faculty members are provided with a built-in curriculum and support system (for examples, see 10,12,18,19).

Lab courses have been modified into CUREs through individual faculty decisions, as well as department-level initiatives; either route requires faculty participation and buy-in, making faculty members a critical factor in a transition towards teaching CUREs in lab courses. In general, any type of pedagogical change can be difficult to achieve, in part because of the competing demands of research, teaching, and service (20–24). Further, for faculty whose primary responsibility is to maintain high research productivity, an individual's time restrictions may greatly constrain major pedagogical innovation (25).

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However, CUREs can simultaneously serve two purposes: research and teaching. In the same classroom at the same time, faculty can achieve scientific research milestones while teaching a formal lab course that counts toward their teaching load. This dual function of research and teaching makes the decision for a faculty member to teach a CURE unique compared with other types of pedagogical innovations that only impact teaching.

To date, most of the current literature on CUREs is centered on the impact of CUREs on students (5). Yet, researchers have proposed that only presenting data illustrating student benefits from pedagogical innovation is not enough to promote systemic change; progress is more likely achieved through a systems-level approach considering the students, the institution, and the faculty (20). In considering faculty members as leverage points in the implementation of CUREs, there is an emerging research literature showing that CUREs can benefit faculty directly (17,18). As we have previously reported, CUREs can provide faculty with a number of possible benefits including having students collect pilot research data as part of the course, generating research publications resulting from data collected in the CURE, producing trained undergraduates who continue to do the research, and obtaining grant funding to support innovations to integrate research into teaching (17)—all of which can directly benefit a faculty member's own research program.

Although faculty benefits related to CUREs have begun to be documented, we currently know little about faculty motivation for teaching a CURE. In general, faculty motivations to participate in new teaching strategies are complex and dependent on many factors, including student outcomes, promotion and tenure, advice from colleagues, and monetary rewards (26–33).

In an exploratory interview study, we probed faculty perspectives regarding their original motivations to teach a CURE and what they perceived they gained from teaching the CURE. We were interested in whether the faculty-related outcomes of their CURE paralleled their original motivations for teaching a CURE, and whether they would pitch CUREs to their colleagues based on their initial motivations or their own perceived benefits. We also explored whether there may be differences between faculty who choose to develop and teach a new CURE and those who choose to implement a previously developed CURE.

We intentionally sampled faculty who have taught CUREs from a variety of biology disciplines, ranks, and institutions in order to try to capture a diversity of faculty experiences with CUREs. Our specific research questions were as follows:

1) What are faculty perceptions on:
   (a) Their own motivations for teaching a CURE?
   (b) The benefits that they gained from teaching a CURE?
   (c) How they would "pitch" teaching a CURE to a colleague?
2) Are there differences in the types of motivations, benefits, and pitches between faculty who implement a network CURE and those who develop and teach an independent CURE?

METHODS

Data collection and procedures

We chose to conduct interviews as opposed to a survey because interviews offer a means to gather in-depth qualitative data regarding people's perspectives on choices and behaviors (34,35). Participants for this study were recruited through both targeted emails and snowball sampling (36). Semi-structured interview questions were iteratively developed, and interviews were conducted via Skype, audio recorded, and transcribed (37). This study includes both participants who developed and taught their own unique CURE (represented in our previously published work, 17), as well as participants who implemented network CUREs developed by others. For this article, we refer to individuals as teaching one of two CURE types: they *developed* an independent CURE or *implemented* a network CURE that was designed by someone else. All participants taught the CUREs they describe, including those who developed CUREs. This article focuses on the following open-ended questions asked of all participants: 1) What was your motivation for developing/teaching a CURE?, 2) What were some of the benefits that you as the instructor/developer received from teaching/developing the CURE?, and 3) How would you pitch developing/teaching a CURE to another faculty member?

Qualitative methods

Participants' answers to the three focal questions were transcribed and analyzed using the inductive process of grounded theory (38), allowing the research team (all authors) to infer a number of emergent themes from the interview question answers. From the initial themes, a coding rubric was devised and iteratively revised to address discrepancies among members of the research team. Inter-rater reliability was achieved at over 80% for a subset of the interviews (20%) by the research team and one education researcher outside of the research team (39). The rest of the responses were subsequently coded and the research team addressed the coding of unclear or debatable responses until an agreement was reached (40). The ASU IRB approved this study (00001679).

Response categories

Initial response categories emerged from the interview data, from which we derived recurring themes across responses to all three questions. For example, themes such as student engagement in class, research data resulting from

CUREs, and faculty feelings of self-fulfillment emerged across all three questions. Similar to previous studies regarding faculty motivations (e.g., 31), we found that these response themes could be broadly categorized as being tangible or intangible. We define tangible as any response that could pertain to a quantifiable gain or outcome such as promotion, a publication, a grant, a specific skill learned, or an added line on a resume. Statements that were related to feelings, sense of satisfaction, or, generally, reports that did not directly relate to meeting job expectations or solidifying job security were categorized as intangible. We also found that themes could be categorized across a different axis of being either faculty-centered or student-centered. We define faculty-centered statements as those that refer to the gains, outcomes, and/or feelings regarding faculty members themselves, be it in or out of the classroom. We defined student-centered statements as those in which faculty talked about student outcomes and/or their expectation of student outcomes. Thus, participants' coded responses fell into four categories: tangible faculty-centered, tangible student-centered, intangible faculty-centered, or intangible student-centered (Table 1). We coded participant responses to the three focal questions and binned all statements into one or more categories. Some statements could be coded into multiple categories. For example, the participant quote below contains three categories denoted in parentheses after the statement.

> *The motivation [to develop/teach a CURE] was really, truly to make it fun for me* (**intangible faculty-centered**) *and to make it practical for the students, meaningful. I think it's much more meaningful than learning how to gram stain, not just "here's a technique you can learn"* **(intangible student-centered)**. *Being able to show how you [students] can use the techniques* **(tangible student-centered)***, being able to have the students get motivated and involved in their own education. It's really important* **(intangible student-centered)**.

The manner in which individuals respond to interview questions, such as the length of their answers, can be personality-dependent (41). Thus, we chose to not make a value judgment based on the length of an answer, and if a participant made more than one statement in the same category in response to a question, it was counted only once. For example, in the above statement, the participant would be recorded as making: intangible faculty-centered, intangible student-centered, and tangible student-centered statements. We interpret these data as either the participant said at least one tangible or intangible; student or faculty-centered statement, or they did not. To identify the percent of participants who made a statement falling into a particular category, we divided the number of individuals who made a statement falling into a particular category by the total number of individuals who answered the question.

Tangible and intangible statements. From the binary scores regarding whether an individual made a statement that fell into any given response category or not, we added up the total numbers of tangible and intangible statements made by each individual across the questions. We identified the number of overall tangible and intangible statements each participant made as well as the following sub-categories: tangible faculty-centered, intangible faculty-centered, tangible student-centered, intangible student-centered. We do not report the number of overall faculty-centered or student-centered statements made, as the interviews were intended to capture the faculty perspectives, thus the responses were mostly faculty-centered by design.

Statistical analysis

Mann-Whitney U-tests for non-parametric data were performed to identify whether the mean tangible and intangible statement numbers differed among all participants, and to test for differences among tangible and intangible statements made by participants who teach each CURE type (developed their own CURE or implemented a previously-developed CURE). An unpaired t-test was performed to test for differences among the tangible to intangible statement ratios made by individuals teaching each CURE type. A one-way ANOVA was used to identify variation among the mean number of each participant's statements in each statement category by position, and a Tukey's HSD (honest significant difference) for multiple comparisons was run for *post hoc* analysis. Contingency table analyses were run to test for differences among faculty who either develop independent CUREs or implement network CUREs. We report significance based on Fisher's exact test (a conservative measure for 2 × 2 contingency table analyses with low sample sizes) (42). Dividing these data into sub-categories (e.g., institution type) yielded low sample sizes, and as our goal was to identify whether there were differences among perceptions of faculty that engage in the differing CURE types, we focused the majority of our analyses on differences between CURE types (develop vs. implement), and present statistically significant relationships. Analyses were conducted in JMP 10.

RESULTS

Participant demographics

Results are presented from interviews with 61 faculty members who either developed an independent CURE (n = 39) or implemented a network CURE (n = 22). Participant demographic details are in Appendix 1.

Thematic results

The coded participant responses fell into broad categories of tangible or intangible, and within these, statements

TABLE 1.
Response category descriptions and representative quotes of tangible and intangible categories pertaining to both faculty-centered and student-centered statements.

	Response Category	Representative Quotes		
Tangible	**Faculty-centered:** CUREs present a way to collect data for research programs; pilot research projects; obtain grant money; publications; presentations; career enhancement; recognition by department and/or institution; form collaborations; recruit trained students; platform to merge job expectations (e.g., teaching with research or service); classroom management	"My goal, certainly starting this, was to have a really nice data set that could be publishable. I think we've got enough to probably at least put together a group of students that can present at a conference."	"It [teaching CUREs] has made undergraduate research a cornerstone of my academic career. I am seen as the go-to guy if you want to do anything at [University] with undergraduate research. I was made undergraduate research director. Personally, for me the benefits are great. For the institution there are also benefits as it has been well publicized."	"I'm always pressed for time. I'm contractually obligated to do a certain amount of teaching but also my professional development and promotion depends on grants and publications. I thought, well, if I need to teach the micro lab, I'd like to be doing something that might benefit me as well and get some research in there. In that kind of self-serving way, it's been a way to pilot some types of experiments and to recruit the more talented students or the students that are really into it into my research lab."
	Student-centered: Students learn a particular skill, methodology, or technique; students gain a research experience; CUREs meet national STEM reform goals/active learning pedagogy; recruitment/retention of students in STEM fields; skills learned are transferrable to job/life and/or student résumé	"It [the CURE] lets them go into depth and think for themselves. It lets them explore the literature and practice the things they've learned in other courses about how to analyze data and things like that."	"We're committed here at [University] to intellectual goals that have to do with more than content transmission, so we want our graduates to actually know how to design an experiment and how to critically analyze data, and I think the only way to learn how to do that is to do it."	"I'm going to invent these as often as I can, because I think it's the most important skill that the students can get. Not only are they learning to work in groups, but they are getting experimental design experience. They're having to think on their feet about what might need to be changed. They're consulting with me and other professionals and they're digging into the literature."
Intangible	**Faculty-centered:** Rewarding; fulfilling; enjoy time in the classroom; intellectually stimulating; keeps faculty current with research; matches personal and/or professional identity; CUREs are more fun; faculty are not bored in classroom; they like the interactions with the students; enjoy observing students being engaged and having "aha!" moments	"One of the biggest benefits is just interaction with the students on a really meaningful basis on stuff that they're really excited about."	"It keeps me really engaged. It keeps me interested in the fact that I feel like I always need to find interesting questions for the students to work on."	"I was a junior faculty member at the time looking for ways to better engage the students. I came in and I started teaching microbiology as an untenured faculty, and the microbiology lab was terrible, all these biochemical tests—it was just really boring, and I remember from my undergraduate experience how much I hated these labs. And then I came across this lab and I thought it was so wonderful. I wanted to try out the course. I thought it was such an exciting opportunity."
	Student-centered: Students are more engaged; CUREs generally present a "better" way for students to learn about science; students enjoy time in CUREs; the experiences are meaningful to students	"I would say that this is a way to excite your students, get them really engaged in class and really excited about the material even if the things they try don't work. They will still be excited about it."	"I would say it's important for the students to get thinking as freshmen, get thinking as 'how do we do a science experiment,' not just 'this is what we look at under the microscope.' I think it's a benefit to the person doing it, because it's interesting and stimulating for them, too, because they don't know what the results are going to be. You get to engage with the students more because they are more engaged."	"I do all this for the students—they are excited to come to lab, they prepare, they come in on their own time and prepare by reading ahead of time their petri dishes to see how their bacteria are growing. At the end of the semester I hear so many of them say 'I finally feel like I am doing something to make the world a better place, where before I felt like I was just doing what I was supposed to be doing but not getting anything out of it.'"

CURE = course-based undergraduate research experience.

were either student-centered or faculty-centered. The coded statements sorted into recurring themes among responses to all three of the interview questions. Table 1 provides examples of the themes that comprise each category as well as representative quotes for each category. In total across the three focus questions, 80% of participants made a statement that could be classified as tangible. Overall, 64% of those participants made one or more tangible faculty-centered statement, and 39% made one or more tangible student-centered statement. Regarding intangible statements, 98% percent made a statement that would be considered intangible; only one participant did not make any statements in response to our focal questions that could be classified as intangible. Of faculty who made intangible statements, 56% made one or more intangible student-centered statements, and 97% of participants made one or more intangible faculty-centered statements.

Tangible and intangible response themes by CURE type

The overall mean number of intangible statements made by participants across the three questions (motivations, benefits, and pitches; [2.6 ± 0.12 standard error of the mean (SEM)]) was higher than the number of tangible statements (1.6 ± 0.16 SEM; $U = 993$; $p < 0.0001$; $n = 122$). When disaggregating these data by CURE type, the mean number of tangible statements regarding motivations, benefits, and pitches made by faculty who develop CUREs (2.03 ± 0.18 SEM) was significantly higher than those made by faculty who implement pre-developed CUREs (1.0 ± 0.22; $U = 219$, $p = 0.0008$, $n = 61$, Fig. 1a). There was not a statistically significant difference between intangible statements by CURE type (develop: 2.4 ± 0.15; implement: 2.9 ± 0.20; $U = 310$, $p = 0.06$; $n = 61$; Fig. 1a). *T*-tests indicate significant differences between the mean ratios of tangible to intangible statements made by participants who develop CUREs (1.1 ± 0.16 SEM) and those who implement pre-developed CUREs (0.49 ± 0.15 SEM; $t = 2.36$; $p = 0.03$; $n = 61$; Fig. 1b).

Results by question, CURE-type, and position

All participants clearly answered the questions regarding their motivations for developing or implementing a CURE and the benefits that they received from doing so, while 58 of 61 participants clearly answered the question regarding how they would pitch a CURE to a colleague. Results of how participants answered each question by CURE type are shown in Tables 2 to 4. Statistical differences are based on differences between CURE types. Participants' institution type did not dictate the type of position that they had, nor did their position's research and/or teaching expectations, so we did not feel we could meaningfully analyze participants based on institution type. For example, we interviewed individuals who held instructor positions at research-intensive institutions and assistant professors at primarily undergraduate

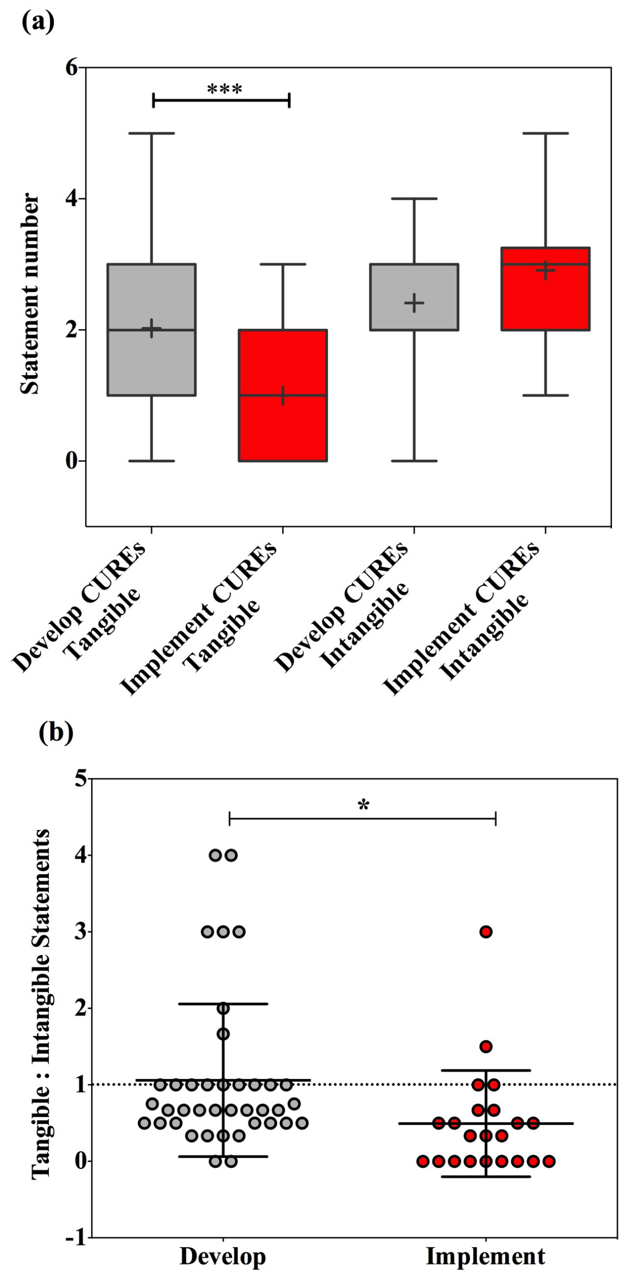

FIGURE 1. Faculty who develop CUREs differ in overall thematic responses from those who implement CUREs. a) Tangible themes are more prevalent in faculty who develop CUREs than in those who implement CUREs ($U = 219$; $p = 0.0008$; $n = 61$). Intangible themes do not differ significantly among CURE types. Boxes represent middle quartiles. Box whiskers represent min to max, data mean are at crosses and median at the horizontal lines. b) Tangible:Intangible statement ratio differs by CURE type. Participants who developed CUREs tangible:intangible ratios are significantly higher ($t = 2.36$, $p = 0.02$; $n = 61$) than those who implemented pre-developed CUREs.

institutions with high research expectations. We did, however, find a significant difference in individual statement type by professional position. Participants who are at assistant or associate professor rank made significantly more faculty-centered tangible statements than instructors did (F = 3.78;

$p = 0.01$; $n = 61$, Fig. 3). Individuals may have made both faculty and student-centered statements; thus the two categories will not add up to equal the "all tangible" or "all intangible." Figure 2 illustrates the overall relative thematic composition of responses to the three focal questions by CURE type. Details on participant responses by position and CURE type can be found in Appendix 2.

Motivations for faculty who develop CUREs are different than those of faculty who implement CUREs in that faculty who develop their own CUREs stated more tangible motivations, both faculty-centered ($p = 0.03$; $n = 61$) and student-centered ($p = 0.05$; $n = 61$), and overall, their stated motivations were more tangible than those who implement CUREs ($p = 0.01$; $n = 61$, Table 3, Fig. 2).

Although we specifically asked what benefits they, as the instructor of the CURE, receive, some faculty still answered the question with what we categorized as student-centered reposes (e.g., "It is just a better way for them [students] to learn science," Table 1). Overall, those who develop CUREs stated faculty-centered benefits more often than those who implement CUREs ($p = 0.003$; $n = 61$), these statements comprised the total tangible statements, as faculty did not state any student-centered tangible benefits for themselves (as expected). Faculty who implement CUREs answered the question with student-centered intangible statements more frequently than those who develop CUREs ($p = 0.03$; $n = 61$, Table 3, Fig. 2). Overall, faculty who develop CUREs stated tangible benefits

TABLE 2.
Faculty responses to the question, "What motivated you to develop/teach a CURE?"

CURE Type		Tangible			Intangible		
		Student-Centered	Faculty-Centered	All Tangible	Student-Centered	Faculty-Centered	All Intangible
Develop	*n* = 39	15	20	28	13	18	29
	%	**38**[a]	**51**[a]	**72**[b]	33	46	74
Implement	*n* = 22	3	5	8	7	14	16
	%	**14**[a]	**23**[a]	**36**[b]	31	64	72
Overall	*n* = 61	18	25	36	30	32	45
	%	30	41	59	33	52	74

[a] $p \leq 0.05$.
[b] $p \leq 0.01$. Statistical differences are specific to the difference between those teaching each CURE type (develop or implement) at each category.
Boldfacing indicates a statistically significant difference between those who develop CUREs and those who implement CUREs in that particular category.
CURE = course-based undergraduate research experience.

TABLE 3.
Faculty responses to the question, "What benefits do you receive from developing/teaching a CURE?"

CURE Type		Tangible			Intangible		
		Student-Centered	Faculty-Centered	All Tangible	Student-Centered	Faculty-Centered	All Intangible
Develop	*n* = 39	0	25	25	5	31	31
	%	0	**64**[b]	**64**[b]	13[a]	79	79
Implement	*n* = 22	0	5	5	8	19	21
	%	0	**23**[b]	**23**[b]	36[a]	86	95
Overall	*n* = 61	0	30	30	13	50	52
	%	0	49	49	21	82	85

[a] Indicates $p \leq 0.05$.
[b] Indicates $p \leq 0.003$. Statistical differences are specific to the difference between those teaching each CURE type (develop or implement) at each category.
Boldfacing indicates a statistically significant difference between those who develop CUREs and those who implement CUREs in that particular category. Faculty were not expected to answer with student-centered responses to this question (but some did).
CURE = course-based undergraduate research experience.

more than faculty who implemented network CUREs. The participants were asked what they perceived to be student benefits from CUREs in another question (see 17, Supplemental Materials), likely explaining why faculty members did not offer tangible student-centered statements (Table 3). As far as how faculty members pitch teaching a CURE to other faculty, the relative frequencies of types of pitches did not differ between CURE types and did not appear to directly parallel the motivations or benefits for either group of participants (Table 4). Correlations among derived themes and participant demographic variables are further explored in Appendix 3, such as the result that the number of years a participant has been teaching CUREs is moderately positively correlated to number of CURE publications, and positively correlated to reported tangible faculty-centered benefits.

DISCUSSION

Integrating research into the undergraduate life science curriculum is endorsed at the national level as essential to a complete undergraduate biology student experience (2). Efforts are being made to better understand course-based research and formalize its place in practice (5). In this paper, we focused on an often-overlooked aspect of course-based research—the faculty who develop and implement CUREs.

Prevalence of intangible themes

Overall, our interview participants discussed both intangible and tangible factors relating to their motivations, benefits from, and reasons why a colleague should teach a CURE. These data specific to faculty teaching CUREs align

TABLE 4.
Faculty responses to the question, "How would you pitch a CURE to another faculty member?"

CURE Type		Tangible			Intangible		
		Student-Centered	Faculty-Centered	All Tangible	Student-Centered	Faculty-Centered	All Intangible
Develop	*n* = 37	7	12	16	7	20	25
	%	19	32	43	19	54	68
Implement	*n* = 21	4	5	9	4	12	13
	%	19	24	43	19	57	62
Overall	*n* = 58	11	17	25	11	32	38
	%	19	29	43	19	55	66

CURE = course-based undergraduate research experience.

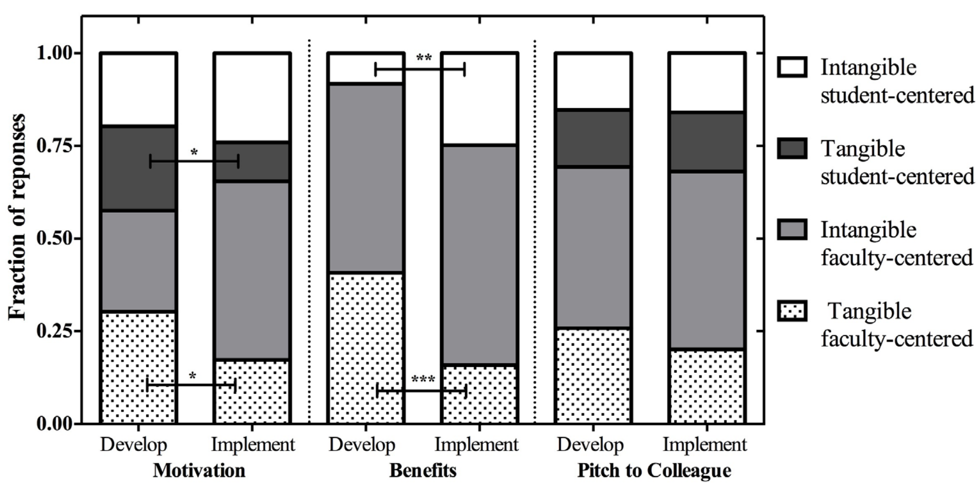

FIGURE 2. Relative frequency of each category of faculty responses. Motivations for faculty who develop CUREs are different than those of faculty who implement CUREs in that they state more tangible motivations, both faculty-centered ($p = 0.03$; $n = 61$) and student-centered ($p = 0.05$; $n = 61$). Those who develop CUREs collectively state faculty-centered tangible benefits more than those who implement CUREs ($p = 0.003$; $n = 61$) and those who implement CUREs state student-centered intangible benefits more often than those who develop CUREs ($p = 0.03$; $n = 61$). The relative frequency of pitch categories is not different between CURE types. Results are based on contingency tests and Fisher's Exact test two-tail test of significance.

with previous literature on faculty motivation (22,43–45) and highlight the need to consider multifaceted faculty motivations in establishing CUREs. The skew toward intangible factors acting as a driving force for faculty teaching CUREs has also emerged from other studies on higher education faculty. Even though one might think that faculty are mostly motivated by tangible gains, intangible themes such as departmental climate, general happiness, engagement, and sense of well being are cited as critical to their job-satisfaction (27,31,46–49). Our work suggests that CUREs are avenues for faculty to gain further job satisfaction—which is important for faculty choosing to remain in their academic positions (31,49).

Differences in faculty perspectives based on CURE type

We found significant differences among individuals who teach the two CURE types, namely that faculty who develop their own CUREs report more tangible benefits than faculty who implement a CURE developed by someone else (Fig. 2). This finding may be rooted in faculty perceptions that they can obtain differential benefits from investing in developing their own CURE compared with implementing a CURE developed by someone else. Because so many of the tangible benefits mentioned by those that develop CUREs related back to the specific research project in the CURE, it appears that those developing a CURE are at least in part geared toward tangible research scholarship outcomes. It is not surprising that faculty would have a higher probability of obtaining pilot data for a grant or developing highly trained undergraduates to work in their research lab when students conduct research aligned with the research interests of the faculty. This implies that faculty who are broadly interested in teaching a CURE may want to consider what types of benefits they are most interested in—and choose the CURE type based at least in part the prospective outcomes.

Another consideration is the level of investment needed. It is likely that the barriers to developing a CURE are greater than the barriers to implementing a pre-developed CURE because the implementers have an established curriculum and a network of support. Therefore, faculty who persist in developing CUREs might have higher expectations for tangible outcomes because of their greater time investment. Such reasoning would support the findings that participants who developed CUREs reported more tangible faculty-centered motivations and actualized benefits from CUREs than those who implement CUREs. If developing a CURE is more effort than implementing an already developed CURE, perhaps these tangible research-centric benefits are key to faculty developing CUREs.

Differences in faculty perspectives based on position

Participants who held an assistant or associate professor position were more likely to make faculty-centered tangible statements than those who held an instructor position (Fig. 3), and instructors were more often implementing CUREs (n = 11) than developing CUREs (n = 5). As discussed earlier, faculty-centered tangible benefits were most often related to the scholarship of research, the hallmark of CUREs. Perhaps assistant and associate professors are under pressure to obtain tangible outcomes because of tenure and promotion whereas instructors are able to use their intangible benefits to drive their decisions. It also could be that instructors are more removed from their own research interests, which makes it harder for them to develop their own CURE as opposed to implementing a CURE developed by someone else.

Indistinguishable pitches to a colleague

Although our participants made a variety of pitches for why another faculty member may want to develop and/or teach a CURE, their endorsements are not indicative of either what motivated them to teach a CURE or what they gained from CUREs. Although we saw significant differences in motivations and differences in the reported benefits between the two CURE types, our participants' pitches to a colleague were indistinguishable from one another. Although participants reported numerous faculty-centered tangible benefits from CUREs, they undersold the potential for faculty-centered gains when they hypothetically pitched the CURE to another colleague. Notably, faculty who develop their own CUREs reported significant tangible gains

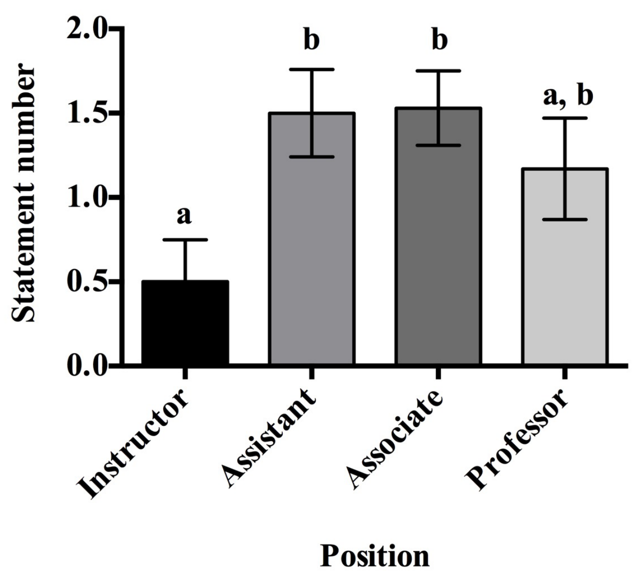

FIGURE 3. Tangible statements differ by the position that a faculty member has. The mean number of tangible statements made by participants across the three focal questions differed by position type. Instructors made significantly fewer tangible statements than did assistant or associate professors (p = 0.01; n = 61). Full professors did not differ in mean number of tangible statements made from the faculty with other positions.

for themselves (64%), but included them in their pitch to a colleague less often (32%; Tables 3 and 4). We can speculate as to why faculty pitches did not fully reflect their own reported benefits and motivations. One possibility is that faculty are accustomed to speaking about student outcomes. Another possibility is that faculty members do not want to appear self-centered in discussing possible tangible gains, and instead focused on the potential for intangible faculty-centered outcomes. Yet, if a national goal is widespread implementation of these research courses in the undergraduate curriculum, it will be important to accurately represent the full spectrum of possible benefits of CUREs to faculty to encourage them to teach CUREs.

Limitations

One of the primary limitations of this study is that our participants represent a self-selecting group of individuals, as they made the choice to respond to our invitation to participate in a study without compensation for themselves and we do not represent individuals who have chosen to not teach a CURE. Additionally, each participant reported on their motivations retrospectively, therefore we cannot disaggregate how the participant responded to the motivation question from the experiences that they actually had. We cannot rule out that various factors drive trends in the data, such as that developing and teaching a CURE over multiple years could influence inclinations to recognize certain benefits. Finally, although we made a specific effort to recruit more individuals who implemented CUREs, as well as community college faculty, our dataset consists of fewer individuals who implemented CUREs compared with developers and is deficient in community college faculty voices.

CONCLUSION

This work contributes the largely missing component of faculty perspectives to a growing understanding of course-based undergraduate research models. Here we present the first data on the perspectives of a diverse national group of faculty who have already developed and taught a CURE or have implemented nationally networked pre-developed CUREs. Our findings show there is no single motivator for faculty to undertake the development or implementation of a CURE, thus suggesting that a singular model to incentivize CUREs at the national level will not be sufficient. Depending upon what a faculty member intends to gain from teaching a CURE, this study provides insight into why they might choose to implement an already-developed network CURE or to develop their own unique CURE. The disconnect between realized faculty outcomes and their "pitches" to teach a CURE leads us to encourage faculty who have experience and insight on CUREs to be transparent when discussing why others may want to consider teaching CUREs, particularly in light of the potential benefits for the faculty themselves. Challenges to implementing CUREs will likely vary across institutions and disciplines, but faculty testimony regarding both tangible and intangible outcomes may resonate with others in unforeseen ways. In their efforts to integrate CUREs into the undergraduate curriculum, we recommend individuals and institutions take a transparent and holistic approach toward educating colleagues and administrators on the challenges and benefits of research-embedded courses.

SUPPLEMENTAL MATERIALS

Appendix 1: Participant demographics
Appendix 2: Additional methods and response categories by faculty position
Appendix 3: Exploratory factor analysis and results

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REFERENCES

1. Auchincloss LC, Laursen SL, Branchaw JL, Eagan K, Graham M, Hanauer DI, Lawrie G, McLinn CM, Pelaez N, Rowland S. 2014. Assessment of course-based undergraduate research experiences: a meeting report. CBE Life Sci Educ 13:29–40.
2. American Association for the Advancement of Science. 2011. Vision and Change in Undergraduate Biology Education: A Call to Action: a summary of recommendations made at a national conference organized by the American Association for the Advancement of Science, July 15–17, 2009. Washington, DC.
3. Brownell SE, Kloser MJ. 2015. Toward a conceptual framework for measuring the effectiveness of course-based undergraduate research experiences in undergraduate biology. Stud Higher Educ 40:525–544.
4. National Research Council (NRC) 2003. BIO2010: Transforming undergraduate education for future research biologists. The National Academies Press, Washington, DC.
5. National Academies of Sciences and Medicine. 2015. Integrating discovery-based research into the undergraduate curriculum: report of a convocation. The National Academies Press, Washington, DC.
6. Laursen S, Hunter A-B, Seymour E, Thiry H, Melton G. 2010. Undergraduate research in the sciences: engaging students in real science. John Wiley & Sons, San Francisco, CA.

7. Seymour E, Hunter AB, Laursen SL, DeAntoni T. 2004. Establishing the benefits of research experiences for undergraduates in the sciences: first findings from a three-year study. Sci Educ 88:493–534.
8. Bangera G, Brownell SE. 2014. Course-based undergraduate research experiences can make scientific research more inclusive. CBE Life Sci Educ 13:602–606.
9. Weaver GC, Russell CB, Wink DJ. 2008. Inquiry-based and research-based laboratory pedagogies in undergraduate science. Nat Chem Biol 4:577–580.
10. Bascom-Slack CA, Arnold AE, Strobel SA. 2012. Student-directed discovery of the plant microbiome and its products. Science 338:485–486.
11. Brownell SE, Kloser MJ, Fukami T, Shavelson R. 2012. Undergraduate biology lab courses: comparing the impact of traditionally based "cookbook" and authentic research-based courses on student lab experiences. J Coll Sci Teach 41:18–27.
12. Jordan TC, Burnett SH, Carson S, Caruso SM, Clase K, DeJong RJ, Dennehy JJ, Denver DR, Dunbar D, Elgin SC. 2014. A broadly implementable research course in phage discovery and genomics for first-year undergraduate students. MBio 5:e01051–01013.
13. Kloser MJ, Brownell SE, Shavelson RJ, Fukami T. 2013. Effects of a research-based ecology lab course: a study of nonvolunteer achievement, self-confidence, and perception of lab course purpose. J Coll Sci Teach 42:90–99.
14. Rodenbusch SE, Hernandez PR, Simmons SL, Dolan EL. 2016. Early engagement in course-based research increases graduation rates and completion of science, engineering, and mathematics degrees. CBE Life Sci Educ 15(2):ar20.
15. Shaffer CD, Alvarez C, Bailey C, Barnard D, Bhalla S, Chandrasekaran C, Chandrasekaran V, Chung H-M, Dorer DR, Du C. 2010. The Genomics Education Partnership: successful integration of research into laboratory classes at a diverse group of undergraduate institutions. CBE Life Sci Educ 9:55–69.
16. Shapiro C, Moberg-Parker J, Toma S, Ayon C, Zimmerman H, Roth-Johnson EA, Hancock SP, Levis-Fitzgerald M, Sanders ER. 2015. Comparing the impact of course-based and apprentice-based research experiences in a life science laboratory curriculum. J Microbiol Biol Educ 16:186.
17. Shortlidge EE, Bangera G, Brownell SE. 2016. Faculty perspectives on developing and teaching course-based undergraduate research experiences. BioScience 66:54–62.
18. Lopatto D, Hauser C, Jones CJ, Paetkau D, Chandrasekaran V, Dunbar D, MacKinnon C, Stamm J, Alvarez C, Barnard D. 2014. A central support system can facilitate implementation and sustainability of a classroom-based undergraduate research experience (CURE) in genomics. CBE Life Sci Educ 13:711–723.
19. Shaffer CD, Alvarez CJ, Bednarski AE, Dunbar D, Goodman AL, Reinke C, Rosenwald AG, Wolyniak MJ, Bailey C, Barnard D. 2014. A course-based research experience: how benefits change with increased investment in instructional time. CBE Life Sci Educ 13:111–130.
20. Austin AE. 2011. Promoting evidence-based change in undergraduate science education. American Association for the Advancement of Science 2013 Annual Meeting.
21. Boyer EL. 1998. Reinventing undergraduate education: a blueprint for America's research universities. The Boyer Commission on Educating Undergraduates in the Research University, Stony Brook, NY.
22. Boyer EL. 1990. Priorities of the professoriate. Carnegie Foundation for the Advancement of Teaching, Princeton, NJ.
23. Glassick CE, Huber MT, Maeroff GI, Boyer E. 1997. Scholarship assessed. Jossey-Bass, San Francisco, CA.
24. Sunal DW, Hodges J, Sunal CS, Whitaker KW, Freeman LM, Edwards L, Johnston RA, Odell M. 2001. Teaching science in higher education: faculty professional development and barriers to change. School Sci Math 101:246–257.
25. Fairweather JS. 2002. The mythologies of faculty productivity: implications for institutional policy and decision making. J Higher Educ 73:26–48.
26. Abes ES, Jackson G, Jones SR. 2002. Factors that motivate and deter faculty use of service-learning. Mich J Comm Serv Learn 9(1):5–17.
27. Austin AE. 1990. Faculty cultures, faculty values. New Dir Inst Res 1990:61–74.
28. Bouwma-Gearhart J. 2012. Research university STEM faculty members' motivation to engage in teaching professional development: building the choir through an appeal to extrinsic motivation and ego. J Sci Educ Technol 21:558–570.
29. Feldman KA, Paulsen MB. 1999. Faculty motivation: the role of a supportive teaching culture. New Dir Teach Learn 1999:69–78.
30. Lee J. 2001. Instructional support for distance education and faculty motivation, commitment, satisfaction. Brit J Educ Technol 32:153–160.
31. Matier MW. 1990. Retaining faculty: a tale of two campuses. Res Higher Educ 31:39–60.
32. Shulman LS. 1993. Forum: teaching as community property: putting an end to pedagogical solitude. Change Mag Higher Learn 25:6–7.
33. Trowler P, Knight PT. 2000. Coming to know in higher education: theorising faculty entry to new work contexts. Higher Educ Res Dev 19:27–42.
34. Johnson B, Christensen L. 2008. Educational research: quantitative, qualitative, and mixed approaches. Sage, Thousand Oaks, CA.
35. Leydens JA, Moskal BM, Pavelich MJ. 2004. Qualitative methods used in the assessment of engineering education. J Engineer Educ 93:65–72.
36. Atkinson R, Flint J. 2001. Accessing hidden and hard-to-reach populations: snowball research strategies. Soc Res Update 33:1–4.
37. Cohen D, Crabtree B. July 2006. Semi-structured interviews. Qualitative Research Guidelines Project. Robert Wood Johnson Foundation. http://www.qualres.org.
38. Strauss A, Corbin JM. 1997. Grounded theory in practice. Sage Publications, Thousand Oaks, CA.

39. Stemler SE. 2004. A comparison of consensus, consistency, and measurement approaches to estimating interrater reliability. Pract Assess Res Eval 9(4):1.
40. Campbell JL, Quincy C, Osserman J, Pedersen OK. 2013. Coding in-depth semistructured interviews: problems of unitization and intercoder reliability and agreement. Sociol Meth Res 42:294–320.
41. Rubin HJ, Rubin IS. 2011. Qualitative interviewing: the art of hearing data. Sage, Thousand Oaks, CA.
42. Raymond M, Rousset F. 1995. An exact test for population differentiation. Evolution 49(6):1280–1283.
43. Blackburn RT, Lawrence JH. 1995. Faculty at work: motivation, expectation, satisfaction. Johns Hopkins University Press, Baltimore, MD.
44. Lechuga VM, Lechuga DC. 2012. Faculty motivation and scholarly work: self-determination and self-regulation perspectives. J Professor 6(2):59.
45. Tien FF, Blackburn RT. 1996. Faculty rank system, research motivation, and faculty research productivity: measure refinement and theory testing. J Higher Educ 67(1):2–22.
46. Boyer EL. 1994. The academic profession: an international perspective. A special report. ERIC. Carnegie Foundation for the Advancement of Teaching, Princeton, NJ.
47. Callister RR. 2006. The impact of gender and department climate on job satisfaction and intentions to quit for faculty in science and engineering fields. J Technol Transf 31:367–375.
48. Johnsrud LK, Rosser VJ. 2002. Faculty members' morale and their intention to leave: a multilevel explanation. J Higher Educ 73:518–542.
49. Rosser VJ. 2004. Faculty members' intentions to leave: a national study on their worklife and satisfaction. Res Higher Educ 45:285–309.