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Article

Project-Based Learning in Interdisciplinary Spaces: A Case Study in Norway and the United States

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Abstract: The research described in this case study features a cohort of five exchange students from post-secondary institutions in Norway and the United States who collaboratively engaged in a project-based learning experience infused with aspects of place-based education, lesson study, and the pedagogical technique "students as partners". The students were tasked with crafting an interdisciplinary lesson combining mathematics and environmental science to address a localized problem in the Southeastern United States. This study reflects on how the students participated in project-based learning as well as the instructional practices that supported student engagement. Students identified an increase in understanding of interdisciplinary and multicultural Science, Technology, Engineering, and Mathematics (STEM) education, a broader understanding of instructional practices, and exposure to educational research. Data were collected throughout the study using a variety of techniques, including discussion posts, collaborative documents, and reflections to gauge student experience and project progress. The results provide evidence to support the use of project-based learning in postsecondary STEM classrooms and emphasize the benefits of engaging students in curriculum development.

Keywords: project-based learning; lesson study; students as partners; curriculum development; interdisciplinary STEM; cultural exchange; higher education

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1. Introduction

The traditional model of education, with the instructor as the sole source of knowledge, has been challenged by calls for more student-centered, real-world learning experiences [1,2]. Project-based learning, combined with place-based education, offers a promising approach to meet this need by empowering students to actively engage in the creation of meaningful, contextually relevant curricula [3–8]. This case study examines a unique project-based learning course in which post-secondary STEM exchange students from Norway and the United States collaborated to develop and implement an interdisciplinary lesson integrating mathematics and environmental science. The course, designed for both undergraduate and graduate students, fostered an environment of co-creation, where students became "lesson architects", driving the curriculum development process [9]. This approach not only equipped students with practical skills but also deepened their understanding of interdisciplinary STEM education, cultural exchange, and instructional practices [8–10]. This study explores how the integration of project-based learning, place-based education, lesson study, and the "students as partners" pedagogy created a transformative learning experience [2,7,9].

By examining the students' engagement as decision-makers, the instructional supports and barriers encountered, and the impact on their conceptual understanding of interdisciplinary STEM education, this research provides valuable insights into fostering inclusive, student-led project-based learning environments in higher education STEM classrooms. The findings shed light on the potential of project-based learning to empower students, enhance their understanding of STEM concepts, and promote their development as future educators and researchers. As such, this study seeks to answer the following research questions focusing on the engagement, implementation, and conceptual impact of the lesson architects' experience:

1. Student Engagement: How did exchange students actively participate as partners in the project-based learning process to create an interdisciplinary STEM lesson integrating mathematics and environmental science concepts?
2. Implementation: What were the key instructional barriers and supports encountered when implementing a project-based interdisciplinary STEM lesson where students were involved as co-creators?
3. Conceptual Impact: How did participation in the project-based lesson development process influence exchange students' understanding of interdisciplinary STEM education and its practical applications?

2. Conceptual Framing and Background

This study uses the tenets of project-based learning to engage a group of undergraduate and graduate students in a student-led lesson study. This study melds the world of project-based learning with lesson study [3–6,11,12] and serves as a novel adaptation of the two concepts where students and instructors act as partners in curriculum development [9]. We frame the entire study as a project-based learning experience that leverages and infuses (1) place-based education, (2) lesson study, and (3) students as partners in curriculum development (see Figure 1).

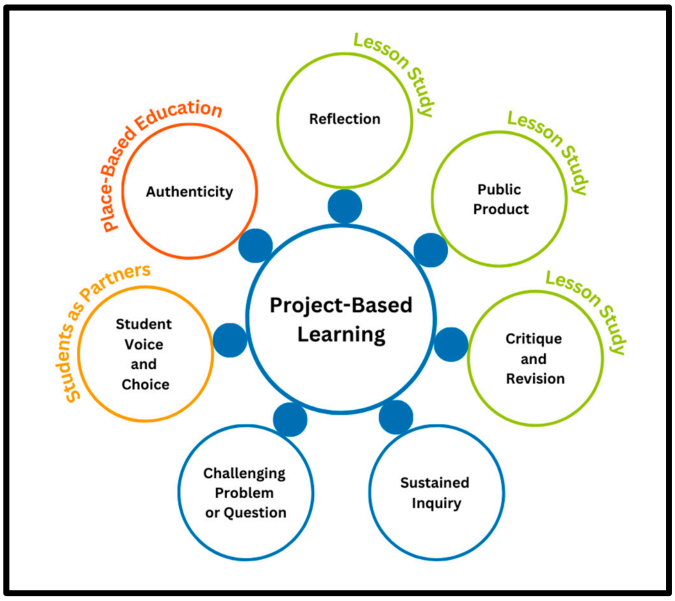

Figure 1. Adapted conceptual framework from the Buck Institute for Education's [3] design elements infused with aspects of place-based education, lesson study, and students as partners in curriculum development.

2.1. Project-Based Learning: Design Elements

Project-based learning has been implemented in a variety of forms and contains a multitude of different design principles, yet there is no consensus on a standard set of principles that make project-based learning successful [6]. We aligned our study with the framework of "gold standard" design elements from Ref. [3] adapted from Ref. [13]'s depiction of exemplary design practices to create a project-based learning classroom. These design elements include (1) a challenging problem or question, (2) sustained inquiry, (3) authenticity, (4) student voice and choice, (5) reflection, (6) critique and revision, and (7) public product [3]. Each design principle contributes to implementing a thoughtfully crafted project that students can engage in for an extended period. A common thread in project-based learning includes providing students with a challenging, complex problem or question that is open-ended and serves as a starting point for student thinking [3,5,14]. While project-based tasks need to maintain student inquiry for an extended period of time, they also require an iterative process of investigative inquiry to solve a challenging problem or answer a challenging question [3]. By incorporating these seven design elements, instructors develop strong project-based learning environments that engage students in a larger scale, self-sustained task that can promote creativity and independence [15].

2.2. Connection to Place-Based Education

Study [14] suggests that in addition to being complex, the problem or question students are provided should also be realistic or, as Ref. [3] claims, authentic. Article [13] defines authenticity as (1) featuring real-world context, including (2) the ability to make a real impact and (3) the potential to connect to students' lives. Thus, a requirement for the students was to design a lesson that included a place-based aspect. Place-based education is influenced by Freire's beliefs in developing critical consciousness and Dewey's emphasis on learner-centered, socially collaborative approaches to foster real-world learning experiences [2,16,17]. Through place-based learning, students are taught the curriculum through the lens of their local community and are encouraged to develop their own solutions to identified problems. Emphasizing the importance of physical space and surrounding environment in education allows for a better understanding of culture, social atmospheres, and community engagement and resilience [7]. With an overlap of living and learning concepts, students are often able to see beyond the content of a classroom and can apply the curriculum to a larger picture, fostering the students' ability to expand their realm of knowledge on an independent level [7].

2.3. Infusion of Lesson Study

The students addressed an educational problem by creating a lesson study, an iterative Japanese teaching technique where a group of educators plan a lesson on a specific instructor-generated vision of a pedagogical practice [11]. By engaging in a lesson study, the students were naturally able to incorporate reflection, critiques, and revisions into their projects. A key feature of lesson study includes recording the implementation via observational protocols as a way to gather data for reflection during the debrief of the observed lesson [11]. The research in [12] references similar features of a successful lesson study while describing an iterative process of revising and re-teaching the lesson. The re-taught lesson would also be observed and debriefed on, which leads to the last step of sharing results with communities of educators, a public product [9]. The cyclical nature of a lesson study produced numerous opportunities to reflect, critique, and revise the lesson throughout the process, all key elements of project-based learning.

2.4. Engaging Students as Partners in Curriculum Development

The intent of incorporating student voice and choice into project-based learning is to hear differing perspectives from students and embrace students incorporating outside knowledge into their solutions [3]. Encouraging students to make decisions for themselves and be "producers of knowledge" pushes students to think critically about a problem and develop a solution on their own [14]. Due to prevailing beliefs of instructor-led curricula, students are rarely engaged in a course where they guide the decision-making process and learning outcomes of the course. However, student–instructor co-creation of the curriculum is increasing in popularity due to its active nature and collaboration between students and instructors [9]. By positioning students as experts in curriculum creation, student–

instructor co-creation has the potential to produce a transformative experience for students and instructors, as well as empower students to elevate their unique knowledge, skills, and perspectives [18].

2.5. Project-Based Learning: Teaching Practices

Project-based learning teaching practices were developed to support the project-based learning design elements [4,19]. The intent of having specific teaching practices is to provide educators with the tools to adjust from traditional teaching methods to project-based learning teaching methods, which focus on supporting students' curiosity [4]. The teaching practices identified in [19] include (1) design and plan, (2) align to standards, (3) build the culture, (4) manage activities, (5) scaffold student learning, (6) assess student learning, and (7) engage and coach [4]. The research in [20] found similar practices identified by instructors actively practicing project-based learning.

A successful project-based learning course is supported by both the design elements and teaching practices defined by the authors of [3,4]. In conjunction with these practices, educators must develop a project that is aligned with standards, includes a challenging prompt, has a clear timeline for completion, and incorporates formative and summative assessments [4,20]. Educators need to ensure students are organized and on schedule by actively managing their activities or providing concrete project management tools students are responsible for to scaffold student learning [4,20]. Similar to scaffolding student learning, instructors need to engage and coach students to identify when they need assistance or praise to support student growth [4]. Yet, without the collective commitment of the course, the designing, planning, managing, and scaffolding, the course will not be successful. Students need to be exposed to a classroom culture that fosters independence, self-management, and individual exploration with clear expectations of student work [4,20]. Each teaching practice contributes to ensuring students are receiving a rich learning experience that addresses more than the aligned standards.

3. Methods

3.1. Data Context

The data analyzed for this study originates from a larger project focused on cultural exchange between two universities (note these university names are used in place of the true names of the universities to protect the identities of the participants): one in Norway and the other in the United States. The larger exchange program was funded by an Anonymized Funding Source and had a lifespan of three academic years. The exchange program started in the Fall of 2023 with three Norwegian students spending the Fall Semester at Isunigu University, Southeastern United States (the Cherokee town of Isunigu was flooded in the 20th century by the creation of Lake Hartwell in South Carolina, resulting in the loss of artifacts and the history of the place, Isunigu), and continued into the Spring of 2024 with two American students spending the Spring Semester at the University of Egðir, Norway (an Old Norse word from the Viking Age that describes the people of the Southern region of Norway). As a focus of the exchange, the students engaged in this project-based interdisciplinary STEM course. Due to the participants' success and autonomy in developing the lesson, the term *lesson architects* was used to distinguish them from the students in the class where the lesson was implemented. The term lesson architects aimed to capture the co-construction of knowledge that was instrumental in the finished lesson.

3.2. Course Description

The course encouraged the lesson architects to think in terms of interdisciplinary STEM disciplines while attending to place-based problems within the localized context of Isunigu University. The unique nature of the course included students as co-creators to explore a variety of STEM topics, with the learning objectives centered around interdisciplinary STEM education. The course aimed for students to meet the following learning objectives through the creation of an interdisciplinary STEM lesson and engagement in a lesson study: (1) demonstrate critical thinking through the design and analysis of an integrated STEM education place-based lesson study to address a global challenge; (2) evaluate how varying perspectives influence the outreach and communication with communities impacted by a global challenge; (3) identify the contextual factors (regional, national, global, and ethnic) that impact how an integrated STEM education place-based research project can be implemented in a localized context; (4) define and provide examples of integrated STEM research, education, and outreach. The lesson architects were tasked with developing an interdisciplinary STEM lesson that included mathematics and environmental science, focused on a challenge within the localized context of the Southeastern United States, and had the potential to be scaled to a globalized context. Students were required to implement the lesson in either a classroom or an alternative setting.

The course leaned on the disciplinary and cultural backgrounds of the lesson architects and instructors to construct the interdisciplinary place-based STEM lesson to implement in a water sustainability course. Additional time was dedicated to learning about STEM education research methods and creating data collection tools that assess the success of the lesson. By the end of the semester, the lesson architects created and implemented an interactive environmental science and mathematics lesson set in the localized context of the Savannah River Watershed, South Carolina, United States, and within the international context of Norway.

3.3. Participants

Five students from two universities, Isunigu University and the University of Egðir, participated in this course as part of a larger STEM education cultural exchange program. Students were recruited from the two universities through platforms promoting cultural exchange programs at Isunigu University, tutoring programs at the University of Egðir, and snowball sampling. In order for the lesson architects to partake in the abroad program and the course, they were required to be in a STEM field and have an interest in STEM education. The student participants, who represented a diverse group of STEM disciplines, collaboratively constructed new knowledge utilizing various cultural and educational experiences to develop a place-based and interdisciplinary lesson on harmful algal blooms in the Southeastern United States and the coast of Norway. As a way to capture the backgrounds of participants, Table 1 includes a brief biography of the lesson architects and course instructors.

Table 1. The lesson architects (students) and instructors in this project-based learning course.

Pseudonym	Position	Brief Biography
Florence	Undergraduate Lesson Architect (United States)	She is a Bachelor of Science student in Civil Engineering at Isunigu University.
Maria	Undergraduate Lesson Architect (Norway)	She is a Bachelor of Science student in Civil Engineering at the University of Egðir.
Red	Graduate Lesson Architect (Norway)	She is a Master of Science student in Civil Engineering and Industrial Economy and Technology Management at the University of Egðir.
Salix	Graduate Lesson Architect (United States)	She is a recent graduate with a Master of Science in Biological Sciences from Isunigu University. Her research focus is plant ecology.
Sophia	Graduate Lesson Architect (Norway)	She is a Master of Science student in Industrial Economy and Technology Management with a Bachelor of Science degree in Electronics and Electrical Engineering from the University of Egðir.
Gigi	Graduate Student Teacher of Record; Lead Researcher (United States)	She is a current PhD student in Engineering and Science Education at Isunigu University with previous secondary mathematics and science teaching experience, as well as experience in Biomedical Engineering.
Saoirse	Faculty Co-Instructor (United States)	She is an assistant professor at Isunigu University with a joint appointment in the Department of Engineering and Science Education and the Department of Environmental Engineering and Earth Sciences.
Maximilian (Max)	Faculty Co-Instructor (United States)	He is an assistant professor at Isunigu University in the Department of Engineering and Science Education.

3.4. Study Design

The researchers of this study held multiple responsibilities within the course. The lead researcher was tasked with the development of the course structure, leading classes, analyzing data, and crafting the narrative of the article. Additional researchers acted as faculty co-instructors during the course or lesson architects during the course. All researchers collectively contributed to the interpretation of themes and "thick descriptions" [21] (p. 29) encountered in this study.

To capture the unique nature of the project-based learning course, we situate our collective experiences as a case study [21] with an ethnographic lens. Our deep involvement in planning, implementing, and engaging in the course allowed us to approach this qualitative case study with an increased depth of understanding. We used Merriam's [21] definition of a case study, which characterizes a case study as particularistic, descriptive, and heuristic, meaning a case study should provide thick descriptions and provide the audience with an in-depth understanding of the specific phenomenon [22]. Due to the duality of researchers as instructors and lesson architects within the course, we were able to draw on our experiences to provide a more narrative-focused analysis and additional context to our data. The immersive nature of this case study assisted in developing a collaborative partnership [21,23] between the researchers and participants since the roles were fluid throughout the course. Engaging in the cultural exchange, as well as a project-based learning course that empowered the lesson architects to develop a lesson of their choosing and the educational research, not only broke the all too common "sage on the stage" narrative of undergraduate education but reversed the narrative of what it means to be a student.

3.5. Data Collection

Throughout the semester, the lesson architects engaged in various assignments that contributed to data sources for this study and included collaborative documents, discussion posts, and end-of-semester reflections. The collaborative documents contain any lesson architect-generated material, including the class agenda, the three final lesson plan documents, and the two observation protocols. The class agenda was particularly rich with qualitative data as it included a timeline of how the course was structured, evidence of the multitude of activities the lesson architects engaged in, and lesson architect-generated ideas. In addition to collaborative documents, the lesson architects were asked to reflect and respond to five discussion posts to generate ideas about localized problems, reflect on the course overall, and provide constructive feedback for how the implementation of their lesson could be improved. Lastly, the lesson architects individually wrote one-page reflections on the course and the lesson they implemented. The end-of-semester reflections provided additional context for lesson architect growth and insight into their experiences in a project-based learning course. Each type of data was utilized to capture the full picture of the course, including how lesson architects engaged in curriculum development, the pedagogical approaches used, and the impact this course had on lesson architects' knowledge of interdisciplinary place-based STEM education.

3.6. Data Analysis

Due to the research team's positioning within the course, we were already familiarized with the raw data; however, we read through the data multiple times to re-orient ourselves. The data were coded abductively using a combination of deductive and inductive coding. Using the Seven Essential Project Design Elements and Seven Project Based Teaching Practices from [3,4], the data were coded deductively using the qualitative coding software MAXQDA v. 22.2.1, with each coding pass focused on a single standard. The data were then coded inductively to determine the lesson architects' shifts in conceptual understanding. The codes were collapsed into themes using thematic analysis [24] to gain a better understanding of the answers to our research questions. Once the initial analysis was completed, the lesson architects engaged in member checking to provide feedback on the analysis and ensure the validity of the study.

3.7. Validity and Reliability

Merriam's [21] definition of a case study includes six strategies for internal validity, including triangulation, member checking, long-term observation, peer examination, participatory research, and disclosure of researcher bias [22]. Due to the ethnographic lens of this case study, member checking, peer examination, and participatory research were woven into the data collection, analysis, and reporting processes. Triangulation and disclosure of researcher bias took place throughout the data analysis phase, and long-term observation was inherent in our semester-long case study. Similarly, Marriam's standards for reliability include stating the investigators' positionalities, triangulation, and well-kept records of qualitative data and analysis [21,22]. All three of these standards took place during the data analysis or reporting phase. Lastly, a main technique to ensure external validity is reporting thick descriptions of the case/results to which the results section adheres [21,22]. Due to the qualitative nature of the case study, this study is unable to be generalizable; however, this study is transferable.

4. Results

Three major themes emerged from the data that encapsulated each research question. The first theme discusses how the lesson architects engaged as the primary decision-makers while engaging in project-based learning. The second theme addresses the instructional supports and barriers that assisted or hindered the lesson architects' progress in the development of the lesson study. The third theme amplifies the areas of self-growth the lesson architects identified.

4.1. Students as Decision Makers and Lesson Architects

Students were the lead decision makers throughout the entire course, earning the title of lesson architect because of their commitment to designing and building the lesson from minimal instruction. The course provided the lesson architects with scaffolded activities to guide the process of building a lesson, prompting them to think about aspects they may not have been familiar with that are important in creating a lesson (e.g., learning objectives, scaffolding, and assessment).

Throughout the semester, the lesson architects engaged in active decision-making while collaborating on the end-of-semester product: the place-based, interdisciplinary STEM lesson. Their voices were heard throughout the choices they were making. The lesson architects had to decide on everything, including the lesson's focus on mathematics and environmental sciences and how the lesson was implemented. As a scaffold, the lesson architects were prompted to brainstorm local-to-them challenges in Southern and Western Norway and the Southeastern United States using Jamboard. The challenges identified included limited public transportation, high electricity costs, and flooding across the Southeastern United States and Southern Norway. Florence, originally from the Southeastern United States, demonstrated her extensive expertise in the Southeastern United States by focusing on the Savannah River Watershed, a body of water that runs along the border of South Carolina and Georgia. Florence's Jamboard can be seen in Figure 2. Her Jamboard evoked conversation from the other lesson architects on the similarity of flooding between the two locations, which ultimately resulted in the lesson architects narrowing in on water-based challenges.

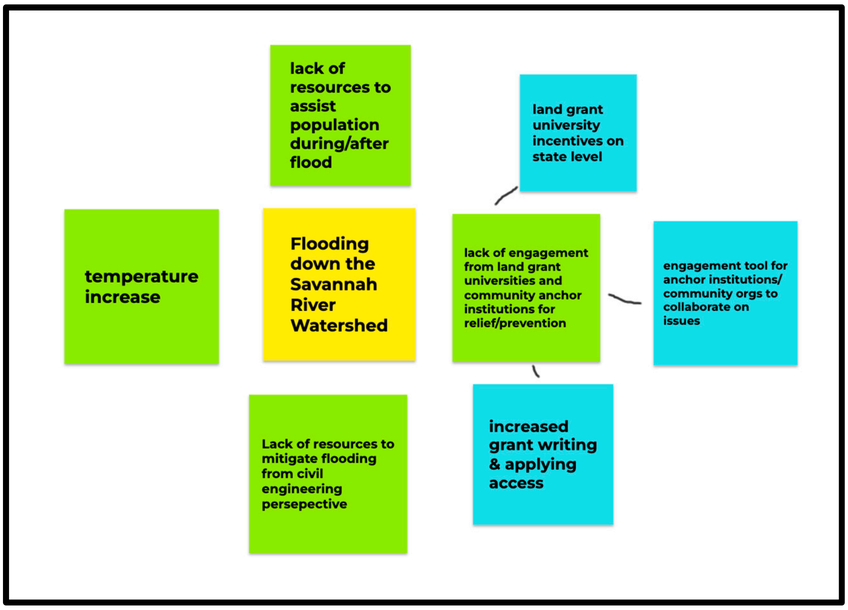

Figure 2. Florence's Jamboard from brainstorming challenges on the Savannah River Watershed.

Once the lesson architects agreed to focus on the flooding of the Savannah River Watershed, Gigi (the graduate teacher of record) tasked the lesson architects with exploring resources that could provide a deeper understanding of problems the Savannah River Watershed faces and assess the stakeholders who are affected by these problems. Overall, the lesson architects narrowed down their search to pollutants within the watershed and the effects on minoritized communities. Florence elaborated in a discussion post on flooding in the Savannah River Watershed by identifying possible causes:

> *"One problem that affects the Savannah River Watershed and the surrounding communities is heavy pollution into the basin. . .Communities are affected by this problem because it damages the aesthetic of the environment, but also because pollution can cause blockages that can contribute to things like flooding."* Florence

Maria unearthed new knowledge about a racially minoritized community in Savannah, Georgia, which was "experiencing the brunt of climate change, pollution, and environmental racism" because of pollution from a nearby "nuclear weapons production site". Red identified chemical pollution's effect on the environment, citing, "the habitats get less suitable for native species that are depending on this habitat to survive". With new knowledge of the local watershed, primary sources of pollution, and the communities most affected, the lesson architects advanced to selecting a lesson topic.

Together, the class brainstormed overarching questions, including "How badly is the water contaminated?", "What are the factors contributing to water contamination?", "What are effective mitigation strategies?" and "How can we use technology to understand the distribution of contamination?". The lesson architects brainstorming about the Savannah River Watershed became focused on testing the water quality for varying forms of contaminants. After assessing the feasibility of having future students conduct water testing within the limited time frame, they reassessed the type of pollution students could investigate. Saoirse, one of the two faculty co-instructors who specialized in geology, suggested that the lesson architects consider an alternative type of pollution: algal blooms. The lesson architects, having little prior knowledge of algal blooms, were interested in learning more and decided to investigate further. Ultimately, deciding on algal blooms as the environmental science topic would be the foundation for the lesson.

After deciding on the lesson topic of algal blooms in the Savannah River Watershed, the lesson architects individually wrote learning objectives on mathematics, environmental science, and environmental justice. Yet, when the lesson architects began to create activities that resulted in each learning objective, they found that the activities they were creating were not interdisciplinary. The monodisciplinary activities did not meet the criteria of the final lesson, prompting the lesson architects to adjust the learning objectives. However, Salix and Sophia, together, came up with the mathematics activity of students graphing and running a *t*-test or other statistical tests. The rest of the team supported this activity idea and suggested that graphing and running statistical tests should be the primary activity with different datasets. With the primary activity chosen, the lesson architects finalized the learning objectives, which can be seen in Table 2.

Table 2. The learning objectives developed by the lesson architects for their lesson study project.

Learning Objective	Description
Learning Objective 1	Students will plot various types of algal bloom data and conduct multiple statistical tests on data derived from different locations, including the Savannah River Watershed and Norwegian Coastline.
Learning Objective 2	Students will be able to interpret the results of the graphs and statistical tests by making connections within and across data sets to draw conclusions about how algal blooms grow and the impact algal blooms have on the environment.

The lesson architects searched for different datasets that could demonstrate a holistic understanding of algal blooms in the Savannah River Watershed and on the coast of Norway. The data from the Savannah River Watershed demonstrated the effects of land runoff on harmful algal bloom growth, connecting the type of land use to the increase in runoff. The data from Trøndelag, Norway, connected the longitudinal fish population data to the amount of cytotoxins over time. However, the lesson architects also wanted students to have an active learning experience, so Gigi suggested having students collect water samples and grow algae themselves. The third data set was created using student-collected water samples from the on-campus pond and varying the levels of phosphates and nitrates to promote algae growth.

Once the vision was firmly established, the lesson architects collaboratively created the prompts and slides for the implementation (see Supplementary Materials). The lesson architects wanted to set the stage for the lesson and started with an introduction to who they were and why they were teaching this lesson. They then contextualized algal blooms and their effects on individuals through a launch activity where the students observed a video posted on social media, read comments on the video, and discussed what was happening and its impact. Prior to implementation, the lesson architects completed each task to assess the clarity and feasibility of the tasks with the future students in mind. They adjusted their drafts to provide greater clarity on where the data came from, how to access the data, how to plot graphs using Google Sheets, what statistical tests were, and how to interpret graphs and test results. In their slides, the lesson architects also provided context on the format of the lesson, explicitly describing how the jigsaw activity would work.

In addition to constructing the lesson, Maria, Red, and Sophia developed qualitative and quantitative observation protocols to collect field note data on how the lesson was received by the students as part of the lesson study. These protocols streamlined the observations by allowing observers to document the data the lesson architects found most interesting, which would help inform the evolution of the lesson when the lesson is revised and re-implemented in a Norwegian classroom. During the lesson, unbiased observers were brought in to record their observations of the lesson, utilizing the observation protocols. Additionally, Maria, Red, and Sophia created a focus group protocol and conducted a focus group with students from the class who engaged with the lesson to gain more insight into how the lesson was received.

Not only did the lesson architects orchestrate data collection on student engagement with the lesson, but they also reflected on their individual observations of student perception of the lesson. Each lesson architect shared their insight on the implementation and provided constructive criticism for improvements. The criticisms included adding different pedagogical techniques such as "think-pair-share or turn-and-talk to engage multiple voices" or addressing the different groups' needs. The lesson architects found that some groups "needed prompting to collaborate" and found that "Group 3's [task] was less straightforward" whereas "Group 1's was more straightforward". The lesson architects also discussed how the overall layout of the classroom limited peer-to-peer collaboration, citing that "a different physical layout of the classroom would have allowed for more conversation". The suggestions the lesson architects produced will serve as a guiding force for the ongoing revisions during the Spring 2024 semester.

With the help of scaffolding, the lesson architects were positioned as the primary decision-makers throughout the course. They engaged in thought-provoking activities to connect different aspects of curriculum development to ideas they already generated. By learning about lesson development as they approached different decision points in the process, they were able to make informed and decisive decisions about the lesson, as well as learn about the nuanced details of student learning.

4.2. Effective Instructional Supports and Barriers

The following section presents multiple supports that proved effective in engaging students in project-based learning as well as effectively eliminating the barriers the lesson architects faced during the semester.

4.2.1. Create a Welcoming and Collaborative Culture

The course intentionally started by creating a collaborative set of norms that every student contributed to and agreed upon. Instead of vocalizing their expectations out loud, the lesson architects engaged in an anonymous brainstorming session via Jamboard. Figure 3 shows the Jamboard the lesson architects populated.

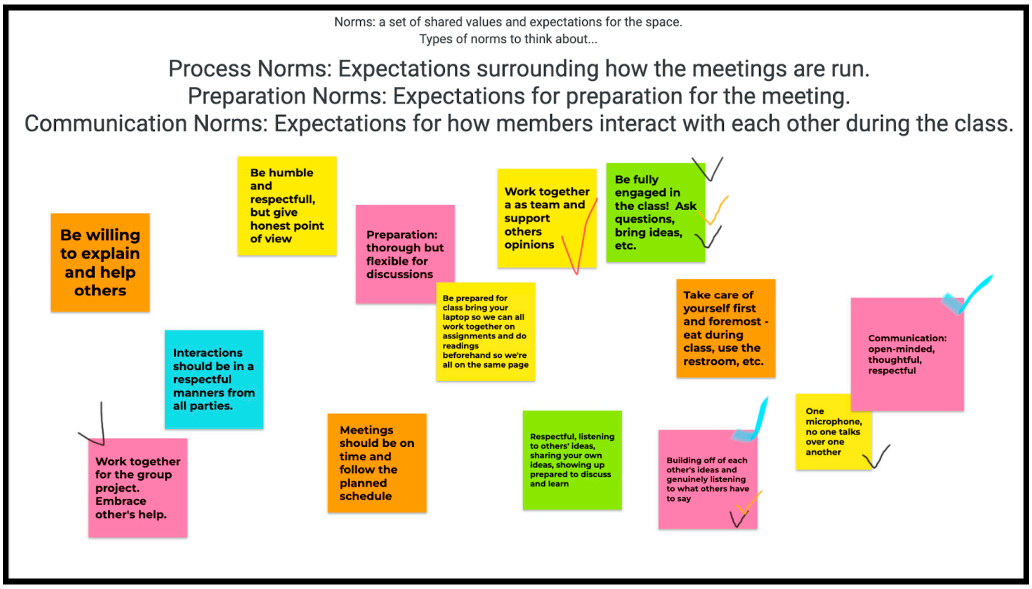

Figure 3. The Jamboard the lesson architects brainstormed expectations for each other and the instructors. Checkmarks indicate norms that were agreed upon by lesson architects and implemented into the top of the agenda.

After filling out the Jamboard, the lesson architects had the opportunity to speak to any norm on the document. Once the norms were finalized (see Figure 4), they remained at the top of the running agenda throughout the semester to remind the lesson architects of our agreed-upon expectations.

Communal Norms

Team Work/Engagement:

- Work together as a team and support others opinions
- Be willing to explain, help others, and embrace other's help
- Be fully engaged in the class! Ask questions, bring ideas, etc.
- Building off of each other's ideas and genuinely listening to what others have to say

Preparation:

- Be prepared for class bring your laptop so we can all work together on assignments and do readings beforehand so we're all on the same page
- Preparation is thorough but flexible for discussions
- Show up prepared to discuss and learn

Communication:

- Be humble and respectful, but give honest point of view
- Share your own ideas
- Open-minded, thoughtful, respectful
- One microphone, no one talks over one another

Structure:

- Meetings should be on time and follow the planned schedule
- Take care of yourself first and foremost, eat during class, use the restroom, etc.

Figure 4. The finalized communal norms that were placed at the top of the running agenda for the course.

In their final reflections from the course, Sophia and Red both discussed the comfort they felt within the course. Red referred to the course as "a safe and low-key environment". Sophia emphasized that "the dynamics within the class have been nothing but amazing" and cited that "the creation of a safe and inclusive environment for open discussions and the sharing of thoughts has been an important aspect of [her] learning experience".

Throughout the semester, the lesson architects engaged in many collaborative activities to provide structured avenues for students to form connections. The groups would fluctuate between being from the same institution (the University of Egðir and Isunigu University) and being mixed as the students became more comfortable. It is important to note that the Norwegian students spoke English in mixed groups but were encouraged to speak in Norwegian when together as a way to recognize their ability to linguistically code-switch, honor their native language, and ensure they felt comfortable engaging with their peers. Red disclosed that initially, "it was a bit hard to adapt to the language and ways things are done [at Isunigu University]," and Sophia expressed that initially, "I felt the challenge of formulating my thoughts in English in a precise manner". Yet, Sophia continued by saying, "this safe environment has encouraged me to keep trying to formulate my thoughts and engage in discussion without any reservation about my proficiency in English".

4.2.2. Scaffold Activities Responsive to the Lesson Architect's Needs

Multiple scaffolded activities took place throughout the semester to assist in broadening the lesson architects' knowledge of interdisciplinary STEM, place-based education, and lesson design. Two scaffolded activities involved the lesson architects reading articles on interdisciplinary STEM education and place-based education outside of class. During class, the lesson architects derived definitions from the articles and their own experiences to accurately define interdisciplinary STEM education and place-based education. When defining interdisciplinary STEM education, the lesson architects were tasked with combining two random STEM disciplines into an interdisciplinary lesson. Figure 5 shows one group of lesson architects' work combining physics/technology, and Figure 6 shows the other group of lesson architects' work combining precalculus/geology into two interdisciplinary lessons.

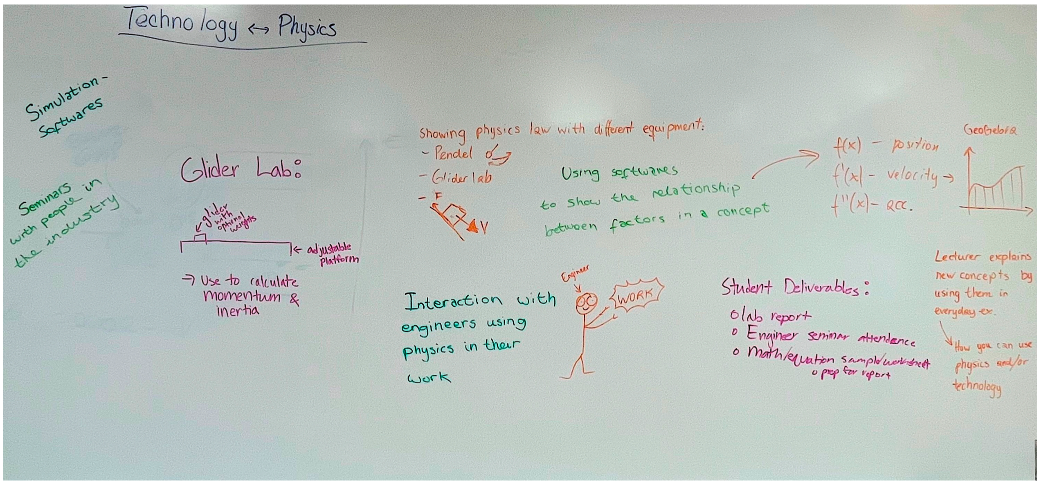

Figure 5. One group of lesson architects practiced combining physics and technology into an interdisciplinary lesson.

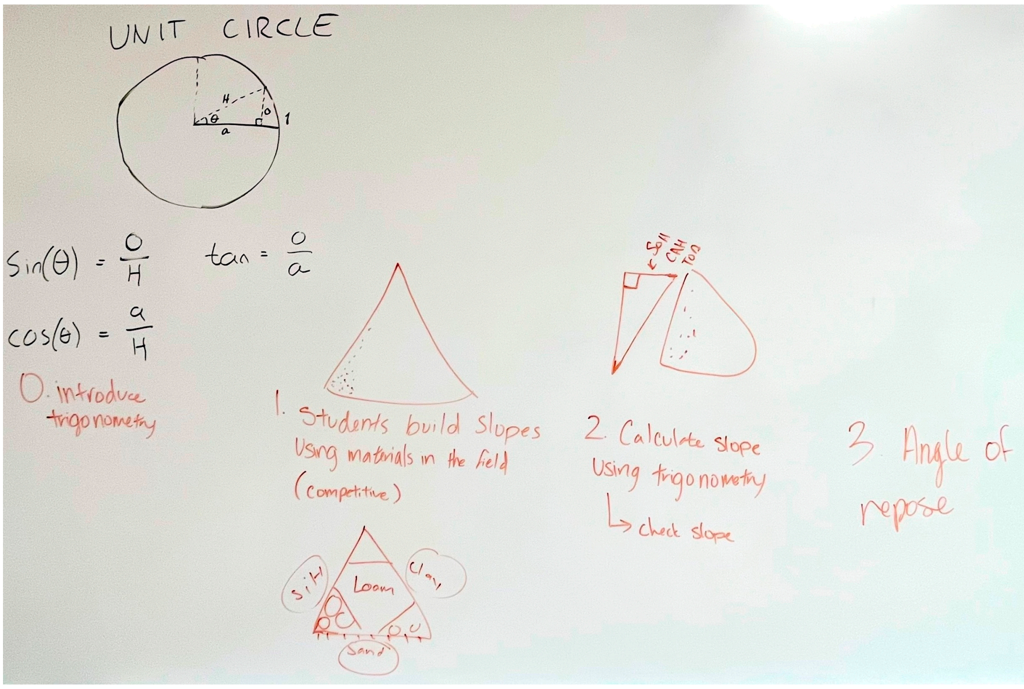

Figure 6. The other group of lesson architects practiced combining precalculus and geology into an interdisciplinary lesson.

An additional scaffolded activity the lesson architects engaged in was qualitative and quantitative observational data collection. They watched an open-access physics lesson while taking observational notes and evaluating what they thought was important data to collect as a way to consider what data the lesson architects were interested in collecting during their lesson implementation. The lesson architects used this experience to decide on the types of data they wanted to collect during the lesson study, including qualitative observational data answering, "how do students interact with each other during the task?" and "how do students interact with the task?" and quantitative observational data counting the number of times "students ask clarifying questions related to the task or activity" or "students ask questions related to the topic to further their understanding".

4.2.3. Additional Structure to Assist the Lesson Architects in Decision Making

Although the scaffolding supported the lesson architects' decision-making throughout the lesson development, the lesson architects still struggled to coalesce on a finalized topic for their lesson. The structure provided at the beginning of the course was responsive to where the lesson architects were in the design process, but as they built out the activities, the scaffolding was removed to allow them the space to work collaboratively on what they deemed important. In the middle of the semester, the decision-making process stalled. The lesson architects crafted four distinct learning objectives (two for mathematics, one for environmental science, and one for geography), yet the categorized learning objectives made it difficult for the lesson architects to envision an interdisciplinary lesson, and they found themselves at a standstill. At this point, Gigi realized she was not managing the activities as closely as necessary for the lesson architect's success. As a response, she took a more active role in managing the process by leading the collaborative effort of reimagining the learning objectives into two interdisciplinary objectives (see Table 2) and creating a document of necessary lesson components and tasks that needed to be accomplished. By delegating what tasks remained, the lesson architects were given momentum to continue finishing the lesson, and as Salix stated, "our final project was truly a team effort".

4.3. Multifaceted Understanding of Interdisciplinary STEM Education

The following theme highlights the lesson architects' reflections on their experiences and areas of growth the lesson architects identified. As Florence eloquently stated, "I believe I have learned more practical knowledge in this class than I do in most of my content-based classes". The sentiment from Florence's end-of-semester reflection was echoed in the other lesson architect's reflections. Salix similarly expressed that she "learned a lot about the need for implementing interdisciplinary STEM education at all levels, and the high need for an interdisciplinary understanding of STEM in the workforce". Together, the lesson architects identified five nuanced areas of growth in their conceptual understanding of interdisciplinary STEM education: environmental science, multiculturalism, learning theories, research, and instructional practices.

4.3.1. Expanding Knowledge of Environmental Science

One lesson architect, Red, was adamant that she expanded her knowledge of environmental science and scientific methods by engaging in this project-based interdisciplinary STEM lesson. Through the course, she "learned a lot [about] algae bloom and how one can create a lesson of STEM, collecting water samples and measur[ing] pH, turbidity, and color". Prior to this course, the lesson architects had limited to no exposure to algal blooms and their effects on the environment and local ecosystems. The lesson architects engaged deeply in researching algal blooms, discovering how algal blooms appear, how algal blooms affect the surrounding environment, including various stakeholders, and how to measure the growth of algal blooms.

4.3.2. Multiculturalism within Interdisciplinary STEM Education

As a way to define place-based education and explore local and global problems, the lesson architects read multiple articles on interdisciplinary STEM education within the context of other countries in addition to the United States. Red recognized these articles as "interesting" and "really liked the international perspective of STEM". The articles led to discussions that enabled students to gain insight into other cultures, education systems, and other countries' views of STEM. Additionally, the conversations branched into the lesson architect's own experiences in the United States and Norway, which allowed them to compare the educational structures between Norway and the United States. Florence identified growth "in [her] ability to recognize multicultural differences in education" and how her new understanding of multiculturalism expanded how she perceives her future as she hopes "to work around the world, in a variety of different cultures, backgrounds, community structures, and levels of resilience".

4.3.3. Understanding of Learning Theories

The learning architects' conceptualization of learning and learners' experiences expanded throughout the course. The lesson architects completed scaffolded activities to encourage them to consider components of a lesson that they were unfamiliar with, including learning objectives and scaffolding for diverse groups of students. The majority of the lesson architects did not have prior experience with the research in [25] or the learning objectives, so they initially reflected on their own learning to inform the lesson development. In particular, Maria was fascinated with "how students learn and motivate themselves within STEM courses", while Sophia found the research in [25] to be an interesting insight into how her previous education considered various levels of learning. The lesson architects similarly engaged in discussion about various forms of instruction for different levels of students and different types of students. Florence found addressing "approaches to differences in student learning and developing adequate instructions for diverse groups of students" to be insightful in recognizing each student as an individual learner. Sophia acknowledged "that designing a lesson that engages the students to work with their peers in [addition] to being memorable/interesting will foster a good learning environment for the students".

4.3.4. Engagement in Educational Research

Prior to this course, the lesson architects had experience as students, tutors, mentors, and teaching assistants; however, they had limited experience engaging in educational research. An integral aspect of a lesson study is collecting data throughout the implementation, and by engaging in a lesson study, the lesson architects naturally participated in educational research. The lesson architects were responsible for determining what data would provide valuable feedback for the team to revise the lesson. The three Norwegian lesson architects were responsible for creating data collection instruments. Through this task, Maria, Red, and Sophia learned about qualitative and quantitative observational protocols, Likert-scale surveys, and focus group protocols. They developed two observation protocols (one qualitative and one quantitative), an exit ticket questionnaire, and a focus group interview protocol. The experience of engaging in educational research left an impression on all three lesson architects as each identified educational research in their end-of-semester reflections. For example, Red emphasized how this project-based lesson development broadened her mindset on what data is and taught her "how to collect different [types of] data". Maria similarly cited how she grasped "various methods for collecting data and the diverse data that can be obtained by choosing different methods (both qualitative and quantitative)". Engaging in project-based lesson development influenced how the lesson architects saw data and the tools used to collect them.

Similarly to Maria's and Red's accounts of expanding their educational research abilities and definitions, Sophia's end-of-semester reflection described how the entire project-based lesson development course influenced how she saw education research:

> *"The exposure to various theories through reading research papers has been crucial in broadening my understanding for conducting research. Delving into these papers has not only enhanced my theoretical knowledge but has also offered practical insights into the methodologies employed in research. It's even more fascinating to witness how these theories come to life through the implementation of the algal bloom lesson."* Sophia

Sophia discussed how the scaffolds throughout the course provided insights into how to use various theories and methodologies when conducting educational research. The experience provided Sophia and the rest of the lesson architects with the practical knowledge of how to turn educational theories into educational practices, something they had previously not been able to witness in their STEM courses.

4.3.5. Broadening the Understanding of Instructional Practices

The majority of the lesson architect's reflections emphasized how they would have revised the lesson and instructional practices to support the students' learning. Red called out that the lesson implementation "could have been more effective" and expressed the need for the more targeted practice of implementing a lesson "as it could have enhanced the overall flow of the lesson". The four other lesson architects had similar critiques and specific suggestions for improvement, which demonstrated their expanding knowledge of instructional practices.

Collectively, the lesson architects noticed that "some of the student[s] struggled identifying the objective of the task and that they were to combine their knowledge to reach a collective conclusion"; thus, "some students did not respond to the objectives. . .failing to draw the conclusions we intended". Through an instructional lens, Red suggested that "we should have encouraged the students to evaluate each case and then foster the connection between the three 'big groups'". Maria proposed to have "the specific objectives presented on a slide. . . [to] help students understand what they need to answer". As students were divided into groups, initial student engagement was low, which could have been due to the lack of clarity on the objectives of the task. Florence similarly noted that student engagement initially started low but "progressed over time throughout the lesson" and established that in the future, she would mitigate the lack of engagement by "prepar[ing] more questions to ask [students] to enhance understanding throughout the lesson". Red, Maria, and Florence recognized the students' confusion around the task, which hindered the students' ability to work with each other. Yet, all three provided instructional-based solutions that they could implement to improve the students' experiences with the lesson.

The lesson architects identified specific content components that students were fixated on, specifically conducting and interpreting a *t*-test. Red observed that the "*t*-test might have been too ambitious to make students do", while Maria concluded that "it might be wise to introduce the *t*-test to the students earlier". In a similar vein, Sophia recommended providing students with a preparatory homework assignment, including a short video on how to interpret a *t*-test. "This way, the educators can ensure the students [have an] understanding of [the *t*-test] before the lesson is implemented". Red also proposed to assign preparatory homework that includes some pre-selected statistical tests where "they had to read about [statistical tests] and identify which one to use where". The lesson architects developed plans to restructure how students were introduced to the *t*-test as a response to observations that were made during implementation.

Not only did the lesson architects' knowledge of instructional techniques grow through a critical analysis of the implementation, but the lesson architects' pedagogical knowledge increased throughout the whole process. In reflecting on instructional practices beneficial to student learning, the lesson architects thought having the students jigsaw into multidisciplinary groups was beneficial in engaging all students and having students gain different perspectives. Although the "classroom layout also didn't quite work" because "at times, it was difficult to move around" due to the immobile nature of the seating, the lesson architects appreciated trying an unfamiliar instructional technique. Florence even found that "having three different groups [was] a great technique in teaching a wide variety of content at once as the students are then able to teach each other".

5. Discussion

The success of the lesson architect's engagement and growth is tied to three primary lessons learned: (1) facilitation of effective communication, (2) centering of the lesson architects, and (3) inclusion of authentic engagement with interdisciplinary STEM education. In this discussion, we describe key takeaways from lessons learned and future directions of project-based learning with students as partners.

5.1. Facilitate Effective Communication

A key component of the course that supported the lesson architects was facilitating open and effective communication throughout the course. Students rarely engage in project-based learning in higher education STEM disciplines [26], which is why course design [4] should emphasize the importance of fostering an environment that is inclusive to students from different backgrounds and conducive to project-based learning. By having the lesson architects create their own classroom norms, they were able to express their expectations of their peers and their instructors. These expectations could differ between the cultures of the United States and Norway or even regionally across the United States. However, having the lesson architects relay their unspoken expectations to their peers allowed everyone to have a shared understanding of the expectations within the course. The anonymity allowed the lesson architects to be honest with their expectations without having the initial discomfort of speaking to a group of people they just met.

By modeling effective communication and establishing classroom norms, the lesson architects were able to address possible cultural differences between Norway and the United States. Cultural differences, together with speaking in a foreign language (in this case, in English for the Norwegian lesson architects), can easily result in the native speakers taking the lead in conversations, potentially leaving the Norwegian lesson architects to simply agree with what is being said due to possible language barriers. Using Jamboard and discussion posts, the Norwegian lesson architects could more easily express their thoughts individually without being influenced by the other students. Another positive effect of using these tools was increasing the number of visible opinions, as well as encouraging all parties to share their thoughts on an issue. Given that the Norwegian lesson architects have different cultural perspectives and localized issues, the ability to express differing opinions highlighted multiple facets of society. During the development of the lesson plan, the lesson architects provided a different perspective on a local issue, in this case, algal blooms, and attempted to draw connections between their previous experiences in Norway and the United States. In this way, facilitating an environment with open communication allowed new connections to be made and seen across cultures and STEM disciplines, which was pivotal to the success of developing an interdisciplinary STEM lesson.

5.2. Lesson Architect-Centered: Focus on the Interests, Experiences, and Knowledge of the Lesson Architects

The class was designed to have structure for the lesson architects but was also responsive to their needs throughout the lesson design process. The open-endedness of the course allowed students to call on their previous knowledge and interests. For example, Florence employed previous knowledge from growing up in the Southeastern United States as well as experiences testing the Savannah River Watershed to suggest the location for the lesson. Florence's valuable insight into problems affecting the Savannah River Watershed was the foundation of the place-based aspect of the lesson and made it easier to determine a focus area every lesson architect could work on, namely water pollution. Equally as passionate about the topic of water pollution, the Norwegian lesson architects brainstormed water-based challenges in localized regions of Norway, resulting in the parallel challenge of harmful algal blooms. Finding a joint environmental problem between the Southeastern United States and Norway increased the authenticity of the lesson, providing strong reasoning for why algal blooms are important in real life, a key pillar in place-based learning [2].

Similar to Florence's place-based expertise, Salix expressed continued interest in using statistics in the lesson, given her strong background in the subject. Salix quickly became the statistics expert and provided suggestions for how to intertwine statistics with the environmental science topic of algal blooms. The use of statistics expanded to include technology skills and data interpretation, with Sophia and Salix suggesting that students make two graphs and run two statistical tests to prove or disprove an algal bloom incidence. The use of statistics prompted the lesson architects to think about potential datasets that could be incorporated into the lesson. The group landed on incorporating fish mortality data from Norway, algal bloom toxin data from water testing sites along the Savannah River Watershed, and student-collected algal growth data from localized water sources, including the pond on Isunigu University's campus.

5.3. Include Authentic Engagement with Interdisciplinary STEM Education

Structuring the course to promote an authentic and engaging project-based learning experience was critical in the lesson architects' personal and academic development. After engaging in this course, the lesson architects grew their understanding of what defines education, what tools educators employ to develop a successful lesson, and how to conduct education research. The lesson architects expanded their own knowledge base of environmental science as they quickly had to become experts in the causes of algal blooms as well as affected ecosystems. Through this expansion of knowledge, the lesson architects grew to recognize how local problems can have a global impact or how local problems can exist on a global scale.

Not only did the lesson architects expand their personal knowledge of environmental science, but they witnessed first-hand that educators can initially be novices on a topic and expand their knowledge enough to create a well-thought-out lesson. Their view of an educator expanded to include a wider variety of instructional practices as well as recognition that exceptional educators tend to have an understanding of how a multitude of students learn and construct learning objectives catered to the depth in which students are to learn a topic. Broadening the view of educators included recognizing that educators engage in education research even through techniques as accessible as lesson study. Lesson architects were also introduced to the importance of including more underutilized methods in STEM education, including place-based and interdisciplinary methodology. As we foster passion and skills in future educators, it is valuable to include these methods in order to create ripples of passion in STEM and continued community engagement.

5.4. Future Directions for Project-Based Learning with Students as Partners

This case study provides a dive into student perspectives of a novel undergraduate course framework, where students played the leading role in curriculum development. Developing a classroom where students and instructors share responsibility for course development creates a community where students are encouraged to challenge themselves (see discussion in Section 5.2 for the lesson architect-centered focus), and participation in a safe learning community simulates the group dynamic that students may experience in the workforce or "the real world" [9,10,27]. In our study, these elements were strengthened by instructor scaffolding and effective communication facilitated through the use of Google apps (Jamboard, Docs, and Sheets) and a learning management system (Canvas; see discussion in Section 5.1 on facilitating effective communication). The use of technology in this case study facilitated an open discussion space for the lesson architects to brainstorm ideas and provide feedback during the process of lesson development. Across other studies, the use of technology has facilitated learning and peer-to-peer collaboration [28,29]. As technology continues to advance through increasingly collaborative and interactive platforms and through the use of artificial intelligence, the way students learn and complete projects will continue to evolve. Increasing student autonomy and investment in their coursework may lead to authentic work and participation by students in the classroom and allow them to engage with STEM topics in realistic ways.

6. Conclusions

The semester proved to be a challenging and rewarding experience for the five lesson architects and instructors from Norway and the United States. Aligning the course instruction with project-based learning standards and teaching methods [3,4] assisted the lesson architects in developing a successful place-based, interdisciplinary lesson on algal bloom growth in Norway and the United States. Ultimately, the project-based standards were key frameworks that influenced the structure of the course and contributed to student growth.

The structure of the course was unique for a higher education institution, yet the authentic, open-ended task of creating an interdisciplinary lesson provided the lesson architects with a variety of directions to take the lesson while also allowing them to recall previous knowledge they had. By engaging in a place-based, project-based learning course focused on creating an interdisciplinary STEM lesson study, the lesson architects gained a greater understanding of the inner workings of interdisciplinary STEM education, inclusion of multiculturalism within STEM education, ways in which students learn, and instructional practices that enhance student learning and engagement. The lesson architects ultimately participated and highly benefited from the concepts of place-based and interdisciplinary methodology, allowing them to further develop their global perspectives and lesson development skills.

Although the course featured in this case study took place in the Fall of 2023, the exchange program continued into the Spring of 2024, and the second iteration of the course took place at the University of Egðir. During the Spring of 2024, the lesson architects and Gigi traveled (or returned) to Norway to revise and re-implement the algal bloom lesson in Norwegian higher education classrooms. In the Fall of 2024, the exchange program will continue at Isunigu University with a new group of instructors, exchange students, and students. From this experience and our subsequent research on the project-based learning course, we encourage other educators to use project-based learning to foster an inclusive environment with appropriate scaffolding to construct a transformative experience for all students.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/educsci14080866/s1, File S1: Group 1: Reflection Pond Algal Blooms; File S2: Group 2: Impact of Algal Blooms in Trøndelag, Norway; File S3: Group 3: Land Use and Algal Blooms in the Savannah River Watershed.

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Data Availability Statement: The data presented in this article are not readily available because the data contains sensitive information and may be re-identifiable given the rich nature of the data. The raw data from this study may be made available upon request after providing a written rationale and intended use of the data. Requests to access the datasets should be directed to mkvoigt@gmail.com.

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References

1. King, A. From Sage on the Stage to Guide on the Side. *Coll. Teach.* **1993**, *41*, 30–35. [CrossRef]
2. Gruenewald, D.A. The Best of Both Worlds: A Critical Pedagogy of Place. *Educ. Res.* **2003**, *32*, 3–12. [CrossRef]
3. Buck Institute for Education. Gold Standard PBL: The Essential Project Design Elements. 2022. Available online: https://my.pblworks.org/resource/document/gold_standard_pbl_essential_project_design_elements (accessed on 27 February 2024).
4. Buck Institute for Education. Gold Standard PBL: Project Based Teaching Practices. 2019. Available online: https://my.pblworks.org/resource/document/gold_standard_pbl_project_based_teaching_practices1 (accessed on 27 February 2024).
5. Krajcik, J.S.; Shin, N. Project-based learning. In *The Cambridge Handbook of the Learning Sciences*, 2nd ed.; Sawyer, R.K., Ed.; Cambridge University Press: Cambridge, UK, 2014; pp. 275–297.
6. Condliffe, B. *Project-Based Learning: A Literature Review*; Working Paper; MDRC: New York, NY, USA, 2017.
7. Yemini, M.; Engel, L.; Ben Simon, A. Place-based education–A systematic review of literature. *Educ. Rev.* **2023**, 1–21. [CrossRef]
8. Van den Beemt, A.; MacLeod, M.; Van der Veen, J.; Van de Ven, A.; Van Baalen, S.; Klaassen, R.; Boon, M. Interdisciplinary engineering education: A review of vision, teaching, and support. *J. Eng. Educ.* **2020**, *109*, 508–555. [CrossRef]
9. Lubicz-Nawrocka, T. From partnership to self-authorship: The benefits of co-creation of the curriculum. *Int. J. Stud. Partn.* **2018**, *2*, 47–63.
10. Ngereja, B.; Hussein, B.; Andersen, B. Does Project-Based Learning (PBL) Promote Student Learning? A Performance Evaluation. *Educ. Sci.* **2020**, *10*, 330. [CrossRef]
11. Lewis, C.C.; Tsuchida, I. A Lesson Is Like a Swiftly Flowing River: How Research Lessons Improve Japanese Education. *Improv. Sch.* **1999**, *2*, 48–56. [CrossRef]
12. Stigler, J.W.; Hiebert, J. *The Teaching Gap: Best Ideas from the World's Teachers for Improving in the Classroom*; The Free Press: New York, NY, USA, 1999; pp. 103–128.
13. Larmer, J.; Mergendoller, J.R. *Gold Standard PBL: Essential Project Design Elements*; Buck Institute for Education: Novato, CA, USA, 2015; pp. 1–4.
14. Darling-Hammond, L.; Barron, B.; Pearson, P.D.; Schoenfeld, A.H.; Stage, E.K.; Zimmerman, T.D.; Cervetti, G.N.; Tilson, J.L. *Powerful Learning: What We Know about Teaching for Understanding*; Jossey-Bass: Hoboken, NJ, USA, 2008.
15. Yu, H. Enhancing creative cognition through project-based learning: An in-depth scholarly exploration. *Heliyon* **2024**, *10*, e27706. [CrossRef] [PubMed]
16. Freire, P. *Pedagogy of the Oppressed*, 30th Anniversary ed.; Continuum: New York, NY, USA, 2005; pp. 43–70.
17. Williams, M.K. John Dewey in the 21st century. *J. Inq. Action Educ.* **2017**, *9*, 7.

18. Lubicz-Nawrocka, T.; Bovill, C. Do students experience transformation through co-creating curriculum in higher education? *Teach. High. Educ.* **2023**, *28*, 1744–1760. [CrossRef]
19. Larmer, J.; Mergendoller, J.; Boss, S. *Setting the Standard for Project Based Learning*; ASCD: Alexandria, VA, USA, 2015; pp. 1–54.
20. Mergendoller, J.R.; Thomas, J.W. Managing project based learning: Principles from the field. In Proceedings of the 2000 Annual Meeting of the American Educational Research Association, New Orleans, LA, USA, 24–28 April 2000.
21. Merriam, S.B. *Qualitative Research and Case Study Applications in Education*, 2nd ed.; Jossey-Bass Publishers: San Francisco, CA, USA, 2009; pp. 39–55.
22. Yazan, B. Three Approaches to Case Study Methods in Education: Yin, Merriam, and Stake. *Qual. Rep.* **2015**, *20*, 134–152. [CrossRef]
23. Brown, P.A. A review of the literature on case study research. *Can. J. New Sch. Educ./Rev. Can. Jeunes Cherch. Cherch. Educ.* **2008**, *1*, 1–13.
24. Braun, V.; Clarke, V. Thematic analysis. In *APA Handbook of Research Methods in Psychology: Research Designs: Quantitative, Qualitative, Neuropsycholog-Ical, and Biological*; Cooper, H., Camic, P.M., Long, D.L., Panter, A.T., Rindskopf, D., Sher, K.J., Eds.; American Psychological Association: Washington, DC, USA, 2012; Volume 2, pp. 57–71.
25. Bloom, B.S. *Taxonomy of Educational Objectives, Handbook: The Cognitive Domain*; David McKay Company, Inc.: New York, NY, USA, 1956.
26. Chang, Y.; Choi, J.; Şen-Akbulut, M. Undergraduate Students' Engagement in Project-Based Learning with an Authentic Context. *Educ. Sci.* **2024**, *14*, 168. [CrossRef]
27. Kaya, T.; Bowlyn, K.N. Building an Innovative Engineering Curriculum from the Ground Up: Lessons and Success Stories Paper. In Proceedings of the 2024 ASEE North East Section, Fairfield, CT, USA, 19–20 April 2024.
28. Tsui, E.; Dragicevic, N.; Fan, I.; Cheng, M. Co-creating curriculum with students, teachers, and practitioners in a technology-enhanced environment. *Educ. Tech. Res. Dev.* **2024**, *72*, 869–893. [CrossRef]
29. Abuhassna, H.; Al-Rahmi, W.M.; Yahya, N.; Zakaria, M.A.Z.M.; Kosnin, A.B.M.; Darwish, M. Development of a new model on utilizing online learning platforms to improve students' academic achievements and satisfaction. *Int. J. Educ. Technol. High. Educ.* **2020**, *17*, 38. [CrossRef]