Preparing Future Educators: Using Service-learning in Mathematics Courses for Prospective K-12 Teachers

Sayonita Ghosh Hajra, Brianna Davis, Jose Alanis, and James Tokunaga
Department of Mathematics & Statistics
California State University, Sacramento

ABSTRACT

Although experiential learning is widely recognized for its benefits, its implementation in content-focused mathematics courses for prospective teachers remains limited. To address this gap, this paper explores the integration of service-learning into three distinct mathematics courses for prospective teachers, detailing how it was implemented in each course. Results highlight opportunities for learning, particularly in developing agency, a sense of belonging, competence, and enriched experience among prospective teachers.

Keywords: Experiential learning, geometry, mathematics capstone course

INTRODUCTION

Secondary prospective teachers (PTs) majoring in mathematics with a teaching emphasis often take the same abstract, content-focused courses—such as algebra and real analysis—as pure or applied math majors. These courses are designed to prepare math majors for advanced undergraduate or graduate-level coursework, with limited emphasis on teaching or pedagogy. As a result, these undergraduates interested in secondary school teaching rarely engage with the practical aspects of teaching within their degree programs before entering a teaching credential program (Cooney & Wiegel, 2003). Consequently, they often express a gap between their coursework and the practical aspects of teaching (Zazkis & Leikin, 2010), and frequently question the relevance of these courses to their future teaching careers (Wasserman et al., 2023).

A similar situation exists for elementary PTs, who typically take mathematics content courses in the mathematics department and separate math methods courses in the College of Education, resulting in a fragmented teacher education program (Wasserman et al., 2023). Such fragmentation has been identified as an area in need of reform (Flores, 2016; Hudson & Zgaga, 2017; Wasserman et al., 2023). Furthermore, PTs often prioritize practicality and applicability in their university courses, seeking content that will be beneficial for their future teaching; thus, when mathematics is presented as disconnected from school requirements, it can lead to motivation issues in university mathematics courses and may contribute to high dropout rates among PTs in teacher preparation programs (Clark & Lovric, 2009; Wasserman et al., 2023).

Providing opportunities for PTs to connect undergraduate mathematics with school mathematics in a meaningful way could help bridge this gap, and service-learning (SL) is one approach to achieve this. When SL, a form of experiential learning, is integrated into mathematics courses could provide students with opportunities to apply mathematical concepts in real-world contexts beyond the classroom. As a well-established

pedagogical approach, SL has been widely incorporated into teacher education programs worldwide, serving as an effective strategy for PTs to bridge theory, practice, and community engagement (Jackson et al., 2018; Barnes, 2016). SL is "a pedagogical and learning strategy used in schools and communities around the world and has produced positive social, emotional, and cognitive growth among students" (Clark, 2017, p. 2). SL integrates community service and academic learning, allowing students to contribute to the needs of the community while applying content learned in the classroom (Carrington & Saggers, 2008; Mortari et al., 2019; Verducci & Pope, 2001). SL methodologies strive to inspire students, offer valuable services to others, establish links between universities or schools and their communities, and offer genuine incentives for introspection (Jackson et al., 2018; Lee & Statham, 2010). Many studies found that participating in SL components of a course enhanced students' understanding of necessary skills and their ability to perform tasks and skills aligned with course learning outcomes (Anderson et al., 2019; Fisher et al., 2017; Gallagher & McGorry, 2015; Scales et al., 2006; Strage, 2000). Hadlock (2013) emphasized that well-designed SL projects in mathematics enrich education by reinforcing curricular goals and fostering civic engagement through careful planning, meaningful partnerships, clear objectives, and institutional support. When these SL projects involve engagement with K-12 students, they also deepen PTs' empathy and understanding, encouraging them to see students as community members with whom they have both a responsibility and a desire to connect (Chambers & Lavery, 2012).

Although experiential learning, such as SL, generally receives favorable reviews, there is a notable gap in the literature regarding its use in upper-division mathematics courses for PTs or content-focused mathematics courses for K-12 teachers that are not the math methods courses. This gap highlights the need for further research and exploration to better understand how SL can be effectively incorporated into mathematics courses for students majoring in mathematics with a teaching emphasis before they enroll in the credential program or into content-focused mathematics courses for K-12 teachers.

In this study, we will explore the following two research questions: (a) What do PTs perceive as the most valuable learning opportunities and skills gained from their involvement in SL activities within content-focused mathematics courses designed for K-12 teachers or in upper-division mathematics courses for math majors in a teaching emphasis track? (b) How do PTs view the relevance and usefulness of SL experiences in their mathematics courses on their future careers?

Conceptual Framework

Our conceptual framework is grounded in Carver's model for experiential education (1997) and Kolb's Experiential Learning Theory (1984), both of which place student experience at the center.

Carver defined this experience through three interconnected facets: agency (A), belonging (B), and competence (C). Agency involves students' self-awareness and their ability to create growth opportunities. Agency empowers students to appreciate their own lives and communities, motivating them to take meaningful action. Belonging refers to students' integration into a community where they contribute and feel connected. Students see themselves as part of the community, with rights and responsibilities, privileges and vulnerabilities. They learn to act responsibly and take action with the well-being of the entire community in mind. Competence involves acquiring and applying new knowledge and skills. Student experience can be seen both as a process and as an outcome of the SL experience; students bring their prior experiences, knowledge, and skills into the current situation, which shapes how they engage and learn, making the experience an ongoing process. As they grow, reflect, and change throughout the SL activity; this

ongoing journey represents the process of learning. After the SL activity, the new experience becomes the result of everything the student has done, felt, and learned, making it an outcome as well. We chose Carver's model because it offers meaningful opportunities for learners by emphasizing learners' development of agency, belonging, and competence (ABC).

The development of ABC occurs as students face challenges, learn from mistakes, build strengths, overcome weaknesses, develop social skills, reflect on experiences, and receive constructive feedback to grow as a person. A few of the outcomes of developing ABC include acquiring new skills; becoming more adaptable and better problem solver; and gaining self-respect, peer respect, and a sense of safety. The learning environment supports ABC development through both setting characteristics (resources, behaviors, and shared values) and program characteristics (active learning, authenticity, drawing from past experiences, and future connections). Resources include both physical materials as well as psychological support such as empathy, trust, authority, compassion, etc. Behaviors include how resources are identified, chosen, distributed, and used. Values include beliefs—compassion for self and others, responsibility and accountability, respect for oneself and others— shared by the members of the learning community. Active learning directly involves students in the learning process while authenticity guarantees that the learning experience is genuine and relevant. Drawing from past experiences allows students to interact and respond to specific situations using the knowledge they have previously developed.

Kolb described the ideal learning process as a four-step Experiential Learning Cycle: Experiencing – Reflecting – Thinking – Acting (1984). In the *Experiencing* phase, students engage directly with a situation, applying their existing knowledge. For example, this could involve PTs participating in a SL event where they facilitate activities. The *Reflecting* phase involves looking back on the experience, processing what happened, and connecting emotions with ideas. This is where PTs are actively engaged in reflecting on their experiences, often through discussions or written reflections. In the *Thinking* phase, students analyze the experience, draw conclusions, and consider how these insights might inform future actions. For example, PTs might reflect on changes they could make in their future teaching practices. Finally, in the *Acting* phase, students apply what they have learned, test their ideas in new contexts, receive feedback, and generate new experiences, thus continuing the learning cycle.

Drawing from the *Acting phase* of Kolb's Experiential Learning Cycle, learners apply what they have learned in new contexts and generate new experiences. By connecting their SL experiences to future scenarios, PTs are encouraged to reflect not only on their involvement in SL but also on how they can apply this learning in their future roles as educators and active community members. These elements contribute to a meaningful student experience and motivate PTs to incorporate similar experiential approaches into their own teaching practices. Thus, we expand on Carver's model by incorporating the future intention of using similar activities or pedagogies as those used during their SL experience (see Figure 1). With positive student experience, we believe that K-12 PTs are more likely to view the relevance and usefulness of experiential learning experiences in mathematics on their future careers. In addition, we also believe that math majors with a teaching emphasis might be able to connect some of their upper division content knowledge with content in the K-12 school settings through positive SL experiences in the math content (capstone) courses. And with positive experiences, PTs will be able to express utilizing similar tasks and/or pedagogies with their future students.

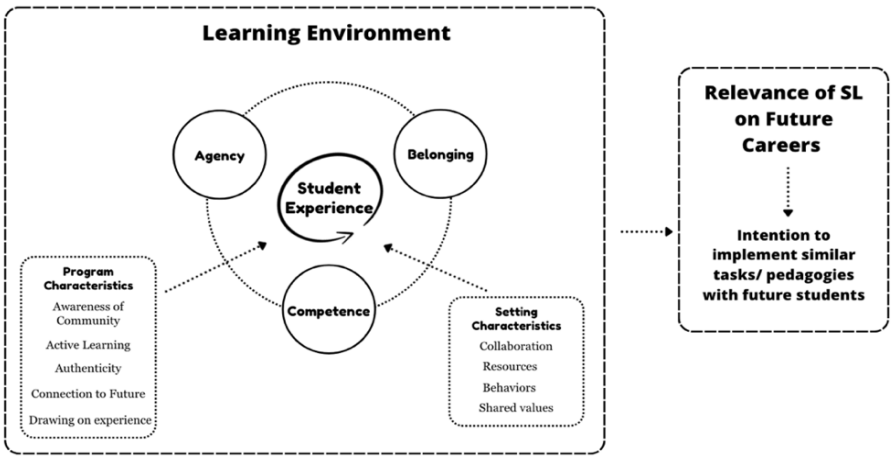

Figure1. A conceptual framework for experiential learning for PTs (adapted from Carver (1997)).

METHODOLOGY

Study Participants

This study was conducted at a public institution on the West Coast of the United States. Participants included 44 students from four SL-designated mathematics courses. The demographics of the PTs included: 20 Female, 23 Male, and 1 Non-binary; 13 Asian, 1 Black/ African American, 13 Hispanic, 3 Multiracial, 2 Pacific Islander, 11 White (non-Hispanic), and 1 PT preferred not to answer. The three courses included in the study were: College Geometry (eight students enrolled), an Elementary Mathematics and Learning Process course (10 students enrolled), and a capstone Mathematics course (26 students enrolled—20 in the spring semester, 6 in the fall semester). Both College Geometry and the capstone courses were for math majors in the Teaching Emphasis track. All the courses were 3-unit courses. The College Geometry class met three times a week for 50 minutes, while the other two classes met twice a week for 75 minutes each, over a 15-week semester. The Institutional Review Board determined the study to be Exempt from 45 CFR 46 (IRB Protocol number: 23-24-15).

Course Context

In the College Geometry course, students examined the axioms and theorems of Euclidean geometry and compared various geometric axioms and theorems of Euclidean, non-Euclidean, and finite geometries. In the Elementary Mathematics course, students explored the relationship between mathematics and how it is learned. They expanded their knowledge of K-8 mathematics and explored how to positively impact children's attitudes toward and understanding of the subject. The capstone course provided a culminating experience that bridged the gap between the advanced mathematics studied in college and the mathematics taught in secondary schools. Throughout the course, students explored the nature of mathematics, with the overarching goal of connecting their experiences as learners to effective mathematics teaching. They actively engaged in hands-on math activities that were based on upper-division core concepts but could be easily modified and adapted to K-12 settings.

Service-learning

Each student completed 10 hours of SL in the College Geometry course, five hours in the Elementary Mathematics course,

and 26 hours in the capstone course. The SL activities involved (co)facilitating hands-on mathematics sessions with K-12 students, teachers, or seniors aged 65 and above, solely based on content learned in the class. In the capstone course, 20 of the 26 SL hours were dedicated to tutoring middle and high school students.

In the College Geometry course, students learned about various finite geometry, such as 3-point geometry, Fano's geometry, and Young's geometry (For details about the concepts, see Wallace and West (2004)). They applied these concepts to create Spot-it games with three symbols per card, four symbols per card, five symbols per card, etc. (See Coggin and Meyer (2013) for details about the game). Students also explored the application of Young's geometry in the SET card game (see McMahon et al. (2016) for details of the game). They developed presentation materials and hands-on manipulatives and facilitated sessions at a Wellness Program for seniors aged 65 and above, a Senior Living community, and a local STEM Conference for middle school girls.

In the Elementary Mathematics and capstone courses, PTs facilitated various non-curricular, hands-on math activities for middle and high school students. They first presented the topics or worked on them with their peers in class, made modifications, and planned their sessions. Some of the topics included applications of number theory, logic, and geometry – Rook's move, Apple Picking, Cup Stacking, Gerrymandering, etc. (see JRMF (n.d.)). In the spring semester, high schoolers from two local schools visited the university on a Saturday and the PTs facilitated hour-long math activity sessions for them. During the fall semester, the PTs hosted hour-long math activities tabling sessions at two local middle schools and also at a senior living facility. Additional facilitation opportunities were provided to PTs who were not able to attend the main events.

PTs were introduced to key norms for working with both K–12 students and senior citizens. These included speaking slowly, allowing for pauses, and asking thoughtful questions. To support this, we incorporated the use of the Nine Talk Moves framework (The Inquiry Project, n.d.). When working with K–12 students, PTs not only explored the reasoning behind math games but also provided opportunities for the students to design their own games. In contrast, their interactions with senior citizens centered more on playing the games and deepening their understanding of the underlying mathematical concepts, with an added emphasis on supporting cognitive health.

Data Collection

Data was collected through pre- and post-surveys and beginning- and end-of-semester reflections on students' SL experiences. The pre- and post-surveys included several Likert scale questions, ranging from "strongly agree" (5) to "strongly disagree" (1), along with open-ended questions. The pre-survey questions were adapted from Manolis (2004), while the post-survey questions were adapted from the University of Georgia - Office of Service-Learning survey (2015). While the two surveys share common questions, the post-survey includes additional items designed to capture more information from PTs after their SL experience. This allows us to compare responses over time while also gaining deeper insights into their learning and development. The end-of-semester reflection was adapted from the Campus Compact's "The What? So What?? Now What??? Reflection Model" (Rolfe et al., 2001). "The What?" component describes the event, i.e., facilitating the activities. The "So What" component examines the event's significance in relation to classroom concepts and personal experiences. The "Now What" component reflects on future actions that relate to the broader context of using mathematics in the "real world."

Data Analysis

We used descriptive statistics and an a priori and descriptive coding process (Miles

et al., 1994) to interpret the data. The first round of coding involved members of the research team identifying and categorizing codes guided by Carver's conceptual framework on student experience. One PT was counted twice, as they were enrolled in both College Geometry and the Capstone course in successive semesters. In the beginning semester reflection, none of the students had prior experience with SL in a mathematics course before taking the SL courses associated with this study. Six students self-reported having previous SL experience in their education courses, and four other students reported having SL experience through Child and Adolescent Development classes, an art class, and through tutoring students in English. One of the PTs reported supporting small groups of Spanish speaking students with math and English translation for the SL experience in one of their education courses. Out of 43 PTs who completed the pre-survey Likert scale questionnaire, 27 PTs (63% of PTs) reported that they were unaware of the SL component of the course when they enrolled in the course. Also, 27 of the 43 students were bilingual. Some of the languages included Bicol, Chinese (Mandarin and Cantonese dialects), Farsi, French, Hindi, Hmong, Spanish, Tagalog, and Vietnamese. The pre-survey data (Table 1) suggest that PTs felt highly comfortable engaging with diversity, with 98% comfortable working with people of different races and ethnicities and 88% comfortable talking with those from different backgrounds. However, comfort levels were lower in areas such as public speaking (63%), working with unfamiliar people (70%), and a sense of agency in solving community problems (72%). Only 63% felt confident addressing community needs, suggesting room for growth in civic engagement and communication skills. Overall, PTs showed strong openness to diversity but moderate confidence in leadership and community action before participating in the SL events.

Table 1: Pre-survey data (n = 43) on PTs experience and beliefs on community outreach before they participated in the SL component of the course.

.

Pre-survey Items	Percentage of PTs who strongly agreed or agreed with the statement
I feel comfortable speaking in a group setting.	63%
I can have an impact on solving the problems in my community.	72%
I feel comfortable working with people who differ from me in terms of race and ethnicity.	98%
I feel comfortable working with people I don't know well.	70%
I feel comfortable talking with people who have a different background than me.	88%
I feel addressing community needs affecting the quality of life in my town/city.	63%

Research Question (a): What do PTs perceive as the most valuable learning opportunities and skills gained from their involvement in SL activities within content-focused mathematics courses designed for K-12 teachers or in upper-division mathematics courses for math majors in a teaching emphasis track?

Some of the valuable learning opportunities and skills gained from PTs' involvement in SL activities within content-focused mathematics courses designed for K-12 teachers included citizenship skills;

functional life skills such as problem-solving, critical thinking, communication, and assertiveness; intercultural communication skills and leadership skills; as well as an enhanced awareness of community issues and their responsibilities as community members. Out of 40 post-survey responses, the majority of PTs reported positive outcomes from the SL component of their courses. Specifically, 80% agreed it helped them develop citizenship skills, while 95% felt it increased their awareness of community responsibilities. About 93% agreed it expanded their knowledge of the communities they engaged with and the issues those communities face. The SL component also contributed to skill development, with 95% reporting growth in functional life skills such as problem-solving, critical thinking, communication, and assertiveness. Furthermore, 85% noted improved intercultural communication skills, 90% saw enhanced leadership abilities, and 82.5% experienced increased self-confidence. Students also reported improved collaboration with peers and individuals of diverse ages, abilities, and socioeconomic backgrounds. Here, "agreed" includes both "*strongly agree*" and "*agree*."

From the end-of-semester reflections, student experiences are highlighted through three interconnected facets: agency, belonging, and competence, including student experience at the center of this. We developed a code book to note the different learning opportunities for PTs that was reported by PTs as they engaged in the SL events (see Table 2).

Table 2. Opportunities of learning for PTs emerged as they participated in the SL events.

Agency Agency empowers students to see and value their abilities and contributions to communities; to inspire and drive meaningful actions.	**Belonging** Belonging refers to students' integration into a community where they contribute and feel connected.	**Competence** Competence involves acquiring and applying new knowledge and skills.	**Student Experience (Process)** Student experience (process) refers to students utilizing their past experiences to make choices about their present.	**Student Experience (Output)** Student experience (output) refers to an outcome of student participation in an activity.
See themselves as educators – expressed interest in teaching and/or decided to pursue Teaching Credential.	**Collaboration** – cooperated with their peers through facilitating math activities.	**Real-world connections** – linked math concepts from class and SL to real-world applications/ teaching.	**Past connections** – drew on past experiences, recognizing their relevance in the current SL experience.	**Fulfilling experience** – found the SL event rewarding and meaningful.
Increased confidence – demonstrated increase in confidence in their (mathematical/soft-skill) abilities.	**Sense of belonging** – experienced being part of their (teaching/ personal) community.	**Skill development –** enhanced interpersonal, adaptability, and communication skills through SL-experiences.	**Personal observations** – shared past experiences informatively without making explicit connections to current SL experience.	**Authentic teaching** – experienced real teaching with K-12 students.
Practicing growth mindset – embraced mistakes, learned from them, and recognized potential for improvement.	**Co-learning** – taught or learned from a peer.	**Teaching insights** – experienced diverse strategies, pedagogy, and the impact of language and culture on learning.		
Proactive – took responsibility and initiative in preparing and planning.	**Networking** – valued the opportunity to network with faculty, teachers, and community members.	**Knowledge about students –** becoming cognizant that each learner is unique and processes information differently.		
Adopting skills for future teaching – expressed intent to apply acquired skills as a future teacher.	**Fostering generational sharing** – different groups (PTs, seniors, and K-12 students) engaged in learning from one another.	**Awareness of engaging tools and their appropriate use** – recognized the value of using mathematical games and puzzles for effective teaching and learning.		
Decision-making – involved making choices or judgments about a course of action while facilitating.	**Personal relationship with mathematics or teaching** – reflections on past experiences and personal connections, often expressed through "I" statements, relating to mathematics or teaching.	**Sense of accomplishment** – experienced an "a-ha" moment during SL, feeling accomplished either in teaching and/ or problem solving.		

Improvement ideas – suggested ways to improve the SL experience.	**Intent of community involvemen**t – motivated to be more involved in the community.			
Adaptability – adjusted to the environment, e.g. explained math in Spanish.				
Awareness of opportunities for math majors – recognized jobs available to them after graduating with a math major.				
Recognizing and responding to community issues – identified challenges facing communities and considered ways to address them.				
Applying math skills when facilitating activities – supported and guided math activities using mathematical concepts and techniques successfully.				
Introspection – learned about self and grew from the experience.				

Next, we highlight a few examples of ABC that were reported by PTs after they engaged in the SL events. Regarding agency, many PTs developed a stronger connection to their future roles as teachers or began envisioning themselves pursuing teaching after participating in the SL sessions. They gained confidence in actively engaging with the sessions and pushed themselves beyond their comfort zones. As one PT reflected, "I learned that I was very introverted before and would let others take that role of being involved. I have been challenging myself because of this course to step into that role more." PTs also learned to make decisions about their lessons, making in-the-moment choices to support student learning while facilitating. One PT wrote, "When hosting the "Rook's Move" game, we went over time with every group because they were so competitive and excited to play. We were on a time-crunch, but it felt right to slow down and let the students enjoy what they were doing and learn." PTs also had the opportunity to reflect on their adaptability in working with diverse student populations. One PT shared their growth in communication strategies, stating, "I grew in how to help and speak to the students, whether they knew English or not. Many of the students didn't fully know English yet, and their primary language was or still is another language besides English." Through introspection, PTs recognized their own growth and the value of learning from others. One PT reflected, "The service-learning component of this course has shown me how much others know and how much I want to learn from them. When people share their stories or lessons, it's captivating to listen and learn. They aren't just sharing for the sake of telling a story—they want you to learn, to engage, and to truly listen." This reflection highlights how SL fosters a deeper appreciation for collective knowledge and the importance of active listening, encouraging PTs to embrace lifelong learning in their journey as educators. Finally, PTs considered the challenges facing their communities and how they could contribute to meaningful change. One PT in the capstone course reflected:

> "From my hometown community, there were issues with lack of educational resources and education as a whole (especially mathematics as a subject) was not taken seriously. I intend to solve these issues to allow proper education be easily accessible to ensure the success of the students I teach in the future."

This reflection underscores PTs' commitment to advocating for equitable education and fostering positive change within their communities.

Concerning belonging, PTs valued getting to know members of their community and showed a genuine interest in connecting with others on a personal level. One PT enrolled in the College Geometry course wrote, "I feel there was also merit in simply being there and interacting with people, listening to their stories and conversing about a myriad of topics, the simple act of interacting was welcomed." Another PT realized the power of networking; they wrote, "Participating in outreach activities showed me how building connections with students and their communities can break down barriers to learning and increase engagement." Through community involvement, PTs were also able to engage in generational sharing. During the SL events, PTs were eager to share what they learned in the classroom and became more open to learning from community members. A PT in the College Geometry class working with seniors wrote:

> "I want to help others, I want people to learn from me as much as I want to learn from others. I want to be a part of my community, working with others and lending a helping hand in any way I can."

The SL events fostered generational sharing between different groups (PTs, seniors, and K-12 students) by learning from one another. One PT wrote, "I grew as a learner as I was able to interact with people who were out of my age range and people who came from different backgrounds and different world[s]. Meeting people who are younger than me […] gave me a brand-new perspective on how they act and view education." PTs' personal experience with mathematics has grown through these experiences. They now see how mathematics can be integrated into their community. One PT wrote,

> "Service learning shined a light on how I am able to use my knowledge on mathematics to elevate my community, specifically the elderly adults in this case, in encouraging them to think critically of why certain puzzles or games work the way they do. I think my motivation for being involved in the community has certainly changed because I didn't think of employing my math knowledge to contribute to my community."

Finally, PTs learned something new about their community or surroundings from their peers that they had not been aware of. One PT wrote, "By engaging with other peers helped me to learn a few things. One example would be the Japanese Garden when one of my classmates introduced it. For the past five years I have been at [University name], I didn't know [University name] has a mini Japanese garden near the library until we took a tour with the high schoolers during the event." These opportunities strengthened students' integration into their community where they contributed and felt connected.

With regard to competence, several PTs became aware of engaging tools and their appropriate use. One PT wrote, "It is said that to truly know any subject well enough, one must be able to teach it. While it may seem trivial to teach card games, there is more than meets the eye given the math principles they use. Thanks to this class I was able to not only teach the games we used, but why they work as well." PTs felt a sense of accomplishment through practicing lessons in the real context of teaching. One PT reflected,

> "I was surprised at the level of interest and how quickly they [high school students] were able to get the strategies that my leading questions were intended to provoke. It was inspiring to take the lead and teach such a large group of high schoolers and have them be so engaged with the task. It was also an exciting opportunity to try out some of the techniques we learned in the readings and course, and to see them work in a real world scenario."

PTs also gained teaching insights and became cognizant that non-curricular math games and puzzles can engage students

deeply in doing mathematics. One wrote, "Participating in these outreach activities gave me valuable insights into how interactive learning and educational development connect. Through hands-on engagement with the puzzles, students not only reinforced their understanding of mathematical concepts but also refined their critical thinking, collaboration, and creativity skills." On a similar note, a second PT shared,

> "I think that it is important to have your students encouraged to do math since math is the least favorite subject in typical middle school classes. So, making math fun for students will definitely make students encouraged to do math. This event really demonstrated the different strategies to make math fun for students and to also challenge them as well, which is also important to me as well to assess where they are struggling and how to best help them."

Another PT mentioned the relevance to the application of mathematics, saying, "Something new I learned about my service topic is that it is [not] just about math or geometry. It's about how we can use this math or geometry and apply it to real-world problems to solve them." Other PTs claimed that this experience enhanced their communication skills, with one PT writing that "facilitating the event allowed me to hone my communication and leadership skills, as I guided students through the various activities and encouraged their participation. I also was able to modify the games for students who needed it." Another student reflected on how the SL experience challenged them to make impromptu decisions and produce solutions to challenges they experienced during the SL events, saying,

> "There were a lot of English Learning students that came to visit and finding ways to communicate the rules and get them involved was truly a challenge. In my group we did not have a native speaker to assist the students the best we could, but we managed to get by and adapt. I think I personally grew because of this as I was forced to find ways to communicate the material I was teaching to my visitors."

In connection with student experience as process, PTs drew on past experiences, recognizing their relevance in the current SL experience. One PT commented, "these experiences were different from the math classes I've been used to, where the focus was on formulas, steps, and the 'right answer.' Instead, these events encouraged creativity, interaction, and personal connection."

In connection with student experience (as output), it was observed that PTs found SL to be a fulfilling experience, one stated, "I definitely enjoyed working/ facilitating the event and to be able to inspire students to pursue the STEM field as they begin their college journey." PTs also expressed that the SL allowed them to actively engage in authentic teaching experience. PTs were able to experience the teaching aspect – "The significance of these events was that I was able to really see what it is really like to be a part of a middle school classroom and high school classroom."

Research Question (b): How do PTs view the relevance and usefulness of SL experiences in their mathematics courses on their future careers?

Many PTs shared that they plan to adopt some of the practices they learned through SL events in their future careers as teachers. They expressed that their experience with SL has provided them with insights into how they want to teach in the future. Among the courses from which we collected data, 37 out of 40 participants expressed that their experience with SL helped them see how the content covered in these courses could be useful in everyday life or in other situations.

The PTs developed clear and concrete ideas about how they would apply the tools they learned through SL, with one student

reflecting, "In the future, I want to use what I learned from these outreach activities in my teaching. I will be adding fun, hands-on games and puzzles to my lessons to get students more involved and help them engage in math." Another PT noted, "As a future educator, I plan to utilize these math games to encourage my future students to harbor their math skills and to be able to encourage their peers when they are struggling and help them." Another PT shared that the event not only helped them as an individual future teacher but also gave them insight into what their math department can do – "This also taught me that I can help my math department at my future school be more in touch with the student body and engaging. We can run events that are both relating to math and fun. That I believe is the biggest takeaway. I will also be taking the idea of the flexibility and different routes of stem [STEM] fields to my students to help them understand fully what is available to them." A main theme that emerged across all PTs was the realization of how effective math games can be in engaging students and fostering the development of their problem-solving skills —and many expressed a desire to incorporate these math games into their future classrooms. One PT reflected, "In the future, I want to make sure that my students are enjoyable [can enjoy] so that they are interested in what I have to teach. I could do that by making it relatable and showing them examples of how it occurs in the world around them. Many activities and games we did throughout the day [SL event] did exactly that….Expecting students to come into class daily and sit at a desk to learn math will only get you so far with your teaching. However, when you can make the lesson fun by seeing real-world examples and manipulatives and incorporating some games or activities, it will boost the amount of interest and learning in your classroom. I intend to do just that. I want to be an educator in the future that is not only teaching the students but making it exciting for all my students to learn in my classroom. I want my students to know that learning can be fun and exciting when it is being taught the right way. Hopefully in the future I am able to be successful to do just that. I am so happy that I got to take part in an event like this to witness what it is like to promote learning to students in many different ways."

Another student shared that their experience with SL has better prepared them to obtain their teaching credential, saying,

> "This experience taught me the value of collaboration and the importance of working together towards a common goal. As I prepare to start my credential program at [University] and begin my placement at [High School], I am excited to apply the insights and skills I gained from this event. I am eager to create lesson plans that are engaging, culturally responsive, and collaborative. I want to ensure that my students see the relevance of math in their daily lives and feel confident in their ability to succeed."

Through SL, the undergraduate students could see themselves as future and current educators, gaining valuable tools and experience that will help them succeed in the future by making mathematics engaging and relevant to their future students. One student reflected,

> "Participating in this event was a significant learning experience for me as a teacher. It taught me the importance of making math engaging and relevant to students' lives. Through hands-on activities and interactive games, I witnessed firsthand how students' enthusiasm for math grew when they saw its real-world applications. This helped me grow in my ability to create inclusive and interactive learning environments. I learned to tailor activities to students' individual needs and interests, ensuring that every participant felt valued and motivated to learn."

Some students demonstrated an eagerness to share mathematics with their future students in a way that combats

negative stereotypes and seeks to avoid issues like math anxiety or other negative experiences with mathematics, with one student sharing that, "By attending this event, I learned much about how I can diverge from traditional mathematics education and teach it in a more exciting and grounded way, which I hope will help absolve mathematics of its negative connotation." It is known that teachers pass math anxiety to students (Schaeffer et al., 2021), so having teachers be more cognizant of this and how they can tailor their classroom to their teaching styles will benefit their future students greatly.

CONCLUSION AND DISCUSSION

Written reflections from PTs offered valuable insights into their perspectives on their SL experiences in mathematics courses. Our results provide support for incorporating SL into mathematics courses, upper-division or otherwise, as SL offers significant benefits for students planning to become teachers, whether at the elementary, middle, or high school level. Through SL, students can engage in experiential learning within their mathematics courses and develop essential work skills including collaboration, communication, and practical career competencies. Students developed a stronger connection to their future roles as teachers or envisioned themselves pursuing teaching in the future and they strengthened their collaboration and interaction with others in the community. Many students expressed that SL allowed them to actively engage with the course content and complemented what they were learning in class. In addition, a majority of the students agreed that the SL opportunity enhanced their understanding of their own strengths and weaknesses, helped them see how the material covered in the course could be useful in everyday life or in other situations, and enriched their application of classroom knowledge.

Well-designed SL experiences enhance classroom learning and help students not only grasp the content but also develop career-ready skills. This is especially important for undergraduates in upper-division mathematics courses who are preparing to become K-12 teachers. It is not necessary for PTs to wait until enrolling in the teaching credential program or student teaching, where the focus is primarily on curricular instruction, to gain teaching experience. SL can demonstrate how and why upper-division mathematics can be meaningfully used in lesson planning for middle and secondary students. Further research is needed to explore the development of upper-division mathematics SL courses that can offer valuable experiences for PTs. In addition, our study's demographic data show that over 50% of participants were either Asian or Hispanic. The gender breakdown included approximately 52% male and 45% female students. Conducting a similar study with a different student population could provide valuable insights into the learning opportunities that SL in mathematics courses may offer across diverse groups.

REFERENCES

Anderson, K. L., Boyd, M., Ariemma Marin, K., & McNamara, K. (2019). Reimagining service-learning: Deepening the impact of this high-impact practice. *The Journal of Experiential Education*, *42*(3), 229–248. https://doi.org/10.1177/1053825919837735

Barnes, M. E. (2016). The student as teacher educator in service-learning. *Journal of Experiential Education*, *39*(3), 238–253. https://doi.org/10.1177/1053825916643831

Carrington, S., & Saggers, B. (2008). Service-learning informing the development of an inclusive ethical framework for beginning teachers. *Teaching and Teacher Education*, *24*(3), 795–806. https://doi.org/10.1016/j.tate.2007.09.006

Carver, R. L. (1997). Theoretical underpinnings of service learning. *Theory into Practice*, *36*(3), 143–149.

https://doi.org/10.1080/00405849709543760

Chambers, D. J., & Lavery, S. (2012). Service-learning: A valuable component of pre-service teacher education. *The Australian Journal of Teacher Education*, *37*(4), 128–137.

Clark, T. (2017). *The K-12 service-learning standards and fourth grade students' math achievement: A quasi-experimental study in Georgia* [Unpublished doctoral dissertation]. Northcentral University.

Clark, M., & Lovric, M. (2009). Understanding secondary–tertiary transition in mathematics. *International Journal of Mathematical Education in Science and Technology*, *40*(6), 755–776. https://doi.org/10.1080/00207390902912878

Coggin, R., & Meyer, A. (2013). The mathematics of "SPOT IT!" *Pi Mu Epsilon Journal*, *13*(8), 459–467.

Cooney, T. J., & Wiegel, H. G. (2003). Examining the mathematics in mathematics teacher education. In A. J. Bishop, M. Clements, C. Keitel-Kreidt, J. Kilpatrick, & F. K. Leung (Eds.), *Second international handbook of mathematics education* (pp. 795–828). Kluwer.

Fisher, E. E., Sharp, R. L., & Bradley, M. J. (2017). Perceived benefits of service learning: A comparison of collegiate recreation concentrations. *The Journal of Experiential Education*, *40*(2), 187–201. https://doi.org/10.1177/1053825917700922

Flores, M. A. (2016). Teacher education curriculum. In J. Loughran & M. L. Hamilton (Eds.), *International Handbook of Teacher Education* (pp. 187–230). Springer. https://doi.org/10.1007/978-981-10-0366-0_5

Gallagher, M. J., & McGorry, S. Y. (2015). Service learning and the capstone experience. *International Advances in Economic Research*, *21*(4), 467–476. https://doi.org/10.1007/s11294-015-9550-z

Hadlock, C. R. (2013). Service-learning in the mathematical sciences. *PRIMUS: Problems, Resources, and Issues in Mathematics Undergraduate Studies*, *23*(6), 500–506. https://doi.org/10.1080/10511970.2012.736453

Hudson, B., & Zgaga, P. (2017). History, context and overview: Implications for teacher education policy, practice and future research. In B. Hudson (Ed.), *Overcoming fragmentation in teacher education policy and practice* (1–26). Cambridge University Press.

Jackson, C., Mohr-Schroeder, M., Cavalcanti, M., Albers, S., Poe, K., Delaney, A., Chadd, E., Williams, M., & Roberts, T. (2018). Prospective mathematics teacher preparation: exploring the use of service learning as a field experience. *Fields Mathematics Education Journal*, *3*(1), 1–21. https://doi.org/10.1186/s40928-018-0010-5

Julia Robinson Math Festival (JRMF). (n.d.). *Puzzles.* https://jrmf.org/puzzle/?filter=recommended

Kolb, D. A. (1984). Experiential learning: Experience as the source of learning and development. Englewood Cliffs, NJ: Prentice Hall.

Lee, K.-H., & Statham, A. (2010). The impacts of a service-learning experience on pre-service mathematics teachers. *Issues in the Undergraduate Mathematics Preparation of School Teachers*, *2*.

McMahon, L., Gordon, G., & Gordon, H. (2016). *The joy of SET: The many mathematical dimensions of a seemingly simple card game*. Princeton University Press. https://doi.org/10.1515/9781400884483

Manolis, A. (2004). *Service learning pre-service survey for students* (Evaluation/Reflection No. 56). University of Nebraska at Omaha.

https://digitalcommons.unomaha.edu/slceeval/56

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: an expanded sourcebook* (2nd ed.). Sage Publications.

Mortari, L., Silva, R., & Ubbiali, M. (2019). A case of service-learning and research engagement in preservice teachers' rducation. *Journal of Higher Education Outreach and Engagement*, *23*(3), 145–158.

Rolfe, G., Freshwater, D., & Jasper, M. (2001). *Critical reflection for nursing and the helping professions: A user's guide*. Palgrave Macmillan.

Scales, P. C., Roehlkepartain, E. C., Neal, M., Kielsmeier, J. C., & Benson, P. L. (2006). Reducing academic achievement gaps: The role of community service and service-learning. *The Journal of Experiential Education*, *29*(1), 38–60. https://doi.org/10.1177/105382590602900105

Schaeffer, M. W., Rozek, C. S., Maloney, E. A., Berkowitz, T., Levine, S. C., & Beilock, S. L. (2021). Elementary school teachers' math anxiety and students' math learning: A large-scale replication. *Developmental Science*, *24*(4), e13080-n/a. https://doi.org/10.1111/desc.13080

Strage, A. A. (2000). Service-learning: Enhancing student learning outcomes in a college-level lecture course. *Michigan Journal of Community Service Learning*, *7*, 5–13.

The Inquiry Project. (n.d.). *Goals for productive discussions and nine talk moves.* *https://inquiryproject.terc.edu/prof_dev/Goals_and_Moves.cfm.html*

University of Georgia - Office of Service-Learning survey. (2015, July 16). *Course Survey*. Retrieved August 8, 2023, from https://servicelearning.uga.edu/faculty-resources/course-survey/

Verducci, S., & Pope, D. (2001). Rationales for integrating service-learning in teacher education. In J. B. Anderson, K. J. Swick, & J. Yff (Eds.), *Service-learning in teacher education: Enhancing the growth of new teachers, their students, and communities* (pp. 2–18). Washington, DC: American Association of Colleges for Teacher Education (AACTE).

Wallace, E. C., & West, S. F. (2004). *Roads to geometry* (3rd edition). Waveland Press.

Wasserman, N. H., Buchbinder, O., & Buchholtz, N. (2023). Making university mathematics matter for secondary teacher preparation. *ZDM–Mathematics Education*, *55*, 719–736.

Zazkis, R., & Leikin, R. (2010). Advanced mathematical knowledge in teaching practice: Perceptions of secondary mathematics teachers. *Mathematical Thinking and Learning*, *12*(4), 263–281.

ACKNOWLEDGEMENTS

The authors would like to thank the Pedagogy Enhancement Awards at Sacramento State and CSU Louis Stokes STEM Pathways & Research Alliance at Sacramento State for partially supporting this work.

AUTHOR BIOGRAPHIES

Sayonita Ghosh Hajra is an associate professor in the Department of Mathematics & Statistics at California State University, Sacramento. She incorporates games and puzzles into her lessons to gamify the learning experience and integrates service learning into her math courses to support student learning by engaging students beyond the four walls of the classroom, enabling them to apply what they have learned.
Email: Sayonita.ghoshhajra@csus.edu

Brianna Davis is a graduate student of mathematics at California State University, Sacramento. She works on bringing attention

to social justice issues in teaching and learning, with a focus on mathematics.
Email: briannadavis@csus.edu
https://briannamath.weebly.com/

Jose Alanis is a mathematics graduate student at California State University, Sacramento. He is interested in all areas of mathematics, but his favorites are mathematical physics, especially quantum mechanics and mathematics education.
Email:josealanis2@csus.edu,
https://freddyalanis.github.io/Website2.1/

James Tokunaga is an undergraduate student in the Department of Mathematics & Statistics at Sacramento State. He is currently pursuing a BA degree in mathematics with Teaching emphasis. He is interested in mathematics education research.
Email: jamestokunaga@csus.edu

AUTHOR NOTE

We have no conflicts of interests to disclose. The study was supported by Sacramento State's 2023-2024 Pedagogy Enhancement Award.

Correspondence concerning this article should be addressed to Sayonita Ghosh Hajra, 6000 J Street, Sacramento, CA 95826.
Email: Sayonita.ghoshhajra@csus.edu