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Student interest development in course-based undergraduate research experiences (CUREs): a longitudinal case study analysis

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Introduction: Student participation in course-based undergraduate research experiences (CUREs) leads to improved academic performance and increased intent to persist in STEM, especially when compared to traditional lecture courses with standard assignments. Despite the benefits of CUREs, less is known about a student's week-by-week experiences in CUREs and how specific CURE course features contribute to student development toward learning outcomes. Previous research found that students' levels of frustration in CURE courses moderates the relationship between their feelings of challenge and interest. This study provides more context for how specific CURE course activities moderate students' week-to-week experiences of interest-challenge-frustration dynamics.

Methods: This longitudinal study develops and analyzes detailed case studies for seven students by: (1) analyzing surveys distributed at seven time points throughout a semester in a CURE, (2) conducting interviews with students during the summer following their CURE to gain qualitative insights to survey data, and (3) analyzing surveys distributed to students over a year after their CURE.

Results and Discussion: Findings highlight a number of factors that are important for student interest in CURE courses. These include peer and professor interactions, student autonomy, relevance of course activities to personal goals, and development of research skills. Findings also suggest that students' interest in CUREs can promote sustained content knowledge, project ownership, science identity, and confidence. To better support student interest in CUREs, instructors should continue to promote student collaboration, offer mentorship, and encourage students to see the relevance of CURE tasks.

KEYWORDS

course-based undergraduate research experiences (CUREs), student interest, student outcomes, undergraduate STEM education, discovery-based learning

1 Introduction

Course-based undergraduate research experiences (CUREs) are important research opportunities for undergraduate STEM students. CUREs differ from traditional lectures in that they allow students to make discoveries, iteratively solve problems, and engage in authentic and relevant research. This makes the characteristics of an authentic research lab accessible within a course setting, giving students hands-on experiences and valuable research skills (Corwin et al., 2015; Gin et al., 2018). CUREs are becoming increasingly adopted in college STEM classrooms, such as the Freshman Research Initiative (FRI) at the University of Texas in Austin and the Howard Hughes Medical Institute's SEA-PHAGES program (Zhu et al., 2024). CUREs have been linked to desired student outcomes including gains in research skills, self-efficacy, content knowledge, and persistence in STEM (Lopatto et al., 2008; Shaffer et al., 2010; Harrison et al., 2011; Hanauer et al., 2017; Rowland et al., 2012; Graham et al., 2013) with the same effectiveness as research internships (Shaffer et al., 2010; Harrison et al., 2011; Rowland et al., 2012). There is an extensive body of research on student outcomes pre- and post-participation in a CURE (Hanauer et al., 2017). Less is known, however, about the specific course experiences that contribute to these outcomes (Corwin et al., 2015; Zhu et al., 2024).

Given the positive outcomes of CUREs, it is important to investigate how students engage in CUREs and to identify student psychological factors that enhance their positive effects. For example, student interest, conceptualized as a consistent preference for a topic, subject, or activity and includes feelings of enjoyment and perceptions of personal relevance (Hidi, 1990; Schiefele, 1991; Renninger and Hidi, 2011; Chiu, 2024), has been linked to improved attention, engagement, and advancement of goals within learning environments (Hidi and Renninger, 2006; Harackiewicz et al., 2016). Understanding how student interest develops in CUREs may therefore be one avenue for improving engagement within these research experiences. In their model, Hidi and Renninger (2006) put forward that interest is developed in four key stages: triggered situational interest, maintained situational interest, emerging individual interest, and well-developed individual interest (Figure 1). Situational interest is defined as a temporary level of attention or engagement that is primarily driven by activities, events, or stimuli present in one's larger environment. It refers to a fleeting, emotional reaction that responds to contextual factors and connects with feelings of excitement or enjoyment. Since situational interest is largely driven by external stimuli, it typically fades when the stimuli are no longer present. This makes situational interest different to individual interest which is more enduring in nature (Hidi and Renninger, 2006). While situational interest is temporary and mostly triggered by the external environment, individual interest is an internal form of interest that is primarily driven by personal factors (Hidi and Renninger, 2006). Student interest in CUREs can therefore be influenced by both the course environment as well as personality traits, competencies, and preferences (Chiu, 2024). This distinction helps us understand how students develop and maintain interest in their CURE courses and identify the complex factors that influence this development.

Several factors that can impact student interest development and subsequently influence their engagement and motivation in the classroom have been identified in previous work. Students can encounter feelings of challenge and frustration as they learn new skills (*appraisals of novelty*) or recognize the need to solve a problem (*comprehension demands*), which are important for situational interest development (Lehman et al., 2012). As noted by Przybylski et al. (2010), challenges can enhance student engagement, however, challenges that are not matched to students' levels of skill can heighten their frustration. Indeed, students who engage in challenge-based learning, in which they work to solve authentic problems in collaborative teams, are shown to develop heightened interest and achievement in their classes (Ogbuanya et al., 2021). Within STEM education contexts, challenge-based learning can promote student interest by fostering active learning, critical thinking, problem-solving skills, and students' overall sense of self-efficacy (Taconis and Bekker, 2023; Lockwood, 2023; McKay et al., 2015). Interest development can also be influenced by how important a task is for one's future goals (Hidi and Renninger, 2006). Within undergraduate STEM education, students' ability to connect the content they are learning to their personal lives is positively associated with their academic performance (Hulleman et al., 2010). Autonomy, competence, and relatedness—three psychological needs highlighted in self-determination theory—are also important for interest in STEM (Chiu, 2024). This framework identifies autonomy as one's sense of ownership over their learning, competence as their belief in their ability to complete

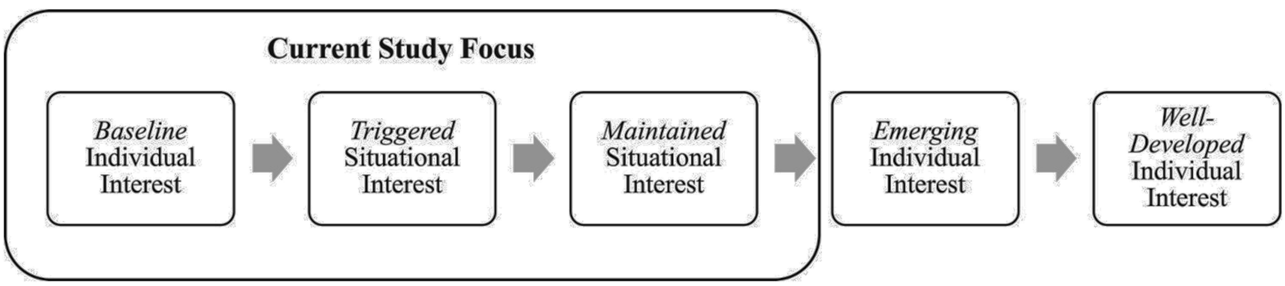


FIGURE 1
Adapted version of Hidi and Renninger's (2006) four-phase model of interest development as seen in Zhu et al. (2024).

a task, and relatedness as their feelings of connectedness to the social environment (Deci and Ryan, 2008; Ryan and Deci, 2017). Students who attain these three needs within course environments experience increased intrinsic motivation and engagement, aligned with Hidi and Renninger's (2006) model of interest development (Duboff, 2021). Instructors who foster students' connection to the course, incorporate appropriate challenges, and encourage student autonomy, competence, and relatedness can help students sustain interest in CUREs.

Indeed, previous research investigating students' experiences in CUREs found that students' interest development in CUREs is influenced by their levels of challenge, frustration, and personal connection to the course material (Zhu et al., 2024). In this study, individual interest was considered a stable variable and only measured at the start of the semester. Individual interest was considered a stable variable because it is largely driven by one's personal values and preferences, meaning that it is more consistent than situational interest as it is less influenced by changes in the environment (Renninger, 2000). Situational interest was, therefore, considered a dynamic variable and assessed longitudinally at multiple time points over the semester. Students who experienced higher levels of frustration reported a decrease in situational interest when perceiving greater challenges in CUREs. Conversely, students experiencing lower levels of frustration reported increased situational interest even when the CURE became more challenging. Students who could connect their learning to their own personal goals– a process defined as meaning-making (Wang, 2019) — sustained higher levels of situational interest in the CURE course overall (Zhu et al., 2024).

Studying student interest trends across different CURE contexts involves identifying and analyzing common CURE course features and student outcomes. Although CURE courses vary across contexts, such as in the methods used or degree of research authenticity, previous work has systematically identified common course features informed by student experiences across a variety of CUREs (Burmeister et al., 2023). These experiences include the following: (1) use of the scientific process, (2) use of technical methods and protocols, (3) building skills in professional behaviors, and (4) receiving mentorship and scientific identity development. CURE course features are implemented in the service of achieving desired student outcomes such as self-efficacy and career clarification (Auchincloss et al., 2014; Gin et al., 2018). As with common CURE course features, previous work has also identified common student outcomes resulting from CURE participation. Common CURE student outcomes put forward by Corwin et al. (2015) include increased technical skills, enhanced science identity, and increased access to mentorship. Having an existing CURE classification system for course features and student outcomes allows for comparisons to be made across different settings.

The current study aims to build upon our research team's previous findings that students' experience of frustration and ability to make meaning out of the course material significantly modulate their interest and response to challenge (Zhu et al., 2024). Notably, in the previous study, students on average reported a sustained decline in situational interest over time that may be caused by decreased curiosity or knowledge in the CURE. The 2012 President's Council of Advisors on Science and Technology report called for the widespread adoption of CUREs to improve undergraduate STEM student retention (PCAST, 2012). Thus, it is critical to develop a better understanding of how different CURE course features influence students' week-by-week experiences of frustration, challenge, meaning-making, and ultimately, interest. Here, we conduct an exploratory longitudinal analysis of how student situational interest develops as students experience different course features during a CURE and subsequently investigate the long-term impact of expected CURE student outcomes more than a year after the CURE. This study defines "long-term" as over a year after their CURE to probe the benefits of CUREs that remained with students long after their experiences. To maintain consistency across CURE contexts, this study uses the CURE course features and common student outcomes identified by Burmeister et al. (2023) and Corwin et al. (2015), respectively. Our specific research questions are as follows: (1) How do students contextualize changes in their situational interest in a CURE over a semester, and how are these changes impacted by CURE course features and student levels of challenge and frustration? and (2) How do students' patterns of situational interest in their CURE courses influence their perceptions of the benefits of their CURE participation over a year later?

The current study presents case studies representing seven CURE students. We analyzed data collected from surveys distributed during the CURE semester, follow-up interviews held the summer after the CURE, the CURE course syllabi, and a final survey sent over a year after the CURE. By providing qualitative explanations for quantitative data collected via surveys during the CURE semester and course features derived from provided syllabi, this study elucidates how and why students' situational interest is heightened, lost, or maintained during a CURE course. This study then examines the impact of CURE courses on student development one year later. Based on previous studies examining student experiences in CUREs (Zhu et al., 2024), we hypothesize that students experience peak situational interest in CURE courses during moments when they develop research skills, take ownership over their learning, and feel connected to their course environment (Hypothesis 1). On the other hand, we anticipate that students will report situational interest troughs [i.e. the lowest point(s) of situational interest] when CURE course activities are challenging and frustrating (Hypothesis 2). We also predict that students who experience high situational interest over an entire CURE course will find their CURE course meaningful 18 months after finishing the CURE course (Hypothesis 3). We chose this time frame to investigate the lasting impact of the CURE courses that were deemed meaningful over a year after the experience. Exploratory insights on student interest development and long-term outcomes in CUREs derived from this study can inform holistic teaching strategies for instructor use to maximize CURE benefits (Burmeister et al., 2023).

2 Methods

We organize the "Participants", "Materials", and "Procedures" sections based upon data collection efforts that span over a year:

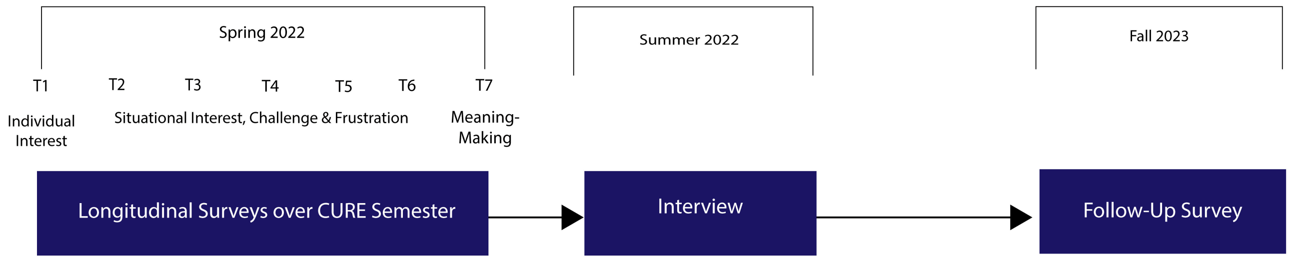


FIGURE 2
Timeline of data collection efforts employed in this study.

(1) surveys distributed to students at several timepoints over the CURE semester, (2) student interviews conducted the summer after the CURE course, and (3) a follow-up survey distributed to students a year after CURE course participation. See Figure 2 for the stages of data collection. All seven students presented in these case studies completed every longitudinal survey distributed at each time point over the semester and participated in interviews. Six out of the seven students completed the follow-up survey distributed over a year since their CURE participation. Integrating data collected from semester surveys, interviews, and the follow-up surveys, we developed detailed case studies to better understand students' individual experiences during and after their CURE course.

2.1 Participants

2.1.1 Longitudinal surveys over the CURE semester

The total number of participants were undergraduate students (n = 7) enrolled in one of 16 CURE courses from six research universities over the 2021–2022 academic year. While CUREs vary by classroom context, the CUREs selected in this study involved authentic research experiences where students engaged in discovery-based learning, conducted experiments, analyzed their own data, and presented findings. For instance, in the biology CURE, students worked on genome assembly and phylogenetic analysis while sharing findings through oral and written presentations. Moreover, the CUREs in this study were all led by faculty members at their respective institutions. We selected these seven students from a larger dataset of 63 students who completed surveys at all seven time points over the semester. A total of 170 students consented to the study, with 37% (n = 63) completing all questions at each survey time point over the semester (note: for our research team's statistical analysis of the CURE semester survey responses for the entire dataset of 170 students, refer to Zhu et al., 2024). Three participants self-identified as women and three participants self-identified as first-generation college students. During the 2021–2022 academic year, most students were sophomores (n = 4), followed by seniors (n = 2), and one freshman (n = 1). Participants were primarily majoring in a STEM-related field including industrial engineering (n = 1), neuroscience (n = 1), biology (n = 2), biochemistry (n = 1), and psychology (n = 1). One student remained undecided at the time of data collection. Students were enrolled in four CURE courses spanning the following disciplines: virology (n = 1), physical chemistry (n = 2), genetics (n = 2), and neuroscience (n = 2). One of the CURE courses spanned two semesters, and some students were interviewed after their first semester. See Table 1 for complete demographic information of the seven students presented in case studies.

2.1.2 Student interviews

Based upon their responses to semester surveys, we selected students who had completed the surveys at all seven time points and reported different patterns in situational interest to participate in follow-up interviews. In Summer 2022, we conducted interviews with seven out of eleven students enrolled in one of the Spring 2022 CUREs invited to participate. We only recruited students from the Spring 2022 semester because they had recently completed the course and could offer insight into their immediate experiences.

2.1.3 Follow-up survey

In Fall 2023, we followed up with all 170 students who had originally provided online consent in the Fall 2021-Spring 2022 academic year, marking over a year since the completion of their CURE course. Six of the seven students interviewed the previous summer provided complete responses to the follow-up survey.

2.2 Materials

All materials are provided in full in the Supplementary material.

2.2.1 Longitudinal surveys over the CURE semester

Herein is a description of the surveys distributed to students at different timepoints during their semester in a CURE. These surveys probed students' interest development, frustration, challenge, and meaning-making. Students' *individual interest* was examined in the first 2 weeks of the course with six items adapted from the Harackiewicz et al.'s (2008) Individual Interest Questionnaire that uses a 1–7 Likert scale from 1 (not true of me) to 7 (very true of me). Example item: "I chose to take this

TABLE 1 CURE focus and demographic information for each case study.

Student	CURE focus	Major (spring 2022)	Major (fall 2023)	Gender	Race/Ethnicity	First-generation
A	Physical chemistry	Industrial engineering	Industrial engineering	Male	White	No
B	Genetics	Biology	Biology	Male	White	Yes
C*	Neuroscience	Psychology	Psychology	Female	White	No
D	Virology	Undecided	Allied health science	Female	White	No
E	Physical Chemistry	Biochemistry	Not provided	Male	Not provided	Yes
F	Genetics	Biology	Biology	Female	Asian or Pacific Islander	No
G	Neuroscience	Neuroscience	Neuroscience	Male	Asian or Pacific Islander	Yes

*Student C did not provide their major in spring 2022 surveys but mentioned their major in the interview.

class because I'm really interested in the topic." This measure showed good internal consistency in our data sample ($\alpha = 0.86$). We then probed students' *situational interest*, *challenge*, and *frustration* every 2 weeks during the semester with surveys. Students' levels of challenge and frustration levels were assessed with the following single items: "Rate how challenging the class is at the current moment" and "Rate how frustrating the class is at the current moment" using a 1–7 Likert-scale from "not enough" to "too much". Situational interest was examined with three items using a similar 7-point Likert scale from 1 (extremely low) to 7 (extremely high). Example items included: "Rate your current level of interest in this class". Situational interest showed excellent internal consistency across all time points (Cronbach's alpha coefficients ranging from 0.94 to 0.96). Students' levels of meaning-making (i.e. their connection between course content and personal goals) were assessed at the end of the course using six items from Wang's (2019) rationale generation orientation scale. This scale measures the extent to which students can explain their actions and behaviors. In previous work, students' ability to justify their actions (i.e. meaning making) was strongly associated with their motivation and overall identification with their actions (Wang, 2019). The survey uses a 5-point Likert scale for items, from 1 (never) to 5 (always). An example item is as follows: "In this course, I was able to see the connections between learning and my academic or professional goals." Cronbach's alpha for this data sample was good (0.91). These measures were similarly used in our research team's previous study on the full dataset of 170 students (Zhu et al., 2024).

2.2.2 Follow-up survey

We distributed a brief survey to students more than a year following their participation in their CURE. This survey consists of the initial question stem: "The ways in which my professor taught my course made me..." and includes 15 items with binary-response questions, including "...more motivated to do well in this class," "...better able to work with a diverse group of people," and "...feel more like I belong in the science field." These items are then followed by four open-ended questions related to student academic major and career plans. Demographic data were also collected. Instead of using a pre-existing, validated measure, we opted for this custom survey to investigate the unique outcomes of CURE participation and gather information about participants' academic and career goals. The binary-response items also simplified data collection and reduced the burden placed on participants.

2.3 Procedures

2.3.1 Longitudinal surveys over the CURE semester

Students enrolled in CUREs were recruited via email to participate in the study (170 out of 295 students gave online consent). Students could win one of three digital gift cards if the surveys were completed at every time point. Students' levels of situational interest, challenge, and frustration were assessed at five time points: Week 4 (Time 2) to Week 14 (Time 6) over two 15-week semesters (Fall 2021 or Spring 2022). Students' individual interest was assessed at the beginning of the semester (Time 1) and their level of meaning-making was assessed at the end of the semester (Time 7). The study was approved by the Yale Institutional Review Board Human Subjects Committee (IRB #2000026056).

2.3.2 Student interviews

During Summer 2022, eleven students were invited via email to participate in follow-up interviews on their CURE courses and incentivized with a $50 digital gift card for their participation. Seven students were interviewed in total. Prior to the interview, CURE instructors were contacted for a copy of their syllabus. Interviews were 10 to 15 minutes long and conducted online by a member of the research team via Zoom. The interview followed a predetermined protocol. Students were first probed with introductory questions about their academic background. The interviewer then presented the course syllabus to students and asked them to label course activities that were the most interesting, least interesting, most frustrating, and most challenging. The interviewer asked students to explain their own situational interest graph and describe what was happening in the course that impacted their response to the survey at each point in time. Students were finally asked to reflect on the future benefit of the CURE course and explain the extent to which the pandemic impacted their experience. See the Supplementary material for a full list of interview questions.

2.3.3 Follow-up survey

We investigated students' reflections about their CURE course by distributing a brief survey over a year after the completion of their CURE course. Survey data were collected using Qualtrics. In Fall 2023, we followed up with the original 170 students who had provided consent to the semester surveys. Participants were recruited via their university email addresses and incentivized with a $15 digital gift card to complete the survey. Participants were sent no more than three email reminders. As stated previously, of the seven interviewed students, six completed the follow-up survey in Fall 2023. See the Supplementary material for the follow-up survey.

2.4 Analysis

This study focuses on developing unique case studies for the seven students who completed the CURE survey at all seven time points during the semester and participated in interviews after the CURE. Quantitative analysis of surveys distributed throughout the semester was performed according to methods previously described in Zhu et al., 2024. For the seven students in the present study, we performed a qualitative analysis of interview responses to investigate how they contextualized changes in their situational interest during the semester. Then, we analyzed the course syllabus to identify which CURE course features (taken from a list previously established by Burmeister et al., 2023) were occurring at each time point. Next, we connected this qualitative data and syllabus information to the student's reporting of individual interest, challenge, frustration, and meaning-making to fully capture their experiences. Finally, we analyzed how students' interest patterns and interview reflections compared to survey responses provided over a year later. While exploratory, this approach allowed us to develop seven data-intensive case studies. Each student offered unique perspectives about how their experiences were influenced by CURE course features during the semester in a follow-up interview and survey distributed one year later. Herein, we present each step in this case-study analysis, detailing how we organized each case study to analyze similarities or differences across interest patterns.

The qualitative analysis of student data was conducted by two researchers, whose identities and backgrounds may have influenced their analysis or interpretations of the data. The first researcher has been educated in both the United States and South Africa. Her perspective may have impacted her analysis of educational courses in the United States. Moreover, her experiences as a non-STEM major and recent college graduate may influence her perspective on students' experiences in CUREs and the CURE course syllabi. The second researcher, who is a current college student, has studied STEM in both China and the United States. Her background may have influenced the perception of Western educational programs. The two researchers gave their best efforts to avoid making assumptions or interpretations from a place of bias when conducting the qualitative analysis.

2.4.1 Qualitative analysis of interviews

We adopted the qualitative approach described by Auerbach et al. (2018) to extract themes from interviews. This process involved creating an *a priori* list of codes from the CURE outcomes tables developed by Corwin et al. (2015) that summarizes the student outcomes of CURE participation. Once we had established a set of codes, two members of the research team independently coded interview transcripts sentence by sentence, considering the context of the sentence within the broader paragraph. One transcript was unavailable, however, detailed notes from the interview were used for coding in place of the missing transcript. The independent coders added codes where the data did not fit an *a priori* list of codes (such as "challenging tasks", "academic burnout", and "increased personal interest in scientific research"). The coders then consolidated their codes, adding, combining, and removing codes where there was overlap or confusion. This process was highly collaborative and iterative. One round of interrater reliability was calculated using NVivo after final codes were determined, which resulted in a Cohen's Kappa value of 0.76. The codebook resulted in 22 total codes (including 16 CURE outcomes proposed by Corwin et al., 2015). See the Supplementary material for the final codebook.

2.4.2 Syllabi analysis

The same two members of the research team then analyzed course syllabi using the CURE course features list put forward by Burmeister et al. (2023). This involved extracting the course activities that occurred during the weeks in which each situational interest survey was distributed from the syllabus. The two research members independently assigned CURE course features to the activities occurring during each surveyed week (from Week 4 to Week 14). After their independent review, the two researchers met to discuss their decisions and consolidate features upon discussion. In cases where a student mentioned a course feature in their interview, but it did not appear during that week in the syllabus, it was still included to accurately represent the students' perceptions.

2.4.3 Triangulation of data

To triangulate qualitative codes with survey data and syllabus course features, one member of the research team first placed interview codes onto a graph depicting students' levels of situational interest, challenge, and frustration to visually represent what was happening at each time point in the course. These codes consolidated the following qualitative feedback: (1) student labeling of the most interesting, least interesting, and most challenging and frustrating parts of the syllabus and (2) student reflections on their graph of situational interest provided during the interview. For example, when labeling their syllabus, one student said, "*I think it was this week that was the most interesting. If I remember correctly, it was the first time we met the rats and got to interact with them, which was interesting.*" This was coded into a theme from the codebook (e.g., increased technical skills). If the syllabus labels coincided with a survey time point, we included this qualitative data with the quantitative survey points. Similarly, when students commented on their situational interest graphs, the codes from their responses (e.g., "*I thought that my group and I kept thinking about how we could apply this to our topic, and I feel like that's what* *really jumpstarted and increased my interest,"* which was coded to "Improved collaboration and peer interactions" and "Increased analytical skills") were integrated at the corresponding time points. When the exact time point was not clear, the researcher used their best judgement to determine where the qualitative code belonged between Time Points 2 and 5. In such cases, the researcher would consider the context of the students' responses to determine a logical sequence of events and cross-reference the course syllabus to ensure the accuracy of that interpretation. The researcher would then organize qualitative codes to the corresponding time points that followed the determined sequence of events and aligned with the syllabus. Once the qualitative codes had been organized according to each time point, the research team then organized the course features occurring at Time Points 2–5 as determined by analyzing the syllabus. This triangulation added a new layer to the analysis as we were able to investigate how CURE course features (obtained from analysis of the syllabus) impacted students' impressions of the course (provided by qualitative interview data) in addition to their levels of situational interest, challenge, and frustration (provided by quantitative survey data).

2.4.4 Follow-up survey

Once we identified themes from student interviews, we considered the CURE outcomes reported in the follow-up survey. We compared the follow-up survey responses across students to investigate how students' interest during their CUREs impacted their academic development or growth a year later. To ensure alignment between interview codes and follow-up survey responses, two research team members independently coded binary-response items using the codebook developed from the *a priori* student outcomes codes (Corwin et al., 2015) and reached consensus on final codes for items upon review. For example, the item, "More aware of the content and purpose of the scientific discipline," was coded as "Increased content knowledge," and the item, "Better able to work with a diverse group of people," was coded as "Improved collaboration and peer interactions." Student responses to the follow-up survey also allowed for a form of content-validation of themes derived from their interviews.

2.4.5 Case study analysis

To analyze each case study, we integrated the coded course syllabi information, the semester-long quantitative survey data, and the qualitatively coded interview data. We then considered each student's follow-up survey responses (collected over a year had passed) and compared them across student interest patterns (see a more detailed description below). Three of the seven case studies are presented in Results, with the remaining four case studies presented in the Supplementary material.

2.4.6 Comparison of student interest patterns

To analyze differences across interest patterns, we categorized case studies into the following groups: (1) high, fluctuating interest ($n = 2$), (2) low interest ($n = 2$), and (3) high, stable interest ($n = 3$). Interviewed students were grouped into interest categories based upon the general trajectory of their responses to the situational interest surveys and numeric differences at all five time points in which this construct was probed. For instance, a student was classified as "high" if their situational interest consistently scored four or higher out of seven across at least four of the five surveyed time points. If their situational interest scores fluctuated by more than two points, they were categorized as "fluctuating." If it changed by less than two points during the surveyed period, they were categorized as "stable". Students in the *high, fluctuating interest* category experienced oscillations in their situational interest throughout their CURE course, though their overall interest remained high. Students in the *low interest* category may have experienced changes in their situational interest, though their overall interested remained relatively low. Students in the *high, stable interest* category experienced stable levels of situational interest throughout their CURE course, with only minor changes occurring at each time point. Given that only one student exhibited *low, fluctuating* interest and another experienced *low, stable interest*, we chose to group these students into a general low interest pattern to make meaningful comparisons between students with high and low interest patterns. We compiled common course features and qualitative codes occurring at situational interest peaks and troughs (obtained from the semester-survey data) for every student within a distinct interest group. This allowed us to investigate how course activities impacted students based upon their overall interest patterns. We also compared follow-up survey responses across interest pattern groups to assess how interest development within CURE courses impacts student reflections over a year after their CURE.

3 Results

We provide an overview of three representative case studies (with the remaining four presented in the Supplementary material) from each interest pattern, comprising one student who displayed high, fluctuating interest, one student who displayed low interest, and one student who displayed high, stable interest. In addition to a narrative description of each student, we provide a visualization of each student's individual interest assessed at Time Point 1, situational interest, challenge, and frustration trajectories assessed from Times 2–6, and level of meaning-making assessed at Time Point 7. The visualization is accompanied by a table listing the qualitative interview codes and course features occurring in each student's CURE course at the surveyed time points (see Figure 2). This triangulation paints a cohesive picture of how each student's interest responded to course activities appearing in the syllabus.

3.1 Student A (high, fluctuating interest)

3.1.1 Introduction

At the time of the follow-up survey, Student A was a junior at a large public university majoring in industrial engineering. This was their same major during their CURE course which focused on physical chemistry. In their interview, Student A described themselves as a "*science and math-focused person.*" They were initially excited about the opportunity to conduct scientific research. They described how they were first unsure about the CURE course and thought that they needed an advanced degree to conduct research. Therefore, Student A was surprised by how much independent research they did during the course. In their interview, Student A reflected: "*I don't know how this is going to work, but I might as well try...so I just kind of went for it and I'd say I loved it....I never had anything like that, where here I felt like I was actually giving back to the scientific community and helping the world progress.*"

3.1.2 Semester survey data, qualitative interview codes, and course features

Figure 3 shows Student A's individual interest, situational interest, challenge, frustration, and meaning-making during the CURE semester, as well as the qualitative codes and course features occurring from Time Points 2 to 6. Key drivers of Student A's situational interest include increased confidence in their research skills and interactions with peers and faculty. Their declines in situational interest were attributed to tedious course activities such as scientific writing. The student had an initial interest of 5.83 out of 7 at the start of the course, which they attributed to their excitement about conducting research in the lab. Their levels of situational interest and challenge peaked at Time Point 3, which corresponded with completing a Hot Injection (HI) synthesis. The student found this activity challenging. They also explained how their CURE instructor emphasized that only a few students on their campus knew how to perform the technique. The student reflected how this feedback gave them a sense of accomplishment when their group managed to complete the synthesis. Student A said, "*Our professor was showing us this hot injection lab and explaining that there are probably only about 15 people on campus who can actually perform hot injection successfully. Even though I would say it was definitely one of the most challenging labs and parts of the course, my group and I were all able to successfully complete the lab. I thought it was very interesting and cool that we are now among the 15–20 people on campus who can actually use this method.*" Despite this success at Time Point 3, the students' situational interest declined at Time Point 4 to its lowest point throughout the course. This decline coincided with a decline in challenge and frustration. The student attributed this decline to writing a research proposal which the student did not enjoy. They said, "*And we also started doing our actual writing of our, um, what was it? Research proposal, where we had to create an abstract and methods. I hate writing, so having to write a five- or eight-page paper was not something I was happy with in the course at that time.*" At Time Point 5, Student A's situational interest rebounded when the course transitioned to X-ray Diffraction and Technology, Entertainment, and Design (TED) demos. The student identified these demonstrations as the most interesting part of the CURE. Students also worked independently on their projects and engaged in peer reviews of their papers during Time Point 5. Explaining their resurgence in situational interest at Time Point 5, Student A described a greater sense of project ownership and collaboration. The student's situational interest then slightly tapered off at Time Point 6, coinciding with a rise in frustration. Reflecting on this moment in the course, Student A said: "A*nd then toward the end, I think it did start to be like, oh gosh, research on your own is actually hard, but I still was pretty interested...it really taught me how to (do) research and also as much as I hated (writing), the importance of writing and actually having to write.*" At Time Point 7, the student reported a meaning-making score of 3.5 out of 5. Overall, Student A's interest remained high but fluctuated throughout the course, peaking at the same point as their highest level of challenge. Their frustration remained relatively stable in the course before spiking toward the end, coinciding with a decline in their situational interest.

3.1.3 Situational interest peaks and low points

Student A's situational interest was largely driven by completing a challenging technique with peers and feeling encouraged by their professor. Their peak situational interest occurred at Time Point 3, when the course focused on following protocols, using technical tools and equipment, and conducting peer reviews of papers (Figure 3). They experienced their lowest point of situational interest, however, at Time Point 4. This occurred when the course involved learning content knowledge and quantitative approaches in addition to using technical tools and equipment (Figure 3). The student also mentioned how they did not enjoy writing a research proposal even though they recognized the value of this skill toward the end of the course.

3.1.4 Follow-up survey

Over a year after their CURE, Student A reported gains that correspond to their interview themes. These include increased technical skills, analytical skills, self-efficacy, science identity, project ownership, content knowledge, improved collaboration and peer interactions, as well as an enhanced understanding of the nature of science. The student did not report that their CURE made them more likely to pursue a science career a year later. They still remain an industrial engineering major, however, and plan to pursue a career in industrial engineering. In their follow-up survey, the student writes: "*This was a very interesting course and gave me a lot of knowledge on the practices of research as a whole.*" Please refer to the Supplementary material for a comparison of Student A's interview and follow-up survey themes.

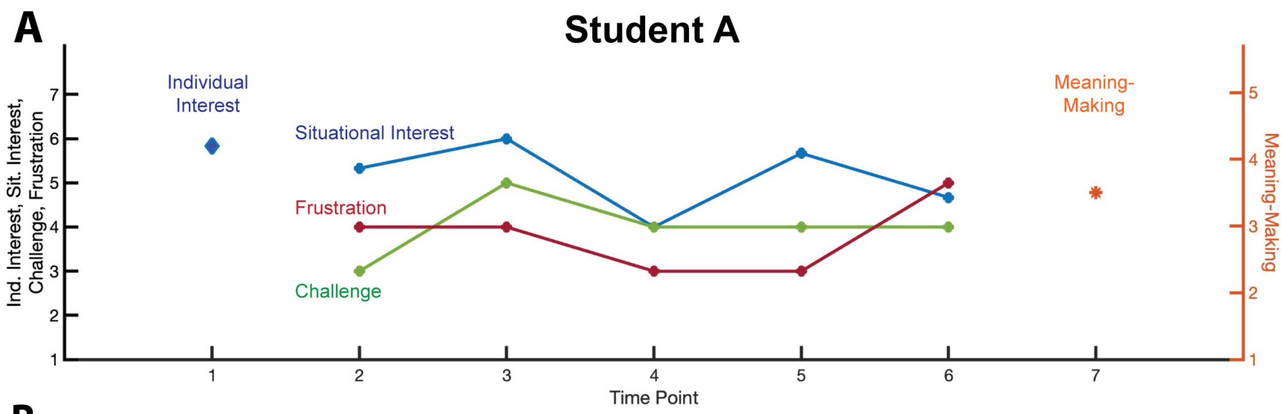
3.2 Student B (low interest)

3.2.1 Introduction

During their CURE, Student B was a fourth-year student majoring in biology at a large public university. At the time of the follow-up survey, Student B was a graduate student. The student decided to take the CURE course, which focused on genetics, because they were interested in genetics. Student B described how excited they were to participate in the course owing to past positive experiences in CUREs.

3.2.2 Semester survey data, qualitative interview codes, and course features

Figure 4 depicts Student B's individual interest, situational interest, challenge, frustration, and meaning-making during the CURE semester, as well as the qualitative codes and course features occurring from Time Points 2–6. Key factors influencing Student B's low interest include challenges with data analysis and lack of



B

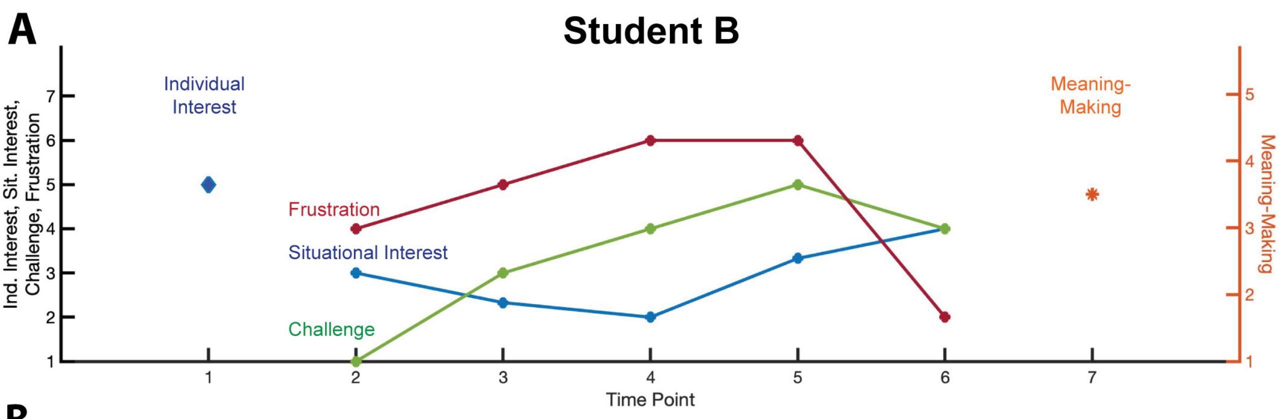
Time Points	2	3	4	5	6
Interview Codes	• Increased motivation in science	• Challenging tasks • Improved collaboration and peer interactions • Increased self-efficacy • Increased access to faculty interaction and mentorship	• Tedious tasks • Challenging tasks	• Increased project ownership • Improved collaboration and peer interactions	• Enhanced understanding of the nature of science • Increased tolerance for obstacles
Course Features	• Learn required content knowledge • Read the scientific literature	• Follow specialized protocols • Use technical tools and equipment • Provide constructive criticism to classmates and challenge each other's interpretations • Write components of a scientific article	• Learn required content knowledge • Use technical tools and equipment • Use quantitative approaches	• Use technical tools and equipment • Collaborate as part of a networked research project • Provide constructive criticism to classmates and challenge each other's interpretations • Write components of a scientific article	• Collaborate as part of a networked research project • Take responsibility for their own research progress

FIGURE 3
(A) Individual interest, situational interest, challenge, frustration, and meaning-making for Student A (high, fluctuating interest). X-axis represents time points of data collection. Left y-axis represents Student A's average score on individual interest, situational interest, challenge, and frustration surveys. Right y-axis represents Student A's average score on meaning-making survey. **(B)** Qualitative codes and course features occurring at each time point for Student A. Student A described writing a research proposal at time point 4, although this feature did not appear in the syllabus at this time point.

instruction. The student reported an individual interest score of 5 out of 7. They experienced low situational interest, however, for the remainder of the course. Their situational interest decreased steadily before increasing again mid-semester and peaking in the final weeks. Their frustration levels remained high during the course. The student described many of the course activities as "busy work" and questioned whether the course was right for them. The student's situational interest declined from Time Point 2 to Time Point 4, coinciding with a rise in challenge and frustration. This decline occurred when the course focused on data collection and analysis; the student mentioned that coding in R was the most challenging and frustrating part of the course. At Time Point 4, their situational interest reached its lowest point, when the student described an overwhelming courseload and was intimidated by the instructors' lack of guidance. Their situational interest, however, began to rise (as observed at Time Points 5 and 6) as the student developed a sense of accomplishment once their challenges in coding in R were overcome. Student B also developed a closer relationship with their professor who showed special attention to their project. The student mentioned how the instructor's interest in their research project motivated them to do well. At Time Point 6, Student B experienced a peak in situational interest and a sharp decline in frustration. The student mentioned how the presentations at the end of the course improved their communication skills, which they viewed as valuable for their goal of attending graduate school. At Time Point 7, Student B reported a meaning-making score of 3.5 out of 5. The student highlighted that overall, the course met their expectations.

3.2.3 Situational interest peaks and low points

As shown in Figure 4, Student B experienced their lowest point of situational interest at Time Point 4 when students collected and analyzed data and wrote poster content. The student reported challenges with analyzing data and felt intimidated by their instructor's lack of instruction. They also questioned whether they belonged in the course. The student, however, experienced their peak situational interest at Time Point 6. During this point in the course, students worked on their presentations and met with their instructor. In their interview, the student mentioned how



B

Time Points	2	3	4	5	6
Interview Codes	• Lack of instruction/ belonging • Tedious tasks	• Lack of instruction/ belonging • Frustrating tasks • Challenging tasks	• Lack of instruction/ belonging • Frustrating tasks • Challenging tasks	• Increased tolerance for obstacles • Increased self-efficacy • Increased technical skills • Increased analytical skills	• Increased motivation in science • Increased access to faculty interaction and mentorship
Course Features	• Collect data • Analyze pre-existing data • Use quantitative approaches • Provide constructive criticism to classmates and challenge each other's interpretations • Write components of a scientific article	• Keep records of methods and data • Analyze pre-existing data • Use quantitative approaches	• Keep records of methods and data • Analyze their own (individual or course) data • Write a poster or slide content	• Integrate multiples lines of evidence to make an argument or judgment • Write components of a scientific article • Write a poster or slide content	• Revise drafts of written research findings or presentations based on feedback • Take responsibility for their own research progress • Discuss and receive mentorship about science, careers, professional development, and related topics during designated class time

FIGURE 4
(A) Individual interest, situational interest, challenge, frustration, and meaning making for Student B (high, stable interest). X-axis represents time points of data collection. Left y-axis represents Student B's average score on individual interest, situational interest, challenge, and frustration surveys. Right y-axis represents Student B's average score on meaning-making survey. **(B)** Qualitative codes and course features occurring at each time point for Student B.

their interest increased because they felt more motivated as their instructor took special interest in their project.

3.2.4 Follow-up survey

A year after the CURE, Student B reported gains that aligned with interview themes, including increased motivation in science, self-efficacy, technical and analytical skills, personal interest in science, and career clarification. They also reported over a year later that their CURE experience made them more likely to pursue a career in science and interested in attending graduate school. The student's relationship with their instructor was important during their CURE. This relationship was emphasized by Student B in the open-ended comment about their CURE a year later: "*Dr. X was very approachable.*" The student is currently enrolled in graduate school after graduating with a biology degree. The student did not specify the specialization of their post-graduate studies. Please refer to the Supplementary material for a comparison of Student B's interview and follow-up survey themes.

3.3 Student C (high, stable interest)

3.3.1 Introduction

Student C was a third-year student majoring in psychology at a large, public university at the time of the follow-up survey. The student chose their CURE—which focused on neuroscience—because it aligned with their psychology major. The student reported that their CURE course met expectations and gave them important research skills. A year later, the student reported persisting in their psychology major and continuing to pursue clinical psychology as a career.

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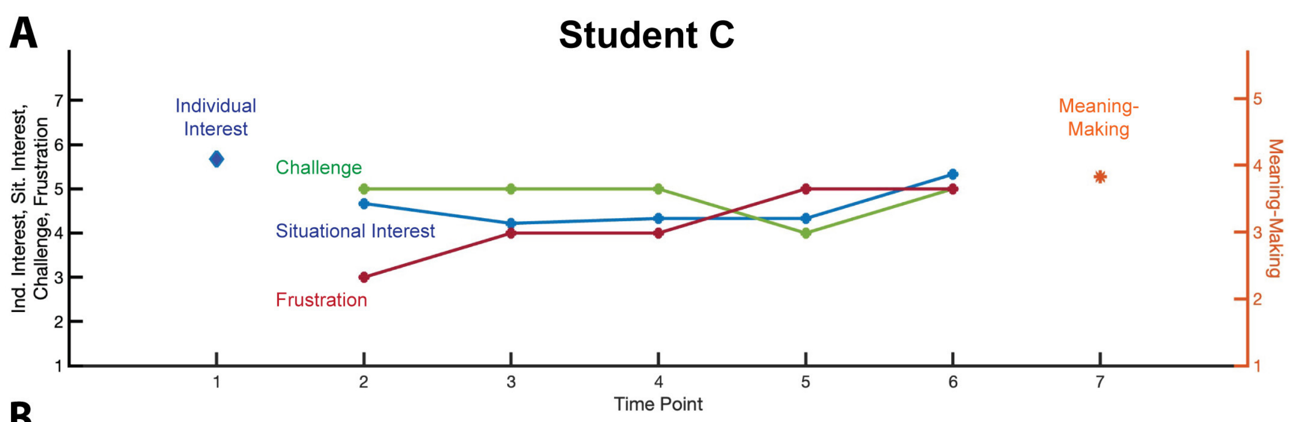

B

Time Points	2	3	4	5	6
Interview Codes	• Increased personal interest in scientific research	• Tedious tasks			• Increased project ownership • Enhanced understanding of the nature of science • Increased technical skills
Course Features	• Learn required content knowledge • Follow specialized protocols • Use technical tools and equipment	• Learn required content knowledge • Follow specialized protocols • Use technical tools and equipment • Write components of a scientific article	• Analyze their own (individual or class) data • Use technical tools and equipment • Follow specialized protocols	• Analyze their own (individual or class) data • Write components of a scientific article • Discuss and receive mentorship about science, careers, professional development, and related topics during designated class time	• Analyze their own (individual or class) data • Follow specialized protocols • Use technical tools and equipment

FIGURE 5
(A) Individual interest, situational interest, challenge, frustration, and meaning making for Student C (high, stable interest). X-axis represents time points of data collection. Left y-axis represents Student C's average score on individual interest, situational interest, challenge, and frustration surveys. Right y-axis represents Student C's average score on meaning-making survey. **(B)** Qualitative codes and course features occurring at each time point for Student C.

3.3.2 Semester survey data, qualitative interview codes, and course features

Figure 5 shows Student C's level of individual interest, situational interest, challenge, frustration, and meaning-making over the CURE course as well as the qualitative interview codes and course features occurring from Time Points 2 to 6. At Time Point 1, Student C reported an individual interest score of 5.67 out of 7. The student continued to report high and stable situational interest throughout the course. Student C described their interest in the early weeks of the course: "*I feel like I was pretty interested from the start, and I guess it increased a little bit as I got more invested in it.*" Their situational interest then declined at Time Point 3 as their frustration levels increased. The student connected this slight decline in situational interest to scientific writing assignments. They said, "*I guess this would be the lowest point where it stayed constant for a little while…that was when we were doing a lot of the scientific writing.*" Notably, at Time Point 2, students were tasked with writing components of a scientific article in addition to learning the required content knowledge and following specialized protocols. Their situational interest remained stable until Time Point 5, as students continued to write scientific articles, learn course content, use technical equipment, and follow protocols. At Time Point 6, however, the student's situational interest rebounded to its highest level during the course. This increase coincided with a rise in challenge. During this point in the course, students finished their experiments. Reflecting on this increase in situational interest toward the end of the course, the student notes that, "*I think at that point I saw how everything was coming together more.*" Overall, Student C's sustained levels of situational interest were driven by course features facilitating hands-on lab activities and opportunities to see their research project through. They mentioned that the CURE course was more interesting than other courses they had taken in the past and said that this was "*because we're more involved in doing hands-on work…*"

3.3.3 Situational interest peaks and low points

As seen in Figure 5, Student C experienced their peak situational interest toward the end of the course, when students finalized their experiments. The student reflected on how seeing the research projects through contributed to their high situational interest. On the other hand, Student C experienced their lowest point of situational interest at Time Point 3 when the students engaged in scientific writing, which the student did not enjoy.

3.3.4 Follow-up survey

In their interview, the student reported how their experience in a research lab will benefit their future work in psychology. Reflecting on the course as a whole, they said, "*Yeah, it's always good, especially as a psychologist, to have lab work. And in this case, it allows you to work in a lab while still having someone help you and ease you into the process*". The student also reported positive outcomes in the follow-up survey that aligned with interview themes. These include increased project ownership, technical skills, enhanced understanding of the nature of science, and science identity. Over a year later, the student also reported gains in collaborative skills, content knowledge, confidence, motivation, and persistence in science that were not relayed in their interview immediately following the CURE.

3.4 Summary of remaining case studies

Through qualitative analysis of student interviews and course syllabi, we gained insights into how CURE course design and students' unique experiences interact with their situational interest longitudinally across a semester. We categorized all seven case studies into an observed pattern of situational interest: high, fluctuating interest ($n = 2$), high, stable interest ($n = 3$), and low interest ($n = 2$). The three case studies presented above provide an example of each interest pattern. Herein we present a brief summary of the remaining four case studies, focusing first on the course features and qualitative codes that correspond to their situational interest peaks and low points (provided via semester surveys), followed by each student's response to the follow-up survey distributed over a year later. For a more detailed description of these four case studies, please refer to the Supplementary material.

3.4.1 Summary of Student D (high, fluctuating interest)

3.4.1.1 Introduction

At the time of the follow-up survey, Student D was a second-year student majoring in allied health science at a large, public research university. During their CURE course, the student was a freshman and reported being undecided in their major. They originally intended to study computer science, before learning that it was not right for them. Student D enrolled in the CURE course because they were interested in the topic and the CURE had not been offered before. Student D found the CURE course to be interesting and mentioned that they enjoyed learning about phages.

3.4.1.2 Situational interest peaks and low points

Student D experienced their highest point in situational interest when their CURE course features involved students learning required content knowledge, using technical tools, as well as quantitative approaches. The student experienced high challenge levels during this time point as well, as they engaged in more hands-on lab activities. The student specifically said, "*Once we started doing the hands-on work, like the labs, it was interesting learning about what phages were and trying to annotate things.*" On the other hand, Student D experienced their lowest point of situational interest when they felt burned out and overwhelmed by the course. Course features during this time point included learning content knowledge and analyzing data.

3.4.1.3 Follow-up survey

Student D's responses to the follow-up survey reflected several themes from their interview. Over a year after their CURE, Student D reported gains in content knowledge, technical and analytical skills, understanding of the nature of science, interest in science, as well as heightened project ownership. This confirms the student's cognitive and practical development from their CURE experience. In the follow-up survey, the student also mentioned benefits including increased self-efficacy, science identity, career clarification, persistence in science, and increased sense of belonging. The student additionally reported in the open-ended response to the follow-up survey: "*I loved this course. This course was the first science course I received an A in.*" During their CURE, the student reported being undecided in their major. Over a year since their CURE course, the student reported majoring in health science and exploring their career options.

3.4.2 Summary of Student E (high, stable interest)

3.4.2.1 Introduction

During their CURE semester, Student E was a freshman majoring in biochemistry at a large public institution with the goal of going to medical school. Student E described their passion for science and decided to take the CURE because they enjoyed learning more about chemistry. Overall, Student E reported they enjoyed their CURE. They noted how the CURE research topic differed from their career plans. They felt that the CURE nonetheless exposed them to broader scientific research areas, which would be valuable in medical school.

3.4.2.2 Situational interest peaks and low points

Student E's situational interest remained relatively high and stable during the CURE. Their lowest point occurred when CURE course features focused on learning required content knowledge and reviewing scientific literature. The student described these activities as boring. Their situational interest, however, peaked when students collaborated with their peers on their research projects. Reflecting on this peak in interest, Student E said: "*Now I'm really in love with my topic, and I'm really excited for next semester to conduct it...and my professor taught us how we can apply this to our research because we did a lot of different synthesis methods...and changing this part of an experiment to see what would happen differently. And me and my group...we kept thinking how we could apply this to our topic... and I feel like that's what jumpstarted my interest and increased my interest in the class.*" The student explained how this growing interest was encouraged by applying different research methods to their project with their teammates.

They also noted that their autonomy in their project and their professor's guidance heightened their excitement.

3.4.2.3 Follow-up survey

During their interview, Student E mentioned how their CURE experience gave them a better understanding of the nature of science. They explained how they were able to make connections between scientific disciplines and gain a broader exposure to scientific research. Student E reported that these interdisciplinary skills would benefit their future and position them as a well-rounded candidate for medical school. Student E did not respond to the follow-up survey distributed a year later.

3.4.3 Summary of Student F (low interest)

3.4.3.1 Introduction

At the time of the follow-up survey, Student F was a full-time energy sector employee who graduated with an accelerated master's degree in biology at a large, public institution. During their CURE in genetics, they were a fourth-year student majoring in biology and planned to work in the biopharmaceutical industry upon graduating.

3.4.3.2 Situational interest peaks and low points

Student F experienced their peak situational interest in their CURE when students kept records of data, collected data, and wrote slide content. The student explained their situational interest peak, mentioning that, "*And then toward the middle of the class, we started working on a group project away from the coding that we were doing, which could be why it went up a little*". Student F experienced their lowest point of interest when students worked on their posters and received feedback from teaching assistants. The student explained how their interest decreased because they found course activities tedious.

3.4.3.3 Follow-up survey

Student F's responses to the follow-up survey confirm the themes emerging from their interview. These include increased collaboration, as well as technical and analytical skills. The student also reported an enhanced science identity over a year after their CURE. The student did not report that their CURE impacted their persistence, despite graduating with a STEM degree and persisting in a STEM career.

3.4.4 Summary of Student G (high, stable interest)

3.4.4.1 Introduction

At the time of the follow-up survey, Student G was a third year student majoring in neuroscience at a large public university and aspired to become a dentist. During their CURE, Student G had recently declared a major in neuroscience, after being inspired by an AP psychology course taken in high school. The student explained how excited they were to take the course because they had no prior research experience. They felt that the CURE course would be an ideal opportunity to gain exposure to research. Reflecting on their CURE course, they share that they not only enjoyed the research project but were also able to develop important skills.

3.4.4.2 Situational interest peaks and low points

Student G experienced their highest point of interest when students learned content knowledge, followed protocols, used technical tools and equipment, analyzed data, and wrote components of a scientific article. The student mentioned how the hands-on learning aspect of the course increased their situational interest. They said, "*I think it was this week, that was the most interesting. If I remember correctly, it was like the first time we met rats, and we actually got to interact with them.*" However, the student experienced their lowest point of situational interest due to academic burnout. Explaining the decline in interest, the student explained, "*Just the stress of studying for like near the end, like finals and tests and all that got me so burnt out and tired.*" Although the student enjoyed the course, they mentioned feeling stressed by final examinations.

3.4.4.3 Follow-up survey

The themes emerging from the student's interview—including motivation, enhanced understanding of the nature of science, career clarification, persistence in science, and increased collaboration—were confirmed by their reflections over a year later in the follow-up survey. The student also reported an increased sense of belonging, self-efficacy, science identity, and project ownership stemming from their CURE experience over a year later.

3.5 Findings across interest patterns

Building from our analysis of individual case studies, we consider the course features and qualitative codes coinciding with situational interest peaks and low points within and across all three interest patterns (Table 2). Common patterns that emerge across interest categories provide exploratory findings into how students' situational interest is developed, maintained, or lost. For each case study, we examined the outcomes reported by interviewed students a year later to validate interview themes. The follow-up responses also allowed us to consider similarities or differences across situational interest patterns over a year later. Table 3 shows CURE outcomes mentioned by students in their follow-up survey across different interest patterns.

As seen in Table 2, students with high, fluctuating and high, stable interest patterns experienced peak situational interest when they learned or used technical tools and equipment. Both students with high fluctuating interest reported situational interest peaks when they learned new technical skills and felt challenged. Across all three situational interest patterns, students experienced peak situational interest when collaborating with peers, interacting with faculty, and writing components of a scientific article (Table 2). Conversely, students across interest patterns experienced their lowest situational interest points when analyzing course data and engaging in tedious tasks. Both students with low interest patterns reported their lowest point of situational interest when experiencing feelings of challenge and frustration, as well as perceiving a lack of instruction or guidance (Table 2). The practical implications of these findings are discussed in more detail in the Discussion.

TABLE 2 Course features and qualitative codes linked to interest peaks and troughs across interest patterns.

Interest pattern	Qualitative codes at highest situational interest points	Course features at highest situational interest points	Qualitative codes at lowest situational interest points	Course features at lowest situational interest points
High, fluctuating interest (Students A and D	• **Challenging tasks** • Increased analytical skills • **Increased technical skills** • Improved collaboration and peer interactions • Increased self-efficacy • Increased access to faculty interaction and mentorship	• Learn required content knowledge • **Use technical tools and equipment** • Use quantitative approaches • Follow specialized protocols • Provide constructive criticism to classmates and challenge each other's interpretation • Write components of a scientific article	• Academic burnout • Challenging tasks • Tedious tasks	• **Learn required content knowledge** • Understand content and data on which they will/can build • Analyze their own (individual or course) data • Use technical tools and equipment • Write components of a scientific article • Use quantitative approaches
High, stable interest (Students C, E, and G)	• Increased technical skills • Increased analytical skills • Improved collaborations and peer interactions • Increased access to faculty interaction and mentorship • Increased project ownership • Enhanced understanding of the nature of science • Enhanced science identity • Increased motivation in science • Increased personal interest in scientific research	• **Use technical tools and equipment** • Collaborate as part of a networked research project • Take responsibility for their own research progress • Analyze their own (individual or class) data • Follow specialized protocols • Learn required content knowledge • Provide constructive criticisms to classmates and challenge each other's interpretation • Write components of a scientific article	• Tedious tasks • Academic burnout	• Learn required content knowledge • Read the scientific literature • Follow specialized protocols • Use technical tools and equipment • Write components of a scientific article • Analyze their own (individual or class) data • Discuss and receive mentorship about science, careers, professional development, and related topics during designated class time
Low interest (Students B and F)	• Increased motivation in science • Increased access to faculty interaction and mentorship • Improved collaboration and peer interactions • Increased communication skills • Increased project ownership	• Revise drafts of written research findings or presentations based on feedback • Take responsibility for their own research progress • Discuss and receive mentorship about science, careers, professional development, and related topics during designated class time • Keep records of methods and data • Analyze their own (individual or class) data • Write a poster or slide content • Write components of a scientific article • Integrate multiple lines of evidence to make an argument or judgement	• **Lack of instruction/belonging** • **Frustrating tasks** • **Challenging tasks** • Tedious tasks	• **Keep records of methods and data** • Analyze pre-existing data • Use quantitative approaches • Analyze their own (individual or course) data • Write a poster or slide content • Revise drafts of written research findings or presentations based on feedback • Take responsibility for their own research progress • Discuss and receive mentorship about science, careers, professional development, and related topics during designated class time

Items in bold were present across all students within a specific interest pattern group and underlined items indicate codes or features that appeared across all three interest groups.

As seen in Table 3, students reported increased technical and analytical skills and a better understanding of science over a year after their CURE. The students with high interest patterns (high, fluctuating and high, stable) reported increased science identity, self-efficacy, personal interest in science, and content knowledge over a year after their CURE participation. These outcomes were less consistently mentioned across students with low interest patterns. Interestingly, only two students reported an increased sense of belonging in science more than a year later (Table 3). These findings are discussed in more detail in the Discussion.

4 Discussion

This study is an exploratory analysis of how CURE course features influence student interest over a semester. Prior research emphasizes the need to mitigate students' frustration during challenging moments and highlights the role of meaning-making in CUREs to maintain students' situational interest (Zhu et al., 2024). Our study expands upon this work by identifying specific course activities based on student reflections that contribute to the dynamics between interest, challenge, frustration, and meaning-making. We predicted that peaks in situational interest would be linked to course features that relate to students' personal goals and encourage their competence, connectedness, and autonomy (Hypothesis 1); low points of students' situational interest would be linked to CURE course features that students perceive as challenging and frustrating (Hypothesis 2); students with high interest in CURE courses would continue to find their CURE experience meaningful in a follow-up survey conducted more than a year later (Hypothesis 3). Analysis of seven case studies confirms previous findings that situational interest is dynamic in nature and evolves in response to students' experiences of CURE course features. Interviewed students continued to report several benefits

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TABLE 3 Follow-up survey outcomes across students in each interest patterns ($n = 6$)*.

CURE outcome	High, fluctuating interest $n = 2$		High, stable interest $n = 2$		Low interest $n = 2$	
Increased analytical skills	✓	✓	✓	✓	✓	✓
Increased technical skills	✓	✓	✓	✓	✓	✓
Increased motivation in science	✓		✓	✓	✓	
Increased content knowledge	✓	✓	✓	✓		
Enhanced understanding of the nature of science	✓	✓	✓	✓	✓	✓
Increased project ownership	✓	✓	✓	✓		
Increased personal interest in scientific research	✓	✓	✓	✓	✓	
Increased self-efficacy	✓	✓	✓	✓	✓	
Enhanced science identity	✓	✓	✓	✓		✓
Career clarification	✓		✓	✓	✓	
Persistence in science	✓		✓	✓	✓	
Increased sense of belonging to a larger community	✓		✓			
Improved collaboration and peer interactions		✓	✓	✓		✓

Student E (high, stable interest) did not complete the follow-up survey and is therefore not included in this table. Check marks represent individual students, with each check mark corresponding to a specific student within the interest pattern.

*The follow-up survey did not include items related to increased communication skills, access to faculty interaction, and increased tolerance for obstacles.

from their CURE experience more than a year after the course had ended.

4.1 Hypothesis 1: interest peaks across students

Building from research on interest development (Hidi and Renninger, 2006) and self-determination theory (Deci and Ryan, 2008; Ryan and Deci, 2017), we hypothesized that students would experience peak interest when they gained research competencies, felt connected to their learning environment, and took ownership over their learning. Our analysis supported this hypothesis. Four students in the high interest groups (fluctuating and stable) reported peak situational interest in their CURE courses when they gained technical or analytical skills and participated in hands-on learning activities such as conducting a synthesis or interacting with laboratory rats (Table 2). Across interest groups, peaks in situational interest occurred when students collaborated with their peers, such as conducting peer review of papers and working on research projects, or when they interacted with their professors through receiving guidance and feedback (Table 2). These findings align with previous research showing that mentorship and faculty interactions contribute to students' science identity and STEM persistence (Thiry and Laursen, 2011)—corresponding with self-determination theory's emphasis on relatedness (Ryan and Deci, 2017). Ultimately, findings support our first hypothesis. Results show that peaks in students' situational interest correspond to course features that promote competence (through skill development), relatedness (through peer and mentor interactions), as well as autonomy (through hands-on learning) in the CURE.

4.2 Hypothesis 2: interest troughs across students

We hypothesized that student's low points of situational interest would coincide with course features that students perceive as challenging or frustrating. Findings supported Hypothesis 2; students reported their lowest points of situational interest when engaging in course activities they found frustrating. There was an important distinction, however, in students' responses to challenging tasks based upon their general interest pattern (high fluctuating, high stable, and low). Specifically, the two students in the low interest group experienced interest troughs during tasks they found challenging. In contrast, students in the high, fluctuating interest group reported peaks in situational interest during tasks they described as challenging (Table 2). Additionally, all students except one in the high interest groups reported their lowest points of interest during academic burnout (Table 2). This pattern suggests that students with high, fluctuating interest may be more engaged and less frustrated when presented with challenges, whereas students with lower interest are more frustrated by challenges. Moreover, academic burnout may cause decreased situational interest for students with high, overall interest patterns. These findings re-emphasize the importance of managing frustration levels to sustain student interest during challenges in CUREs (Zhu et al., 2024).

Across interest patterns, tedious class activities or assignments were linked to situational interest low points in CURE courses (Table 2). These findings align with Hidi and Renninger's interest development framework that highlights how unchallenging or irrelevant tasks hinder situational interest development (2006). Notably, students perceived course features involving their use of the scientific process (e.g., reading literature or learning required content knowledge) as tedious, or "busy" work. While these skills are important for scientists, findings suggest that students view these course activities as unimportant and do not recognize their value. Additionally, students experience situational interest troughs when engaging in CURE activities that are overwhelming and accompanied by lack of instruction. As seen in Table 2, students across interest groups experienced their lowest points of interest when the course focused on data analysis. Notably, both students in the low interest groups mentioned struggles with analyzing data. These two students were enrolled in the same CURE course and both reported a lack of guidance from their instructor. Without clear instruction during these challenging activities and assignments, the students may have struggled to develop competencies in the CURE and sustain high situational interest. These patterns also confirm the importance of social connections for interest development in CUREs as both students with low interest patterns felt unsupported by their instructor (Connors et al., 2021). Although CURE environments encourage student independence, these patterns suggest that instructional support during difficult tasks, such as analyzing data, is important for student interest.

4.3 Hypothesis 3: follow-up survey themes

Our third hypothesis predicted that instructors' ability to trigger student's situational interest through CURE course features would influence student reflections on their CURE over a year later. Responses to the follow-up survey support this hypothesis (Table 3). Students in the high interest groups (both fluctuating and stable) reported increased content knowledge and project ownership a year after their CURE. These two outcomes were not mentioned by students in the low interest group in the follow-up survey (Table 3). Similarly, four students with high interest reported that their CURE developed their interest in science, confidence in their ability to do research, and ability to think like a scientist a year after their CURE. On the other hand, outcomes related to increased personal interest, confidence, and science identity were only mentioned by one student in the low interest group (Table 3). These patterns suggest that students with high interest in CURE courses experience personal and cognitive growth over a year after the CURE and value the CURE course for developing practical research skills, regardless of their interest in the specific CURE topic itself. Overall, the follow-up study highlights how CURE courses promote practical skill development across interest patterns. Notably, the majority of interviewed students remained in a STEM major or career after their CURE.

The follow-up study also highlights how CURE courses contribute to key outcomes linked to increased persistence in STEM. Prior research within undergraduate STEM education emphasizes the importance of students' sense of project ownership, self-efficacy, science identity, and scientific community values for their persistence in STEM (Chemers et al., 2011; Estrada et al., 2011; Hanauer et al., 2016; Hanauer and Dolan, 2014). Additionally, students' cognitive ability and motivation are shown to be important factors on student retention in a STEM major and their academic performance (Cromley et al., 2016). This study highlights how CUREs promote these outcomes. As seen in Table 3, students reported increased technical and analytical skills, motivation in science, personal interest in scientific research, and increased collaboration and positive interactions with peers in their follow-up survey more than a year later. These outcomes mentioned consistently in the follow-up survey connect to the motivational and cognitive factors that are important for STEM student success. For instance, more communal opportunities (i.e., collaboration or teamwork) offered to students in their STEM courses have been linked to increased interest and motivation in STEM (Boucher et al., 2017). Additionally, interaction between students has also been shown to increase individual students' knowledge, as well as their cognitive and skills development (Nikiforos and Kolyvas, 2020). This study also highlights noteworthy gaps in the outcomes that CUREs are designed to promote. For instance, previous research highlights the role of students' level of connection to a scientific community for their persistence in STEM (Chemers et al., 2011; Estrada et al., 2011; Hanauer et al., 2012; Hanauer and Dolan, 2014). In the follow-up survey, however, the majority of sampled students did not report increased sense of belonging in the scientific community from their CURE experience. Future research should, therefore, seek to investigate how CUREs might more consistently foster students' sense of belonging in the STEM community.

4.4 Practical implications

Overall, this study highlights factors that contribute to sustained student interest in CURE courses and offers practical implications for CURE instructors. These include interactions with peers and professors (i.e., student relatedness), greater sense of project ownership (i.e., autonomy) and skill development (i.e., competency). To sustain student interest, instructors can implement course activities that encourage students to collaborate with one another as they solve complex problems. The nature of CURE courses promotes student independence as they conduct their own research projects (Gin et al., 2018). This study, however, emphasizes the need for instructional support during challenging tasks presented in CUREs, such as analyzing data, to effectively sustain student interest. Examples of pedagogical strategies or course activities that foster peer-to-peer and student-instructor interactions include peer reviews of papers, group problem-solving activities, regular check-ins, and personalized feedback on assignments (Prince, 2004; Topping, 2005). This study also emphasizes the role of meaning-making for student interest in CUREs, as students experienced dips in situational interest during tedious tasks. To promote student interest, instructors can encourage students to understand the relevance of activities and connect them to students' personal goals. Through these interventions, instructors can help sustain interest in CUREs and promote their academic and personal development more than a year after the experience.

4.5 Limitations and future directions

By addressing the following limitations, we can contribute to a better understanding of a student's interest development in CURE courses. The sample size was very low, which limits the generalizability of findings. However, by focusing our analysis on a small number of case studies, we were able to appreciate the richness of individual student data. As detailed by Stake (1995), when the purpose of research is to provide an explanation, the low sample size necessitated by case studies is disadvantageous. On the other hand, when the purpose of research is to enhance our understanding of a known finding, as it was here, the case study is no longer at a disadvantage (Stake, 1995).

The students enrolled in this study participated in four CURE courses led by different instructors. While we aimed to make consistent comparisons across courses by using previously developed categorization systems to organize their features and intended outcomes (Corwin et al., 2015; Burmeister et al., 2023), we could not account for different instructor styles, course objectives, and alignment between actual course activities and classification features. We determined the course features occurring at each time point by analyzing each syllabus. The syllabus may have changed throughout the semester and thus not entirely reflect the actual course activities occurring at each time point. The research team also did not contact instructors to determine if any changes were made to the course that differed from the syllabus, limiting the accuracy of the various course features that corresponded to high and low situational interest points. However, our analysis is grounded in students' own accounting of what occurred at each time point in their CURE. Similarly, interviews were conducted the summer after the CURE experience. Therefore, students' reflections may not be accurate because of the amount of time passed and influence of hindsight.

One student from the sample did not respond to the follow-up survey. We also lacked one interview transcript, so analysis subsequently relied on coding notes taken by the interviewer. This missing data may not completely capture students' experiences, limiting the depth of our analysis and introducing potential bias. We also aimed to accurately represent each student's experience by using their interview data and course syllabus information; the positioning of qualitative codes in each student's figure, however, may reflect the researchers' subjective interpretations. While three of the study subjects self-identified as women and three self-identified as first-generation college students, no interviewed students self-identified as a member of a historically marginalized racial or ethnic group. Future research should consider interest development in CURE courses for students from underrepresented groups.

There are also important limitations with our follow-up survey. For example, while we used themes from the follow-up survey to confirm interview themes, caution is recommended when comparing differences between the short-term interview and follow-up survey themes. This is because interviews consisted of open-ended questions that allowed students to reflect on their own experiences, whereas the follow-up survey presented students with a predetermined set of outcomes that they could select from. As a result, students may have selected outcomes in the follow-up survey that aligned with their experiences, even if those outcomes did not come to mind during their interviews. Because the interviews probed students on the benefits of CUREs, their follow-up survey responses over a year later may be influenced by a recall bias and likelihood to report benefits that they mentioned in the interview (Sudman et al., 1996). Since our study was primarily qualitative, we selected a less validated measure for the follow-up survey as the items aligned with the exploratory nature of our research. To better investigate outcomes of CUREs, future studies could use a pre-validated instrument [e.g., Hanauer et al.'s (2016) Persistence in Science measure].

4.6 Conclusion

This research provides exploratory, qualitative insights into students' week-by-week experiences in CUREs over a semester. This study then investigates how student's immediate experiences align with outcomes over a year later. Overall, findings highlight how situational interest in CURE courses is dynamic in nature and influenced by course features, presented challenges, and opportunities for collaboration. Course features that promote student autonomy, competence, and relatedness are found to foster student's situational interest, while tedious tasks and lack of instructional support inhibit students' situational interest. Practical implications are discussed. This research further suggests that high situational interest in CURE courses contributes to sustained positive outcomes over a year later. Since CUREs have been recognized as a viable option for improving student retention in the STEM major and STEM careers, further research into the mechanisms within CUREs that promote desired student outcomes is needed to maximize the impact of these research-based, interactive experiences.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the Institutional Review Board at Yale University. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

JB: Formal analysis, Methodology, Project administration, Writing – original draft, Writing – review & editing. KZ: Visualization, Writing – review & editing. PY: Formal analysis, Writing – review & editing. JG: Conceptualization, Data curation, Investigation, Methodology, Project administration, Writing – review & editing. LC: Conceptualization, Data curation, Investigation, Methodology, Writing – review & editing. MB: Conceptualization, Funding acquisition, Project administration, Resources, Writing – review & editing. MG: Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that no Gen AI was used in the creation of this manuscript.

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2025.1562677/full#supplementary-material

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