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Impacts of a citizen science research initiative at a 2YC

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ABSTRACT

We developed a new Citizen Science Undergraduate Research Experience that engages two-year college students in application of the scientific method in order to increase STEM participation, interest, and skills. The research experience was designed to leverage the local, flood-prone urban setting of the two-year college with the class structure and flexibility of an 8-week course to provide students with diverse academic backgrounds and interests the opportunity to conduct an authentic research project on the consequences of flooding in central Texas. We describe our adaptable Citizen Science Research Experience course model and survey and assessment-based evaluation methods. Participation in the research experience is associated with higher rates of student success in terms of transfer and graduation rates, contributing to increased STEM retention. The research experience also increased student confidence in using the scientific method, formulating a research question, and working with numerical data, which support gains in science skills and integration into STEM culture. Close faculty mentoring contributed to the success of this course-based research experience. We recommend increasing instruction efficiency, structuring the course as a 2-term elective science credit course, and securing consistent faculty funding as ways to improve this and similar undergraduate research experiences at 2-year colleges.

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Introduction

Purpose and objectives



As defined in the Crowdsourcing and Citizen Science Act, citizen science encourages voluntary, public “participation in the scientific process” in part by “formulating research questions, conducting scientific experiments, collecting and analyzing data, and interpreting the results of data” (United States Congress, 2016). Involving community members in science that seeks to understand local natural hazards (Garcia et al., 2024), local environmental problems, and local impacts of climate change (Rosenthal et al., 2024) is not only productive but prudent. We developed a Citizen Science Undergraduate Research Experience (CS-URE) to provide science and non-science majors at a two-year college (2YC) with a course-based, mentored, hands-on research experience in a single, condensed-semester term program. This CS-URE gives 2YC students of diverse backgrounds the opportunity to: A) apply the scientific method to the study of the local natural hazard of stream flooding and the impacts of flooding in a heavily urbanized area of central Texas, B) work with scientific tools, techniques, and publicly-available scientific data sets, C) communicate scientific results, and D) explore academic, professional, and public opportunities for scientific research in geosciences and related fields.


Providing this citizen science-style research experience to 2YC students will contribute to meeting the National Academies of Sciences’ (NAS) goals of expanding STEM participation, increasing STEM knowledge and skills, and integrating students into STEM culture (NAS, 2017). In achieving these goals, this CS-URE will promote appreciation for the role that science plays in understanding and addressing local issues and encourage life-long public participation in scientific data collection in their local communities.

Literature context

Benefits of undergraduate research

Many studies have documented academic and professional benefits of involving college students in intensive and authentic undergraduate research experiences (UREs). For example, participation in UREs has been correlated with students’ enhanced research skills, increased interest in academic research careers, increased total science courses taken, and increased overall post-participation grade point averages (Junge et al., 2010). Undergraduate research experiences can also strengthen computational, problem-solving, technical, and communication skills that are essential to successful graduate studies and careers (Mosher et al., 2014). Emphasizing the importance of early-undergraduate research experiences,

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Rodenbusch et al. (2016) found that college students that participate in undergraduate research over the first three semesters of college are more likely to complete their college degree in six years and more likely to earn a STEM degree than students that did not participate in a URE. Furthermore, early-college undergraduate research experiences are correlated with increased STEM program participation, persistence, performance (Vincent-Ruz et al., 2018), and retention (Gamage et al., 2022; NAS, 2017; Scott et al., 2020; Smaglik, 2015). As the benefits of UREs in general, and early-undergraduate UREs specifically, have become clear, many four-year colleges (4YCs) have begun incorporating undergraduate research practices into the introductory curricula (NAS, 2015).

UREs at 2YCs

Despite the recognized benefits of early-undergraduate research experiences, UREs are largely underutilized at 2YCs. Compounding the underutilization of UREs at 2YCs are the relatively low transfer rates from 2YCs to 4YCs, where one is more likely to encounter URE opportunities (Packard et al., 2011). This means that 2YC students have fewer opportunities than 4YC students to participate in and benefit from authentic research projects. The American Association of Community Colleges (AACC) reports that 2YCs serve a large percentage of U.S. undergraduates in ethnic minority groups (53% of Native Americans, 49% of Hispanics, 39% of African Americans, and 34% of Asian/Pacific Islanders) as well as a large percentage of students facing additional challenges to academic success; of 2YC students, 32% are first-generation college students, 23% are people with disabilities, and 13% are single parents (AACC, 2025). Therefore, the underutilization of UREs at 2YCs disproportionately disadvantages marginalized student populations (i.e., low-income and first-generation college students, who are more likely to begin their undergraduate education at 2YCs), by limiting their ability to access and potentially benefit from undergraduate research experiences (Bangera & Brownell, 2014) and potentially limiting their participation in STEM activities and pursuit of STEM degrees and careers. In STEM fields in particular, the enrollment and retention of marginalized groups, such as ethnic minorities, women, and first-generation students, has been less than that of others (Bangera & Brownell, 2014). This marginalization in STEM fields underscores the need to provide more research opportunities to 2YC students. The National Research Council (NRC, 2011) recommends undergraduate research at 2YCs as a tool for encouraging STEM education for marginalized students, which may contribute to increased participation and retention of 2YC students in STEM beyond their 2YC education.

Institutional challenges to UREs at 2YCs

The development of successful UREs at 2YCs institutions is challenging. Compared to 4YCs, 2YCs have limited access to the capital and facility resources necessary for providing students with research experiences (Gamage et al., 2022;

Hewlett, 2009; Langley, 2015; Perez, 2003). Other obstacles to UREs in the 2YC environment include inadequate institutional support for URE initiatives, short-term URE program endurance, relatively low faculty incentive, and lack of training in the initiation of URE programs (NAS, 2017). The ability of college faculty to provide research experiences for the 2YC student can be restricted by heavy teaching responsibilities. Adjunct faculty, who are faculty that are appointed on single-term, not benefits-eligible, often part-time contracts (OIRA, 2024a), serve an essential role at 2YCs (Wallin, 2004), and comprise a majority of 2YC faculty (Hurlburt & McGarrah, 2016). While adjunct faculty may represent a valuable resource for developing UREs at 2YCs, their participation in these processes can be limited by short-term and/or part-time employment contracts with the 2YC and compensation uncertainty (Gamage et al., 2022). Other hindrances to 2YC faculty participation in UREs include time limitations due to secondary employment, physical isolation from discipline colleagues due to varied teaching schedules and campus locations, and logistical challenges due to teaching obligations at more than one campus in regional, multi-campus 2YC systems. However, adjunct faculty, who often have more flexible teaching schedules, reduced institutional responsibilities, expertise in the field of study, and professional connections may be better positioned to work on URE programs. Therefore, in order to provide research opportunities at 2YCs, adjunct faculty need to be provided the support and resources to develop and implement UREs.

Participation challenges to UREs at 2YCs

Developing UREs that 2YC students can participate in is another challenge to UREs at 2YCs. According to the AACC (2025), 66% of 2YC students are enrolled part-time and 59% of part-time students at 2YCs have full-time employment. Compared to 4YC students, 2YC students are more likely to have local work and/or family demands that limit the students ability to participate in research activities off campus and outside of class time. Financial resource and schedule limitations may contribute to 2YC students being less likely to seek out unpaid and/or non-credit-earning research experiences. Therefore, to encourage student participation, UREs at 2YCs should be local, convenient, and financially feasible for students.

Overcoming institutional challenges to UREs at 2YCs with 2YC-4YC collaborations

One approach to overcoming the challenges that resource and faculty limitations present to the development and implementation of UREs at 2YCs involves a collaboration between a 2YC and a 4YC. 2YC-4YC URE collaborations can provide 2YC students with hands-on research opportunities in 4YC environments and mitigate 2YC-4YC transfer barriers (Dowd, 2012; Eggleston & Laana, 2001; Hagedorn et al., 2008; Packard et al., 2011; Townsend & Wilson, 2006; Wang, 2020; Wyner et al., 2016). One example of the 2YC-4YC approach is the Summer Undergraduate Research

Experience Course (SUREC), a collaboration between a large 2YC and a leading 4YC in the Southwest (Gamage et al., 2022). The program provided 2YC students with hands-on STEM research opportunities in scientific ocean drilling, leveraging faculty expertise and institutional resources at the 4YC. It also established an articulation agreement to ensure research credits from the 2YC were transferable to 4YCs in the region and secured external funding to sustain the program. The SUREC program was successful with respect to its program goals (Gamage et al., 2022); however, logistical issues and faculty work burdens still remained in the development and implementation of this 2YC-4YC collaborative URE, leading to the development of an alternative model for this URE.

Overcoming participation challenges to UREs at 2YCs with course-based and place-based UREs

Course-based undergraduate research experiences (CUREs), which provide a research experience as part of a structured, term-limited, credit-bearing course, are another strategy to increase participation in UREs at 2YCs. CUREs can be designed to provide a research experience while meeting course learning objectives, earning course credit, and satisfying degree requirements. When used in large-enrollment introductory courses, CUREs have the benefit of extending research opportunities to more students (NAS, 2017). However, a disadvantage of having large-enrollment CUREs is that they may be less-suited to student-directed research experiences and provide fewer opportunities for faculty-student mentoring. Nonetheless, participating in CUREs as an introductory-level non-science major has been found to increase student motivation and appreciation for the sciences (Kortz & van der Hoeven Kraft, 2016). Furthermore, combining aspects of both course-based UREs and place-based UREs (discussed next) have been shown to foster discovery and collaborative applications of scientific practices to better understand issues relevant to students (Auchincloss et al., 2014).

Because 2YCs serve a predominantly local and part-time student population, place-based UREs are a convenient strategy to engage 2YC students in UREs. Place-based UREs allow students to apply scientific concepts and skills to local and community-relevant issues, which can produce impactful learning experiences (Boger et al., 2014; van der Hoeven Kraft & Kortz, 2021). Participating in practical, place-based science activities that address local problems can contribute to students' forming a deeper connection to their studies, enhance their scientific identity, and improve retention and transfer success (Semken, 2005; Semken et al., 2017; Woodhouse & Knapp, 2000). These benefits led us to incorporate aspects of both course-based and place-based learning experiences into the CS-URE.

Enhancing CURE success through mentorships

Close and long-term faculty-student mentoring is recognized as a strength of apprentice-style faculty research group UREs (NAS, 2017). However, mentoring can be defined more

broadly to include not only long-term and formal interactions that occur between a supervising faculty member and a student, but also short-term, informal interactions that occur between students and instructors, students and professionals, and students and their more experienced peers (NAS, 2017). Defined as such, mentoring can also be incorporated into the context of a CURE. In a course-based research experience with an intentionally low faculty to student ratio, faculty can serve as mentors that help guide the research process, recent course alumni can serve as peer-advisors in the research process, and course guest speakers can provide insights into academic and career pathways and expose students to employment and research possibilities. Supporting the benefits of incorporating mentoring into CUREs, Houser et al. (2013) found that mentoring can be an important factor in student success in UREs by influencing research productivity and decisions for future research partnerships, and Haacker (2015) found that effective mentoring in UREs can also increase retention in STEM fields. Incorporation of UREs into 2YC curricula as mentored, limited-enrollment CUREs is likely to contribute to increasing STEM student transfer rates, four-year degree completion rates, and ultimately, a more diversified STEM workforce (Higgins, 2013; Horsch et al., 2012; Rodenbusch et al., 2016). Therefore, opportunities for mentoring were incorporated into this CS-URE.

A new approach to 2YC undergraduate research

Rather than implementing a 2YC research experience that relies on a 4YC-partnership, or a faculty-directed and large-enrollment CURE, we developed a new citizen science-style URE (CS-URE). This CS-URE combines the structure and efficiency offered by a course-based URE, the convenience and sense of relevancy offered by a place-based URE, the authentic research experience, limited-enrollment, and mentorship offered by UREs. This blended CS-URE model provides an inclusive and stipend-supported opportunity for science and non-science majors attending a regional, urban 2YC to participate in student-directed scientific research on the impacts of flooding in the local urban environment.

CS-URE goals

This CS-URE was developed to meet the three main goals of UREs as identified by the National Academies of Sciences (NAS, 2017). One of the NAS-identified URE goals is to increase participation and retention of STEM students (i.e., by increasing participation of non-STEM and STEM majors at 2YCs in STEM courses and research experiences). The course-based format and place-based aspect of this CS-URE as well as the recruitment process and student stipend for this CS-URE seek to increase 2YC student participation (including science and non-science majors) in the process of the scientific method. Another NAS-identified URE goal is to promote STEM disciplinary knowledge and practices (i.e., by providing 2YC students opportunities to apply STEM concepts to relevant issues, practice STEM skills and

Table 1. URE goals, learning activities, objectives, and outcomes.

Graded and ungraded course learning activities are aligned to National Academies of Sciences (NAS)-identified Undergraduate Research Experience (URE) goals as well as course-specific objectives and student learning outcomes. For graded learning activities, each assessment's percentage of the overall course grade is provided. Minor assessments were scored by completion of required elements. Major assessments of student achievement were scored by the instructors' evaluation of each assessment according to rubric criteria.

| Learning activities | Overall course grade (%) | NAS URE goals | CS-URE objectives | Learning outcomes |
|---|--------------------------|---------------|-------------------|-------------------|
| Ungraded Learning Activities | | | | |
| Course Lectures, Readings, and Videos | – | 2 | B, C, D | – |
| Mentoring Opportunities | – | 1, 2, 3 | B, C, D | – |
| Graded Learning Activities | | | | |
| Minor Assessments | | | | |
| Pre-Course and Post-Course Surveys | 10 | – | – | – |
| Lab and Field Exercises for Research Skills and Project Background | 6 | 1, 2, 3 | A, B, D | i, iv |
| Reflections (Developing a Research Project) | 2 | 2 | A, B | i |
| Research Project Plan | 12 | 2 | A, B | i |
| Guided Project Status Updates | 6 | 2 | A, B, C | i, ii, iii, iv |
| Major Assessments | | | | |
| Written Abstract | 14 | 2 | A, C | i, ii, iii, iv |
| Research Poster | 20 | 2 | A, C | i, ii, iii, iv |
| Oral Presentation | 20 | 1, 2, 3 | A, C | i, ii, iii, iv |
| Intern Expectations | 10 | 2, 3 | A, C | i, ii |
| NAS-identified URE Goals | | | | |
| 1. increase participation and retention of STEM students | | | | |
| 2. promote STEM disciplinary knowledge and practices | | | | |
| 3. integrate students into STEM culture | | | | |
| CS-URE Objectives | | | | |
| The course will create an opportunity for students to: | | | | |
| A. apply the scientific method to the study of the local natural hazard of stream flooding and the societal impacts of flooding in a heavily urbanized area of central Texas. | | | | |
| B. work with scientific tools, techniques, and publicly-available scientific data sets. | | | | |
| C. communicate scientific results. | | | | |
| D. explore academic, professional, and public opportunities for scientific research in geosciences and related fields. | | | | |
| CS-URE Student Learning Outcomes | | | | |
| Upon completion of this course, the student will be able to: | | | | |
| i. Apply the steps of the scientific method to a research question, including gathering relevant data to test a hypothesis. | | | | |
| ii. Analyze, interpret, and form conclusions based on relevant data. | | | | |
| iii. Summarize the scientific study and communicate results in a written abstract and poster presentation. | | | | |
| iv. Use the scientific method to better understand a local environmental issue or natural hazard and explain how the research project results might be relevant to society. | | | | |

techniques, collect and interpret data, and communicate scientific results). In order to promote STEM disciplinary knowledge and practices, this course-based CS-URE incorporates field and lab exercises and a research project focused on the local impacts of flooding. A third NAS-identified goal of UREs is to integrate students into STEM culture (i.e., by developing a STEM identity, instilling ownership in a STEM project, performing collaborative STEM work, developing a sense of belonging or inclusion in the STEM community, and overcoming STEM stereotypes). The inclusive and mentored nature of this CS-URE seeks to integrate non-science and science majors at a 2YC into STEM culture by providing an authentic, student-directed, faculty-supported, small-group research experience. Course learning activities (ungraded mentoring opportunities and graded assessments) are aligned to these three general URE goals, CS-URE-specific objectives, and student learning outcomes (Table 1).

Methods

Recruitment

For each offering of the CS-URE, a small number of students applied for and were selected to participate in the CS-URE. Applications for the CS-URE were solicited by announcements posted on campus and distributed online by department faculty. The program was advertised widely to the

social science, business, arts, and science departments. To be considered for the CS-URE, applicants submitted an online form, a statement of interest, and a letter of recommendation from a professor or employer. Among the selection criteria were: 1) current enrollment at the 2YC, 2) completion of at least 1 semester of college-level course work, 3) a 2.5 minimum GPA, 4) a strong letter of recommendation, 5) a high level of interest expressed in the personal statement, and 6) a high likelihood to benefit from participation in the CS-URE. Applicants having previous URE experience and applicants holding college degrees were not excluded from consideration. For the first 2 years of the CS-URE, 25 students were accepted from 53 applications. At least one-third of the applications and accepted students were from non-STEM students (i.e., fashion and psychology). Over half of the applicants were enrolled in one of the Department of Earth and Environmental Sciences' (the host department) courses. For the third year, 8 students applied; all students were accepted; 7 students (all students currently taking a course offering from the host department) enrolled in the CS-URE.

All participants received a grant-funded stipend and the first two cohorts of students additionally received grant-funded tuition reimbursement. The first two years, students were provided a \$2,200 stipend and tuition reimbursement to participate in the CS-URE. In the third offering of the CS-URE, stipend funds were limited. Initially students were initially offered a \$550 stipend to participate in the course;

however, additional funds became available to increase the total student stipend in Spring 2024 to \$1,550.

Study population and setting

The CS-URE was developed as an introductory-level, 3-credit hour elective geology course to provide an opportunity for undergraduate students attending an urban 2YC in central Texas to participate in locally-relevant geosciences research. This 2YC has a large and diverse student population with an undergraduate, credit-seeking student enrollment of almost 40,000 students across 11 campuses (OIRA, 2024a). At this 2YC, 61% of the instructors are adjunct faculty (OIRA, 2024a). Notably, with grant-funding, the CS-URE was developed, instructed, and administered by part-time adjunct and temporarily-appointed full-time faculty. Over the three course offerings, a total of 32 students participated in the CS-URE (11 students in Summer 2022, 14 students in Spring 2023, and 7 students in Spring 2024). Participating students represented both science and non-science majors concurrently enrolled at the 2YC. Demographic data for the population of CS-URE participants and the host 2YC (OIRA, 2025) are provided in Table 2. Similar to the host 2YC student population with an average age of 24, CS-URE participants (from all cohorts) had an average of 25 years old. About one third (34%) of CS-URE participants were classified as having full-time enrollment status compared to 27% of students at the host 2YC. The CS-URE student population included fewer non-white students (34%) and more female students (69%) than the host 2YC student population (64% non-white and 57% female). While family and employment data is not available, several CS-URE participants self-identified as parents and many held positions of employment while participating in the course.

Materials and implementation

Course structure

The course was offered as a co-taught, 3-credit, condensed-term course. The initial course was offered as a 5-week Summer-term course with two full-day, weekly, in-person class meetings. To better accommodate working, full-time students, allow for longer-duration field and lab experiences during in-person class meetings, and time field activities to more favorable weather and stream flow conditions, the course was subsequently offered in the second eight-week Spring semester, with eight weekly 6-h Friday class meetings as well as weekly to

bi-weekly online, evening class meetings used for guest speaker presentations, communicating course logistics, and students' sharing project updates and receiving instructor feedback.

Instructional resources

Through lectures, readings, and videos, students were introduced to the local ecology, climate, geology, hydrology, and flood hazard. These instructional resources also introduced students to local surface water and groundwater resources, climate change projections, the concepts of tipping points and stakeholders, and citizen science initiatives.

Field and lab exercises

In the first half of the course, students participated in field activities led by the two course instructors to a nearby stream to become familiar with the natural and urban stream environment, identify community stakeholders in the issue of stream flooding, and observe evidence of historical flood events and mitigation measures taken by the local government in response to these events (i.e., flood control, erosion control, and water filtration features). These field activities and associated graded field exercises not only served as an introduction to the local environment and flood hazard, but also provided context for research projects and opportunities to practice scientific research skills and methods (i.e., creating field notebook entries, following field safety protocols, and site sketching) and employ available research tools (i.e., stream flow and water quality monitoring tools).

To provide scientific background and introduce non-science majors to geoscience techniques and hydrologic data, students completed lab exercises, which included activities like interpreting geologic and topographic maps, delineating a watershed, interpreting hydrographs to estimate the magnitude and frequency of flood events, measuring stream velocity and channel depth and using this information to calculate discharge, and performing and interpreting water quality analyses. Exercises also guided students to interact with online sources of flood-related data (i.e., LCRA Hydromet, USGS Water Data, EJScreen, and FloodPro).

Research projects

In the first quarter of the course (first 2 weeks in an 8-week course), students were introduced to the local flooding problem, as well as tools and skills to better understand the problem. By the end of the first quarter of the course,

Table 2. Population data for CS-URE participants and Host 2YC.

Student demographics data are provided for individual cohorts and combined cohorts of CS-URE participants (Summer 2022, Spring 2023, and Spring 2024) and the student body of the host 2YC. CS-URE population information is from OIRA (2025). Host 2YC demographic information is from the district-wide, credit-seeking undergraduate student profile for Fall 2024 (OIRA, 2024a). Small counts of 1–4 students have been masked (*) to protect student privacy. Percent of non-white students is based on students' unduplicated race/ethnicity selections. Full-time enrollment is defined as taking 12 or more credit hours in a semester.

| Student population | CS-URE Participants (Combined Average) | CS-URE Participants (U22 Cohort) | CS-URE Participants (S23 Cohort) | CS-URE Participants (S24 Cohort) | Host 2YC Students (F24) |
|--------------------------|---|-------------------------------------|-------------------------------------|-------------------------------------|----------------------------|
| Full-Time Enrollment (%) | 34 | 0 | 57 | 43 | 27 |
| Average Age (Years) | 25 | 24 | 24 | 27 | 24 |
| Non-White (%) | 34 | * | * | * | 64 |
| Female (%) | 69 | * | 57 | * | 57 |
| Number of Students (#) | 32 | 11 | 14 | 7 | 39,727 |

students began the process of the scientific method by collectively formulating a research question, based on their interests and curiosities, about the impacts of flooding to the environment and/or community. Then, each group outlined a research plan that included: asking a research question and stating a testable hypothesis, developing a method for testing the hypothesis, and planning necessary field and lab data collection activities and materials. Approximately half-way through the course (week 4 in an 8-week course), students began collecting data for their research projects. As students proceeded through their research, reformulation of group hypotheses were required after initial analyses of collected data in accordance with the steps of the scientific method. Groups shared weekly project status updates and gathered feedback from classmates in other groups in class discussions and/or in online discussion board forums. In each course, research was conducted by 2 to 4 different groups, with 3 to 4 students in each group. Research project topics are provided in [Table 3](#).

Toward the end of the class, (weeks 6 to 7 in an 8-week course), students composed individual abstracts, which were used as a basis for collaboratively writing a group abstract that efficiently and effectively communicated the group's research project. In the last quarter of the course (weeks 7 and 8 of an 8-week course), each group created, practiced, and presented a poster summarizing their research projects. On the last day of the course, students shared their research with students and faculty from multiple college departments and received informal feedback and encouragement at an end-of-course poster presentation session. The abbreviated course syllabus provided in [Supplemental Materials A](#) outlines the timeline, structure, and assessment details of the course and serves as an example for the development of similar courses.

Mentoring opportunities

An important aspect of the CS-URE was the informal undergraduate mentoring provided by course instructors, who were serving as adjunct faculty at the 2YC. These instructors played a crucial role in guiding student research project development, supporting field and lab data collection, and offering constructive feedback on research deliverables. Additionally, other adjunct faculty supported students

in the CS-URE by administering stipends, providing course materials, reviewing poster drafts, and offering encouragement during practice presentations and the final oral poster session. Students had the opportunity to hear presentations from and participate in small-group conversations with geoscience researchers and professionals. While guest speakers varied between course offerings, they included climate researchers at a local 4YC, hydrologists and geologists monitoring surface water and groundwater at federal agencies, state agency hydrologists involved in water resources management, an adjunct professor at the host 2YC using Geographic Information System (GIS) tools for data analysis, a karst professional from a local environmental consulting firm assessing the environmental impacts of dam construction, a non-scientist former President of the local Audubon Society involved in citizen science birding events, and a former alumnus of the 2YC and current director of a regional office of the USGS Water Science Center. The formal presentations and informal discussions with these professional geoscientists and citizen scientists allowed for advising conversations about academic and career trajectories. After the initial course offering, some former participants in the CS-URE were invited to be peer-mentors to the next cohort of students, presenting their research projects and sharing their experiences during and since the CS-URE.

Evaluation methods

Overall design and strategy

As part of meeting the broader program goals of UREs, each learning activity was aligned to course-specific (yet adaptable to future course offerings) course objectives and student learning outcomes ([Table 1](#)). The evaluation of meeting the CS-URE goals, course objectives, and student learning outcomes was based on the following course metrics: 1) student pre-course and post-course surveys, 2) individual reflections on the internship experience, 3) student assessment results, and 4) institutional data on student success outcomes. In compliance with ethical standards for research subjects, all students completed an IRB form consenting to use of aggregated data as a prerequisite for participating in the course; student data are presented in summary form, without personally-identifiable information.

Data sources

Pre-course and post-course surveys

To assess changes in STEM confidence, interest, and engagement, as well as changes in the perceived value of mentoring, students were given pre-course and post-course surveys. Pre-and post-course survey questions asked students to rate their level of confidence in scientific and mathematical skills and their level of interest in pursuing a STEM major or STEM career. Students were also asked to rate the likelihood that they would engage with science-related news reports and stories. Students were asked to share their experiences with faculty mentoring and rate the value of those mentoring experiences to their

Table 3. Student group research project topics.

Student group research project topics for each cohort are listed by research poster title.

Summer 2022

Assessing the Relationship Between Household and Flood Risk Awareness at Shoal Creek and Walnut Creek

How Do Rainfall and Flooding Events Impact Barton Creek Water Quality?

Investigating the Intersection of Race, Income, and Flood Risk in Austin, Texas

Spring 2023

The Relationship Between Impervious Cover and Flood Risk in Austin, Texas

Financial Impact of Austin Flooding between Socioeconomic Groups

The Connection Between Income Level and Water Quality

Impacts of Impervious Cover on Macroinvertebrate Biodiversity and Water Quality

Spring 2024

Investigating the Relationship between Streamflow and Water Quality

Investigating the Effect of Bioswales on Water Quality and Flooding in Shoal Creek Watershed, Austin, TX

academic success. The pre-and post-course survey instrument, including instructions, questions, and response options is provided in [Supplemental Materials B](#). Pre-course and post-course survey questions were developed in accordance with best practices as laid out by Champagne (2014) in order to minimize any biases. The questions were designed to be unambiguous, were reviewed by an academic dean with expertise in assessment who was not involved in teaching the course to ensure that they had no implicit biases, and did not promote a particular answer. Survey instructions stated that the survey was for the purpose of gathering information and educational insights. Students were also informed that, although completion of the surveys was required as part of their course grade, survey responses would not impact their grade. To encourage participation in the pre- and post-surveys, after the initial course offering, a survey completion grade was added as a minor component (8-10%) of the course grade ([Supplemental Materials A](#)). All students completed both surveys and answered nearly every question.

Responses to pre-and post-course multiple choice-format survey questions are reported as frequency of responses and percentage of valid responses for all three cohorts (Summer 2022, Spring 2023, and Spring 2024 courses). To highlight the variation in the responses, the researchers followed the methodology used by Mann and Wang (2019). A Likert Scale value (1 to 3) was assigned to each students' pre-course survey response and post-course survey response. The difference between the Likert Scale values of valid, and therefore, comparable post-course and pre-course survey responses for each student represent a Likert Shift. Student responses (and analyses of those responses) to close-ended questions on the pre- and post-course surveys are provided in [Supplemental Materials C](#) (confidence-related responses), [D](#) (interest-related responses), [E](#) (engagement-related responses), and [F](#) (mentoring-related responses).

We hypothesize that the course will have a beneficial effect on students and this will be evidenced by a positive Likert Shift between pre- and post-course survey responses. For each close-ended survey question, a paired right-tailed t-test was performed on the pre- and post-course Likert Scale ratings to determine the statistical significance ($\alpha=0.05$) of directional changes between the pre-course and post-course responses. Additionally, the Cohen's d value (effect size) was calculated to determine the relative size of that change. We used standard thresholds for small, medium, and large effect sizes (0.2, 0.5, and 0.8, respectively). Statistical analysis was performed using a free, online statistics calculator (Statistics Kingdom, 2017). This method of statistical analysis was chosen because: 1) each student's pre- and post-course survey responses represent paired, dependent data, 2) the survey responses represent the entire population of responses, which makes the distribution of the responses less relevant, 3) we assume participation in the URE will increase the Likert Scale ratings between pre-and post-course surveys, and 4) because an alternative Wilcoxon signed-rank test for paired, ordinal, non-parametric data is less reliable for determining the statistical significance of changes between paired

responses when there are many paired responses that show no change (Ford, 2023).

Individual reflections on the internship experience

To further evaluate the effect of the CS-URE, at the end of the course, each student was asked to reflect on the internship experience by responding to open-ended post-course survey questions and a series of questions in the internship reflection. All students (100%) responded to all or some of the open-ended post-course survey and internship reflection questions. Responses from open-ended post-course survey and internship reflection questions were reviewed by two course faculty, who by concurrence, identified emergent themes in the responses, categorized each response according to theme, and quantified the percentage of responses addressing each theme. Responses from open-ended post-course survey questions are provided and identified by theme in [Supplemental Materials G](#). Responses from open-ended internship reflection questions are provided and identified by theme in [Supplemental Materials H](#).

Student evaluations by instructor assessments

While students' pre-and post-course survey and internship reflection responses provide valuable information, it is useful to triangulate this information using students' performance that directly measure their achievement of the learning outcomes. The faculty scored each student's performance on these learning outcomes through embedded assessments. The internship expectation assessment, research project written abstract, research poster, and oral presentation represented summative measures of the CS-URE learning outcomes ([Table 1](#)) and were evaluated using rubrics that specify multiple levels of achievement for one or more criteria. Although there were some minor course-to-course variations in the assessment details, the assessment expectations and rubrics were similar. Examples of each of the major assessments (abstracts, posters, presentations, and level of meeting internship expectations) and their grading rubrics are provided in [Supplemental Materials I](#).

Institutional data

Institutional data on student demographics, enrollment, persistence, and transfers were obtained from the 2YC's Office of Institutional Research and Analytics (OIRA, 2025). These data were used to determine the longer-term post-course impacts on participating students' academic success and compare these outcomes to the outcomes of the larger student population at the institution hosting the CS-URE (the host 2YC).

Validity and reliability of evaluation data

Due to the potential bias introduced in student assessments and self-reported survey results, several provisions were taken to minimize concerns about the reliability and validity of the evaluation data. For example, student performance was evaluated by the co-instructors both grading the students' work and

agreeing on an appropriate score for major course assessments. To increase the reliability of each evaluation measure employed, changes in pre-course and post-course survey data were interpreted along with open-ended responses to survey and internship reflection questions, grade performance data, and institutional data on student success. We recognize that the small numbers of students participating in the surveys (maximum $N=32$) may impact the statistical analysis of the responses. Additionally, institutional data on the success outcomes of the 2YC student body includes data for students with a wide variety of goals. Therefore, the survey data and institutional data on success outcomes are best regarded as being qualitative in nature, but the broader conclusions about the value and impact of a program are valid.

Results

Student confidence

Results from scientific confidence-related questions on the student pre-course and post-course surveys are presented in Table 4 and Figure 1. In general, student confidence in science-related activities increased over the CS-URE. Analysis of pre-course and post-course survey responses show a statistically-significant and large increase in students' confidence in their ability to explain the scientific method to another person, $t(31)=7.2$, $p<.001$, Cohen's $d=1.3$). At the end of the CS-URE, 63% of students reported an increase (Likert Shift >0) in their confidence in explaining the scientific method. The percentage of students that responded as "very confident" in their ability to explain the scientific method increased from 31% of pre-course survey responses to 94% of post-course survey responses. There was also a statistically-significant and large increase in students' confidence in their ability to formulate a research question that could be answered by the collection of data, $t(31)=7.3$, $p<.001$, Cohen's $d=1.3$). Seventy-five percent of students reported an increase in their confidence in formulating a research question that could be answered by the collection of data. The percentage of students that responded as "very confident" in their ability to formulate a research question increased from 22% (pre-course) to 88% (post-course). There was a statistically-significant and medium increase in student's confidence in their ability to work with numerical data, $t(30)=4.1$, $p<.001$, Cohen's $d=0.7$). The percentage of students that responded as "very confident" in their ability to work with numerical data increased from 31% (pre-course) to 77% (post-course). Over half (58%) of students reported an increase in their confidence in working with numerical data as indicated by a positive Likert Shift between pre- and post-course survey responses (Table 4, Figure 1). Only 38% of students reported an increase in their confidence in giving an oral presentation, which represents a small, statistically-significant increase in confidence $t(20)=2.1$, $p=.025$, Cohen's $d=0.46$).

The low percentages of Negative (-1) Likert Shifts between pre- and post-course survey responses for science confidence-related questions (A-D) indicate that only a small percentage (0-10%) of students expressed a decrease in confidence in science-related skills from the start to end of the

course. Notably, no students expressed a decrease in confidence in their ability to explain the scientific method, and only one student expressed a decrease in confidence in their ability to formulate a research question (Table 4).

STEM interest

Results from STEM interest-related questions on the student pre-course and post-course surveys are presented in Table 5 and Figure 1. Pre- and post-course survey results show that student's involvement in the research course produced little change in students' interest in environmental science, geology, and STEM fields in general. At the end of the CS-URE, only 13% of students reported an increase in their interest in taking more environmental science or geology classes. This is not a statistically-significant increase, $t(31)=1.4$, $p=.09$, Cohen's $d=0.2$). Only 9.4% of students reported an increase in their interest in declaring a major in environmental science or geology; this is a small, but statistically-significant increase in interest, $t(31)=1.8$, $p=.04$, Cohen's $d=0.3$). Only 13% of students reported an increase in their interest in pursuing a career in environmental science or geology, which is not a statistically-significant increase, $t(31)=1.4$, $p=.08$, Cohen's $d=0.3$). Only 9.7% of students reported an increase in their interest in pursuing a career in any field of science, mathematics, or engineering, which is not a statistically-significant increase in interest, $t(30)=0.33$, $p=.37$, Cohen's $d=0.06$). The vast majority of student responses show no change between pre- and post-course survey responses, a 0 Likert Shift, for questions related to STEM interest, including: 1) interest in taking more environmental science or geology classes (84% of responses unchanged), 2) interest in declaring a major in environmental science or geology (91% responses unchanged), 3) interest in pursuing a career in environmental science or geology (84% responses unchanged), and 4) interest in pursuing a career in any science, math, or engineering field (81% responses unchanged).

Science news and article engagement

As an indicator of science engagement, students were asked in pre- and post-course surveys to characterize the likelihood that they might read or look closely at a science news or journal article, and at the end of the course, attribute a change in their likelihood of engaging with the article to participation in the CS-URE. Results from these science article engagement-related questions are presented in Table 6. Pre- and post-course survey results show little change in students' likelihood to engage with science news or articles. At the end of the CS-URE, only 24% of students reported an increased likelihood of engaging with a science news story or article; this is not a statistically significant increase in engagement, $t(20)=1.1$, $p=.13$, Cohen's $d=0.3$). Approximately 77% of students reported no change in their likelihood of engaging in a science-related article. Excluding the responses of the two students that reported a decrease in likelihood of engagement in science news between the beginning and end

Table 4. Confidence question results. Combined data (Summer 2022, Spring 2023, and Spring 2024 cohorts) for pre-course student survey and post-course student survey responses to scientific confidence-related questions A-D. Survey results are presented as frequency of valid responses (#), percent of total valid responses (%), and change in valid responses between the pre-course survey and the post-course survey ("shift on Likert Scale"). Notes on survey questions and response options are provided in Supplemental Materials B. Student responses and analyses for questions A-D are provided in Supplemental Materials C.

| Responses | A. How confident are you in being able to explain the scientific method to another person? | | B. How confident are you in your ability to formulate a research question that could be answered by the collection of data? | | C. How confident are you in working with numerical data, for example, in determining the potential amount of error in a measurement, or using the data to calculate some other number? | | D. How confident are you in making an oral presentation? | |
|------------------------------|--|-------------------|---|-------------------|--|----------------------------|--|-------------------|
| | Pre-Course # (%) | Post-Course # (%) | Pre-Course # (%) | Post-Course # (%) | Pre-Course # (%) | Post-Course # (%) | Pre-Course # (%) | Post-Course # (%) |
| Very confident | 10 (31) | 30 (94) | 7 (22) | 28 (88) | 10 (31) | 24 (77) | 7 (33) | 11 (52) |
| Fairly confident | 22 (69) | 2 (6.3) | 21 (66) | 4 (13) | 16 (50) | 7 (23) | 11 (52) | 10 (48) |
| Not at all confident | 0 (0.0) | 0 (0.0) | 4 (13) | 0 (0.0) | 6 (19) | 0 (0.0) | 3 (14) | 0 (0) |
| Shift on Likert Scale | # (%) | # (%) | # (%) | # (%) | # (%) | # (%) | # (%) | # (%) |
| -1 | 0 (0.0) | 1 (3.1) | -1 | 1 (3.1) | 3 (10) | -1 | 2 (9.5) | |
| 0 | 12 (38) | 7 (22) | 0 | 7 (22) | 10 (33) | 0 | 11 (52) | |
| 1 | 20 (63) | 22 (69) | 1 | 22 (69) | 13 (42) | 1 | 7 (33) | |
| 2 | 0 (0.0) | 2 (6.3) | 2 | 2 (6.3) | 5 (16) | 2 | 1 (4.8) | |
| > 0 (Increased Confidence) | 20 (63) | 24 (75) | > 0 (Increased Confidence) | 24 (75) | 18 (58) | > 0 (Increased Confidence) | 8 (38) | |

of the course, a majority of students (63%) attributed a change in interest in science-related news or articles to participation in the CS-URE course (Table 6).

Value of mentoring

Results from the mentoring question on the student pre-course and post-course surveys are presented in Table 7. Analysis of pre-course and post-course survey responses show a statistically-significant increase in the value students' place on mentoring (defined as individualized faculty-student guidance) to their academic success. Pre-course surveys indicate that at the start of the course, 44% of students assigned high importance to the role of faculty mentoring to their general academic success. At the end of the course, 78% of students assigned high importance to the role of faculty mentoring to their success in the CS-URE course (Table 7), which is a statistically significant, medium increase in the students' view of the importance of academic mentoring, $t(31)=4, p<.001$, Cohen's $d=0.7$). By the end of the course, the percentage of students that reported having no helpful mentoring experiences decreased from 22% to 0% (Table 7). Of all survey questions, responses to the value of mentoring question showed the greatest increase between pre-course and post-course surveys, with 38% of responses corresponding to a positive Likert Shift, including 19% of responses that corresponded to the highest possible (+2) Likert Shift (Table 7).

Responses to the open-ended post-course survey question about mentoring are consistent with students' placing high-value on individualized instructor guidance to their academic success in the CS-URE. For example 49% of student responses to the post-course survey's open-ended mentoring question, attribute value to the research project guidance and feedback provided by the course instructors and supporting faculty (Table 8). Appreciation of the resources, information, and tools provided by the course faculty was another common response (mentioned in 16% of the responses to the open-ended mentoring question). Students also valued the course instructors' efforts to create a supportive and/or positive learning environment (mentioned in 16% of the responses to the open-ended mentoring question).

Learning outcomes

Instructor evaluation of major student assessments provide evidence for successful student achievement of the course's student learning outcomes and support students' attainment of STEM knowledge and skills. Scores for the four major student assessments are provided in Table 9. Scores ranged from 85 to 100%, including the scores for the internship expectations ($M=98.1\%$, $SD=3.4$), abstract ($M=94.6\%$, $SD=4.9$), poster ($M=97.0\%$, $SD=5.0$), and oral presentation ($M=95.3\%$, $SD=5.3$). All students (100%) attained "acceptable" to "excellent" levels of achievement on the four major course assessments, including the internship expectations assessment, and the research project abstract, poster, and oral presentation (Table 9). In fact, a majority of the

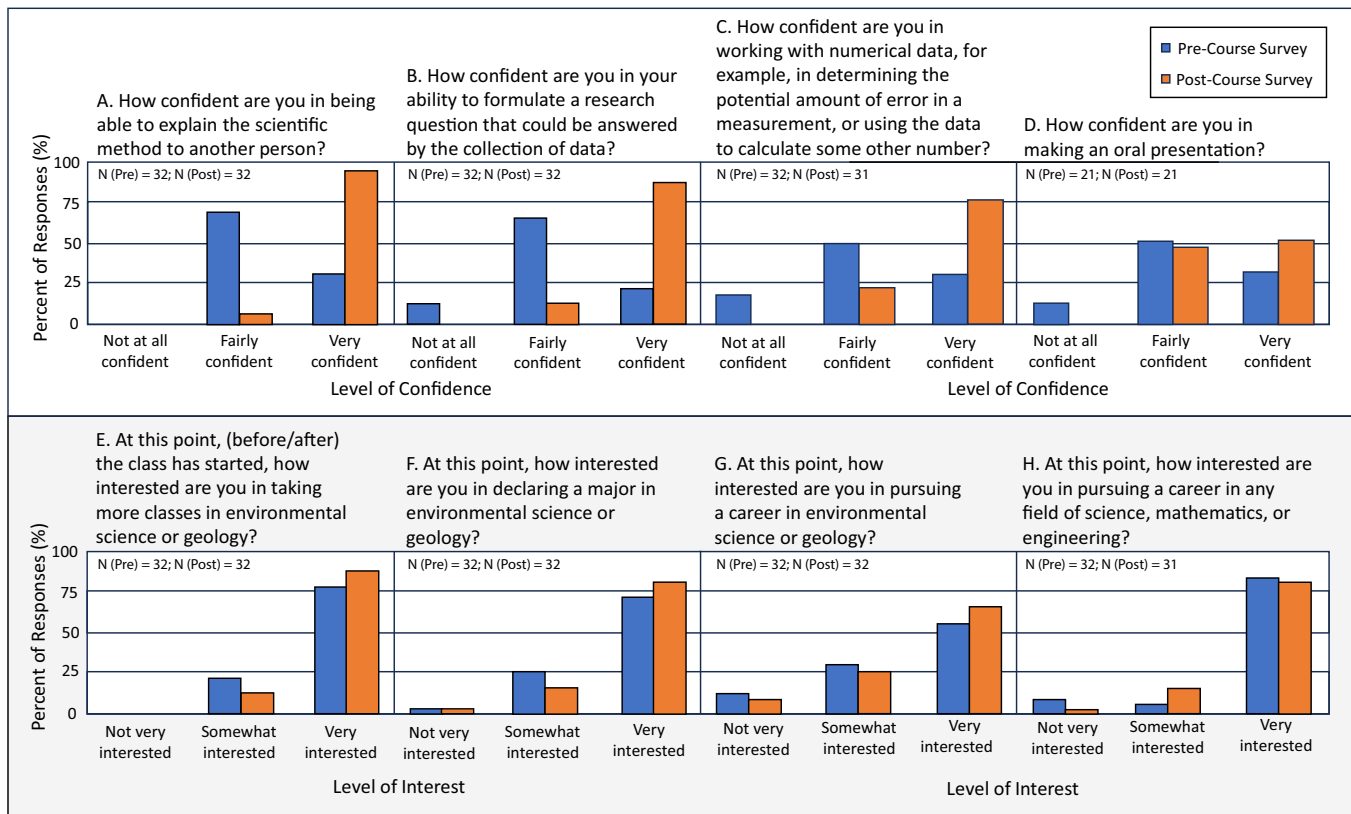


Figure 1. Combined data (Summer 2022, Spring 2023, and Spring 2024 cohorts) for pre-course and post-course survey responses to scientific method confidence questions A-D (Table 4) and to STEM academic and professional interest questions E-G (Table 5). For question E, data represents only valid and comparable survey responses. Percentage of responses are compared for the pre-course (blue) and post-course (orange) surveys. Number of valid responses for pre-course and post-course surveys responses for each question are provided as (N=pre-course, post-course).

students (69%) met an excellent level of achievement for the internship expectations and poster assessments, and almost half (47%) of the students met an excellent level of achievement for the oral presentation assessment (Table 9).

Persistence, transfer and graduation rates

Institutional data for several measures of student academic success outcomes are reported in Table 10. In general, it appears that participating in the CS-URE is associated with a varied degree of improvement to academic success outcomes. The combined CS-URE participants' average persistence rate (to the next full term) is 59%, which is about the same as the 2YC's average Fall-to-Fall persistence rate (56%). However, the average transfer rate of CS-URE participants is 50%, which is 20% higher than the 2YC's average 3-year transfer rate (30%). The average graduation rate for the combined cohorts of the CS-URE (through Fall 2024) is 34%, which is 11% higher than the 2YC's average 3-year graduation rate (23%).

Course feedback

Themes that emerged from end-of-course student internship reflection responses are provided in Table 11 with detailed

responses in Supplemental Materials H. In general, students had positive comments about the course learning activities, but recommended improvements to the structure of the course. When asked about what worked well in the course, the top two response themes were: participating in field and/or lab activities (mentioned in 22% of responses) and interacting with guest lectures, and/or course instructors and supporting faculty (mentioned in 21% of responses). When asked about what did not work well in the course, the two most frequent themes were the condensed-term course format that made it challenging to complete their research projects within the time constraints of the course (mentioned in 61% of responses), and a broad course focus and/or unclear purpose of course activities (mentioned in 19% of responses).

Student CS-URE reflections also indicate that some students would prefer that the course focus on the research experience (as opposed to other learning activities). In response to the solicitation for constructive feedback, 32% of responses (the most frequent response theme) recommend that the course could be improved by allocating a greater percentage of the course and/or more class time for the research projects. The second most frequent recommendation was to narrow the course focus, improve the structure of the course, and/or more clearly communicate expectations (mentioned in 20% of responses).

Table 6. Science engagement question results.

Combined data (Summer 2022, Spring 2023, and Spring 2024 cohorts) are post-course student survey responses to likelihood of engagement with science news or article questions I and J. Survey results are presented as frequency of responses (#) and percent of total responses (%). Responses to question J exclude the two students who indicated a decrease in likelihood of engagement between the pre- and post-course surveys in question I. Student responses and analyses for science news engagement questions I-J are provided in [Supplemental Materials E](#).

| Responses | Pre-Course | | Post-Course | |
|--|--------------|---------|---|-------------------|
| | # (%) | # (%) | Responses | Post-Course # (%) |
| Very likely | 13 (62) | 15 (71) | Yes | 19 (63) |
| Somewhat likely | 7 (33) | 6 (29) | It is about the same as before taking this course | 11 (37) |
| Not at all likely | 1 (4.8) | 0 (0.0) | No | 0 (3.1) |
| Shift on Likert Scale | # (%) | | | |
| -1 | 2 (9.5) | | | |
| 0 | 14 (67) | | | |
| 1 | 5 (24) | | | |
| 2 | 0 (0.0) | | | |
| > 0 (Increased Likelihood of Engagement) | 5 (24) | | | |

Table 7. Mentoring question results.

Combined data (Summer 2022, Spring 2023, and Spring 2024 cohorts) are pre-course and post-course student survey responses to mentoring experience question K. Survey results are presented as frequency of responses (#), percent of total responses (%), and change in responses between the pre-course survey and the post-course survey ("Shift on Likert Scale"). Notes on the survey question and response options are provided in [Supplemental Materials B](#). Student responses and analyses for question K are provided in [Supplemental Materials F](#).

K. How important do you feel that faculty mentoring (defined as one-to-one guidance by a faculty member) has been to your academic success thus far/ in this course?

| Responses | Pre-Course # (%) | Post-Course # (%) |
|---|------------------|-------------------|
| It has helped me a great deal. | 14 (44) | 25 (78) |
| It has helped me to some degree. | 11 (34) | 7 (22) |
| It has not helped me very much or at all. | 7 (22) | 0 (0.0) |
| Shift on Likert Scale | # (%) | |
| -1 | 0 (0.0) | |
| 0 | 20 (63) | |
| 1 | 6 (19) | |
| 2 | 6 (19) | |
| > 0 (Increased Value of Mentoring) | 12 (38) | |

(Table 10). Although not necessarily causal, the higher persistence, transfer, and graduation rates for CS-URE participants compared to the host 2YC average are consistent with the CS-URE having a positive effect on student academic success. This supports other studies which have correlated early-undergraduate participation in research to improved academic outcomes. For example, Kelly et al. (2024) found that participation in UREs at 2YCs has been shown to increase student interest in transferring to a 4YC. Gamage et al. (2022) found high rates of transfer and pursuit of STEM degrees among participants in a collaborative 2YC-4YC summer research experience. Rodenbusch et al. (2016) found early-undergraduate CUREs to be associated with a greater likelihood for graduating in 6 years and earning a STEM degree. More specific survey questions, long-term success tracking, and better control of compared student populations would help to determine the extent of the influence of participating in the CS-URE (versus other factors like the student's level of motivation, degree progress,

and long-term academic goals) on outcomes like persistence, transferring to a 4YC, graduation, and STEM retention.

STEM knowledge and practices

Another goal of the CS-URE was to promote STEM disciplinary knowledge and practices by providing an intense and authentic research experience (as in a traditional URE) that is both course-based and place-based. In the context of conducting a collaborative scientific research project on the relevant and local issue of flooding, the CS-URE participants were exposed to STEM concepts (like the scientific method) and practiced STEM skills including formulating research questions, collection and interpretation of numerical data, and the communication of scientific results in technical abstracts, posters, and presentations. High assessment scores for the graded CS-URE learning activities are consistent with students gaining STEM knowledge and skills (Table 9). Another indicator of the CS-URE's success in promoting STEM disciplinary knowledge and practices is the increase in students' confidence in their ability to explain the scientific method, formulate a research question, and work with numerical data (Table 4). Similar gains in science-related skills and confidence in these skills were observed in the SUREC 2YC-4YC collaborative research program (Gamage et al., 2022). Open-ended post-course survey question responses further corroborate the effectiveness of this CS-URE in promoting STEM disciplinary knowledge and practices. When asked to comment on any aspect of the CS-URE, the most frequent response theme (mentioned in 38% of responses, Table 8) recognizes that the CS-URE provided students with valuable experience in field work, work as a science professional, and/or scientific research.

Integration into STEM culture

A third goal of this CS-URE was to integrate 2YC students into STEM culture. The inclusive citizen-science style approach of this CS-URE invited non-science and science majors to participate in a student-directed, faculty-supported research project that instilled ownership in a collaborative

Table 8. Post-course survey response themes. Responses to open-ended post-course survey questions are categorized into emergent themes and responses for each theme are quantified. The number of responses and percentage of total responses that mention each theme are provided. Numbers of responses for each theme are: benefits of mentoring (N=49), recommendations for improvement (N=49), recommendations for improvement (N=11), and benefits of course participation (N=21). Detailed student responses to open-ended post-course survey questions are available in [Supplemental Materials G](#).

| Emergent Themes: Benefits of Mentoring | # Responses: Benefits of Mentoring Theme (%) | Emergent Themes: Recommendations for Improvement | # Responses: Recommendations for Improvement Theme (%) | Emergent Themes: Benefits of Course Participation | # Responses: Benefits of Course Participation Theme (%) |
|--|--|--|--|---|---|
| Provided Research Project Guidance and Feedback | 24 (49) | Recommend a Less-Condensed and/or Longer Course Format | 4 (36) | Provided Valuable Field, Professional, and/or Research Experience | 8 (38) |
| Provided Helpful Information, Tools, and/or Resources | 8 (16) | Recommend Spending More Time on Research Projects | 2 (18) | Provided a Positive Learning Community Experience | 5 (24) |
| Created a Welcoming, Encouraging, Supportive, and/or Positive Learning Environment | 8 (16) | Recommend Increasing Oral Presentation Experiences and Presentation Guidance | 1 (9.1) | Provided Opportunity to Learn About and/or Be Engaged with the Local Community's Environment, Hydrology, Flooding Processes, and/or Flood Impacts | 3 (14) |
| Facilitated Making Professional and/or Academic Connections, and/or Provided Exposure to and/or Experience in Scientific Research, Science-Related Careers, and/or Academic Pathways | 3 (6.1) | Recommend Adding a Prerequisite Science Course | 1 (9.1) | Improved Communication Skills and/or Provided Experience in Professional Communication | 2 (9.5) |
| Promoted Student Confidence | 3 (6.1) | Recommend Allowing Greater Flexibility in Research Topics | 1 (9.1) | Provided a Self-directed Learning Experience | 1 (4.8) |
| Improved Learning Experience | 2 (4.1) | Recommend Participants Follow-up with Next Cohort of Participants | 1 (9.1) | Promoted Student Confidence | 1 (4.8) |
| Helped Navigate Group Dynamics | 1 (2.0) | Recommend Bringing in a Statistics and/or Data Analysis Mentor | 1 (9.1) | Improved Ability to Work in Teams and/or Provided a Positive and/or Valuable Group-Work Experience | 1 (4.8) |

STEM project. Increased engagement with science-related news could be interpreted as increased integration in STEM culture. However, students in the CS-URE did not report a significant increase in their likelihood to engage with science related news (Table 6). In opposition to this result, we interpret the increases in confidence in performing STEM-related activities (Table 4) to show increased science identity and science self-efficacy, which are part of integration into STEM culture. This is similar to outcomes of the SUREC program, which built science identity and self-efficacy in its participants (Gamage et al., 2022). These mixed results highlight the need to more clearly assess student integration into STEM culture in future UREs.

Mentoring in the CS-URE

The measured increase in student's STEM confidence could, in part, be due to the mentoring opportunities afforded by the various URE elements that were blended into this CS-URE (i.e., the enrollment-limited small class size of a URE that allowed for instructors and supporting faculty to serve as not only facilitators, but also as mentors in the research project, and the place-based and course-based aspects of the URE that afforded the opportunity for students to engage during class time with local field professionals and discipline experts both within and outside the 2YC through formal presentations and more informal mentoring conversations). Most students had a positive mentoring experience in the course as evidenced by the large increase in positive responses (and largest positive Likert Shifts) between pre-course and post-course survey questions related to mentoring experiences (Table 7). Responses to an open-ended post-course survey question about the helpfulness of mentoring, suggest that students valued the role of faculty in providing research project guidance and feedback (mentioned in 49% of responses, Table 8). This positive student feedback on their experience with mentoring in the CS-URE is in agreement with the conclusion of Houser et al. (2013) that faculty-student relationships are one of the most influential factors to the success of UREs. The intentional incorporation of mentoring in this course-based CS-URE could have contributed to the large increases in confidence that were reported by the students. We maintain that these results demonstrate the value of providing mentoring opportunities in course-based and/or place-based research experiences offered to 2YC students.

Structure and sustainability

Over the three offerings of this course, the course was offered with variations in the term, term length, campus location, modality, amount of stipend, and participating mentors, which demonstrates the adaptability of course. The course structure, assessments, and evaluation methods could be adapted by other faculty in the same department, in other science disciplines, or at another 2YC or 4YC to provide science and non-science majors an opportunity to

participate in scientific research addressing an issue relevant to the local community.

While the CS-URE was successful, student experiences can be improved by making changes to the structure of the course. The condensed course time frame and hybrid format of the course permitted a combination of classroom, field, and lab activities, as well as online opportunities for students to share informal project updates, instructors to provide small group feedback, and communication of background and logistic information to efficiently utilize in-person class meetings for field, lab, and mentoring activities. Although a condensed course time frame has lower opportunity cost to students (i.e., fewer weeks of disruption to students' work and/or family obligations), internship reflection responses (Table 11) suggest that many students found the condensed time frame challenging; 61% of responses mention the research project time constraints as something that did not work well in the course and 32% of responses recommend allocating more of the class time for research projects. This course was designed to provide a student-directed research experience, which enables students (working in a small group) to observe and explore their own curiosities and interests and to develop their own research questions and hypotheses. While this exercise has intellectual value and can contribute to a sense of ownership

of the research project, students had less time to attempt to test their hypothesis and answer the research question. Therefore, we recommend, as is common in CUREs (NAS, 2017), that instructors provide more upfront guidance in defining the research questions and hypotheses to be tested. Instructor-provided, focused research questions would help students spend less time defining and limiting the scope of their projects. This would allow instructors to more intentionally provide instruction in tools, methods, and background information necessary to answer specific research questions and more time for students to test their hypotheses and evaluate their results.

Alternatively, the challenge of a condensed course could be addressed by offering the CS-URE as a two- consecutive-term course, with the first term allocated to background instruction and more formal mentoring experiences (i.e., guest speaker presentations) and the second term devoted to informal mentoring experiences (i.e., project development consultations with faculty), research project implementation, completion, and presentation.

Funding for faculty mentors, particularly, for adjunct faculty and students, can limit the course offering and involvement of students in UREs at 2YCs. As observed in this CS-URE, adjunct faculty at 2YCs can play a pivotal role in promoting undergraduate research. Providing robust

Table 9. Assessment scores. Combined assessment scores for major learning activities (Summer 2022, Spring 2023, and Spring 2024 cohorts; N=32). Major examples of each major assessment are available in [Supplemental Materials I](#).

| | Scores for Major Course Assessments | | | |
|---|-------------------------------------|--------------|------------|-----------------------|
| | Internship Expectations (%) | Abstract (%) | Poster (%) | Oral Presentation (%) |
| Average Grade for All Cohorts (%) | 98.1 | 94.6 | 97.0 | 95.3 |
| Grade Range (Minimum %, Maximum %) | 85, 100 | 85, 100 | 85, 100 | 85, 100 |
| Standard Deviation | 3.4 | 4.9 | 5.0 | 5.3 |
| Number of Students with "Excellent" Rubric Scores (All Expectations Met; 100%) | 22 | 11 | 22 | 15 |
| Number of Students with "Acceptable" Rubric Scores (Most Expectations Met: 80% to <100%) | 10 | 21 | 10 | 17 |
| Percentage of Students with "Excellent" Rubric Scores (All Expectations Met; 100%) | 69 | 34 | 69 | 47 |
| Percentage of Students with "Acceptable" Rubric Scores (Most Expectations Met: 80% to <100%) | 31 | 66 | 31 | 53 |
| Percentage of Students with "Excellent" to "Acceptable" Rubric Scores (All to Most Expectations Met; ≥ 80%) | 100 | 100 | 100 | 100 |

Table 10. Academic success data for CS-URE participants and host 2YC.

Student success data are provided for individual and combined cohorts of CS-URE participants, including: Summer 2022, Spring 2023, and Spring 2024 (OIRA, 2025). CS-URE student success data include: 1) the persistence rate, which represents students that persist in enrollment at the college through the next long term (Fall or Spring), 2) the transfer rate, which represents students that transferred to a 4YC (through Fall 2024), and 3) the graduation rate, which represents students that graduated by the end of Fall 2024; Spring 2024 graduation data remain incomplete until Fall 2025 grades are submitted in December 2025.

| % of Population | CS-URE Participants (Combined) | CS-URE Participants (U22 Cohort) | CS-URE Participants (S23 Cohort) | CS-URE Participants (S24 Cohort) | Host 2YC Students ¹ | Difference Between Host 2YC and CS-URE Participants (All Cohorts) |
|----------------------|--------------------------------|----------------------------------|----------------------------------|----------------------------------|--------------------------------|---|
| Persistence Rate (%) | 59 | 45 | 71 | 57 | 56 | +3 |
| Transfer Rate (%) | 50 | 55 | 64 | 14 | 30 | +20 |
| Graduation Rate (%) | 34 | 27 | 50 | 14 | 23 | +11 |

¹Host 2YC student success data include: 1) Fall-to-Fall persistence rate for Fall 2023 full-time and part-time credit-seeking students), 2) three-year transfer (to another 2-year or 4-year institution) rate for the most recent completed cohort (Fall 2021) of full-time and part-time, first-time-in college students, and 3) three-year graduation rate (graduation is defined as earning an associate or bachelor degree, or a certificate from ACC or another Texas institution of higher education within 3 years) for the most recent completed cohort (Fall 2021) of full-time, first-time in college students (OIRA, 2024b).

Table 11. Internship reflection response themes. Responses to open-ended internship reflection questions are grouped according to response themes and quantified.

| Emergent Themes: What Worked Well | # Responses for "What Worked Well" Theme (%) |
|--|--|
| Field and/or Lab Activities | 16 (22) |
| Guest Lectures, Mentors, and/or Instructors | 15 (21) |
| Course Materials, Lectures, Resources, and/or Tools | 13 (18) |
| Condensed Time Frame | 11 (15) |
| Hybrid Format and/or Format | 10 (14) |
| Campus Location | 4 (5.6) |
| Geology and Hydrology Course Topic | 1 (1.4) |
| Group Work on Research Project | 1 (1.4) |
| Student-directed Research Projects | 1 (1.4) |
| Total Responses | 72 (100) |
| Emergent Themes: What Did NOT Work | # Responses for "What Did NOT Work" Theme (%) |
| Timing of Research Project and/or Course Time Constraints | 19 (61) |
| Course Focus is Too Broad and/or Purpose of Course Activities is Unclear | 6 (19) |
| Guest Lecture Format and/or Associated Learning Activities | 3 (9.7) |
| Unclear Communication of Due Dates | 1 (3.2) |
| Narrow Course Focus | 1 (3.2) |
| Campus Location | 1 (3.2) |
| Total Number of Responses | 31 (100) |
| Emergent Themes: Constructive Criticism | # Responses for "Constructive Criticism" Theme (%) |
| Allocate a Greater Percentage of the Course and/or More Class Time for Research Projects | 13 (32) |
| Narrow Course Focus, Improve Course Organization/Structure, and/or More Clearly Communicate Expectations | 8 (20) |
| Offer as a Less-Condensed and/or Longer Course | 5 (12) |
| Change Timing, Format, and/or Frequency of Guest Speakers | 4 (9.8) |
| Provide a Repository of Research Resources and/or Past Projects | 3 (7.3) |
| Add More Discussion of Tipping Points into Course | 1 (2.4) |
| Later Poster Deadline | 1 (2.4) |
| Improve Coordination of Administration and Course Participants | 1 (2.4) |
| Incorporate Longer Breaks into Class Time | 1 (2.4) |
| Help Mediate Challenging Group Dynamics | 1 (2.4) |
| Recommend Bringing in a Statistics and/or Data Analysis Mentor | 1 (2.4) |
| Change the Campus Location | 1 (2.4) |
| No Grading on Minor Exercises/Assignments | 1 (2.4) |
| Total Number of Responses | 41 (100) |
| Emergent Themes: Would You Recommend the Course? | # Recommendation Responses (%) |
| Yes, I Would Recommend the Course to Others and/or Recommend Continuing to Offer the Course | 31 (100) |
| Total Number of Responses | 31 (100) |

institutional support for adjuncts - such as access to research funding, professional development, and inclusion in academic networks - can empower them to lead and mentor students in research initiatives. This support not only enhances the adjuncts' ability to engage and mentor students in meaningful research experiences, but also enriches the educational opportunities available at the institution, ultimately contributing to the academic growth and success of both students and the 2YC.

While grant-funded stipends and tuition reimbursement financially enabled many students to participate in this elective science credit CS-URE course, future offerings of a similar research experience will not have the same support and, therefore, would be less likely to recruit the same quantity of committed and qualified students. To encourage non-stipend student participation in an undergraduate research course, we recommend that the course be included as an elective, science credit-fulfilling course option for geoscience and related discipline degree plans. This will require strong departmental and college-level support for inclusion of undergraduate research courses in the 2YC curriculum, consistent funding for URE instructors and guest lectures, and transfer credit coordination with 4YC institutions in the region.

Limitations

This CS-URE is a new, single-section, elective course developed at a 2YC that is relatively new to involving students in research. The novelty of the course limits the comparisons that can be made between CS-URE participants and non-CS-URE students. Integrating this research experience into an existing course with multiple section offerings will enable comparison of success of students taking the same course that participated or did not participate in the CS-URE. An important limitation of this study is that the data represents a student population that demonstrated preexisting interest in scientific inquiry, academic aptitude, and/or interest in professional and educational advancement by application and acceptance to the CS-URE program. Additionally, the small sample size, lack of a control group, short time period between administration of the pre- and post- course surveys, and student biases potentially inherent in self-reported survey responses, limit the certainty of the conclusions we draw from the pre- and post-course survey data.

To more meaningfully assess long-term interest and retention, we recommend repeating the post-course survey at 1-year, 2-year, and 5-year post-participation intervals to track student scientific interest and engagement, academic achievements, and professional trajectories. Although the

objectivity of the instructors' assessments of students' research products and meeting internship expectations was strengthened by the use of grading rubrics, assessments scores are likely higher than non-URE courses due to the immersive nature of the course and interactive feedback on assessed deliverables. Institutional data for transfer and persistence rates at 2YCs is also challenging to interpret due to the varied goals and short-term tenure of 2YC students. Furthermore, the narrow scope of institutional data available for comparison limits the conclusions of long-term student success.

Implications

The three-year implementation of the short-term "Citizen Science" research-oriented course, which engaged 32 2YC students, including non-science majors, in a research-focused curriculum has demonstrated significant progress in achieving key goals related to increasing students' STEM participation, STEM skills, and integration into STEM culture. The CS-URE produced measurable gains in scientific skills and disciplinary knowledge and increased student confidence in STEM activities. Positive mentoring experiences likely contributed to these outcomes, as indicated by student's feedback on - and elevated perception of - the value of mentoring to their research experience. The evaluation of the success of the CS-URE offers important insights into effective strategies for undergraduate research experiences.

Despite these successes, the study identified areas for improvement. The condensed course format, while efficient, limited the time available for in-depth data collection and analysis. Student feedback suggested that more time for project development and hypothesis testing would enhance the research experience. Additionally, while the course's collaborative and curiosity-driven approach was valued, clearer guidance on research questions and hypotheses might better support student learning and project execution.

Future iterations of the course should consider extending the time frame, with a two-term structure to allow for comprehensive instruction, research development, and project implementation. Securing consistent funding for faculty mentors, particularly for adjuncts and integrating the course into the 2YC curriculum as an elective science credit option will be crucial for sustaining and expanding these research opportunities. Long-term tracking of student outcomes is also recommended to more accurately assess the enduring impacts of the course on academic and professional outcomes.

Overall, the course has proven to be a valuable tool to increase STEM participation and increase STEM skills among 2YC students. As opportunities to participate in hands-on, relevant scientific research are extended to more 2YC students, we can expect to see, as in this CS-URE, an increase in student confidence in STEM skills. Increased confidence in STEM skills will then contribute to increased integration into STEM culture. With increased skills, confidence, and integration into STEM culture, 2YC students may be more likely to engage with citizen science

opportunities in their communities and support science-based policies and programs. Therefore, we recommend the continued development and refinement of citizen science-style student research experiences to promote appreciation for the role that science plays in understanding and addressing local issues and encourage life-long public participation in scientific data collection in their local communities.

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