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# Faculty Perspectives on Implementing Course-Based Undergraduate Research Experiences (CUREs) Across Engineering Disciplines

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# [Full Research Paper] Faculty Perspectives on Implementing Course-Based Undergraduate Research Experiences (CUREs) Across Multiple Engineering Disciplines


## ABSTRACT

Course-Based Undergraduate Research Experiences (CUREs) are a promising approach to enhancing student learning, particularly in STEM courses. While widely implemented in the natural sciences, their adoption in engineering remains limited. This multi-institutional study analyzed survey data from 21 engineering faculty to identify best practices and challenges in implementing CUREs. Findings highlight that course structure and organization are essential, requiring adjustments to content delivery and timelines. Faculty were found to align CURE topics with their research, benefiting both students and their projects. Project-based learning, especially through collective projects, proved highly effective. Faculty reported that CUREs enhanced student learning, collaboration, writing, and presentation skills. However, challenges included aligning research topics with course content, managing time demands, and providing sufficient scaffolding to support student research. Faculty successfully integrated various research components, including experimental design, research execution, and literature review, to engage students across engineering disciplines. These approaches helped create meaningful research experiences. Overall, this study provides initial insights for faculty looking to implement CUREs in engineering courses. Future research should focus on refining strategies for scaffolding undergraduate research, expanding CURE integration across engineering disciplines, and developing faculty training programs to support broader adoption. Additionally, further studies should explore the long-term effects on student learning and faculty research productivity.

## INTRODUCTION

Integrating research into undergraduate engineering pedagogy has many benefits, including improving both students' technical skills and self-efficacy [1]. Studies have shown that students who participate in undergraduate research have more enthusiasm towards STEM research, report increased feelings of belonging in their field, and demonstrate improvement in their ability to think like a scientist [2], [3]. These benefits are especially meaningful in the case of developing underrepresented or minority students [4], [5], [6]. Undergraduate research experiences also lead to greater retention rates [7], more students pursuing graduate level education [8], [9], and generally helping students clarify their future career goals [10], [11]. However, for a student to participate in research, they generally must take the initiative to seek out a position on a faculty members' research team or through an industry position. The low number of available positions and the inherent challenges of pursuing this pathway for many students is a significant barrier that leaves them without the opportunity to engage in research during their undergraduate careers.

Course-based Undergraduate Research Experiences (CUREs) provide a potential solution to these challenges related to student access. CUREs allow faculty to integrate an authentic research experience into their courses simultaneously providing value for both external stakeholders who benefit from the research (e.g. industry partners, research collaborators, database, etc.) as well as a greater number of undergraduate students. CUREs have been primarily implemented in the fields of the natural sciences, [12], [13], and while a few have been conducted in engineering, there remains substantial room for growth in variety of applications, as well as in the development of ways the CURE model can be adapted to the engineering research and design (R&D) process [14], [15]. However, the perceived challenges of integrating a new pedagogical approach can seem daunting to engineering faculty wishing to incorporate it into their courses [16].

According to CUREnet, a CUREs is defined as "a project that engages whole classes of students in addressing a research question or problem that is of interest to the scientific community" [17] and has five specific goals: contribute to a larger body of knowledge (e.g. scientific database, government researchers), promote problem-solving in respect to research, develop novel research, increase competency in scientific communication, and incorporate collaboration among all that are involved [17], [18], [19]. While the literature provides a general understanding of CUREs and their benefits to students, especially within the science community, there is a scarcity of best practices for CURE implementation for engineering faculty to use while planning and incorporating CUREs into their courses.

To address this knowledge gap for engineering education while building on the existing knowledge and practices of science-focused CUREs, this research explored the experiences of faculty of 21 CUREs across a wide range of engineering disciplines. The overarching research question (RQ) we sought to answer was: What is necessary for faculty to consider when implementing a CURE in an engineering course? To address this research question, our work applies a mixed-method approach to analyze and explore survey responses from several faculty who implemented CUREs in a wide-range of engineering courses.

## METHODOLOGY

CURE implementers were selected from within the Kern Entrepreneurial Engineering Network (KEEN), with 21 distinct CUREs run by 18 faculty members from five different universities including PUIs, R2, and R1 institutions ultimately participating in the study. These CUREs were implemented across a diverse range of engineering course topics, including heat transfer, biomechanics, thermodynamics, physical hydrology, structural engineering, transportation engineering, nanotechnology, and electrical engineering. Implementing faculty had a wide range of prior independent research experience (1-25 years in charge of their own research agendas) and a wide range of prior teaching experience (2-25 years in the classroom). Upon joining the study, faculty were introduced to CUREs and examples of past CUREs to aid in their own CURE development. The faculty were free to decide what proportion of their course they wished to dedicate to the CURE activities, which resulted in CURE integration durations ranging from 1 to 11 weeks long.

Recognizing that it is difficult (if not impossible) to conduct an entire research project during part of the semester, we suggested that faculty should think about choosing smaller portions of a large project for students to work on. To aid in this, we provided faculty with a conceptualization of the research process as a wheel of individual research process domains (Figure 1) and asked them in the survey to identify which research domains that they had their students engage in. We also requested that they contextualize the research project with the students through the lens of the larger project (not just the subpart they were working on).

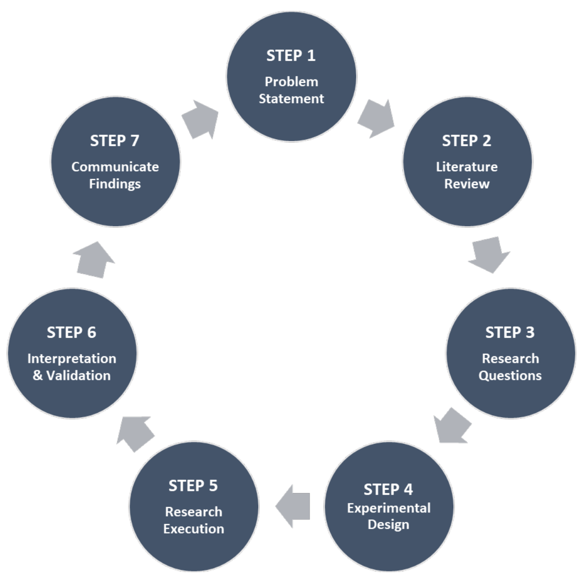


**Figure 1.** The cyclical "wheel" conceptualization of the research process domains presented to CURE implementers.

Separate survey data on CURE implementation was collected over two academic years (2022 and 2023). Prior to starting their CUREs, faculty completed a pre-survey where they were asked to provide demographic information and basic plans for their courses. Following completion of their CURE, the faculty members answered a mix of Likert-type and open-ended survey questions to provide a more detailed picture of each faculty's CURE, including which research domains (Figure 1) they had students engage with (see Appendix A for full list of survey questions). The survey questions also inquired about the CURE focus, operation details, class setup, and general feedback on how faculty felt about the process. The qualitative surveys consisted of a total of 35 questions. Faculty also provided our research team with the course syllabi and any supplemental materials relating to the CUREs.

To further develop understanding of sentiment surrounding CURE implementation, qualitative analysis methods utilizing coding can be applied to yield response categories and representative quotes [20], [21]. The survey data and syllabi information were organized into summary documents containing all the information for that faculty member for a given academic year and prepared for coding in the qualitative data analysis software Dedoose [22]. We coded faculty responses using a set of codes (Appendix B) derived from a previous systematic literature review on this subject [23], using only those codes aligning with our study's overarching RQ relating to CURE implementation and faculties' perceived outcomes. We also added additional codes to address the specifics of the course projects and research stakeholders through an emergent coding process. To verify inter-rater reliability in our coding process, the two coders (M.G. & J. H.) each coded a portion of the data, and spot-checked the coding until consensus was reached.

In our analysis we sought to i.) understand faculty perceptions on successes and struggles, ii.) identify common implementation practices, and finally, iii.) understand overall faculty opinion on the benefit of the CURE. When considering faculty perceptions on success and struggles (faculty sentiment), we counted and visualized the total number of codes applied to this topic, giving us a sense of how much faculty talked about aspects of success or struggles when running their CUREs. To identify common implementation practices, we considered how many of the 21 CUREs utilized a particular activity or practice. Finally, the Likert-type questions related to perceived benefit from the CURE (Appendix A), provided a quantitative measurement about how favorably the participating faculty viewed their experience with the CURE. These three analysis types were complemented with short verbatim 'vignettes' provided by faculty within the various open-ended survey questions regarding how faculty engaged students within the various research domains (Figure 1).

## RESULTS

The specific research activities the faculty chose to engage students within their CUREs varied widely across the research domains (Figure 1), but they most frequently implemented activities with tangible outcomes, such as conducting a literature review and designing and executing an experiment (Figure 2). Domains requiring more nuanced thinking and yielding less tangible outcomes, such as 'communicate findings', were less frequently reported.

The CUREs were implemented in a range of engineering sub-disciplines, most commonly in mechanical and civil engineering courses. Courses available to multiple course levels were counted for each applicable level. We found that CUREs were more frequently implemented in junior or senior level courses, or in courses available to multiple levels including juniors and seniors.

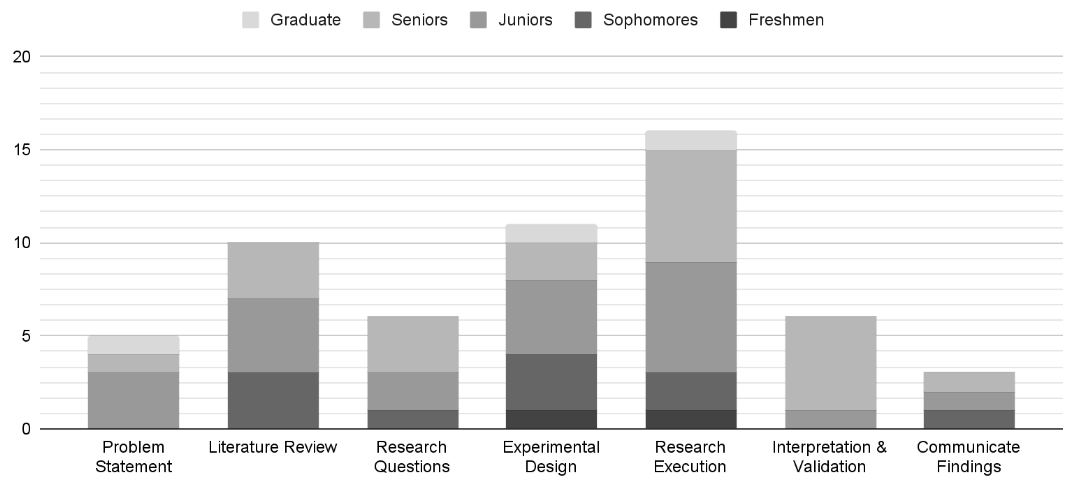


**Figure 2.** Research Domain by Course Level: Which research domains each CURE course implemented by course level**.**

Analysis of code-counts revealed three prevailing topics on faculty's minds as they reflected on their experience: Course Operations Details, Course Content Delivery, and Grading (Figure 3). Respectively, these codes refer to the overall course layout, how students received the content, and the way the student work was assessed.

This result suggests the need for greater faculty attention in these areas. We examined related sub-codes and found that course planning often involved external stakeholders, influencing CURE direction and topics. The most cited stakeholders were outside researchers (8) and government agencies or personal contacts (5) (Figure 4). However, many faculty either did not mention stakeholders or only vaguely referenced external interest, which we coded as 'not specified' (Appendix A).

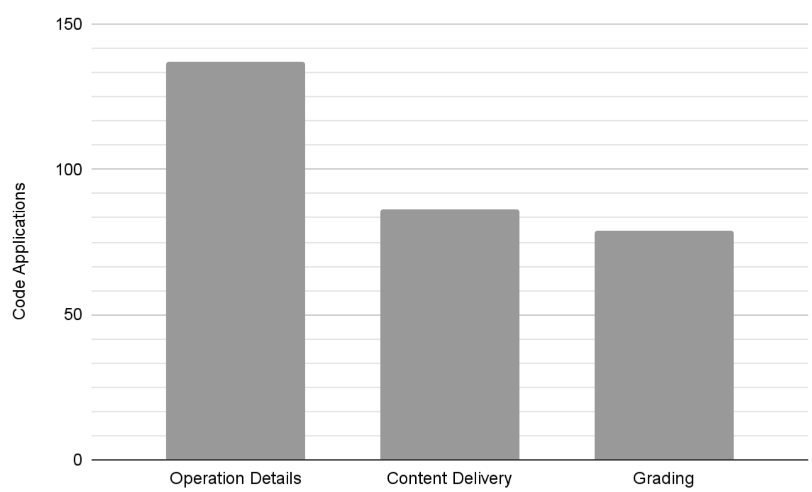


**Figure 3.** Implementation Details: The factors faculty indicated they most had to consider when implementing CUREs.

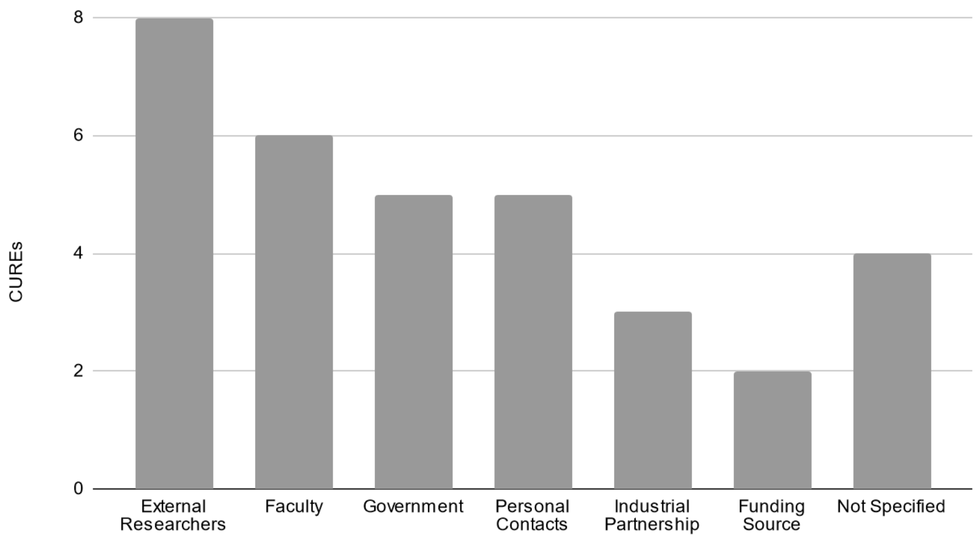


**Figure 4.** The type of stakeholders faculty identified or engaged in their CUREs.

Faculty employed various project and teaming structures in their CUREs. Most (8) had all students work on all project aspects, while others assigned different components (5) or entirely distinct projects (7) (Figure 5A). No faculty had students work on different hypotheses within the same CURE focus (0). Teaming structures included group work (6), individual work (4), or a mix of both (1) (Figure 5B).

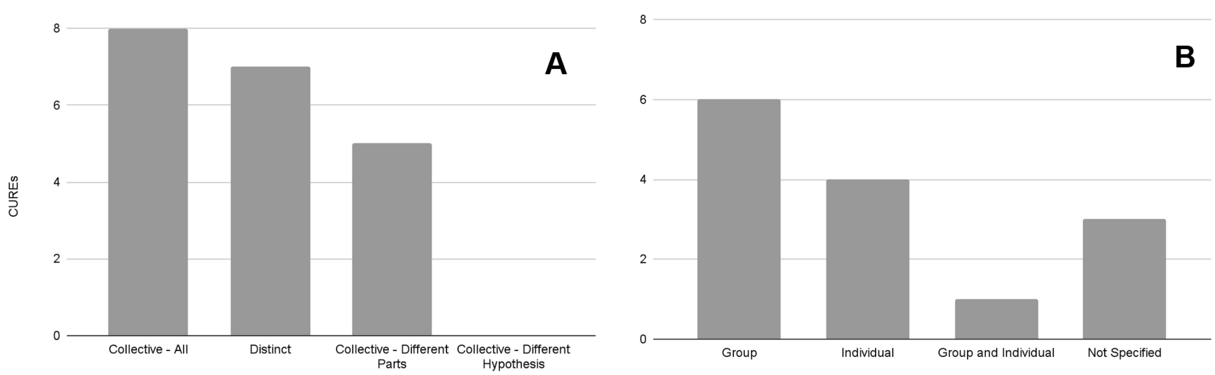


**Figure 5.** (A) Type of CURE projects the faculty ran. (B) Type of student teaming.

With regards to course assessment, 13 faculty implemented a traditional (percentage based) grading system while 7 chose to use a completion- or labor-based grading system (Figure 6A). Faculty members who used the completion-based grading talked about it much more (39 applications) than faculty using a traditional system (24 applications). Regardless of their chosen system, faculty employed a variety of assignments for grading assessment (Figure 6B).

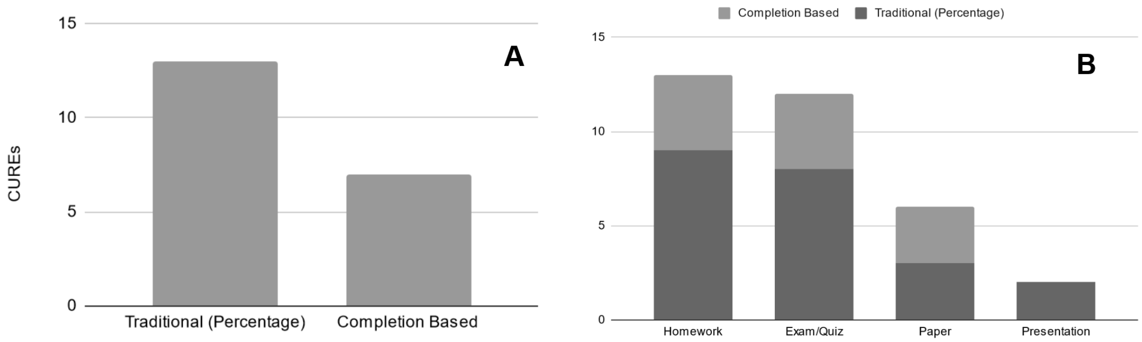


**Figure 6.** (A) Overall grading setup of the course. (B) Activities that contributed towards the grade.

Generally, the data demonstrates that the CUREs were viewed favorably by faculty. The coded responses revealed more references to successes than struggles, from both faculty and student perspectives (Figure 7A). Most of the struggles reported by faculty fell under the area of course organization (Figure 7B).

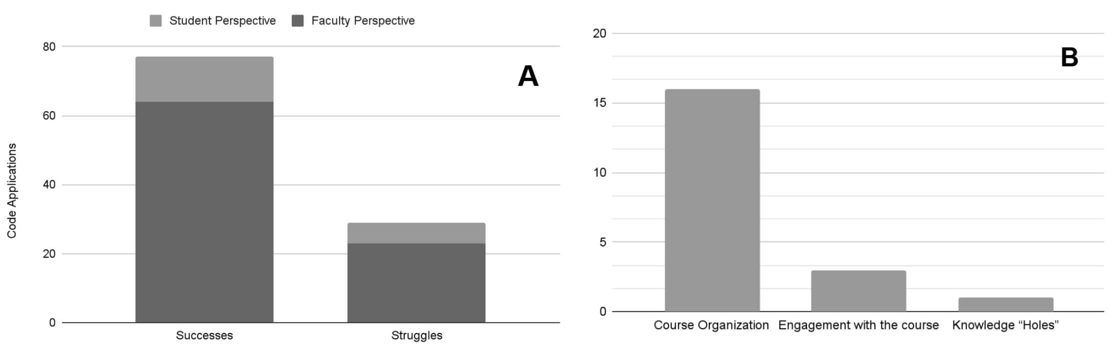


**Figure 7.** (A) Reports of successes compared to reports of struggles, from faculty and student perspectives. (B) Most common struggles faced by faculty.

Faculty rating for perception of overall CURE benefit based on the Likert scale questions indicate that overall, the CURE was useful for advancing their research, that they would do it again, and that they would be willing to implement a CURE in another course (Figure 8). This affirms that faculty found the CUREs to be beneficial and a positive experience.

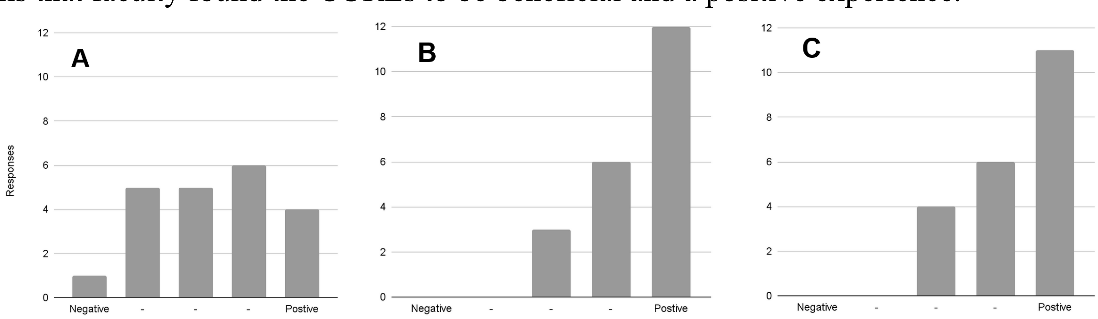


**Figure 8.** Likert Scale Results: (A) Faculty evaluation of how helpful the CURE was in advancing their own research. (B) Whether they would consider running a CURE in the same course or (C) another course.

## DISCUSSION

The study results highlight several salient findings which faculty should consider when implementing a CURE. Below we summarize these findings for the studied CUREs as they relate to i.) organization and structure, ii.) successes, struggles, and benefits, and iii.) student engagement within the multi-domain research process. These results are supported and highlighted through examples and verbatim excerpts from the survey participants.

*Course Structure and Organization*

The three codes most frequently applied to the faculty's open responses (Course Operations Details, Course Content Delivery, and Grading) indicate that faculty had to think carefully about their overall course structures when adopting a CURE (Figure 3). The content delivery methods employed by faculty in their CUREs varied widely, with no clear trends emerging in the way students received course content. While the reviewed syllabi provided insight into how the courses operated, the surveys indicated how the faculty would make further changes if they were to run the course again. For example, one participant stated, "If I were to do it again, I would probably start the process much earlier in the semester. … In future, I would make the problem statement definition aspect start by the second quarter of the semester. Much of the solution development and report writing would probably still take place as they did this semester, but the process would be less rushed." In the context of their other responses, this faculty member felt that the CURE still needed some work to fit their timeframe and course structure, which highlights the importance of faculty carefully designing their course to best aid the research and the students' learning experience.

Another facet to consider during course planning is determining stakeholders for the CURE research. The most often cited stakeholders indicate faculty preference towards other researchers (both their own research and others) and government agencies (Figure 4), or other personal contacts. This may suggest that for faculty planning a CURE, the simplest route would be to align the CURE with current and established research. However, for those who do not have an established research agenda, this provides an opportunity to make connections and potentially establish mutually beneficial relationships with local industry or government agencies. Also, many faculty did not reference a particular stakeholder (Figure 4) further showing that faculty need to consider who needs the research and who will benefit from it.

For most CUREs, student work typically occurs through a course project. The incorporation of project-based learning allows students to show engagement with the project and motivation to complete tasks in a manner that still contributes to a larger research objective [24]. In Figure 4 we saw that there were large variations in the style and collaboration setups of implemented CURE projects. The most common project structure was collective projects, where every part of the CURE was completed by each student individually (Figure 5A). This setup was very helpful to the students, as shown in this excerpt, which notes that the project "helped students better understand the concept of structural analysis." Based on our observations a variety of project organization styles can be successful.

Within academia, there is a growing discussion regarding traditional methods of grading in the classroom, and whether other methods of grading are more equitable and fairer to students. A common alternative to the traditional points-based system is a completion-based system, where students are assessed on their work meeting a predetermined quality standard, rather than the conventional assessment of the perceived quality of the work. A variety of different implementations exist for this including standards grading, labor-based grading, and ungrading [25], [26], [27]. While fewer faculty in our study implemented completion methods than traditional (Figure 6A), the faculty who did talked much more extensively about it in their responses, noting how well it functioned in an environment with open-ended objectives where there is a significant chance of not reaching a conclusive answer or goal. In response to the question "What advice would you give to a faculty member who was trying a CURE for the first time?" these faculty said things like "Thinking about assessment as a binary standards met/not-met (e.g. labor-based or standards-based grading) takes a lot of the pressure off the faculty member to know what the end product is and to let the research process grow organically towards the destination." and "Using an extra labor is a way to mitigate the potential pitfalls of your first attempt [at running a CURE]." Based on these comments we strongly recommend implementing a completion-based grading system, at least for the CURE portion of the course. This setup allows for the inclusion of tasks or deliverables that make the grading and learning process more straightforward and quality research more accessible, as well as removing the barrier to grading for correctness when the correct outcome may not be known.

*Successes, Struggles, and Benefits*

One of the clearest indicators of the potential benefits of CUREs are comments made by the faculty and the students themselves. Figure 7A shows a higher number of successful perspectives than perspectives on struggles. This is reflected in the faculty responses with statements like "Overall I think that CURE enhanced my course this year." and "The CURE model type project was helpful in this class because it promoted the students' learning process." One faculty member commented more extensively about the benefits for themselves as an early-career faculty:

> *"The exchange was worthwhile because it was a great learning experience. Specifically, I advanced my knowledge of establishing a successful undergraduate research program. … Through the class project, I observed students learn how to collaborate effectively, which will be essential for future work tasks. Additionally, they benefited from knowledge-sharing during the collaborative process, providing a valuable opportunity for peer-to-peer learning. They also improved their presentation and writing skills. I also expanded my knowledge on how to spark curiosity among students and motivate students to think deeply about the relevance of the course material to their professional journey, and, most importantly, inspire them to explore the subject further through self-study."*

The strong positive feedback from engineering courses incorporating CUREs highlights faculty recognition of the benefits of integrating authentic research experiences into their teaching. However, CUREs may not be suitable for every course, particularly when research topics do not align well with course content or when balancing research activities with foundational concept learning proves challenging. When effectively integrated, CUREs can align with faculty research interests, potentially advancing their projects while providing valuable real-world context for students [20]. As shown in Figure 8, faculty found CUREs beneficial for their research and expressed willingness to implement them again. However, course operations remained a major challenge (Figure 7B), underscoring the need for a well-defined implementation structure. One common difficulty was scaffolding projects for students, as illustrated by the following comment:

> *"Some students couldn't really plan out what they were supposed to do. They got scared by the big data files and didn't know how to come up with a method of their analysis approach. Normally, I would scaffold this for them. However, in a research situation, I would not. I would guide their thinking/work, but I would not show them exactly how to do it. I really do not know what I would change to make it better without making it more like a class problem/project rather than a research activity."*

This highlights the need to view CUREs as a scaffolded research experience - undergraduate students doing their first (or second) research project are not graduate students and should receive appropriate guidance and coaching. However, despite these difficulties, the faculty found CUREs worth implementing and noted that there were ways to organize the courses more effectively.

*Student Engagement within the Research Process*

All faculty in our study successfully incorporated at least one research domain (Figure 1) into their courses, demonstrating that CUREs can be applied across various engineering disciplines and class levels. Each research domain was included in multiple courses, with a few emerging as clear favorites (Figure 2). The top three—research execution, experimental design, and literature review—likely have more defined processes and clear deliverables for students, suggesting that instructors should prioritize these when adopting CUREs. Notable examples of how faculty engaged students with these research domains include:

- **Problem Statement:** "Introduction to concept mapping exercise - French Fries, … A concept map about the problem", whereby students learn an approach called Concept Mapping to visually organize and represent relationships between different concepts. It helps them learn to structure and clarify their thinking, making it easier to hypothesize and articulate the root causes of a problem [28].
- **Literature Review:** "I brought in a campus librarian to introduce searching databases, boolean logic, and the available campus resources for one lecture. I then had several class periods dedicated to finding literature, reading literature, and interpreting the literature, all centered around the (very important) question "Could T-Rex run?"
- **Research Execution:** "The students were introduced to a basic and generic model of optimizing energy capacities to satisfy demand under varying conditions of their operations. The students were then charged to explore other relevant domains where the underlying model may be expatiated to derive value."

These examples are in no way prescriptive, and the only limits to how faculty can engage students in the research domains are their own imagination and ability to get student buy-in.

However, these examples demonstrate techniques utilized by the faculty and how incorporating these research domains may prove helpful when developing a CURE.

## CONCLUSION

In this paper, we noted potential factors that engineering faculty should consider when integrating authentic research experiences in their undergraduate courses through CUREs. Based on faculty survey feedback and syllabi, we gained insight into their specific CURE experiences and course structures. Despite some common struggles that the faculty faced, such as difficulties in developing a robust course structure, our findings demonstrate that faculty found the CUREs to be a worthwhile endeavor. To better mitigate these struggles, they used completion-based grading, project-based assessment, and found stakeholders that were realistically connected to the research. Such insights from faculties' perspectives exclude the students' learning outcomes from taking courses that adopt CUREs, indicating future research into this area is needed. From these results, we found that faculty see a future in the implementation of CUREs in the engineering discipline and recognize the value of research experiences in undergraduate engineering courses.

This relatively small sample (n = 21) of CUREs reveals a high potential for future application and advancement of CUREs within engineering courses. Toward this end, we believe the engineering community would benefit from additional careful reflective efforts to adopt CUREs into engineering courses. For this current study, expanding the faculty sample size and variety of courses taught would grant a more comprehensive set of course overviews and examples. Furthermore, this paper focused on the faculty perspective and what a faculty planning on implementing a CURE into their course would likely need to be considered but excludes the students' perspectives, especially where this perspective pertains to the benefits of a CURE course in their education. Further investigation into students' learning following a CURE experience would enhance our understanding of the potential benefits of CUREs on student learning, as well as the influence of class size and content delivery on these outcomes. A similar study examining the long-term benefits for faculty, including their growth in course design and teaching, would be valuable. Additionally, comparing these findings to faculty benefits observed in CUREs within the natural sciences would provide further insights. Future work such as this will offer evidence, best practices, and future training modules to promote the wider implementation of CUREs in engineering education.

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## APPENDIX A

### Table 1. Survey Questions

| Qualitative | 22-23 | 23-24 |
|---|---|---|
| **Instructor & Course Background** | | |
| How many years of teaching experience do you have? | ✓ | ✓ |
| How many years of independent research experience (i.e. fully in charge of your research agenda) do you have? | ✓ | ✓ |
| Have you ever tried project-based or problem-based learning (PBL) in the undergraduate university classroom? | ✓ | ✓ |
| Have you ever tried an open-ended research experience in the undergraduate university classroom? | ✓ | ✓ |
| If you answered yes or maybe to either of the previous questions, please briefly describe your experiences (3-5 sentences) | ✓ | ✓ |
| What is your subject area expertise? (e.g. biomechanics, artificial intelligence, structural analysis) | ✓ | ✓ |
| How are you connected to the research the students are conducting? | ✓ | ✗ |
| Whose research will the students be working on? | ✓ | ✗ |
| **Course General Information** | | |
| What is the disciplinary area for your CURE class? | ✓ | ✓ |
| What is the name of the class your CURE is part of? | ✓ | ✓ |
| The students in this class are typically (choose as many as apply) [Class level] | ✓ | ✓ |
| This course is (Elective, Required for Majors, ect.) | ✓ | ✓ |
| How much in-class time did you dedicate to the EM-CURE project? | ✓ | ✓ |
| How much out-of-class time did you dedicate to the EM-CURE project? | ✓ | ✓ |
| How many students were enrolled in your class this term? | ✗ | ✓ |
| When do you plan to have students start the CURE activity(s) in your course? | ✓ | ✗ |
| How many weeks or class periods do you plan to have students work on the CURE activities in class? | ✓ | ✗ |
| How many weeks or class periods do you plan to have students work on the CURE activities outside of class? | ✓ | ✗ |
| **CURE Focus** | | |
| What is the research question or domain for your CURE? | ✓ | ✓ |
| Please briefly elaborate on your previous answer above - who will benefit from the value your students create during your CURE? | ✓ | ✓ |

| | | |
|---|---|---|
| Complete the research wheel from the general research process assignment for your CURE project. Circle the area(s) that you plan to have students engage and make a note of how. | ✓ | ✓ |
| Briefly elaborate on the activities you plan to do in the classroom. | ✓ | ✓ |
| Briefly describe how you plan to incorporate the CURE activities into your course assessment and/or grading structure. | ✓ | ✓ |
| Write an "elevator pitch" (3-5 sentences) describing your EM-CURE project. | ✓ | ✓ |
| How did you incorporate the CURE experience into your assessment/grading for the course? | ✓ | ✓ |
| **Research Activities** | | |
| How did you engage students in the research exploration phase (problem statement, literature review)? | ✓ | ✓ |
| How did you engage students in the planning phase of the research (timeline and stakeholder engagement in identifying needs)? | ✓ | ✓ |
| What research tasks did you have students do related to the execution of the research (i.e., data collection, prototyping, data analysis)? | ✓ | ✓ |
| How did you lead students through the task of interpreting the research findings? | ✓ | ✓ |
| How did you engage students in a reflection on the real-world impacts of the research findings? Did any of your efforts to engage students focus on EM? | ✓ | ✓ |
| **Feedback** | | |
| What trade-offs did you have to make in your class to include the EM-CURE experience? Do you think the exchange was worthwhile? Why or Why not? | ✓ | ✓ |
| Did you notice any noteworthy growth in student learning this semester (particularly compared to previous years teaching this course if you've taught it before)? | ✓ | ✓ |
| What do you think went well in your EM-CURE? If you were to do an EM-CURE again, what would you keep the same? | ✓ | ✓ |
| What do you think didn't go well in your EM-CURE? If you were to do an EM-CURE again, what would you change to make it better? Why? | ✓ | ✓ |
| If [the CURE model] was helpful, why? If not, why not? | ✓ | ✓ |
| If you would do a CURE again, why? If not, why not? | ✓ | ✓ |
| What advice would you give to a faculty member who was trying a CURE for the first time? | ✓ | ✓ |
| What questions/comments/concerns do you have about designing and implementing your EM-CURE? | ✓ | ✗ |
| Was the CURE model (or another classroom activity) useful for you in advancing your research? If so, how? If not, why not? | ✓ | ✗ |
| Would you do a CURE again in this course? | ✓ | ✗ |
| | | |
| **Quantitative (Rank 1-5)** | | |

| | | |
|---|---|---|
| Was the CURE model (or another classroom activity) useful for you in advancing your research? | ✓ | ✓ |
| Would you do a CURE again in this course? | ✓ | ✓ |
| Would you consider doing a CURE in another course you teach? | ✓ | ✓ |

Note: Question set was modified between years to acquire necessary information in a more concise manner.

## APPENDIX B

### Table 2. Codes

| Code | Subcode | Definition | Added Emergently |
|---|---|---|---|
| CURE Topic | | What was the CURE about? | |
| | Multiple Topics | The CURE course had multiple topics | |
| | Singular Topic | The CURE course focused on a single topic | |
| Challenges: Personal Scale | | Personal challenges faced by Faculty, TA’s, students | |
| | Research Feasibility | The research was difficult to perform | |
| | Faculty barriers | Challenges to faculty motivation, balancing teaching and research | |
| | Faculty need support | Faculty didn’t feel adequately prepared to teach the course | |
| | Methods of Teaching/Delivery | Course content delivery was a challenge | |
| | Organization of Research Material in the course | Material of the course was too challenging | |
| | Equipment/Resources | Challenges using the equipment | |
| | Student Attitudes | Challenges relating to student attitudes | |

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|---|---|---|---|
| | Student Mistakes | Students messed up their research | |
| | Students were underprepared | Students were underprepared for the research | |
| | Time Constraints | Time constraints with the course (institutional scale) | |
| Course Learning Objectives | | An explicit mentioning in the paper about Course Learning Objectives | |
| | Personal Growth | Goal is to Broaden student's horizons, improve soft skills | |
| | Research Related | Goal is to expose students to a research environment | |
| | Subject Specific | Goal is to teach the course material | |
| Course Operation Details | | How the class is laid out in general. A bucket to catch details on what is done in the class. | |
| | Project: Individual Person | One person on an individual project or part of a project | |
| | Project Collective - All | All students perform the same research | |
| | Project Collective - Different Hypothesis | Students work on the same research topic, but make their own hypothesis on the data | |
| | Project Collective - Different Parts | Students contribute different parts to a larger project | |
| | Project Individual - Distinct | Distinct research projects | |

| | | | |
|---|---|---|---|
| | Project: Not Specified | Students working in groups or individually was not specified | |
| | Project: Group | Students worked in groups | |
| | Project: Group and Individual | Students had both group and individual responsibilities | |
| | Teaching Strategy | Teaching strategies employed during the course | |
| | Instructor Preparation before class time | Preparations taken before the course began | |
| | Overall structure of the class | What was done throughout the course | |
| | Time Management & Length | How class time was used | |
| Course Content Delivery | | How did students receive the content? Classroom? Online? | |
| | Literature Review | Course content consisted of literature reviews | |
| | Flipped Course Design | Content was delivered using the flipped classroom structure | |
| | Lecture based approach | Majority of classes take the form of lectures | |
| | Lecture incorporated into lab time | Short lecture was incorporated during lab time | |
| | Online/Remote | Course content was delivered in an online setting | |

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|---|---|---|---|
| | Out of class work | CURE content was distributed through homework | |
| | Project Scaffolding | One part of the project builds upon previous part(s) | |
| | Assignment | Students were prepared using assignments | |
| | Discussion | Students were prepared using discussions | |
| | Lecture | Students were prepared using lectures | |
| | Research Project | Students were prepared using a research project | |
| Failures from faculty perspective | | What aspects of the CURE did faculty think failed? | |
| | Course Organization | Course organization failure from faculty POV | |
| | Engagement with the course | Was the course engaging? | |
| | Knowledge “Holes” | Topics and concepts faculty didn’t think the students learned | |
| Failures from student perspective | | What aspects of the CURE did students think failed? | |
| | Course Organization | Course organization related failure from student POV | |
| | Engagement with the course | Was the course interesting? Did students find it worth-while? | |

| | | | |
|---|---|---|---|
| | Knowledge “Holes” | Topics and concepts students felt they didn't learn | |
| Stakeholder Deliverables | | Any final product from the CURE from the students' work that contributes to the Stakeholders needs/final deliverables | ✓ |
| | Internal Report | Research was never presented nor submitted to publications | |
| | Database | Research was added to a larger database, or used in future courses | ✓ |
| | Publication | Research was published in a scientific journal | |
| | Local/ Community Presentation | Research was presented at a local/community level presentation | |
| | Scientific Conference | Research was presented at a scientific conference | |
| Course CURE Product | Report | Any final product from the CURE from the students' work that is specifically for the classroom and for the faculty to assess | ✓ |
| | | Any mention of a course-based report that contributes to the CURE. | ✓ |
| | Presentation | Any mention of a presentation in the course that is referencing the CURE. | ✓ |
| | Project | Any mention of a project that incorporates the CURE in the final product. | ✓ |
| Grading | Project Based | Assessment of Student work | |
| | | Student’s grades were partly based on projects | |

| | | | |
|---|---|---|---|
| | Homework | Homework assignments were used in the grading process | |
| | Exam/Quiz | Exams/Quizzes were used in the grading process | |
| | Weight/ Distribution/ Letter Grade | How the grade was determined in the class | |
| | Completion Based Grading | Tasks are graded for completeness and completed tasks contribute to course grade | ✓ |
| | Traditional (Percentage) Grading | Grading using percentages and a weighted averages or points-based system | ✓ |
| How is CURE connected with research outside of class | | Did the CURE extend beyond the classroom into faculty research? Summer research? | |
| | Multiple Terms | The research spans more than one term | |
| | Non course-based continuation | The research continues after the course ends, but isn't course-based | |
| | Faculty Research | The CURE connects with the faculty's research | |
| | Broader Community | The research was connected with the broader community | |
| | Database | Research contributed to a database | |
| | Science/ Research Community | The CURE was connected with the science/ research community | |
| | Local/General Community | The CURE was connected with the local/ general community | |

| | | | |
|---|---|---|---|
| Intentions for the learning experience | | What were the students expected to learn? Advancing current research? research practices? Classroom topics? | |
| | Faculty Benefits | One intention of the CURE was for the experience to benefit the faculty involved | |
| | Attitudes/ Motivation in Science | Improve student attitudes in science | |
| | Community outreach | One intentions for the CURE was to have the research be involved with the local community | |
| | Educational | Student’s sufficiently learning the topics covered in the course | |
| | Advance current Research | One Intention for CURE was to advance current research | |
| | Increased Diversity | Retain and recruit those from underrepresented groups into doing research | |
| | Research Skills | One intention for the CURE is for student’s to improve their research-related skills | |
| | Student Research Opportunities | Allow more students the opportunity to conduct research | |
| Mentoring Strategies | | What forms of mentoring strategies are typically used in CURE’s? | |
| | Mentor Responsibilities | Specific responsibilities that Mentors have | |
| | Scheduled Check-Ins | The faculty had scheduled check-ins with students | |
| | Instructor Feedback | The faculty provided feedback to student work | |

| | | | |
|---|---|---|---|
| | Interactions with Experts | Interaction with subject-matter expert | |
| | Lecturing/ Traditional Mentoring | Traditional lecture-based mentoring strategies were used | |
| Nodable :) | | Excerpts we thought could be incorporated into the paper | |
| Reason for CURE focus | | Explicit reference to why the research project was chosen for a CURE project/how it was identified | |
| | Ease of implementation | The CURE topic was easy to implement into a course | |
| | Broad relevance and interest | The CURE topic is relevant and interesting to students | |
| | Advancement in science | CURE Topic chosen to advance research in a subject | |
| | Low cost | CURE Topic chosen because of it's low cost | |
| | Needed Skills | CURE Topic chosen based on skills student's needed to learn | |
| Recommendations | | Codes related to recommendations for doing it better next time (or doing at all) | |
| | Student Related | Recommendations are student related | |
| | Faculty | Recommendations are faculty related | |
| | Course Operations | Recommendations are course operations related | |

| | | | |
|---|---|---|---|
| | TA | Recommendations are TA related | |
| Stakeholders | | Any and all references to stakeholders, stakeholder engagement, etc. If the faculty member is explicitly mentioned as | |
| | Government | Stakeholders included government agencies | |
| | Faculty | Faculty members in the CURE were stakeholders | |
| | Found through Faculty/ Student Personal contacts | The stakeholder(s) had connections to faculty and/or students | |
| | Not Specified | The specific stakeholder's weren't mentioned | |
| | Industrial Partnership | The stakeholders included industry partners | |
| | Researchers from Outside Organization | The stakeholders included researcher's from outside organizations | |
| | Funding Source | Stakeholder was a part of the funding process. | ✓ |
| Student involvement in scoping Research | | How the student was engaged with research project scoping: research question, topic identification. | |
| | Students control every aspect | Faculty provides guidance, while students scope the research | |
| | Faculty- general, student-specific | Faculty choose a general topic from which students pick a specific topic | |
| | Experimental design | Experimental design was up to the student's | |

| | | | |
|---|---|---|---|
| | Unclear | Unclear how students were involved in scoping research | |
| | Faculty control every aspect | Student's support faculty research, and are not involved in scoping research | |
| Successes from faculty perspective | | What did faculty think were successful | |
| | Feasibility of CURE | Methods used which made the CURE easier to implement | |
| | Faculty were positively impacted | The CURE experience benefitted faculty in some way | |
| | CURE fulfilling its intentions | Intentions for the CURE were mentioned to be fulfilled | |
| | Students meeting learning objectives | Students were mentioned to have met the course learning objectives | |
| | Students were positively impacted | Students benefited in some way from the CURE experience | |
| Successes from Student perspective | | What did students think were successful | |
| | Sense of project ownership | Student's reporting that they felt a sense of ownership for the project | |
| | Enjoyment of the course | Did student's find the course interesting? Did they enjoy the CURE format? | |
| | Acquired Sufficient Knowledge | Student reporting learning gains relating to the CURE topic | |
| | Students were positively impacted | The course benefitted student academic/ professional careers | |

| | | | |
|---|---|---|---|
| | Teaching Methods | Students liked the way that the course was taught | |
| Teaching Staff Involve | | What kinds of faculty were involved? | |
| | Faculty with significant research experience | Teaching staff had significant research experience | |
| | Faculty with little/no research experience | Teaching staff had little/no research experience | |
| | Graduate/Postdoctoral student involvement | Teaching staff included graduate teaching assistants | |
| | Experienced instructor | The instructor was experienced, not new at teaching | |
| | Inexperienced instructor | The instructor was not experienced, new at teaching | ✓ |
| | Outside project manager/ evaluator | Teaching staff included an Outside project manager/ evaluator | |
| | Undergraduate Student TA | Teaching staff included Undergraduate Student TA's | |