Literature Review

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Course-based Undergraduate Research Experience, which are often referred to as CUREs, are a new innovative tool being increasingly adopted by institutions to enhance undergraduate research training and engagement. CUREs integrate authentic research experience in undergraduate classes, which “have the potential to exert a greater influence on students’ academic and career paths than research internships that occur late in an undergraduate’s academic program” (Auchincloss et al., 2014). CUREs are an extremely powerful tool which brings students together, practicing all parts of the scientific research process: “[...] asking questions, building and evaluating models, proposing hypotheses, designing studies, selecting methods, using the tools of science, gathering and analyzing data, identifying meaningful variation, navigating the messiness of real world data, developing and critiquing interpretations and arguments, and communicating findings.” (Auchincloss et al., 2014). However, while CUREs are being adopted into more and more courses, the integration of Bioinformatics and computational data analysis CUREs remain limited (Yang and Korsnack, 2024). This strongly limits the range of scientific research students can benefit from, and therefore creates a gap in modern data-driven scientific techniques.

Course-based Undergraduate Research Experience, or CUREs, are a demonstrated successful strategy to increase undergraduate research participation (Sweat et al., 2025): “[...] students have a clearer idea of what it meant to think like a scientist, they felt as though they had acquired these skills as a result of taking this course.” (Brownell et al., 2015). These skills, such as the thought process of a scientist, are important to have for many professions and degrees, as they help students develop problem-solving abilities and analytical thinking. CUREs also contribute to long-term career skills, as they provide students with real-world research experience that not only increases their scientific research skills, which creates a mindset, but also collaboration, and critical thinking—skills that are essential in both industry and academia (Auchincloss et al., 2014). CUREs have shown that it benefits students even in short length classes: "[...students] they appreciated learning new skills, they liked doing a project that was hypothesis-driven, they were able to carry the project out from inception to completion, and they themselves generated the experimental design and hypothesis." (Sweat et al., 2025), and is even often preferred over lab work only (Sweat et al., 2025). CUREs also benefit inclusivity in STEM by being accessible to underrepresented students: Hispanics, African Americans, and Native Americans are often underrepresented in STEM, even more in the availability of CURE opportunities (Bangera and Brownell, 2014). Despite the proven benefits of CUREs, their full potential and strength remain sparse, especially in fields like Bioinformatics and computational sciences. Many institutions face problems when it comes to resources, training, and seamless integrations in their courses, which can limit the availability of CURE initiatives.

Despite their benefits, CUREs are not as broadly available as they could be due to varying factors, from financial support to limitations in space and faculty (DeChenne-Peters and Scheuermann, 2022). Without proper funding, proper equipment, faculty training, or even with lack of faculty or resources, CUREs are too challenging to implement and successfully run to benefit everyone. These challenges are reflected through the faculty experience, where a recurring concern is often "time constraints, lack of professional development, and the need for additional institutional support" as barriers to successfully integrating CUREs into their classes and laboratories (Mills et al., 2021). From a student perspective, transitioning from regular laboratories to full scientific research can be overwhelming, especially for those with little to no prior experience, as scientific research is often related to more difficult materials, which requires a higher level of knowledge, or require skills and "cognitive complexity" that students might not have (Zhu et al., 2024). For students, this often decreases motivation, which then hinders the successes of undergraduate scientific research opportunities. (Brownell et al., 2015). A survey of students in research-based biology courses found that many "felt unprepared for the level of independent thinking and troubleshooting required", leading some to disengage from the learning process (Fey et al., 2020). While CUREs come with strong benefits, the problems it brings to institutions can't be overlooked, which highlights the need for accessible programs for students.

A call to evaluate the impacts of CUREs on student groups from community colleges and underrepresented areas in STEM suggests the need for custom, engaging and accessible interactive tools that address their learning objectives and constraints (Leonetti et al., 2021). Implementing effective, interactive data-analysis tools relies on how well faculty are trained to use, troubleshoot, and teach the tools, so that students are able to reliably, and accurately use and analyze the data provided from the software. It is extremely important for any tool to provide students with real, collaborative scientific research, which are critical for faculty sustained success (Sedlacek et al., 2022). Reviews of CUREs shows that many courses only partially teach and involve students with the full scientific research process, especially when it comes to independent data analysis (Buchanan and Fisher, 2022). Many students in introductory CUREs struggle with large, "messy" datasets and the uncertainty coming from real-world data (Zhu et al., 2024), and the transition from structured labs to open-ended analysis is often overwhelming, which requires structured guidance (Brownell et al., 2015). A successful software filling this gap would guide students through understanding where the data comes from, how the data is being processed, what the output means and how to work with it —all steps that help them practice scientific reasoning and analytical thinking. National recommendations on undergraduate research experiences points out the importance of authentic inquiry and iterative feedback loops, which are facilitated by modern data analysis tools (Gentile et al., 2017). In environmental variables studies, this translates to testing, visualizing, and revising hypotheses about pond ecosystems.

Course-Based Undergraduate Research Experiences (CUREs) have appeared as a powerful tool for increasing undergraduate engagement in authentic scientific research. Research has shown that CUREs enhance students' scientific thinking, analytical skills and research confidence, often providing a more accessible pathway into

STEM careers than traditional lab-based coursework (Auchincloss et al., 2014; Sweat et al., 2025). While CUREs have proven benefits, challenges in implementing them, from financial limits to faculty training, have limited their full potential, especially in computational and data-driven research fields such as Bioinformatics and environmental sciences (Mills et al., 2021; DeChenne-Peters and Scheuermann, 2022). Interactive data-analysis tools have the potential to revolutionize how students interact with research data by providing an simple, structured tool for hypothesis testing, data visualization, and statistical analysis (Buchanan and Fisher, 2022). In conclusion, interactive data-analysis tools show great value for advancing the effectiveness of CUREs, especially in environmental sciences and Bioinformatics. As CUREs evolve throughout the years, developing interactive, user-friendly data tools will be essential in making undergraduate research more inclusive, engaging, and impactful.

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