An Integrated Project-Based Methods Course: Access Points and Challenges for Preservice Science and Mathematics Teachers

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Abstract

Two instructors in a secondary preservice teacher preparation program address the need to better prepare future teachers for the increasing role project-based learning has taken on in K-12 education. We describe an integrated instructional planning course where a mathematics educator and a science educator collaborated to teach preservice teachers how to design integrated project-based lessons. We found that the preservice teachers valued the integrated approach but had difficulty translating their learning to practice in traditional, clinical-based field placements. We report on recommendations for future course iterations.

Introduction

It has long been understood that our abilities to transfer knowledge to new situations depend on the context in which the knowledge was acquired (Barab, 1999; Boaler, 2002b, 2016; Dewey, 1939). As the nature of jobs continue to change, there is a greater recognition that educational systems must also adapt to keep pace with shifting job markets (Markham, Larmer, & Ravitz, 2003; Pink, 2005) and changing understandings of the skills that will be required by the demands of the 21st century (Bell, 2010; Partnership for 21st Century Learning (P21), 2009; Pink, 2005). Recently, reform efforts have responded to this shift by redesigning the school experience around learning contexts that promote 21st century skills (Partnership for 21st Century Learning (P21), 2009). As state and national organizations continue to advocate for instruction that emphasizes conceptual understandings, connections, and problem solving (Berlin & Lee, 2005; National Council of Teachers of Mathematics (NCTM), 2000, 2014; NGSS Lead States, 2013; Virginia Department of Education (VDOE), 2016, 2017)—particularly in mathematics and science—it is becoming even more essential that teacher preparation programs reconsider how they are preparing graduates to teach within this new educational landscape.

Interdisciplinary science and mathematics education may support calls for preparing students for a workforce that demands the application of diverse content and skills to solve challenging problems and design innovations (McDonald & Czerniak, 1994). These transferable connections between disciplines allow for real-world applications and transcend the fragmentation that occurs when subjects are taught in isolation (Hough & St. Clair, 1995; NCTM, 2014). Learning in this manner may simultaneously increase student achievement, autonomy, and motivation—and result in deeper, more connected learning (Barab, 1999;

Berlin & White, 1994; Hough & St. Clair, 1995; Huntley, 1998; McGehee, 2001). Researchers have found that interdisciplinary STEM teaching has been shown to positively affect student attitudes and interests in these subjects (Berlin & White, 1994; Yasar, Maliekal, Little, & Veronesi, 2014).

Despite benefits for K-12 students, many teachers experience apprehension when being tasked with connecting mathematics with science in interdisciplinary teaching due to little to no experience with this type of learning (Frykholm & Glasson, 2005). Research suggests that when preservice teachers (PSTs) are prepared within mathematics and science interdisciplinary collegiate teaching methods course(s), they value interdisciplinary teaching and are more likely to emphasize content integration (Frykholm & Glasson, 2005; Koirala & Bowman, 2003). Thoroughly integrating science and mathematics education is challenging (Huntley, 1998), but can be paired with inquiry-based methodologies—such as project-based learning (PBL)—to foster sustained integration.

PBL has been defined in a myriad of ways (e.g., Blumenfeld et al., 1991; Krajcik & Blumenfeld, 2006; Markham, Larmer, & Ravitz, 2003; Moursund, 1999; Thomas, 2000). For the purpose of this article, PBL will be defined as "a teaching method in which students gain knowledge and skills by working for an extended period of time to investigate and respond to an authentic, engaging and complex question, problem, or challenge" (Buck Institute for Education (BIE), 2018d, para. 1). Utilizing PBL as an instructional framework may reinforce content integration as it highlights the partnership between knowledge and its application (Markham, Larmer, & Ravitz, 2003). Students who learn through PBL approaches are found to efficiently construct and connect knowledge concepts (Blumenfeld et al., 1991; Boaler, 2001; Braden, 2002; Larmer, Mergendoller, & Boss, 2015) which can then be transferred outside of the classroom (Boaler, 2002b; Krajcik & Blumenfeld, 2006).

Moreover, PBL has been shown to provide more equitable instruction to students across socio-economic classes (Boaler, 2002a), and to lower-achieving students (Han, Capraro, & Capraro, 2014). Secondary students who learned through project-based methodologies demonstrated increased engagement (Braden, 2002; Merlo, 2011), motivation (Bell, 2010; Boaler, 2002b; Krajcik & Blumenfeld, 2006), independence (Yancy, 2012), and an awareness of educational purpose (Larmer et al., 2015) compared to those who learn subjects independently. For example, longitudinal comparative studies find that high school students who learned through PBL had higher mathematics and science gain scores, increased problem solving abilities, had higher levels of enjoyment of mathematics, and completed more advanced mathematics courses than students learning through non-PBL approaches (Baran & Maskan, 2010; Boaler, 2002b; Boaler & Staples, 2008).

Although PBL does not require the use of interdisciplinary partnerships, researchers find that mathematics and science PSTs who are trained to teach through interdisciplinary PBL approaches are able to communicate real-life applications to students (see Wilhem, Sherrod, & Walters, 2008). Further, interdisciplinary PBL training of PSTs increase efficacy in content and pedagogy (Frank & Barzilai, 2004). While more research is needed on the effect size of PBL as an instructional approach, Hattie, Fisher, and Frey (2017) found that numerous components of interdisciplinary PBL instruction (e.g., formative evaluation, feedback, goals, concentration, persistence, engagement, second/third chance programs, cooperative learning, integrated curricula programs, inquiry-based teaching) have positive effect sizes in relation to their impact on student achievement. Given the research-based support and positive outcomes of both interdisciplinary STEM teaching and PBL, we merged these two approaches to implement an interdisciplinary mathematics and science methods course for secondary PSTs that utilized the PBL framework described above. This work describes the outcomes of its pilot implementation.

Context

This instructional methods course was part of a one-year teacher preparation program at a liberal arts university in the mid-Atlantic region. Prior to this pilot study, there were two sections for secondary mathematics and science PSTs, respectively, in which PSTs engaged in aligning national and state standards with instructional strategies and appropriate assessments. In the mathematics course, PSTs planned and implemented lessons aligned to state standards as well as those put forth by the National Council of Teachers of Mathematics (NCTM, 2000) while learning about various instructional theories, manipulatives, and instructional models. Similarly, the science planning course required science PSTs to develop 3-dimensional (NGSS, 2013), 5-E lessons (Bybee, 2009) that utilized the NGSS science and engineering practices in relation to disciplinary core ideas and performance expectations. The respective courses were required for science and mathematics majors who were pursuing licensure in secondary science or mathematics teaching and occurred before a 10-week, full-time clinical field experience (e.g., student teaching). This study describes how an interdisciplinary planning course was designed, the initial implementation of this course, and how PSTs utilized and perceived this experience. Prior to this experience, the mathematics and science PSTs had few opportunities to plan and teach together.

The interdisciplinary course was developed as part of a university teaching fellowship that the science educator participated in to diversify innovative experiences and non-traditional teaching approaches for university students. The science educator collaborated with the math educator to co-construct an opportunity for preservice math and science teachers to reflectively apply their skills and knowledge about co-teaching science and math in a PBL course. The instructors designed the course to build on the aforementioned students' knowledge and experiences in their disciplinary-specific methods course that they had completed the previous semester.

The interdisciplinary course was designed to build on these understandings and refine PSTs' ideas about teaching, co-designing math and science curriculum using technology and engineering design for students to investigate science and math problems, adapting instruction for the diverse needs of learners, developing inquiry-based lesson plans, working collaboratively, and engaging in sustained reflection throughout the course. Further, the instructors aimed to facilitate horizontal alignment and instructional collaboration between future teachers in science and mathematics. This goal is in accordance with the Virginia Mathematics Standards of Learning Framework (2009) which states that “science and mathematics teachers and curriculum writers are encouraged to develop mathematics and science curricula that reinforce each other” (p. v). Related to these goals, the instructors required preservice teachers to co-design an integrated science and mathematics unit that incorporated technology and adaptations for diverse learners.

Participants

A total of nine secondary PSTs participated in the interdisciplinary mathematics and science planning course, seven of whom would receive a license in a science teaching discipline, one who would receive a mathematics teaching license, and one who intended to be certified in both disciplines. Seven of the PSTs were pursuing their master’s degree in secondary education, and two undergraduates were working towards their secondary teaching license. The instructors of the course were the co-authors, one a math specialist and a Ph.D. student in Educational Policy, Planning, and Leadership, with vast experiences in project-based and inquiry-based curriculum design and implementation, and the other a professor of science education within the university with over a decade of experience supporting inservice STEM teachers and working on interdisciplinary and culturally responsive engineering designs that are used to inform teacher practice.

Description of Participant Experiences

In an effort to introduce the students to PBL and provide them with a foundational understanding of how PBL can be integrated into classrooms, PSTs observed PBL in action during their discipline-specific methods course the previous semester. These observations took place in a local high school that has partnered with the university. University faculty, including the science educator, worked closely with teachers in the local school to design and implement best practices in interdisciplinary teaching and PBL. Thus, the teachers that PSTs observed were innovative, vetted, and thoroughly immersed in professional development being delivered by institutional faculty. All students observed an interdisciplinary PBL-based physics and algebra class as well as a ninth-grade history-english class. These observations were arranged by the instructors, who accompanied the PSTs during the observations, and were followed up with classroom discussions to ensure that all PSTs had a chance to critically analyze and reflect on both the successes and challenges of PBL. As these observations preceded our instructional planning course, students entered the course with an understanding of how interdisciplinary PBL differed from traditional projects—a distinction we were keen to highlight from the start. Moreover, the PSTs came in with an understanding of how the shift to inquiry-based learning can transform classroom climate and classroom dynamics. Finally, the PSTs entered with an understanding of some of the struggles related to the implementation of PBL and were, therefore, expected to address many of these through the use of rubrics and standards-based intended learning outcomes.

The expectation of the instructional planning course was that the PSTs would work in interdisciplinary teams to develop projects that would engage secondary students in authentic learning (e.g., projects analyzing the impacts of real-world problems such as sea level rise in the local community). Three teams were created around areas of common interest. The first team included two PSTs who had backgrounds in chemistry, one of whom was seeking dual certification in mathematics. The second group included four PSTs—one PST with a mathematics background and three of whom had completed their major in environmental studies. The third group included three PSTs, all of whom had chemistry backgrounds and one of whom had a background in biochemistry as well. Ideally, we would have had more math PSTs in the course, which would have allowed us to make the groups more interdisciplinary. However, as that was not the case, we mitigated the problem by providing all groups numerous opportunities to consult with the instructors and other mathematics and mathematics education faculty members (as discussed later in the manuscript).

The instructors began the course by providing PSTs with a background into the research and history of PBL in order to allow them to ground their aforementioned observations in context and research. This was accomplished by incorporating selected readings (see Appendix A), presentations, and discussions—such as one focusing on the benefits and challenges of PBL-into the course. The instructors also required PSTs to read *Setting the standard for project based learning*, by Larmer, Mergendoller and Boss (2015), and engage with curriculum, resources, planning guides, and the “gold standard” PBL framework put forth by the Buck Institute. “Gold standard” PBL is a term coined by Larmer et al. (2015), and is comprised of eight research-based characteristics that support high-quality PBL: A focus on standards-based content and success skills, a challenging problem or question, sustained inquiry, authenticity, student voice and choice, reflection, critique and revision, and a public product. This framework scaffolded the design process for the PSTs and provided them with a common understanding of what high quality PBL is, and how to plan and structure effective PBL units. These resources were then supplemented with several banks of curated articles and support documents related to interdisciplinary education, project-based learning, collaboration, and on the effective use of rubrics in assessing student collaboration, communication, and learning (see Appendix A). These resource libraries were designed to allow PSTs to access resources as needed for support during the planning process.

After establishing a common understanding of the necessary components of high-quality PBL, PSTs were assigned the task of designing a PBL unit within their interdisciplinary teams. Due to the daunting nature of this task for those inexperienced with PBL, the instructors provided scaffolds by breaking the process up into smaller chunks—as described below—and by providing all groups with the project design template from the Buck Institute

(BIE, 2018b). Furthermore, the instructors created a timeline of suggested due dates to allow groups to assess their progress throughout the course. The instructors met regularly with each group to provide feedback on their progress and formatively assessed PSTs throughout the course. These formative assessments were structured to provide feedback to both instructors and students by requiring various components of their units (e.g., driving questions and entry events), to be presented to the course. These presentations utilized the critical friends protocol (Bambino, 2002), thereby allowing PSTs to receive valuable critique from both peers and instructors within a safe environment.

The first task for each group was to create an authentic driving question and entry event that would engage future middle and high school students in the learning process. Our class used the definition of a driving question from Larmer et al. (2015) of “a statement in student-friendly language of the challenging problem or question at the heart of the project” (p. 92). We also defined an entry event as an intentional event planned by the teacher to stimulate student curiosity and engagement about the project topic (Boss, 2011). After receiving feedback from the instructors and peers, the PSTs used these driving questions to develop content-based and skill-based objectives for their future students that would be necessary to understand the driving question and develop well-articulated projects.

PSTs used blank calendars to align objectives to state mathematics and science standards and to include brief daily pedagogical plans for facilitating instruction. This activity was intended to have PSTs consider the pacing of their units. PSTs also included objectives to intentionally teach critical skills for PBL such as collaboration, critical thinking, communication, and citizenship (P21, 2009; VDOE, 2016) which were discussed and modeled in class and supported by providing the PSTs with copies of the rubrics from the Buck Institute (BIE, 2018e). The students created their calendars on Google Docs and instructors gave iterative feedback to support students in refining their ideas. These calendars provided an overview of their units and allowed the instructors to ensure that all intended learning outcomes were being met within a realistic pacing structure. A sample calendar from one PST group has been included in Appendix B as an exemplar of this process.

The instructors invited additional content experts to class to review entry events, driving questions, real-world connections, and to probe the PSTs to consider or reconsider strategies for building students’ skills. For example, a former practicing engineer and a multi-certified STEM educator came to support students in more thoroughly integrating mathematics in science-driven units. PSTs additionally connected with mathematics educators at the university. Additionally, at the midpoint of the course, the class virtually connected with two PBL experts via video conference to provide feedback on project ideas and driving questions—one of whom was an author of their textbook. The experts were provided with copies of their project ideas and driving questions in advance of the meeting, and spent an hour providing feedback, answering questions, and sharing experiential advice. The instructors facilitated this by reaching out to the author via E-mail, who then invited a second expert to the video conference. These experts drew on their own experiences with PBL to share key insights into designing effective PBL units and one expert even video conferenced in from a tiny-house that his students had built for him—thus making the experience more meaningful for PSTs by providing them with a vision of what is possible. Following this experience, the groups fine-tuned their questions and projects based on their new insights. Finally, PSTs also sought input from the teachers with whom they were working within the field to understand more about pacing and best practices to develop students understanding of selected science and mathematics content and skills.

In addition to unit planning, each peer group had to teach 30-45 minutes of an inquiry-based lab activity to their instructors and peers, clearly communicating expectations for group norms, collaboration, and communication for their students. At the end of the course, students gave a presentation to the class that narrated pedagogical decisions within the unit. Each group engaged their peers in the first day of their unit, presenting their entry event, driving question, and rubric for the project. The instructors asked PSTs to explain to their peers (as fellow colleagues) the learning goals of the project, a brief overview of the project calendar and timeline, and how their project taught 21st century skills while simultaneously covering requisite standards.

The final assignment was to have students complete a modified Buck Institute Collaboration Rubric (BIE, 2018a) for each member of the group. The rubric was adapted to an online format that utilized branching to tailor the questions to each group. Every PST was required to complete the rubric by reflecting on their own contributions as well as those of their peers. Doing so not only allowed for structured reflection on how well they collaborated with their peers, but also allowed for more holistic grading as these rubrics were then coupled with the project rubric to determine the final grades for each individual.

Data Sources and Analysis

The project design rubric from the Buck Institute (BIE, 2018c) was used to assess the quality of the three interdisciplinary PBL unit plans. The unit plans allowed us to see how PSTs operationalized this rubric to plan a small math and science project for future students. Data on the quality of the created units was generated by assessing the units and their subsequent presentations. Applying the Buck Institute Design Rubric (BIE, 2018c), we specifically assessed the following criteria: the inclusion of key knowledge and skills, a challenging, open-ended driving question that would allow students to look at myriad considerations in answering the driving question, multiple inquiry-based activities included in the unit that guide the understanding of the question and the development, the authenticity of the project in terms of its relevance to students' lives within the contexts of their clinical field placements, the incorporation of opportunities to elicit student reflection into the unit, and opportunities for peer critiques and revisions.

Following the final presentation of the unit, PSTs formally reflected upon how the course prepared them to plan and teach through interdisciplinary, project-based learning, as well as their perceptions of the strengths and weaknesses of the newly revised interdisciplinary teaching methods course. We followed-up with PSTs again approximately one year after the completion of the course. Students' responses were read and discussed by both instructors. Each author applied *in vivo* codes (Creswell & Poth, 2018) to understand students' perceptions of the course. The authors compared codes to ensure that all students' experiences were accounted for. The codes were sorted into categories representative of course design, course implementation, and preparation for classroom teaching content. Two themes emerged across each category including "personal meaning and values in course learning outcomes" and "efficacy and practicality of PBL implementation." These themes guided the discussion of students' perceptions of the course, and key quotes were selected and presented within the "reflections from PSTs" section of this article to represent students' perceived strengths and weakness of each theme. The authors elaborated upon quotes with observations that were documented throughout the course, specifically during group presentations, individual meetings, and the rationales of final products.

Quality of Interdisciplinary Projects

The three project units all focused on key knowledge and understandings that were aligned with clear standards-based learning outcomes, thoroughly integrating mathematics and science. All projects contextualized their projects through current issues taking place locally or in the media—organic products in grocery stores, water quality as it relates to health, and global warming. Here, we describe briefly the three units, areas of strengths, and areas that could be improved in terms of their alignment to the BIE Project Rubric (BIE, 2018b).

The first group created an integrated chemistry and personal finance project that focused on organic farming to teach standards related to bonding types, the use of lab equipment, the relationships between chemical properties and biochemistry, the economics of product pricing, advertising and decision making, the life functions of bacteria, protein synthesis, and the principles of scientific investigation. PSTs created the driving question of, "Should people in your community buy organic or traditionally farmed food?" PSTs planned for an opening peer-debate on students' preconceptions of organic and inorganic foods. The PSTs showed how they would explicitly teach students to debate, teaching the skills of having to communicate and critique ideas related to organic farming. The PSTs developed research and inquiry-based activities for students to investigate the sources of organic and traditional foods in their neighborhoods, consider the extent to which genetic modification has played a role in the farming of these foods, and analyze the intended and unintended outcomes stemming from the use of antibiotics, pesticides, and bacterial growth. These labs were open-ended enough to allow for student voice and choice, but would have benefited from the intentional incorporation of time for students to reflect on their findings, reflect on the relevance of these findings to the driving question, and to critique and revise their work. The culminating experience of the unit was a presentation to members of the community and a mini-research paper.

The second group integrated chemistry, algebra II and English to address content standards related to solution concentrations, solubility curves, acids and bases, titrations, creating and conducting experiments, analyzing data, graphing and analyzing exponential and logarithmic functions, and persuasive writing. The group asked, “what are the actual differences between different types of water we drink?” Although this question is relevant to the lives of high school students who drink from water fountains at school, the question may have benefited from being modified into be more open-ended. The entry event demonstrated the Tyndall effect and compared water from the school fountain with a store-bought bottle of water. Students were then expected to assume the role of scientists by collecting water samples from various sources throughout the school and conducting several labs including creating their own purified water and determining the pH levels of water from different sources. Although these labs targeted key learning outcomes, they were structured with a degree of rigidity and with a narrow focus that limited the amount of student voice and choice, the intensity of the sustained inquiry, the amount of productive struggle (NCTM, 2014) that was encouraged, and the degree to which students would be able to critique and revise their work.

Finally, PSTs ended their unit with a jigsaw activity where students assessed the impacts that water quality can have on economic, health, and environmental considerations. Ultimately, students would share their purified water samples and then use marketing techniques to persuade their peers and school learners that their water was the best source. Throughout this process, PSTs planned for their students to have numerous opportunities to reflect on and share their findings by regularly documenting their learning on Instagram.

The final group created a unit that integrated Earth science, algebra 1, and English standards including conducting investigations, utilizing scientific reasoning, maps, the ocean, the impact of human activity on the earth, inferential and descriptive statistics, and oral presentations. These interdisciplinary standards can be seen in context in the project calendar in Appendix B and the project design overview (see Appendix C), which have been included to provide a more holistic picture of the unit. The group utilized a driving question of “how will sea level rise affect your community?” Their rationale for focusing on this topic was their belief that people are motivated to make personal changes when they are able to see the potential impact that rising sea levels will have on their own homes and communities. This topic was made authentic and meaningful for students because it was context-specific, exploring how sea-level rise affects the mid-Atlantic region in the future. PSTs engaged students by using the Maldives—a popular tourist destination which may be underwater in the coming decades. This entry event showed students how sea level rise could potentially devastate an entire nation in the near future. This sparked the impetus for local investigations of how sea level rise could affect students’ homes.

PSTs planned for their students to observe a variety of phenomena that included curated videos and images of thermal expansion and the ice caps. Additionally, students would observe and manipulate data through various modeling and mapping websites, and collect and analyze data to understand and predict the impact of sea level rise within a case-based model. The activities gave secondary students voice and choice in terms of allowing them to focus on their own neighborhoods, choose which sources they collected data from, and allowing the final presentation and infographic to be open-ended and uniquely creative. This final project and infographic was the culmination of sustained inquiry of the data, and showcased study analysis through charts, graphs, and images that displayed how sea-level rise could affect their hometowns. The PSTs planned a culminating event at which students would present their investigations and findings at a local oceanography seminar.

This project was chosen as an exemplar in part because of the intentionality the group showed in integrating key suggestions from the Buck Institute Design Rubric (BIE, 2018c) into their project. For example, as mentioned above, the groups entry event is one that would capture student attention and excitement in a way that would easily transfer to the driving question. Moreover, the group built in authentic, sustained inquiry by curating extensive lists of videos, websites, and sources of relevant data that students were then expected to synthesize and apply to a case-based analysis. Finally, PSTs planned for students to present findings at an oceanography seminar, allowing them to take on the role of scientists who are investigating this important issue. The only aspect of the project that necessitated further consideration was the degree to which independent learning opportunities were extended to K-12 students. Although several aspects of the project allowed for independent learning, we felt that more of the activities that were teacher-lead could have been more open-ended, allowing for a higher degree of student autonomy.

Reflections from PSTs

We asked the PSTs to reflect on the course outcomes immediately following the last class and then followed up with PSTs one year after the course to have them reflect on the aspects of the course that have been useful or not useful to them during their first year of full-time teaching. All PSTs wrote a reflection after the course and 5 of the 9 teachers emailed us a retrospective reflection. Following the course, students noted a more thorough understanding of what interdisciplinary PBL planning and implementation can look like. All PSTs felt more confident planning for a unit that incorporated two or more subject areas, and designing a small-scale project. Specifically, PSTs felt that the course prepared them to consider the logistics, need for communication between teachers, and pacing when implementing interdisciplinary PBL units. Moreover, the PSTs noted that the experience helped them become more creative educators and to value collaboration and peer feedback. PSTs perceived the size of the unit (2-3 weeks) as manageable, and a “great first look at the logistics of planning an interdisciplinary PBL." One of our participants looks back as a first-year sixth grade teacher and notes that the class experience helped her to understand early PBL trainings that she is required to participate in through her school district.

This awareness developed the interest of some of the PSTs to begin implementing PBL into their classrooms. For example, one PST in the course actively sought out a PBL school to teach in during the course and was hired as a first-year science teacher following graduation. Currently, she works with other teachers across disciplines to thoroughly integrate standards and skills across thematic units to develop multifaceted projects. She shares:

> Unlike most of my peers I would imagine, I teach in a school that operates through only PBL teaching, as well as mastery based grading with scientific skills, design thinking, and a set of core values. My current focus has been on building PBL projects that require students to work through several iterations using their design thinking while also developing their values. With a PBL, in my classroom, it has been less of a focus on content, but rather how you use skills to digest and interact with the content.

Other PSTs reported that they are either currently using PBL in their classrooms, using aspects of PBL to frame their instruction, or are hopeful that they will be able to use it in the future. For those who are beginning to incorporate projects in their classroom, a middle school mathematics teacher advises that "it is important to start small when first trying out PBL in your classroom… Don't try to do all of it on your own and go for a really big and complicated project first time out."

Prior to this course, the PSTs had no experience planning across disciplines, nor were they being mentored by teachers who collaborated in this way. PSTs noted the benefit of seeing the two methods instructors planning, culminating resources, and implement the course together. One PST said, "[the professors'] co-planning and organizational skills added to the overall effectiveness of the course." PSTs enjoyed working with each other. This is evidenced by a mathematics PST who stated that their "favorite part [of the course] was getting to work with the science kids and hearing the different experiences they had in the classroom so I could learn from these experiences prior to student teaching." PSTs hoped to collaborate with others in their future job, and viewed the course as "great practice collaborating with peers and different disciplines."

Our analyses also supported the conclusion that PSTs wanted to learn more about the day to day routines and methods in the classroom. Evidencing this, one student shared that the instructors did "a phenomenal job in allowing us to plan on a larger scale…taking more time to identify what a day to day looks like would be more realistic for a classroom." While we assumed PSTs felt confident in teaching methods from their experiences in the semester prior, it became evident that none of the PSTs' cooperating teachers, and few of the positions that they secured post-graduation, utilized project-based learning and the ideas taught in instructional planning were new to the veteran teachers who were mentoring the PSTs. PSTs wanted more models and “more input from teachers that have actually implemented PBL in their units before.” Additionally, the PSTs felt that the course did not adequately prepare them for the difficulties of implementing PBL within schools that have not fully adopted it. As one PST noted, “a lot was left out in terms of actually implementing [the PBL units] and the roadblocks that occur during implementation.” The PST went on to suggest that the experience “revealed the importance of a whole school culture shift and support.”

Because PSTs were not placed within PBL schools with a focus on interdisciplinary planning and teaching, they felt that the course did not align to the actualities of their clinical field placement. While PBL units included a variety of instructional models to teach content and skills necessary for a culminating project, some PSTs had difficult with the overall practicality of the course. For example, one PST shared after the course:

> While PBL mirrors the ideal teaching experience, it is not necessarily the reality of what we will be facing in our 10 weeks of student teaching. I think that the overall course was effective and useful, but I do wish that the course scaffolded our 10 week student teaching experience a bit better.

This point was similarly made by an earth science teacher who looked back on the class:

> The PBL lesson planning remained mostly theoretical and abstract. Since we were not expected to or could not implement them in our student teaching experiences, we could design the best possible PBL units—not the most realistic…Possibly designing a lesson for a school that has already made the switch to PBL rather than designing units for science classes that have had no to very little prior exposure to PBL would have been more practical.

PSTs felt that more practice developing and implementing more traditional lesson plans would have better prepared them for the normal classroom and for their current students, rather than for the ideal. One PST suggested that it would be possible to learn both PBL and traditional teaching methods if “PBL could be factored into the methods course with [the instructional planning] course focusing more on diverse teaching methods.

Despite these feelings, the PSTs valued the course and follow-up reflections suggest that they will continue to draw from their class experiences with their future students. They see interdisciplinary PBL teaching “as way of the future.” Most significantly, the teachers perceived the course with emphasizing the importance of making learning more meaningful and relevant to students. One teacher explains- “I have transferred a lot of the aspects of PBL to my everyday teaching style…Most importantly, the student directed learning, the importance of real, meaningful questions and data and impactful summative assessments.” Our practicing PBL science teacher explained that the class helped to shift her mindset from “grading on something other than content standards and the importance of that in creating well rounded students.”

Conclusion and Implications

The pilot implementation of an interdisciplinary mathematics and science PBL course produced promising outcomes that can continue to be developed through future iterations of this course. By students producing PBL unit plans, PSTs were able to conceptualize how collaborative planning can be achieved as well as interdisciplinary, real world contexts (Wilhem, Sherrod, & Walters, 2008). Importantly, the PSTs valued stepping out of their disciplinary silos and working with others outside of their expertise. The PSTs were able to observe integrating content areas in action, and many noted how integrating mathematics and science instruction enriches both content areas. Such activities are important for preservice teachers to consider what school can look like even when it is different from their own personal experiences (Frykholm & Glasson, 2005; P21, 2009).

A common challenge perceived by the PSTs during and after the course was the alignment of instructional methods courses with clinical field placements, a challenge frequently addressed in teacher education research (see Allen & Wright, 2014). Ideally, such placements would align with coursework to allow PSTs to apply new pedagogical knowledge, such as knowledge of integrated PBL, in the classroom (Zeichner & Bier, 2015). As this was not the case here, the PSTs in this study felt a disconnect between the pedagogical strategies learned in the course and the ones that they were observing from the mentors. The result of this disconnect was that the PSTs preferred a smaller sample of PBL, and more of an emphasis on diverse teaching methods. It is important for the PSTs to realize (and articulate to mentor teachers), that PBL requires a diverse array of pedagogical strategies, mini lessons, and formative assessments to prepare students to develop a final product. PBL is not a strategy, but rather an umbrella that can cover all of the strategies that teachers have learned. It is, therefore, important that PSTs realize that teachers using PBL still have to use diverse instructional strategies like modeling, investigating, and developing explanations to create a comprehensive interdisciplinary project.

As one of our participants noted, interdisciplinary PBL is best supported when there is buy-in from teachers and school leaders. For preservice teachers to realistically see how this method and mindset of planning and teaching plays out, it is important that they have clinical field placements in schools with teachers who have experience with cross-disciplinary planning and PBL (Zeichner & Bier, 2015). It is well-established that the mindsets, experiences, and practices of mentor teachers carry over to teachers-in-training (Carano, Capraro, Capraro, & Helfeldt, 2010). At the very least, methods course instructors should consider including mentor teachers in project development so that unit products can logistically be implemented in classrooms. We also note that a limitation of this study is that we only had one math preservice teacher. In addition to mediating this by having PSTs collaborate with professors in math, science, and engineering in class, it may also be beneficial to have science PSTs collaborate with mathematics mentor teachers (and math PSTs with science mentor teachers) to develop robust, interdisciplinary units.

The development and initial implementation of this interdisciplinary math-science planning course structure suggests benefits of this model to students. While not a focus of this study, the development of this course was a PBL experience for the instructors—a project that was continuously reflected upon and redesigned based on the formative feedback of the PSTs. We, therefore, recommend continuous planning sessions between instructors who desire to co-teach in a similar manner along with reflective sessions after each class to revise instruction for future iterations. We also recommend that instructors intentionally model key components of such structures to their PSTs. Such components include bringing in outside experts, co-planning, and engaging in active reflection throughout the process.

Supplemental Files

Appendix-A.pdf
Appendix-B.pdf
Appendix-C.pdf

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