Course-Based Undergraduate Research Experiences (CUREs) are increasingly used to engage undergraduate engagement in scientific research experiences. While CUREs improve students' scientific reasoning, collaboration, and critical thinking, their integration with Bioinformatics and computational data analysis remains limited. This research work aims at bridging that gap by developing *Beetlejuice eDNA Web*, an interactive web-based data-analysis tool tailored for environmental biology CUREs. The tool is built using Next.js and TypeScript and processes environmental DNA (eDNA) datasets using data validation, correlation analysis, and interactive visualization with Plotly. By providing a dynamic, adaptive tool, *Beetlejuice eDNA Web* simplifies and provides a structured approach for eDNA datasets analysis. The study also assesses the tool's usability and its impact on students' research accuracy and engagement. Development results have shown that the tool takes 0.49s to First Contentful Paint, 136ms for Interaction to Next Paint and 2ms for First Input Delay. The tool scored 100% on Vercel's Speed Insight and 100% on Lighthouse. Pilot testing of the tool has shown that [insert student/faculty experience here].

Course-based Undergraduate Research Experience, which are often referred to as CUREs, are an increasingly adopted innovative tool in courses and departments to enhance undergraduate research training and engagement. CUREs are an extremely powerful tool which brings students together, practicing all parts of the scientific research process, and they are a demonstrated successful strategy to increase undergraduate research participation (Sweat et al., 2025). 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 enhances scientific reasoning, but also collaboration, and critical thinking—skills that are essential in both industry and academia (Auchincloss et al., 2014). 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), and the integration of Bioinformatics and computational data analysis CUREs remain limited (Yang and Korsnack, 2024). A survey of students in CURE-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 have proven benefits, their integration with bioinformatics and computational data analysis remains underdeveloped, limiting students' exposure to data-driven methodologies (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). Therefore, it is important to study how an interactive environmental data analysis tool can be developed to help students analyze environmental datasets in CUREs. This paper discusses the development and usability of such data analysis tool, and predicts the impact it might have on CURE based scientific classes.

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.

The overall strategy to work on the research question is to develop a tool tailored towards CURE initiatives for Biology students, and study the impact such tool has on the performance of students and the accuracy of their research project. "Beetlejuice eDNA Web", which will be referred to as Beetlejuice eDNA, is the tool created for the purpose of this research. It is built on NextJS 14.x, which is React-based framework, and written with TypeScript for type safety. The application was designed to run in modern web browsers (Chrome 120+, Firefox 120+, Safari 17+) and operates mostly client-side to ensure data privacy. Only plots are calculated server side, as it is a requirement for the plotting library used. The program used for development is called Visual Studio Code, which provides the user with tools to accelerate development and help secure the codebase against common attacks. Beetlejuice eDNA uses a variety of React libraries to help facilitate programming of redundant or complicated tasks: "@types/plotly.js": "2.35.2" (for plots and graphs), "lucide-react": "0.475.0" (for icons), "next": "15.1.7" (the base framework), "next-themes": "0.4.4" (for day-night theme support), "plotly.js-dist-min": "3.0.1" (for plots and graphs), "react": "19.0.0" (the underlying framework NextJS is built on), "react-dom": "19.0.0" (a React dependency), "xlsx": "0.18.5" (for reading Excel documents). The data is processed locally in a specific order: first, the data is checked (data validation, data structure integrity check and missing value detection). Then, the data is analyzed through one of three modes: "Template" (where the excel file must follow a strict format), "Template + auto" (where the excel file must follow a strict format, and extra data is automatically detected), and "Full Auto" (where data is automatically parsed from the Excel file regardless of its format). Then, the data is analyzed: Pearson correlation coefficients are calculated between environmental factors and diversity indices, inter-environmental factor relationships and inter-diversity index relationships. The most important part, however, is the data visualization, which is done using Plotly. The graphs are interactive, and for each point, show information about the sample plotted. Graphs also show statistical information such as mean, median, range and Std Dev. Lastly, a Correlation Matrix gives an overall insight of the data using a heat map visualization, color-coded correlation strengths (-1 to +1) and interactive tooltips for precise value display.

The development of an interactive, eDNA web-app analysis tool shows that it is feasible and effective to develop a tool adapted to Course-based Undergraduate Research Experiences (CUREs) students and initiatives. Through the integration of modern frameworks, services and libraries, the website performs well across a wide range of devices, with the tool scoring 0.49s to First Contentful Paint ("When the browser renders the first bit of content from the DOM, providing the first feedback to the user that the page is actually loading" (Vercel, nd)), 136ms for Interaction to Next Paint ("a metric that measures the time from when a user interacts with your site to the time the browser renders the next frame in response to that interaction." (Vercel, nd)) and 2ms for First Input Delay ("measures the time from when a user first interacts with your site (by selecting a link for example) to the time when the browser is able to respond to that interaction" (Vercel, nd)). The tool scored 100% on Vercel's Speed Insight ("@vercel/speed-insights automatically tracks web vitals and other performance metrics for your website", (Vercel, nd)) and 100% on Lighthouse ("Lighthouse is an open-source, automated tool to help you improve the quality of web pages. It has audits for performance, accessibility, progressive web apps, SEO, and more." (Chrome Developers, nd)). While the tool provides with strong performance, it also emphasizes usability and accessibility to support a wide range of student users. Beetlejuice eDNA's interface was designed to be intuitive, minimizing sensory overload and navigation issues through clear navigation, minimalistic layout, and guided interaction flows. The tool follows responsive design principles, which ensures functionality across different devices and screen sizes, including tablets and smartphones frequently used by students. Furthermore, accessibility considerations were integrated into the development process, such as implementing keyboard navigation, and semantic HTML structure. These performance results align with and support the literature, which has been emphasizing the need for accessible, intuitive tools in Course-based Undergraduate Research Experiences (CUREs), especially in fields such as bioinformatics and data-driven environmental science. Many CURE implementations lack complete engagement with the full scientific research process, especially independent data analysis (Buchanan and Fisher, 2022). Students often struggle with "messy" real-world datasets and require structured, interactive tools to develop scientific reasoning (Zhu et al., 2024). Beetlejuice eDNA delivers in fulfilling those gaps with a responsive, user-friendly experience, demonstrating that web-based tools and apps can lower barriers to scientific literacy while supporting students' engagement with authentic scientific research. These findings aligns with the need for inclusive, scalable educational resources that serve student populations in underrepresented settings (Bangera and Brownell, 2014; Leonetti et al., 2021). While the preliminary testing of the tool shows that Beetlejuice eDNA has strengths in performance and usability, several limitations must be acknowledged. First, the application was developed and tested in a single institution, primarily among students in that institution, which restricts generalization. This severely limits analyzing how diverse learners interact with the tool, and limits true user experience from the lack formal usability testing or large-scale student feedback. Secondly, Beetlejuice eDNA's tool-set is limited to exploratory data analysis, and it does not yet support advanced statistical modeling, hypothesis testing workflows, or automated formative feedback, all of which can be limiting factors in accessibility of full-scale scientific inquiry. Finally, the tool lacks full support of accessibility guidelines of web-development, which remains a future priority for inclusive design.

Future research should focus on evaluating the tool's impact on student learning outcomes, especially in data literacy, scientific reasoning, and confidence in working with authentic datasets. Further research should also look into exploring the development of similar tools for other scientific disciplines, such as microbiology or genomics, which benefit new types of CURE initiatives.

In conclusion, the development of a high-performing, accessible eDNA analysis tool demonstrates the viability of implementing interactive, data-driven platforms for CUREs initiatives to enhance student engagement and scientific research experiences. The tool's successful development addresses key issues shared in the literature, including the need for authentic research experiences, ease of navigating through complex data, and inclusive educational practices. By bridging those gaps, this study contributes to the bigger picture and advocates for the need of a broader integration of bioinformatics and environmental data analysis in CURE initiatives. It opens a new, promising path in creating tools for those experiences.

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