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Interdisciplinary project based-inquiry: Empowering students to solve global problems

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Abstract

This study investigates the impact of an interdisciplinary project-based inquiry global project on 9th grade students' science content knowledge and engagement using a mixed-methods research design. Data sources included pre/post tests on science content, pre/post survey on student motivation, and student focus groups interview data. Results indicate there were significant increases in student science content knowledge and significant increases in their feelings of empowerment. Three themes emerged from the focus group interviews: (1) collaborating during the pandemic, (2) motivation through sharing their ideas, and (3) motivation to learn science, technology, engineering, and mathematics content to solve global problems. Discussion focuses on the ways project-based learning help students feel motivated, even in a virtual learning environment.

Keywords: project-based learning, project-based inquiry, science content knowledge, student motivation, empowerment

INTRODUCTION

Project-based learning (PBL) is designed to actively engage all students in learning (Tal et al., 2005). PBL starts with a compelling question that grabs students' interest and draws their attention towards manageable aspects of the task they will investigate (Krajcik & Blumenfeld, 2006; Schneider et al., 2002; Thomas, 2000). This inquiry structure motivates students because they are working with messy complex problems that affect people's lives and have important consequences for society (Condliffe et al., 2016). In addition, the compelling question creates an opportunity, and a need, for students to explore new content, thus deepening their knowledge of the topics they explore (Barron et al., 1998; Kanter & Konstantopoulos, 2010; Krajcik et al., 2008). Project-based inquiry (PBI) global, which is used in this study and is a version of PBL, designed to position students as problem solvers for authentic global problems (Spires et al., 2019). The objectives of the research described in this paper were two-fold:

(1) to implement a multi-week interdisciplinary PBI global across an entire grade level, and

(2) to assess student science content knowledge and factors that influence student engagement and motivation.

THEORETICAL FRAMEWORK

Dewey (1981) argued learning should be positioned in relation to a child's interest and cognition and that it is important to situate curriculum in a child's lived experiences so that learning is not isolated from context. In his work *Logic: The theory of inquiry*, Dewey (1938), argued that inquiry can lead to knowledge; more specifically Dewey (1938) noted "As a truism, it defines knowledge as the outcome of competent and controlled inquiry" (p. 8). Thus, inquiry is a way to attain knowledge. Different frameworks have been derived from Dewey's (1938) findings around learning (Williams, 2017); however, we focus specifically on inquiry-based learning and PBL as to theoretical frames for this work.

Furthermore, inquiry-based classroom approaches are beneficial as they enable students to develop essential skills for the 21st century workplace (Chu et al., 2017; Fancher & Norfar, 2019; Sondergeld & Johnson, 2019). In the workplace, students will need to be able to

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Contribution to the literature

- This study contributes to the existing literature by examining the impact of an interdisciplinary PBI global project on 9th grade students' science learning and engagement through a mixed-methods approach.
- Unlike previous studies, it highlights how PBL fosters motivation and empowerment, even in a virtual setting. The findings demonstrate significant gains in science content knowledge and motivation, emphasizing the role of collaboration and real-world problem-solving in science, technology, engineering, and mathematics (STEM) education.
- This research enhances scholarship by providing insights, from a mixed methods study, into how PBI can support student engagement and learning, particularly during challenging circumstances like the pandemic.

engage with messy, complex problems that do not have clear solutions, and Condliffe et al. (2016) assert that project-based methods create the environment in which students are able to have that experience. For complex problems, the inquiry process encourages students to uncover new causal relationships, where they generate hypotheses and test them through experiments and observations (Pedaste et al., 2012). This, coupled with other components of inquiry such as open-ended group work, engages students in activities that emulate the research processes of scientists (Barrow, 2006; Kesselman, 2003).

Barrow (2006) asserts that teachers of all grades should value inquiry. Indeed, numerous studies highlight the effectiveness of inquiry-based learning at the middle and secondary education levels (Minner et al., 2010), with additional research supporting its suitability as an instructional approach for learners of all ages (Alfieri et al., 2011; Furtak et al., 2012). In science instruction, inquiry has been shown to positively affect students' motivation (Suduc et al., 2015) and knowledge of science processes (McCright, 2012). Additionally, Tal et al. (2005) contend that inquiry has the potential to promote learning for all students, including those with learning difficulties, those who have lost confidence in their ability to "do school," and those who have simply lost interest.

STUDENT LEARNING OF SCIENCE CONTENT THROUGH INQUIRY

As a promising pedagogical approach in the digital age, inquiry is featured prominently in the *next generation science standards (NGSS)*, specifically in the *science and engineering practices* dimension (NGSS Lead States, 2013). Minner et al. (2010) analyzed research regarding inquiry-based science instruction from 138 studies that took place over the span of 19 years. The findings from their research synthesis support inquiry-based instruction as a favorable choice for emphasizing students' active thinking and drawing appropriate conclusions from data. Inquiry has been emphasized as a central strategy of teaching science for many years (National Research Council, 1996; Rutherford & Ahlgren, 1990); yet many inquiry-based learning curricula and models fail to scale across teaching contexts and science topics (Lee et al., 2010). Considering a large number of teaching contexts with varied teachers, schools, student characteristics, and multiple science topics (e.g., middle school: earth, life, and physical science and high school: biology, chemistry, and physics), Lee et al. (2010) measured and compared the performance of students who received inquiry-based instruction to students who did not and found the use of inquiry units had a positive impact overall compared to typical instruction. Similarly, Suduc et al. (2015) found that students who participated in inquiry-based instruction were also applying research skills while constructing meaning and developing scientific knowledge. Additional pre- and post-test study designs have demonstrated direct evidence for inquiry's potential to significantly increase students' STEM content knowledge (Harris & Rooks, 2010).

Considering how inquiry-based learning might influence specific populations, researchers found that 7th and 8th grade urban African-American boys who participated in inquiry science units experienced reduced gender gap achievement on standardized test scores (Geier et al., 2008). English Language Learners have also shown achievement increases not only in science, but math, writing, and reading each year they participated in inquiry-based science instruction (Amaral et al., 2002).

STUDENT ENGAGEMENT AND MOTIVATION IN SCIENCE THROUGH INQUIRY

A key discussion in the learning sciences revolves around the significance of student engagement in relation to achievement in STEM disciplines (Connell et al., 1994; Finn et al., 1995; Marks, 2000). Engagement can be understood as a continuum, ranging from deep involvement in a particular academic task to sustained commitment and persistence in science-related fields that may lead to career pursuits. Skinner and Belmont (1993) offer a definition that emphasizes the more nuanced cognitive, behavioral, and affective aspects of student engagement in learning activities. According to Skinner and Belmont (1993), students who are engaged:

> select tasks at the border of their competencies, initiate action when given the opportunity, and exert intense effort and concentration in the implementation of learning tasks; they show generally positive emotions during ongoing action, including enthusiasm, optimism, curiosity and interest (p. 572).

Similarly, Fredricks et al. (2004) argue that engagement is a multidimensional construct, integrating behavioral, emotional, and cognitive engagement in a cohesive and meaningful manner.

In addition to improving student engagement, inquiry has had positive effects on other desired outcomes. Specifically, in science instruction, inquiry has been shown to positively affect students' motivation (Suduc et al., 2015). From the standpoint that students of the 21st century are required to engage with complex problems arising from issues of the environment and sustainability, McCright (2012) involved students in a semester-long inquiry-based learning project on climate change. The results were threefold: students showed improvement in their knowledge of science processes, became more skilled in research, and demonstrated a higher regard for social science research topics. Based on a study of student engagement from the Fordham Institute, *What teens want from their schools,* (Geraci et al., 2017), Tyner and Howell (2018) note that " … students like doing. They like discussing, creating, researching, and they're less interested in activities that revolve around watching and listening." This type of active learning corresponds well with the activities embedded in inquiry curricula.

PROJECT-BASED INQUIRY GLOBAL

The PBI global process, which utilizes the United Nations sustainable development goals as a foundation for the identified global problems that students set out to help solve, has been studied in a diverse set of learning environments. These learning environments include middle (Spires et al., 2012) and high school classrooms (Spires et al., 2021, 2022) in both the United States and internationally (Himes et al., 2023; Spires et al., 2018a, 2018b). In the PBI global model, students engage in the research process of asking a compelling question, investigating the available resources related to the question, synthesizing the claims and evidence of the resources, evaluating and refining their research findings, and sharing their findings with a larger audience (**Figure 1**).

In this study, the specific research questions we sought to answer were:

(1) *How, and to what extent does inquiry through the PBI global process support student science content knowledge?* and

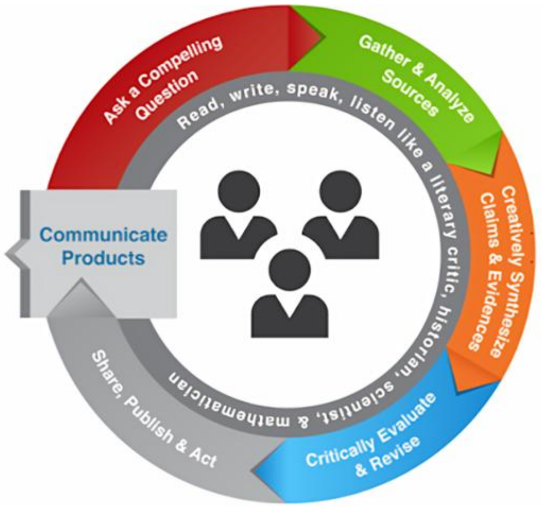

Figure 1. PBI global (adapted from Spires et al., 2019)

(2) *How, and to what extent, can students' motivation and engagement be characterized after participating in the PBI global process?*

This study contributes to the existing literature by examining the impact of an interdisciplinary PBI global project on 9th grade students' science learning, specifically around the content of energy and water, and engagement through a mixed-methods approach. Unlike previous studies, it highlights how PBL fosters motivation and empowerment, even in a virtual setting. This research is important to understanding both the impact of an interdisciplinary PBI global on students' engagement and learning in science, and to fill a void in what the research community knows and understands about learning in a virtual environment.

METHODS

A mixed-methods research convergent parallel design (Creswell & Clark, 2018) was used to explore the effects of the PBI global implementation on student outcomes. Quantitative and qualitative data were collected concurrently throughout the project, analyzed separately, and then merged together for a coherent understanding of the data (Creswell & Clark, 2018).

Context

The PBI global was conducted over two-weeks with 9th grade students at an early college high school (ECHS) in the southeastern US. Students studied how sustainable energy sources could be used to provide clean water in areas that lack access. They were expected to design a sustainable energy device to clean the water used in underdeveloped countries. They learned about the research process, through their study of statistical design in math class, research and writing in social studies, and the iterative process of product development in science class. Further, they shared their solutions at a public virtual showcase and through a school-wide Twitter account.

Four 9th grade teachers led the implementation of the PBI global project. The teachers each taught a different subject (math, science, social studies, and Spanish), complementing the interdisciplinary nature of the project. Due to the COVID-19 pandemic, all project activities and data collection were conducted virtually with each student, teacher, and researcher joining the class sessions via Zoom from their own residence.

Participants

There were 50 students from ECHS who participated in this study. During the period of this study, the school was located in an urban community and had 248 total students with 15% of the students receiving free and reduced-price lunches. Further, 50% of the students were first generation college students.

Data Sources and Analysis

Quantitative data

Before and after implementation of the PBI global, students completed a 19-question content knowledge assessment with items provided from the American Association for the Advancement of Science (AAAS) 2061 science assessment item bank (AAAS, 2018) and the national assessment of educational progress (NAEP) question tool (NAEP, 2018). The AAAS 2061 science assessment item bank has strong content validity, construct validity, and ability to diagnose misconceptions make it a valuable resource for educators. The rigorous psychometric testing ensures that items are reliable, unbiased, and predictive of broader science understanding (DeBoer et al., 2014). Similarly, the NAEP questions tool provides a valid and reliable set of assessment items that have undergone extensive psychometric testing, fairness reviews, and alignment with educational standards (National Center for Education Statistics, 2018).

The assessment contained twelve water and seven energy items and one item asking about their confidence in their own knowledge of water and sanitation. Students were given assessment sub-scores for water and energy and then a total content knowledge assessment score. For the student content knowledge assessment, students were given one point for each correct answer, so the maximum assessment score was 19 on the total assessment, with maximum sub-scores of 12 for the water portion and seven for the energy portion. Paired t-tests were conducted to see if there were any significant differences in students' knowledge of water, energy, or the combined assessment between the pre-assessment scores and the post-assessment scores. The Cronbach's alpha for our assessment is 0.76, which indicates an acceptable degree of internal consistency (Nunnally, 1978).

Students also completed the MUSIC model of academic motivation inventory (MUSIC Inventory) middle/high school student version (Jones, 2017), which measures motivation related to classroom instruction. The MUSIC survey measures constructs recognized to influence motivation and engagement: eMpowerment, usefulness, success, interest, and caring. The MUSIC Inventory was given pre- and post- implementation and consisted of 18 six-point Likert scale items ranging from "strongly disagree" to "strongly agree." For the MUSIC Inventory, a paired t-test was performed on the total score, as well as the five constructs that MUSIC was designed to assess. Thus, students' feelings of empowerment, usefulness, success, interest and caring were analyzed by taking an average of the questions written to represent each construct, as designated by Jones (2017).

The MUSIC Inventory has been extensively validated through multiple studies, demonstrating strong content, construct, criterion-related, and reliability evidence. Content validity is supported by its theoretical foundation in well-established motivation theories and expert review (Jones, 2009). Construct validity has been confirmed through exploratory and confirmatory factor analyses, consistently showing a five-factor structure that aligns with the model's core components (Jones et al., 2014). The inventory also exhibits convergent and discriminant validity, as its subscales correlate with related motivation constructs while maintaining distinctiveness. Furthermore, criterion-related validity is demonstrated by significant relationships between MUSIC scores and key academic outcomes, such as engagement, persistence, and achievement (Jones & Skaggs, 2016). Reliability analyses indicate high internal consistency (Cronbach's alpha > 0.80) and strong test-retest reliability, supporting the measure's stability over time (Jones et al., 2014). The MUSIC Inventory has also been validated across various educational levels and cultural contexts, confirming its generalizability and cross-cultural applicability (Jones & Skaggs, 2016). These findings suggest that the MUSIC Inventory is a psychometrically sound instrument for assessing students' motivational perceptions in learning environments.

Qualitative data

The research team conducted semi-structured focus group interviews (**Appendix A**) with two groups, group 1 with five students and group 2 with six students, before and after engaging in the PBI global. The focus groups helped to provide a variety of insight into the students' perceptions of what they learned and how motivated they felt (Wilkinson, 1998) while engaging in the project. The teacher team selected students that they believed would be willing to share in a focus group and would enjoy the focus group experience, in an attempt to minimize any one person dominating the conversation (Smithson, 2000). The students represented a cross-section of the project groups (eight of 13 groups had focus group participants), which contributed to the diversity of the experiences described. The focus group interviews were conducted via Zoom, due to the COVID-19 pandemic, and were video and audio recorded.

Two researchers conducted the interviews simultaneously during a convenient time for the students to miss class activities, as determined by the teachers in the study. The students remained with the same interviewer from pre- to post-focus group interview to maintain consistency and group rapport. The interviewers facilitated the discussion using a semi-structured interview protocol of about twelve open-ended questions, adjusting questions as needed to preserve the flow of the conversation (i.e., skipping questions when they had already been answered in a previous question).

The Zoom transcription software converted the recordings into transcripts, which were cleaned for the purpose of coding. Two researchers participated in a training session with the codebook, which was previously developed by the research team (Spires et al., 2022) and developed via open coding (Saldaña, 2009; Strauss & Corbin, 1990). Then, they coded a random sample of 20% of the semi-structured interviews and achieved inter-rater reliability with a Krippendorf's alpha of 0.807. The two researchers met to reconcile differences and define any new codes that they felt were necessary to define the data. After achieving reliability, reconciling differences, and defining the new codes, the researchers divided up the remainder of the data and coded it separately.

Merging

After separately analyzing the quantitative and qualitative data, it is important to merge the results to compare the two data sets (Creswell & Clark, 2018). To merge these data, the significant quantitative findings were compared to the qualitative themes. Instances of student quotes that highlight a significant quantitative finding with a qualitative theme are presented and discussed to further answer the research questions.

RESULTS SUBSTANTIATING THIS RESEARCH

Quantitative Results

Students showed significant growth in science content knowledge on items pertaining to water (t_{47} = -2.66, p = 0.005, n = 48) and a non-significant increase on energy items (**Table 1**). Further, on average, students scored significantly higher on their total test score from pre- (μ = 13.00) to post-assessment (μ = 15.42) (t_{47} = -5.39, p < 0.001, n = 48). On a survey item asking them how knowledgeable they were about global water and sanitation students felt more confident in their knowledge of water and sanitation after participating in the PBI global (t_{47} = 5.93, p < 0.0001, n = 48).

Table 1. Pre- and post-means (standard deviation) on the MUSIC and content knowledge measures

Content knowledge	Pre-assessment mean	Post-assessment mean
Water*	8.44 (3.13)	9.67 (1.97)
Energy	5.62 (1.16)	5.69 (1.26)
Total**	13.00 (3.76)	15.42 (2.80)
MUSIC construct	Pre-survey mean	Post-survey mean
eMpowerment*	4.42 (0.75)	4.78 (0.60)
Usefulness	4.53 (0.90)	4.25 (0.94)
Success	5.05 (0.73)	4.75 (0.79)
Interest	4.22 (1.01)	4.33 (0.96)
Caring	5.51 (0.56)	5.34 (0.53)

Note. Indicates a significant increase from pre- to post-assessment at *p < 0.005 and **p < 0.001

Paired t-tests across the five MUSIC constructs showed only one significant result from pre-survey to post-survey. A paired t-test from pre-survey (μ = 4.42) and post-survey (μ = 4.78) showed that students had a statistically significant increase in empowerment after participating in the PBI global (t = 2.85, p = 0.0038, n = 44). The MUSIC inventory measures eMpowerment, defined as whether students feel as if they have control in their learning environment (Jones, 2017).

Overall, the quantitative results showed that after the PBI global students had higher content knowledge of water and felt more empowered over their learning after the experience.

Qualitative Results

To answer the second research question, results related to motivation and engagement are presented, based on three themes that emerged from the student focus groups:

(1) collaborating during the pandemic,

(2) motivation through sharing their ideas, and

(3) motivation to learn STEM content to solve global problems.

Collaborating during a pandemic

Before the project began, students expressed excitement about (11.76% of comments) and concern over (12.83% of comments) working with other students on a project in the midst of virtual learning. They were excited to do this project in teams because, as one student stated, "working with groups motivates me a lot more than working on my own." Another student added, "combining your ideas together [allows you] to create a better idea that neither person could think of on their own." However, they did anticipate challenges with the teamwork experience, such as "having conversations over Zoom it's really difficult to pick up like I said earlier, like cues of like when you should talk, or like when another person is about to talk," more easily getting "distracted like, with your phone and then with your friends, and you know, like taking pictures and stuff like that," or "just [having] miscommunication and just not everyone on the same page."

After the project was over, students shared that, although there were some challenges collaborating with others virtually (6.07% of comments), overall their group was incredibly supportive in producing a quality project (15.39% of comments). For some groups, a specific student stepped up and was particularly helpful in moving the project forward: "one of our group members was super organized … she would send out an email every single day basically telling us what we had to do for homework." Other teams described a general synergy in their collaboration, like "we didn't really have any issues with deciding anything; we were all kind of open to whatever so if somebody would propose an idea like or [if] anybody preferred something [the rest of] us would go along with it."

Reflections on their collaboration show that students appreciated the opportunity to work in groups during the isolating experience of learning at home through the COVID-19 pandemic. While some students wished that they could have picked their teams, others enjoyed their assigned teams. For example, one student noted, "it was nice working with people, especially since we are really don't know each other that much between our circumstances, so it definitely ... gave me the chance to meet more people and work with them". Another student stated,

> this is gearing [us] up for the real world, where you would have to work with coworkers or other contractors from different like companies and you might not know them or like you might be like across the world we're supposed to work together and still solve whatever complicated question or problem you guys are trying to solve.

Students understood it was important to collaborate with their peers and be exposed to working with peers they had not previously worked with. Given the project took place during the pandemic, they had fewer interactions with their peers prior to the project and the PBI global experience facilitated them getting to know, and collaborate with, new peers in their class.

Motivation through sharing their ideas

Producing a quality project was important to students. Before the project, there were a few times that students mentioned being motivated by the showcase (3.74% of comments), but after the project, 22.71% of their comments revolved around preparing to present quality work they would be proud of. A few students even said they would not have worked as hard or done as well had they only been presenting to the class or the teacher: "Oh yeah, I wouldn't have practiced at all." Preparation for this showcase was also different for them because they had to do both a formal presentation and an informal poster session, as the following student explained:

> I've had a couple of, like, showcase opportunities … [but we] just put up our poster board and then they'll just leave it there for people to walk around … but here we have to explain it, and then we have to answer the questions we had, and we had to have knowledge on every single piece and on, you know, what questions might we expect.

Thus, they had to draw upon a deeper understanding of the information to prepare for the question and answer aspect of the showcase in addition to preparing for the formal presentation.

The students also expressed pride over how well they did sharing their ideas with people outside of their classroom. For some of the students, this pride was in the general sense that their team did well on the project. For example, one student shared:

> I think we did really good with that aspect [presenting at the showcase] and the Twitter account, like everyone kept up with it which really helped and everyone like had a lot of creative ideas for what we could put on our Twitter account as well.

Another student said that "it was a very high workload that, to me, made it kind of more satisfying once we finished … [and the audience] saying that it was good … just makes me feel like I accomplished something." For other students, their feelings of accomplishment were more specific. For one student, this manifested in the way that their creativeness in the choice products "helped the audience understand what [they] were trying to do [in terms of] our goals for nuclear dissemination." For another student, getting "multiple chances to present our information to different groups of people who kept coming in" helped them practice calming their nerves to present more slowly. Taken together, this highlights how students were motivated to share their ideas in the public showcase and through their Twitter posts. Students took pride in sharing their solutions and the act of having to share their solutions publicly pushed them to think more deeply about their solutions.

Motivation to learn STEM content to solve global problems

Students were also motivated by the content of the project. In the pre-focus groups, they talked a lot about finding solutions and learning about global problems (15.44% of comments). For example, one student said, "I just want to learn about the different types of solutions that are already out there, [as well as] creating some of my own, if I get any ideas." In contrast to a typical school experience, in which grades are often one of the primary driving factors, this project's context in and of itself was motivating to students, as the following student quote readily captures: "But I'm also motivated when I'm doing something that's, not just for like a grade or for a number, and I know it's actually going to have like application to real world problems." The students were excited to learn about the global problems of clean water and sustainable energy and then had the opportunity to design solutions to those problems.

During the post-focus group interviews, the students expressed that they did find solutions to ongoing global issues by both analyzing solutions that already exist as well as imagining solutions that could exist. They were inspired by the experience, saying: "I learned about renewable energy and how we have so many different solutions that could possibly work, but if we are just all work together, we [can make] some really good stuff". This project also motivated students to want to keep working on these problems. One student stated, "I'm hoping to maybe have a solution that could really help the world or be useful," and another claimed, "I want to, you know, bring this up to somebody who can actually do something about it and give some of the solutions that, you know, some of my peers found." During this project, students used their new knowledge of water, sanitation, and sustainable energy options to creatively address inequalities in the world and wanted to keep going. As one student put it, "finding out things that are unfair for other people kind of lights a fire in me."

Merging Results

The quantitative data showed students had significant increases in their content knowledge of water topics and felt more empowered following the PBI global experience. This section presents student quotes to further detail the relationship between these significant quantitative findings and the qualitative themes. For example, to unpack the significant finding related to feelings of empowerment, it is important to note student empowerment comes from the freedom to choose what they learn about and how they learn it (Jones, 2017). Students explained that PBI global was more empowering for them than other teaching strategies because; for example, one stated:

> PBI global cut out like the part where the teacher lectures us and we had to like go off and find out on our own. We all had to basically start from the bottom and then research and then look through like what this question was about and like how we can answer it. So this is really more of a hands-on approach for, like, the students, where we have to do the research ourselves and then build up our knowledge, instead of having a teacher, to give us, like, a baseline knowledge of the stuff.

This quote highlights how feelings of empowerment, through having autonomy to conduct their own research, helped strengthen their knowledge about the science they were learning.

Further, students' motivation to learn STEM content to solve global problems helped them increase their content knowledge related to water. One student stated, "I would say that this project has really opened my mind to renewable energy and the water problems and the water crises that are happening around the world." This increased motivation led students to want to learn more. For example, in the post focus group, one student stated, "I want to learn more about, just like, water in general. I've done projects in the past about how to make water more sanitary in different countries, and this project really put it in perspective for me."

Students also recognized how collaborating during the pandemic helped increase their knowledge of science and how they were proud to share that knowledge publicly. A student stated:

> I think it was cool to be able to figure out what we could do, even though it is a pandemic like being able to find new ways to come up with solutions rather than just building them ourselves, but like spreading the word through, like, the Gallery Walk.

This quote highlights how the students felt like they learned, even though the entire project was completed during the pandemic.

Students' empowerment was shown to quantitatively increase, which students expressed relating to all three qualitative themes: collaborating during the pandemic, motivation through sharing their ideas, and motivation to learn STEM content to solve global problems. First, empowerment increased as they worked through the project online. A student noted, "I also wanted to add that was cool because I've never done a great little project ever, and [this was] over zoom." This student was really proud of what they accomplished virtually during the project. Second, students were empowered and motivated by what they accomplished. A student explained:

> If we actually think and put our minds together, we could do something, because over the past two weeks, all of us are, as ninth graders, we created solutions to the problems, which means it could be solved by really anybody.

Finally, students were empowered and motivated to solve global problems. A student noted:

> This definitely made me more aware and it's actually kind of like made me think about if I want to get into any environmental groups to try to actually solve this problem and take it one step further than making a project about it, I don't want, you know, to forget about this water crisis that's going on, I want to keep on working towards learning more about this whole entire world problem, including America.

This quote highlights how the student's awareness of the water issues empowered them to learn new STEM concepts to come up with solutions to problems related to the global water crisis.

DISCUSSION

The learning process requires students to be actively engaged, and every student deserves the opportunity to learn. However, according to Tal et al.'s (2005) study of science teachers attempting to use PBL in an urban area, when the circumstances of teaching become overwhelming, teachers resort to passive, whole-class learning techniques, which they say was classified as the pedagogy of poverty. This study provides a direct contrast, heightened by occurring during the COVID-19 pandemic, that the PBL approach provided opportunities for students to be active participants in the learning process. Students felt empowered and motivated by having a choice in the topics that they studied, in the global problems they worked on to understand and solve, and in working collaboratively to create a solution to the problem they chose.

This PBI global project, centered around sustainable energy sources used to provide access to clean water, engaged students in learning specific STEM content similar to the inquiry-based project utilized by McCright (2012). Similar findings between this research and that of McCright (2012) include students in both research studies improving their content knowledge and demonstrating an increased motivation to solve global problems. It is important that students in this study demonstrated growth on disciplinary content while engaging in the PBI global project, since often the pushback from educators not wanting to try PBL is based on not having enough time for students to learn the content (Krajcik & Blumenfeld, 2006).

The importance of student engagement in STEM disciplines is well documented (Connell et al., 1994; Finn et al., 1995; Marks, 2000). This study furthers previous research by studying student engagement in an interdisciplinary STEM project occurring entirely during virtual learning utilizing mixed methods of research. There is emerging research supporting the use of PBI global in virtual settings (Himes et al., 2023; Spires et al., 2021) and strong support of its use in cross-cultural exchanges (Spires et al., 2018a, 2018c, 2023). Findings from this study supplement a growing body of research around the challenges and inequities of virtual teaching (Huck & Zhang, 2021; Kaufman & Diliberti, 2021; Leech et al., 2020), by highlighting how students worked collaboratively to overcome the challenges of learning while apart. This research shows the potential PBI global has to empower students to solve messy real word problems as they harness new STEM content knowledge.

Implications

This research has implications for practitioners and researchers. First, for practitioners, the findings from this study offer important implications for educators seeking to enhance student engagement and learning in STEM disciplines. This research provides a compelling counterpoint to direct instruction, by demonstrating that PBI global fosters active learning, even in virtual environments. The study highlights how students, when given autonomy in selecting global challenges and designing solutions, become more motivated, engaged, and invested in their learning. This is particularly relevant for educators hesitant to implement PBL due to concerns about content coverage and instructional time. The demonstrated growth in disciplinary content knowledge among students suggests that PBI global can effectively integrate rigorous STEM learning with real-world problem-solving, offering a viable alternative to traditional instructional methods.

For researchers, the virtual implementation of PBI global in this study also highlights the need for continued research on effective digital collaboration strategies and on the importance of evolving research techniques to collect data in non-traditional instruction settings. It is imperative that the research community understand and study learning in virtual settings, as the prevalence of online learning is only going to increase overtime. Additionally, researchers are going to have to address inequities in online learning, so this research is an initial step at exploring learning in these online environments.

CONCLUSION

Students demonstrated heightened motivation throughout the project and enjoyed being able to make connections across disciplines. As one student noted the interdisciplinary benefits included working on "all the different classes together, because a lot of the times you take one class and the others you are taking are completely separate; you don't really get any sense of how they relate to each other at all." Students attributed these relationships to the ability to choose their topic, the ability to choose their resources, and the opportunity to share with a public audience. Furthermore, this study highlights how students developed empathy for people and situations in other parts of the world which, for many students, intrinsically motivates them to find, adapt, and create solutions to the problems that they are learning about. Students also see how these complex problems are not only connected to but also rely on each discipline that they have been studying in school.

In the remote learning environment due to the COVID-19 pandemic, teachers had noticed a decrease in motivation and engagement and worried that students would struggle to collaborate remotely on an open-ended project. However, the students reported this type of learning helped them feel motivated. Our findings suggest that PBI global, even in a virtual environment, can increase students' content knowledge and engage them in authentic problem solving of global issues.

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APPENDIX A: INTERVIEW QUESTIONS

Semi-Structured Focus Group #1 (Pre)

1. What are your personal goals for the upcoming PBI global?
2. What types of activities tend to motivate you to learn in school?
3. What challenges do you face when trying to use technology in the classroom?
4. What do you know about the UN sustainable development goals?
5. What do you know about the PBI global topic of clean water and sanitation?
   a. What do you know about the topic of energy?
   b. What more do you hope to learn this semester?
6. What benefits (if any) do you see in collaborating with your peers on this topic?
7. What challenges or obstacles do you think you will encounter during PBI global?
8. What are you looking forward to most during PBI global?
9. Do you have anything else you would like to share?

Semi-Structured Focus Group #2 (Post)

1. Were your personal goals for PBI global met and how?
2. What challenges or obstacles did you face during PBI global?
3. What technologies did your team use during PBI global?
4. How did PBI global foster cross-school understanding among your teammates?
5. With what phase(s) or aspect(s) of the PBI global process did your team most struggle?
   a. Designing your compelling question
   b. Gathering and analyzing sources related to the topic of your compelling question
   c. Creatively synthesizing claims and evidence to respond to your compelling question
   d. Critically evaluating and revising your products
   e. Sharing, publishing, and acting
6. With what phase(s) or aspect(s) of the PBI global process did your team most excel?
   a. Designing your compelling question
   b. Gathering and analyzing sources related to the topic of your compelling question
   c. Creatively synthesizing claims and evidence to respond to your compelling question
   d. Critically evaluating and revising your products
   e. Sharing, publishing, and acting
7. What did you learn from participating in the showcase?
8. How did planning for the showcase affect the quality of your final products?
9. How would you describe the quality of your team's final PBI global products?
10. Is there anything you would do differently the next time you engage in PBI global?
11. What was the most important thing you learned through your inquiry?
12. Do you have anything else you would like to share?

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