Volume 30, Number 1 • Spring 2026

ISSN: 1087-3430

Electronic Journal for Research in Science & Mathematics Education

Flagship Journal of the International Consortium for Research in Science & Mathematics Education (ICRSME)

EJRSME
Electronic Journal for Research in Science & Mathematics Education

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Cover designed by Dusty Crocker

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Volume 30 No. 1 | Spring 2026

RESEARCH / EMPIRICAL

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Electronic Journal for Research in Science & Mathematics Education (EJRSME)

ELECTRONIC JOURNAL FOR RESEARCH
IN SCIENCE & MATHEMATICS EDUCATION
VOL. 30, NO. 1, 1-22

Bridging the Gap Between Beliefs and Practice: Preservice Science Teachers' Orientation Shifts through Experiential Place-based Instruction

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ABSTRACT

This study examined the impact of hands-on, inquiry-based learning experiences in an informal setting on developing preservice teachers' science teaching orientations. Effective science instruction requires educators to adopt adaptive, inquiry-oriented beliefs that guide how they plan, implement, and assess their teaching, extending beyond mere content knowledge. By engaging in authentic, place-based educational activities that offered unique opportunities for experiential learning, participants in this study connected with scientific concepts in real-world contexts. The study explored how outdoor, inquiry-based experiences shaped preservice teachers' orientations and revealed patterns in their orientations toward place-based education as practical instructional teaching models. The findings showed observable and significant shifts as participants expanded their views, favoring more interactive informal or outdoor teaching and learning. The results also showcased the value of hands-on engagement, scientific relevance through localized contextual learning, and peer collaboration. These findings suggest that teacher education programs should include contextually relevant experiential learning strategies to foster students' development of effective, inquiry-driven teaching beliefs. These beliefs promote increased innovative science practices that connect learning to local communities.

Keywords: Place-based education, informal science education, teacher beliefs and orientations, science teacher education, experiential instructional practices.

Introduction

Effective science teaching involves mastering content knowledge and instructional skills (Gess-Newsome, 2013, 2015; Shulman, 1986) and developing appropriate teaching orientations and beliefs. Given the current teacher shortages, preparing effective science teachers is critical for advancing science education that aligns with contemporary educational goals, prioritizing more innovative approaches to teaching and learning. Teacher orientations, including educators' assumptions and attitudes about teaching and learning, significantly shape how they plan, implement, and assess instruction. Research has shown that teacher beliefs and orientations greatly influence their Pedagogical Content Knowledge (PCK), affecting how they translate their knowledge into classroom

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practice (Gess-Newsome, 2013, 2015; Pajares, 1992; Shulman, 1986). Therefore, it is essential to foster adaptive and inquiry-oriented teaching beliefs in teacher education programs (Loughran, 2013; Nilsson & Loughran, 2012).

One promising strategy for influencing preservice teachers' (PSTs) orientations is experiential learning, where hands-on, inquiry-based activities enable them to engage directly with meaningful teaching practices in authentic contexts (Kolb, 2014). Place-based education (Smith, 2017; Sobel, 2004) enhances these experiences by situating learning within the local environment and community, helping teachers connect scientific concepts to real-world contexts.

This study investigated how an immersive experience at Outdoor School, an outdoor education center, impacted PSTs' orientations toward inquiry teaching. Furthermore, it aims to identify patterns in how PSTs perceive and plan to integrate experiential and place-based education into their emerging teaching practices. By focusing on experiential learning, this research provides an in-depth understanding of how real-world teaching experiences might shape PCK development by influencing the beliefs that underpin effective science instruction. The following research questions guided the study:

a) How does an outdoor place-based experience influence preservice teachers' science teaching orientations?

b) What patterns emerge in preservice teachers' perceptions of science teaching through their engagement in place-based education activities?

Theoretical Framework

This study is grounded in Kolb's (1984) Experiential Learning Theory and Sobel's (2004) Place-Based Education conceptual framework. These frameworks offer a robust lens to understand the development of PSTs' science teaching practices during an informal, immersive learning experience.

Experiential Learning Theory

Experiential learning theory (Kolb, 1984) describes that learning occurs through a cyclical process involving four stages: concrete experience, reflective observation, abstract conceptualization, and active experimentation. In this model, learners engage directly with a subject, reflect on their experiences, conceptualize what they have learned, and apply that understanding in new contexts. This iterative cycle allows learners to develop deeper insights and apply knowledge to real-world scenarios. Experiential learning enriches teachers' pedagogical content knowledge and skills, enhancing their professional competence across various disciplines and contexts. According to research, these active experiences in teacher development lead to meaningful changes in classroom practice and shape teachers' beliefs, resulting in significant curriculum innovations (Girvan et al., 2016; Lee, 2019a). In the context of this study, Kolb's experiential learning provides a critical foundation for understanding how PSTs benefit from place-based experiences. The PSTs experienced an inquiry-based learning field trip at a local outdoor school. They reflected on the experience, conceptualized it by including the experience as part of a 5E lesson plan, and then used the lesson plan to represent and apply their teaching philosophy in a final paper.

Place-Based Education

Place-based education (Sobel, 2004) expands on Kolb's (1984) experiential learning approach by grounding learning experiences in the local environment and community. This teaching approach emphasizes connecting scientific concepts to students' immediate surroundings, making learning more relevant and impactful (Lund & Stains, 2015; Semken et al., 2017). It fosters a deeper understanding of scientific phenomena by contextualizing abstract ideas within real-world settings. The outdoor school chosen as the setting for the experience is regarded as a valued part of the community, and many participants had previously visited it in elementary school. Due to the rural setting of the university and the fact that many students matriculated from nearby areas, the outdoor school exemplified the definition of the "local environment." This study's integration of experiential learning theory and place-based education provided a robust theoretical foundation for understanding how PSTs' beliefs and orientations were reshaped through immersive, hands-on experiences. By examining how these experiential and place-based approaches interact to influence preservice teacher development, this study provided a lens through which teacher preparation programs can effectively foster inquiry-oriented and contextually relevant teaching practices.

Literature Review

Teacher Beliefs and Orientations

Teacher beliefs and orientations are foundational to effective science teaching. Orientations shape educators' development and dictate their ability to implement innovative instructional practices (Buehl & Beck, 2014; Gess-Newsome, 2015). Addressing and re-shaping traditional beliefs through reflection and experiential learning is essential for preparing teachers to implement inquiry-driven, student-centered instructional strategies that align with contemporary educational goals (Buehl & Beck, 2014; Lebak, 2015; Loughran, 2013). Although it may seem complex, changing teachers' beliefs can lead to significant shifts in instructional practices, particularly when supported by professional development, reflective practices, and collaborative environments.

Definition and Significance

Teacher beliefs are the fundamental assumptions and values shaping how they think about teaching, learning, and science education. Teachers' beliefs about education meaningfully contribute to their curricular and instructional orientations, yet orientations characterize a more actionable position that can conceivably prevail over individual beliefs (Kind, 2016). These beliefs and orientations are evident in how teachers perceive the goals of science education, their instructional practices, and the dynamic interactions between teachers and students. As a multidimensional construct, science teaching orientations guide how teachers interpret and enact their instructional practices. They play a crucial role in teacher knowledge, influencing how educators combine content knowledge with pedagogy to make science learning meaningful and accessible for students (Buehl & Beck, 2014; Demirdöğen & Uzuntiryaki-Kondakçı, 2016).

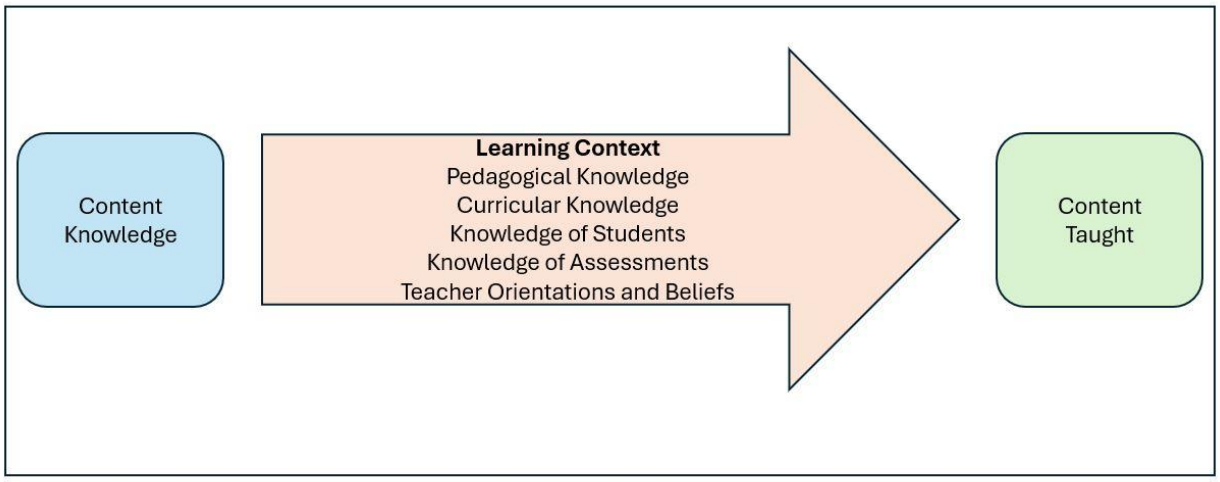
Teacher orientations act as lenses through which instructional decisions are made and determine what teachers prioritize, including their perceptions of student learning and assessment outcomes (Friedrichsen et al., 2011; Gess-Newsome, 2015). For example, a teacher who values inquiry and exploration will likely utilize student-centered, inquiry-based methods, while a teacher who views science as a set of facts to memorize may favor more traditional, lecture-based approaches (Campbell et al., 2017; Demirdöğen, 2016). Thus, a teacher's beliefs and orientation can enhance or hinder their development, depending on how they align with best practices in science education.

Teacher Beliefs, Orientations, and PCK

Teacher beliefs and orientations are pivotal in shaping PCK, influencing how teachers design and deliver instruction. First conceptualized by Shulman (1986), PCK refers to a teacher's ability to translate subject matter into teachable content that is understandable for students. See the model operationalized in Figure 1. Thus, PCK intersects with knowing what to teach (the content) and how to teach it (pedagogy). What teachers bring to practice determines the interactions between the content they know and the practices they implement.

Figure 1.

Pedagogical Content Knowledge in Action



Teacher Beliefs and PCK

Research indicates that teacher beliefs serve as both "amplifiers" and "filters" of PCK (Gess-Newsome, 2015). As amplifiers, beliefs drive teachers to adopt and refine instructional strategies that align with their educational goals. For instance, a teacher dedicated to fostering inquiry actively seeks professional learning opportunities to enhance their inquiry-based teaching skills, thereby expanding their PCK. Conversely, as filters, beliefs can limit PCK development when a teacher holds a rigid view of science as a static body of knowledge. This perspective leads to resistance against new pedagogical approaches, restricting their instructional growth. Addressing teacher beliefs is essential for shaping teaching practices; failing to do so may result in less productive teacher induction or ineffective professional development to improve PCK.

Aligning teacher beliefs with modern educational goals requires reflective and experiential approaches in teacher education. Research has demonstrated that programs encouraging reflective practice through experiential learning or mentorship/coaching yield promising positive outcomes in re-shaping teacher orientations (Demirdöğen & Uzuntiryaki-Kondakçı, 2016; Lee, 2019a; Lee, 2019b; Morris & Ogodo, 2024). Additionally, structured opportunities for reflection, feedback, and hands-on practice enable teachers to examine and critically refine their beliefs, fostering the development of adaptable and robust PCK suited to diverse classroom contexts.

Jones and Jones's (2013) study on the impact of science teacher beliefs on their instructional practices regarding reform-based, inquiry-oriented teaching methods found that teachers' beliefs

played a critical role in interpreting and implementing professional development initiatives. Teachers with strong inquiry-oriented beliefs engaged more with reform-based practices, integrating questioning and exploratory activities into their classrooms. However, when misalignment exists between their beliefs and the recommended instructional strategies, implementing reform practices is often fragmented, which diminishes the efficacy of these approaches.

Another study by Lee (2019a) looked specifically at preservice teacher development. Results showed that participating in experiential learning activities transformed PSTs' beliefs from traditional, teacher-centered instruction to facilitating more inquiry-based, student-centered methods. Through hands-on practice, reflection, and adaptation, they developed critical thinking, lesson planning, and problem-solving skills essential for effective inquiry-based teaching. Thus, research reinforces that immersive experiences and reflective practice are key to developing educators who can adapt to innovative instructional practices and respond to student needs (Girvan et al., 2016; Jones & Jones, 2013; Lee, 2019a, 2019b).

Teacher Orientation and PCK

Teacher orientations and views on instructional goals and the nature of science itself can impede the connections they make between the content and the practice. Research suggests that understanding these nuances is critical for teacher education programs (Campbell et al., 2017; Demirdöğen & Uzuntiryaki-Kondakçı, 2016). Incorporating reflective practices can modify teacher orientations to align more with reformed-based practices, such as inquiry-based, student-centered approaches, leading to positive learning outcomes.

Kind's (2016) investigation of PSTs' science teaching orientations and beliefs about the nature of science revealed that about half of the 237 PSTs in the study preferred teacher-centered, content-focused approaches over student-centered learning, with limited evidence of reform-based practices. This highlights a disconnect between current educational reforms and PSTs' instinctive methods. Many participants held naïve or partially informed views of the nature of science as a static body of facts rather than a dynamic, evolving field, which correlated with their preference for didactic instruction.

The interplay between teacher beliefs, orientations, and PCK is demonstrated in studies on how they interact with various PCK components that affect their science teaching expertise, instructional strategies, curriculum knowledge, and assessment methods (Demirdöğen, 2016; Kind, 2016). Consequently, teachers with clear, purpose-driven orientations can integrate PCK components more effectively and cohesively. Where there is misalignment between teacher beliefs, orientations, and PCK, their practice defaults to a teacher-centered pedagogical approach. While understanding teacher orientations and the development of PCK is crucial for effective science teaching practices, it is equally important to consider how the local context impacts teacher beliefs. This focus is central to place-based education.

Place-Based Education

Place-based education is an instructional approach that utilizes the local environment, community, and culture as the primary context for learning. Rather than relying solely on textbooks, place-based education encourages students to engage with their learning contexts' physical, social, and environmental aspects, making learning more tangible and relevant. This approach to learning emphasizes real-world connections, allowing students to investigate and solve problems directly tied to their community (Sobel, 2004; Webber, 2021; Yemini et al., 2023). By bringing local contexts into the curriculum, place-based education fosters a sense of place and belonging, which can deepen students' understanding of content across various subjects, particularly in science. Through outdoor

or community-based activities, students can observe natural phenomena, engage in fieldwork, and explore ecological and cultural issues significant to their region (Webber, 2021; Yemini et al., 2023). This approach makes learning more meaningful because it connects classroom concepts to the world outside and encourages students to see themselves as active participants in their community's ecosystem and cultural heritage.

Benefits of Place-Based Science Education

Place-based education offers several benefits in science teaching and learning. One of its most significant advantages is the increased engagement it fosters among students (Yemini et al., 2023). When learners can see the direct relevance of scientific concepts to their local environment, they are more likely to be motivated and invested in the learning process. For example, studying water quality becomes more engaging when students collect and analyze samples from a nearby stream, rather than merely reading about it in a textbook. This hands-on, context-driven approach helps science students develop a deeper and more intuitive understanding of scientific principles (Dori et al. 2018).

Place-based education enhances content retention by reinforcing abstract concepts through direct experience, allowing students to apply their knowledge in real-world contexts. Furthermore, it fosters critical thinking and problem-solving skills, as students analyze data, make observations, and draw conclusions based on their local investigations (Smith, 2017). By focusing on local issues and ecosystems, place-based education also encourages learners to cultivate a sense of responsibility for their community and the environment, which aligns well with the goals of science education, promoting scientific literacy and environmental stewardship.

Influence of Place-Based Approach on Teacher Beliefs and Practice

Engaging PSTs in place-based educational experiences can have a transformative impact on their beliefs and teaching orientations. Such experiences expose them to inquiry-based, student-centered approaches that reshape their understanding of how science can be taught effectively within a local context (Lowenstein et al., 2018). Additionally, when PSTs participate in place-based learning activities, they experience firsthand the benefits of engaging with their environment. This shifts their orientation from a more traditional, didactic approach to a dynamic, inquiry-driven perspective. Studies have demonstrated that PSTs who engage in place-based education are more likely to adopt practices that encourage exploration, questioning, and hands-on learning because they see the benefits of connecting curriculum content to the real world (Webber, 2021; Yemini et al., 2023). This shift enhances their PCK and aligns their teaching practices with reform-based science education, which advocates for active learning and critical thinking over passive information transmission.

These extant literatures show the correlation between integrating experiential and place-based education approaches in supporting PSTs' preparation. They are crucial in developing PSTs' confidence and competence in teaching science. Experiential learning encourages active participation and reflection (Kolb, 2014), while place-based education provides a concrete, real-world context for these experiences (Sobel, 2004). Together they enable PSTs to recognize the connection between theoretical concepts and instructional strategies in authentic settings. By participating in place-based learning and utilizing experiential activities, PSTs gain a better understanding of how to use PCK components—content knowledge, pedagogy, and assessment—to promote inquiry and engagement (Chinn, 2012; Lowenstein et al., 2018; Yemini et al., 2023). These methods can provide a foundation which PSTs use to design informative, interactive lessons adapted to the students' local environments and educational needs.

Methods

This study utilized a qualitative case study research design approach (Creswell & Poth, 2016; Yin, 2017) to explore how an inquiry-based outdoor experience influenced PSTs' science teaching orientations and to identify the patterns that emerge in their perceptions of science teaching following the experience.

Context/Participants

The case was bound by the location of the study and the participants involved. The study took place at Outdoor School, located in a 385-acre section of land along the local lake in a southwestern part of the United States. The participants included 38 (37 female/1 male) pre-service elementary education students enrolled in a science methods course at a university in the community. The course was designed to prepare the PSTs for elementary science in grades EC-6.

Following a course module on place-based learning, the PSTs went on a three-hour field trip to Outdoor School and an exploration of two ponds. The onsite outdoor instructor provided boots and safety instructions before they began the investigation by first hypothesizing "which pond is healthier" through mere observation. They took pictures and discussed what they believed were characteristics of a healthy pond. Next, they received instructions on the best method for using the nets provided to scoop specimens from the pond and how to keep the organisms healthy in the "swimming pool" until they were returned to the pond. The outdoor instructor also helped the PSTs remove their catch from the net if they were uncomfortable doing it themselves.

After collecting and separating the specimens, they brought them to the pavilion for microscopic examination. They also took pictures with their cell phones, allowing them to see tiny features when enlarged. They documented their observations and identifications in their journal entries, using a key supplied by the Outdoor School Instructor. After completing the data entry process, which involved identifying and counting the organisms, they discussed their findings. They shared the characteristics that define a healthy pond with the Outdoor School Instructor and compared the results with their initial hypothesis. Finally, they discussed adaptations of the activities for different age groups and possible extensions including testing water pH and turbidity.

Before the PSTs returned to the university campus the following week, they wrote or recorded a reflection on their experience at Outdoor School. During the next class meeting on campus, the PSTs worked on creating a 5E lesson plan utilizing the Outdoor School experience in one of the Es of the lesson. In a follow-up discussion, PSTs brainstormed other local sites (including those on elementary campuses) that might be used for similar types of lessons. For their final paper of the course, they developed their philosophy of science teaching and used the Outdoor School lesson plan to demonstrate their philosophy in action.

Data Collection

Qualitative data were collected from three key sources: the pre-assessment, which was the PSTs' Personal Science and STEM Beliefs Assignment, and two post-assessments, including the written or video reflections and their final philosophy essays. Participants were assigned numbers to replace their names, and all assignment documents and transcripts were numbered to align pre- and post-data.

Personal Science and STEM Beliefs Assignment (Pre-assessment). Before the Outdoor School experience, participants completed a written assignment to articulate the PSTs' existing beliefs about science teaching and learning and how they planned to incorporate various approaches. This pre-

assessment provided a baseline for understanding participants' initial perceptions. Figure 2 illustrates the prompt for the pre-assessment.

Written or Video Reflections (Post-assessment). Immediately following the Outdoor School activity, participants were given two options: a) a written reflection or b) a video reflection. These reflections captured the PSTs' immediate reactions and insights about how the experience influenced their perceptions of science education and highlighted key takeaways. These reflections assessed how participants' views on teaching approaches and place-based education had evolved during the outdoor activities. This assignment played a key role in their experiential learning, fulfilling the reflection portion of the cycle. See Figure 3 for the reflection prompt.

Final Science Teaching Philosophy Essays (Post-assessment). At the end of the course, participants submitted a comprehensive essay outlining their science teaching philosophy. They incorporated their understanding of science teaching, inquiry-based methods, and the integration of place-based learning, particularly from their experiences at Outdoor School. These essays were crucial for understanding their teaching orientations and how they intended to apply the skills and knowledge from the outdoor learning experience to their broader science teaching practices. This assignment prompt is included as Appendix A.

Figure 2

Personal Science and STEM Beliefs Assignment Prompt.

Personal Science and STEM Beliefs Assignment

This assignment is designed to explore the factors impacting your views of science and science education. Share your experiences and address the following:

1. What do you recognize as the beliefs, ideas, and attitudes about science that you bring into this course and that you will potentially bring into your elementary classroom?

2. What were your previous science courses? How did you choose those courses? How did you feel about those courses? How did the courses influence your beliefs, ideas, and attitudes? How do you feel the courses prepared you to teach science to elementary students?

3. How have other experiences (other than science courses and teachers) impacted your beliefs, ideas, and attitudes about science and STEM?

4. Did your family impact your beliefs about science? Explain.

1-2 pages, double-spaced, size 12 font, 1" margins

Figure 3

Outdoor School Reflection Prompt

Outdoor School Reflection

Please reflect on your experience visiting Outdoor School. You may type or record your reflection as a video. However, make sure to address each question fully.

1. What did you learn that you didn't know before?

2. How could this impact the way you would teach science?

3. What were the benefits of visiting Outdoor School?

4. How could the instructor improve the experience in the future?

Data Analysis Procedure

Part 1

Inductive Analysis. The data analysis followed a multi-step process, first utilizing an inductive approach to understand how the immersive, place-based experience shaped participants' beliefs and orientations toward science teaching. The analysis began with a detailed review of the Personal Science and STEM Beliefs Assignment. A line-by-line open coding process was employed, highlighting key phrases related to science teaching practices and place-based education (Saldaña, 2015). Initial codes were developed to capture the essence of the participants' statements. The codes were grouped to form initial themes based on their commonalities. The themes were further refined to better represent the data. Similar themes were merged while overarching patterns were identified (Clarke et al., 2015). It is important to note that real-world, informal, and place-based approaches were included in the initial themes but later categorized within the final theme of inquiry-based approach because each was originally mentioned in conjunction with inquiry-type methods. Table 1 shows examples of initial codes from the "pre" assignment along with the themes that developed for initial beliefs and orientations toward science teaching.

Table 1

Initial Beliefs/Orientations Codes and Themes

Example Codes	Initial Themes	Final Themes
Hands-on, experiments, real life, investigate, explore, inquiry, observations, explanations, ask questions, discuss, test hypotheses, collect data, field trips, real-life examples, science all around us, museums, planetarium, observational projects, curious about the world	Hands-on, place-based, inquiry, informal learning, exploration, experimentation	Inquiry-based approach

Facts, know content, focus on content, standards, objectives, knowledge, given facts, experiments frighten and deter me, explain, facts and equations, science knowledge, concerned about how to implement experiments, not enough time to teach science, cost of materials, I will show interest, ask questions and find answers	Fact-based, teacher-guided, science concepts, limitations to inquiry, standards and objectives	Traditional approach

Part 2

Deductive and Inductive Analyses. This analysis section began with a detailed review of the written and video reflections and final philosophy essays (post-experience data). Using a line-by-line open coding process (Saldaña, 2015), key expressions and statements related to science teaching practices and place-based education were highlighted. This part of the analysis served a two-fold purpose. First, the codes were deductively grouped according to the themes derived from the inductive analysis in Part 1 (Traditional or Inquiry-based). The second step involved an inductive analysis process to identify patterns in participants' perceptions of science teaching after engaging in immersive inquiry and place-based science activities. This portion of the analysis provided insights into developing additional themes which were merged into three overarching themes.

Categorizing Participants' Changes. Each participant's pre-assessment, Outdoor School reflections, and final essays were compared to determine any changes in their orientations and beliefs. The themes from the inductive analysis were used for this deductive step in the process. This portion of the analysis involved identifying instances where participants explicitly expressed support for or reservations about inquiry- or place-based learning after their Outdoor School experience. Instances of support for more traditional, fact-based or objective-based methods were also identified. To better understand how the experience influenced their beliefs, the following categories were used to characterize changes:

- Reinforced Beliefs: Participants whose beliefs about science teaching remained consistent following the Outdoor School experience, regardless of the approach they favored.
- Expanded Beliefs: Participants whose initial beliefs grew or expanded to encompass a broader understanding of the preferred science teaching approach following the Outdoor School experience.
- Shifted Beliefs: Participants whose initial beliefs about science teaching changed following the Outdoor School experience.

Within each category, two subcategories were defined:

- *Valued Inquiry Learning*: Participants whose beliefs were reinforced, expanded, or shifted in a positive manner towards inquiry learning.
- *Did Not Value Inquiry*: Participants whose beliefs were reinforced, expanded, or shifted in a negative manner towards inquiry learning.

Frequencies were utilized to quantify changes in the PSTs' beliefs and orientations toward science teaching methods. The number of participants in each category and subcategory was determined and used to better demonstrate the impact of the experience across the groups.

Emerging Patterns of Participants' Perceptions. The inductive portion of the "Part 2" analysis began with the pre-coded post assessment data. As in the "Part 1" analysis, the codes were grouped to form initial themes based on their commonalities, and similar themes were merged while overarching patterns were identified (Clarke et al., 2015). Table 2 shows examples of initial codes from the "post" assignments along with the themes that developed for participants' perceptions of science teaching after engaging in immersive inquiry and place-based science activities. To ensure trustworthiness in the study, researchers utilized triangulation and member checking. Multiple data sources were used to verify findings including two narrative documents for post data. Additionally, preliminary findings were shared among all researchers for their feedback and verification.

Table 2

Final Beliefs/Orientations Codes and Themes

Example Codes	Initial Themes	Final Themes
Hands on exploring, 5e lesson, student-driven learning, experience, do the work, inquiry-based learning, inquiry-based lessons, authentic hands-on experiences, experiments, test hypothesis, student-led, make discoveries, hands-on activities	Hands-on learning, active learning, scientific practices	Hands-On Engagement
Caring for the environment, enjoy nature's beauty, local activities, outside the classroom, teach science anywhere, real-world observations and investigations, out in the wilderness, immersing them in nature, a different environment, a personal connection, real-life scenarios	Real-world connection, meaningful learning experiences, environmental literacy	Contextual Relevance
Collaborating with my peers, group work, seeing classmates engaged, seeing classmates' interactions and different things that they learned, collaborating with everybody, roles can be important, collaborating, seeing classmates curious, communication, sharing observations, discussing outcomes with classmates, fostering a sense of community, shared discovery	Collaboration, social learning, peer-supported learning	Integrating Collaboration in Learning

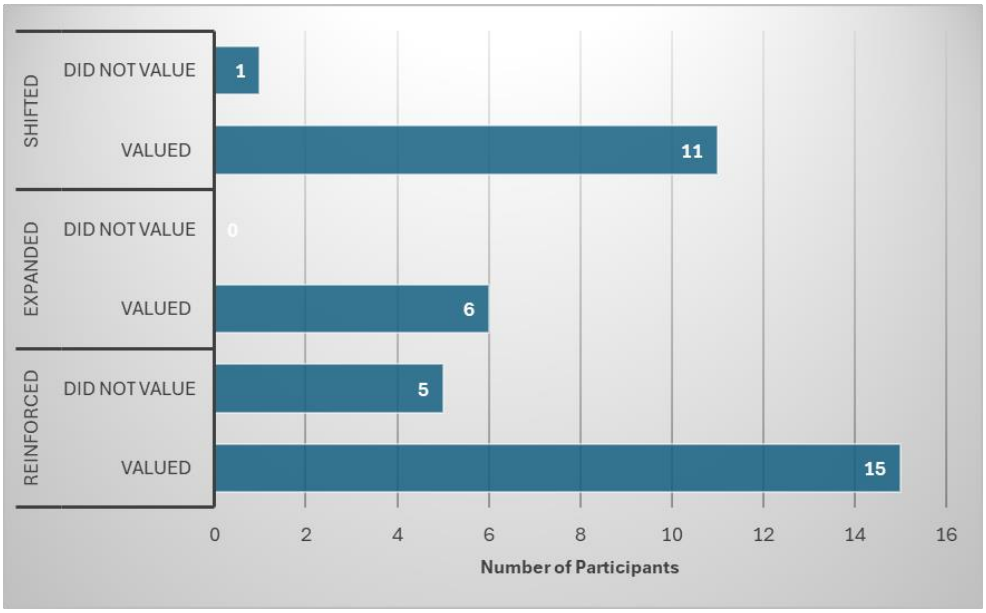
Results

Significant insights were offered into how the Outdoor School experience shaped PSTs' perceptions of inquiry learning. The data findings regarding the first question, "How does an inquiry-based outdoor experience influence PSTs' science teaching orientations?" were organized into three categories: reinforced beliefs, expanded beliefs, and shifted beliefs. These categories were further

divided into subcategories based on whether participants valued or did not value inquiry-based learning. Figure 4 illustrates the frequencies for the categories.

Figure 4

Changes in Beliefs and Orientations toward Inquiry Learning



Reinforced Beliefs. The largest group of 15 participants held positive views on inquiry-based learning before the Outdoor School experience, and their beliefs were reinforced. These participants saw the outdoor learning experience as confirmation of their existing belief that hands-on, real-world interactions are vital for effective science teaching. They often mentioned how observing science in a natural context strengthened their understanding of its relevance and engagement. For example, one participant noted, "Seeing science happen in a real-world setting, like the pond study, validated my approach to making learning hands-on for my students."

A smaller group of five participants maintained their prior skepticism or indifference towards inquiry and/or place-based learning. Even after the immersive experience, they did not demonstrate an observable change in their preference for more traditional, classroom-based teaching methods. Though, their reflections often highlighted logistical concerns or doubts about how outdoor learning could be seamlessly integrated into the curriculum. For example, one participant stated, "I think I would modify the activity and have the bugs picked out and let the students observe them in the classroom. That would be a better way to let them interact with nature but get through the curriculum."

Expanded Beliefs. A group of six participants held positive views of inquiry and/or place-based learning before the field experience, and their beliefs were subsequently deepened and expanded. They gained new insights into how they could apply inquiry approaches to various aspects of science teaching. They expressed increased confidence in facilitating inquiry-based activities and emphasized the benefits of integrating local environmental contexts into their teaching. For example, a participant reflected, "The Outdoor School experience showed me how to teach complex topics like ecosystems through local, hands-on activities, which I hadn't fully considered before. I think being outdoors and experiencing nature and seeing firsthand exactly what we were talking about will change the way I

teach science." It is essential to note that no participants initially fell under the subcategory of not valuing inquiry learning, then expanding their beliefs in a negative direction.

Shifted Beliefs A substantial group of 11 participants experienced a shift in their orientations, moving from uncertainty or skepticism to a strong appreciation for inquiry learning. These participants had prior reservations but found the outdoor activities to be eye-opening. They recognized the impact of engaging with hands-on, inquiry-based activities and were inspired to adopt similar methods in their teaching practices. For example, one participant stated, "Initially, I wasn't sure how effective outdoor learning could be but seeing my classmates so engaged and curious during the pond study completely changed my perspective." One participant indicated a slight shift but did not fully embrace the idea of inquiry learning in an outdoor setting. They acknowledged some benefits of the approach but remained hesitant due to the perceived barriers. This participant fell under the subcategory of "did not value." Table 3 shows examples of quotes and the represented orientations of participants following the experience at Outdoor School.

Table 3

Participant Orientation Quotes Following Outdoor School Experience

Initial Belief and Orientation	**Change**	**Quote (Post)**
Inquiry-Based	Reinforced	This experience just reinforced the importance of hands-on activities or engaging activities to support learning. It didn't feel like I was learning, but I was.
Inquiry-Based	Expanded	I always like hands-on exploring whenever I do science lessons, but I really like the way we learned. It put into perspective how a 5e lesson could fully be used.
Inquiry-Based	Expanded	It raises the value of a 5E lesson. I do believe that I now have a better understanding of how to not only teach students scientific concepts but also help develop important skills that will serve them well beyond the classroom.
Traditional	Shifted	I realized being at Outdoor School that being able to observe allowed me to see more of the organism's habitat and be able to describe it in detail. The way I will teach science will be having students do a lot of hands-on activities
Traditional	Shifted	I really enjoyed it because it got us out of the classroom, and I learned better out of the classroom
Traditional	Shifted	I learned that you could use the outdoors while teaching curriculum. I never knew how well that it would connect the students to the real world of science until we attended Outdoor School.

Traditional	Reinforced	I did not want to touch anything at all. Some students might feel the same way. I would modify the activity.

Three themes emerged from the inductive analysis of the data responding to the second question, "What patterns emerge in PSTs' perceptions of science teaching through their engagement in place-based education activities?" This experience underscored the value of hands-on engagement, contextual relevance, and integrating collaboration into learning.

Hands-On Engagement. This theme centers on students' engagement in hands-on activities and how these experiences deepen their understanding of scientific concepts, such as observing ecosystems~~,~~ identifying organisms~~, and~~ recognizing the benefits of tangible, interactive experiences in enhancing student engagement. Additionally, this theme emphasizes the significance of hands-on interaction with scientific phenomena. Participants valued how these activities sparked excitement and curiosity, which they saw crucial to introduce into their classrooms. One participant highlighted the difference that hands-on, sensory experiences make for students, suggesting that seeing and touching scientific concepts in action made the learning more impactful, "It's different when they can see and touch it themselves."

Contextual Relevance. This theme connects science to students' local environments and everyday experiences. Participants believed that science instruction becomes more powerful when students see how it applies to their lives, communities, and surroundings. Many highlighted that science is more than just abstract knowledge; it's something students can relate to and engage with in their communities. One participant suggested that teaching in local settings can make scientific concepts feel more real and relevant to students, thereby fostering a stronger connection to the content. "I want to teach my students about ecosystems using places they know, like local parks or lakes, because it makes the learning feel real."

Integrating Collaboration in Learning. The collaborative nature of the outdoor activities stood out prominently for many pre-service teachers. They noted the desire to adopt similar approaches in their classrooms, enabling students to work together during activities. The experience highlighted the benefits of teamwork, problem-solving, and collective learning, which participants plan to incorporate into their instructional strategies. One participant stressed the value of working with others and how that can extend from the classroom to the community: "The collaborative aspect of sharing observations and discussing outcomes with classmates added depth to the learning process, fostering a sense of community and shared discovery."

The three themes illustrate how the experience at Outdoor School reshaped pre-service teachers' perspectives on place-based inquiry science education. The instructional approach underscored the value of hands-on engagement, made science relevant through local contexts, and integrated collaboration into learning. Table 4 shows examples of quotes and the represented patterns emerging in PST's orientations following the experience at Outdoor School. These findings reveal that pre-service teachers view place-based inquiry learning as a powerful method for making science education more engaging, relatable, and effective.

Table 4

Patterns Emerging in PST's Orientations Following Outdoor School Experience

Theme	**Example Quotes (Post)**
Hands-On Engagement	I always like hands-on exploring whenever I do science lessons, but I really like the way we learned. It put into perspective how a 5e lesson could fully be used. Being there and doing the assignment firsthand brought it to life and I was allowed to use all senses to understand the content of the assignment better. Because this is a student-led activity, I must allow students the chance to make their own discoveries first. We got to really get dirty and do the work ourselves and not just look at data that we've seen on the screen or a paper that we got passed out.
Contextual Relevance	The Outdoor School experience showed me how I can teach complex topics like ecosystems through local, hands-on activities, which is something I hadn't fully considered before. I feel like it's better to teach kids with real-life scenarios and show them things that in real life they would see. I loved how we got to learn in a different environment than a classroom. Gaining that experience, I now have a personal connection.
Integrating Collaboration in Learning	Collaborating with my peers during the pond study made me think about how I can use group work to teach science concepts more effectively. I also got to see my classmates' interactions and different things that they learned and things that they saw. The collaborative aspect of sharing observations and discussing outcomes with classmates added depth to the learning process, fostering a sense of community and shared discovery. I think that was really cool, just being able to collaborate with everybody.

Discussion

Findings in this study suggest that the inquiry- and place-based science learning experience reshaped the PSTs' teaching orientations and perceptions of science instructional practices. Most participants valued the tangible experiences and knowledge gained. Their interactions with outdoor learning and the activities provided an in-depth understanding of the scientific concepts and enhanced their passion for science teaching. Frequency data showed that the experience at Outdoor School greatly impacted the PSTs' teaching beliefs and orientations with many participants expanding or shifting their views in favor of more inquiry-based teaching methods. Although many began with positive attitudes toward inquiry, they deepened their understanding and appreciation for the approach through this process, and their reflections highlighted their beliefs, which they applied to their lesson plans. These findings support the previous research that traditional beliefs are reshaped through experiential learning methods and prepare teachers to implement innovative active learning strategies (Buehl & Beck, 2014; Lebak, 2015; Loughran, 2013).

For those participants who remained unmoved towards more inquiry methods, the outdoor location may have been a deterring factor. One participant stated, "But I don't know if I would take a group of second graders out into a pond, because that would be scary." Another participant shared, "I am not really an outdoor person. It was fun being there with my classmates, but I did not want to touch anything at all." Thus, a different type of outdoor setting for an immersive experience could have been more effective in shifting their orientations. Preference for and comfort level with the content and context may have played a role in their lack of enthusiasm for the experience. These results support existing literature findings that dynamic experiences during teacher preparation encourage significant innovations in curriculum and practice (Girvan et al., 2016; Lee, 2019a). Using a familiar location, such as Outdoor School, the PSTs appreciated how science can be engaging in a meaningful and relevant way and provide accessibility to all students, thereby promoting a more profound sense of connection.

Additionally, the findings showed the effectiveness of place-based education and its benefits for bridging the gap between school science and local environments and communities along with increasing the engagement of students in the learning process. Several participants emphasized the importance of the local environment and community resulting from the pond study activity. They used phrases such as "environmental stewardship," "informed citizenship," and the "beauty of nature." Several more participants highlighted increased engagement during the outdoor experience. For example, they included the phrases "engage in real-world observations and investigations," and "engage with what they are learning." These findings mirror previous research suggesting the most significant benefit of place-based education is the engagement fostered among students (Yemini et al., 2023).

While many participants shifted towards more inquiry and place-based orientations, a few expressed hesitancies due to perceived barriers such as classroom control or curriculum demands. Their reflections highlighted logistical concerns about how integrating outdoor learning could hamper structured curriculum. Some voiced safety concerns for younger students, while others discussed time constraints and the lack of opportunities in various districts. These worries are not new to science educators. Many veteran teachers in science classrooms have voiced similar reservations about implementing these types of innovative practices (Fitzgerald et al., 2017). To begin addressing these issues, teacher education programs must offer appropriate guidelines for managing and aligning outdoor activities with curriculum standards and provide proper tools for developing PSTs' confidence and self-efficacy with inquiry strategies.

Implications and Limitations

Despite the benefits of inquiry-based approaches, traditional beliefs can be deeply rooted and difficult to change. Many PSTs have pre-formed notions and established beliefs about teaching and learning before entering teacher preparation programs. These beliefs are shaped by their educational experiences and limit their openness to adopting new ideas or reform-based practices (Buehl & Beck, 2014). The findings in this study suggest that teacher education programs should incorporate experiential learning opportunities that expose future educators to hands-on, collaborative, and contextually relevant teaching strategies, which can transform their instructional philosophies and enable them to create more dynamic, inquiry-driven, and student-centered learning environments. Although prior studies have shown that PSTs are more likely to shift from traditional to inquiry-based orientations when they engage in experiential learning and innovative instructional methods (Demirdöğen & Uzuntiryaki-Kondakçı, 2016), this study takes a novel approach by examining these shifts through a lens of "place." Furthermore, these researchers suggest that teacher education programs must move beyond traditional brick-and-mortar settings to create more relevant contexts and environments that broaden PSTs' existing beliefs and encourage conceptual change. Doing so will prepare future educators to design and implement innovative instructional activities in formal and informal settings.

Traditional beliefs may also be engrained in early-career and veteran science teachers who are resistant to inquiry methods of instruction. These teachers might experience systematic barriers and misunderstandings about the nature of inquiry itself (Morris, 2024, 2025). Educational researchers should investigate how these kinds of programs could be structured and implemented to benefit teachers and ultimately, the learning outcomes for students. School districts might then seek experiential learning opportunities that expose science educators to similar hands-on, collaborative, and contextually relevant professional development and induction programs. These platforms could promote more inquiry-based and student-led settings for future K-12 science instruction.

Although the results indicated the experience at Outdoor School impacted PSTs' orientations toward more innovative teaching approaches, some limitations existed in the study. First, with only 38 preservice teachers, the sample size may not be representative of the larger population of future science teachers. The study size and the qualitative nature of the data do not support generalizing the findings to all preservice science teachers. Second, the scope of the place-based experience was limited to ponds in one rural community. These findings may not fully capture the scope of potential benefits and challenges of place-based learning in a broader context or be applicable to place-based learning in other settings. Third, many of the participants described shifted, expanded, or reinforced orientations toward more hands-on and inquiry-based learning; however, the data do not necessarily indicate their level of scientific inquiry literacy. More research is needed to determine if the changes in orientations lend themselves to actual increases in inquiry practices.

Conclusion

As science education reform continues to advocate for more active and authentic learning experiences, this research affirms that equipping future teachers with tools to integrate hands-on, collaborative, and locally relevant activities can lead to more dynamic and effective science instruction. This study illustrates how informal learning can profoundly shape PSTs' perceptions and orientations to teaching science. The immersive and contextual learning experiences used in this course gave participants the ability to engage directly with scientific concepts. Many of the PSTs who participated in this course found the experience more impactful than traditional, classroom-based approaches which enabled them to shift from their previously held notions. The study showed how using such a

template, teacher education programs can purposefully incorporate and present learning opportunities that embrace the duality of integrating formal and informal learning.

The authors received no financial support for the research, authorship, and/or publication of this manuscript

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Appendix A

Personal Science Education Philosophy

An educational philosophy offers a basis for clarifying the purpose(s) of education, and, specific to science, a science education philosophy clarifies the purpose(s) of science education. Zinn (1991) determined that all those involved in the business of education, including teachers, administrators, and college professors, should not address any educational issue "without some underlying purposes, even if the purpose is not explicitly articulated" (p. 39). While many major decisions about the purposes and direction of education are made at the national, state, or school district level, there is still an element of choice for individual teachers when it comes to such things as what to emphasize when teaching, what to downplay or avoid, what materials to use, and how to assess learning. Many determinations of these factors can be resolved, in part, through a teacher's personal philosophy of education, and, when making determinations specific to science content, science materials, and science assessment, determinations can be made through a teacher's personal science education philosophy. Therefore, the purpose of this assignment is to allow you the time and parameters for articulating your personal science education philosophy so that you may use this philosophy as a basis for making well-founded decisions in your science classroom.

Utilizing all the knowledge you have gleaned through your science course discussions, activities, readings, assignments, and experiences, you need to address and answer the following questions within your personal science education philosophy:

- What is the purpose of science education?
- What content should be addressed in a science classroom?
- What instructional practices/approaches should be utilized in a science classroom?

- What is the teacher's role in a science classroom?
- What is the role of students in a science classroom?
- What types of materials should be utilized in a science classroom?
- How should science understanding be assessed?
- How does a teaching for understanding perspective influence your science education philosophy?

To represent your views on science instruction in the classroom, use the Outdoor School activity as the basis for an example of how you could use that type of activity in your classroom to teach according to your philosophy.

- What TEKS would be appropriate for this activity? Explain
- How could you incorporate it within the 5E structure of inquiry? Provide details.
- Reflect on your experience and the content you learned as you describe your activity.

Your philosophy should be at least **3** double spaced pages in length and no more than **5** double spaced pages, and you are to give explanation in support of your philosophical beliefs and ideas. The Outdoor School portion may include diagrams, tables, lists, or other visuals and should be between 1 and 2 pages. **Thus, your total project/paper should be between 4 and 7 pages.**

Upload your paper on Canvas by the date/time of the final. If you have any questions, please don't hesitate to contact me.

Zinn, L. M. (1991). Identifying your philosophical orientation. In M. Galbraith (Ed.). *Adult Learning Methods (pp. 39-77)*. Malabar, FL: Krieger Publishing Company.

ELECTRONIC JOURNAL FOR RESEARCH
IN SCIENCE & MATHEMATICS EDUCATION
VOL. 30, NO. 1, 23-42

Longitudinal Investigation of Pre-service Science Teachers' Future Career Expectations during a Teacher Education Program

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ABSTRACT

The purpose of this study is to examine the future career expectations of 86 Turkish pre-service science teachers at the beginning and graduation stages of a four-year teacher education program. The research design included both the longitudinal (within-subject) and between-subject differences by investigating whether future expectations changed over the four-year time period, and according to participants' gender, and orientation toward the teaching profession. The explanatory-sequential mixed-method design was used in the study, where a panel study was employed in the initial quantitative data collection phase. The quantitative data were collected with the Future Expectations Scale, whereas the qualitative data were obtained through open-ended questions and semi-structured interviews. The findings indicated that the future career expectations of participants were generally positive. These expectations did not differ by participants' gender and semester (freshman-senior) of the teacher education program; however, teaching career-oriented participants were found to have more positive future career expectations than their non-teaching career-oriented peers. The qualitative data indicated that the majority of the participants were willing to be immediately appointed as science teachers after graduation but many of them possessed pessimism due to their concerns about the Turkish teacher appointment system and stated that they unwillingly postponed the start of their teaching career. Based on the semi-structured interview data, some participants were found to hold fears about their future. The most common fears were classified as being afraid of experiencing disappointment, burnout, and failure of facing a generation gap after a certain time.

Keywords: Pre-service science teacher; future career expectation; longitudinal study; panel study; career orientation

Introduction

Improving the systemic and humane elements of educational systems is a common educational reform target for many countries throughout history to increase the quality of education (Plecki et al., 2012). Teacher quality is one of the major factors for improving the quality of education; directing qualified and willing candidates to the teaching profession is critical (Eren, 2012a; Organization for Economic Co-operation and Development [OECD], 2005). However, a significant number of qualified candidates who enter teacher education programs do not complete these programs due to their personal preferences, or quit the profession within a short time after starting teaching (Gallant

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& Riley, 2014; Kyriacou & Kunc, 2007; Peters et al., 2017). Common reasons for this attrition are shown as the content and difficulty level of the teacher education programs, social environment (Meens & Bakx, 2019), negative learning or teaching experiences, financial problems (Lin et al., 2016), declined interest in teaching, and other personal problems (Ryan et al., 2024).

The major reasons for the shortage of qualified teachers are reported as limited numbers of qualified candidates entering teacher education programs, teacher candidates giving up during these programs, some graduates who do not start teaching at all, and many new teachers leaving the profession early in their career (Lunenburg, 2011; Rots et al., 2012; van Rooij et al., 2019). Thus, to be able to make long-term predictions about the future of the teaching profession, the motivations of pre-service teachers and their career goal orientations bear great importance (Thomson & McIntyre, 2013). In this context, this study aimed to examine pre-service teachers' future expectations longitudinally over a four-year program and to address whether career expectations change over time.

Goal Orientation

Goal orientations can be defined as an individual's mental representations of a desired future state (Rüprich & Urhahne, 2015). Goal orientations play decisive roles in many aspects during decision-making and goal-reaching processes. According to the goal-attainment theory, individuals with a goal begin to perceive their environment with a goal-oriented perspective (Thomson & McIntyre, 2013). The importance placed on any phenomenon, the effort exerted on the subject, and perseverance until the target is met, are closely related to future expectations, which are shaped by goal orientations (Çetin & Eren, 2019). People with more positive future expectations are likely to place more importance on situations that they believe will lead to a positive result, apply more effort towards being successful, and strive to achieve success by persevering, even in cases of failure (Arslantaş, 2021). For this reason, one of the most important sources of motivation for any subject is an individual's future expectations about that subject (Rüprich & Urhahne, 2015).

Future Expectations and Teaching Profession

Since the choice of personal profession is one of the main determinants of one's future social status, it is perhaps the most important individual decision where future expectations dominate (Ekinci, 2017). While choosing a profession, individuals tend to make decisions that will satisfy them in different aspects in the future (Eren, 2012b). This situation manifests itself in the choice of the teaching profession as well (Anthony & Ord, 2008; Yavuz Tabak et al., 2021). Therefore, one of the most important indicators of prospective teachers' opinions about their profession is their future career expectations.

Prospective teachers who have more positive future career expectations are likely to aim to work as more willing teachers for a long period (Aydin & İşlek, 2021; Lysaght et al., 2018). For example, prospective teachers with positive attitudes towards teaching stated that when sufficient working conditions are provided, they would not consider low wages a problem (Lysaght et al., 2018; Manuel & Hughes, 2006). Teacher candidates have also expressed that their enjoyment of the teaching profession would be more dominant, even in anxious situations they might encounter in the future (Eren, 2014). It is also noteworthy that a significant portion of teacher candidates with unrealistic/low future career expectations are reported to either leave teacher education programs or leave the profession in a short time after starting teaching (Purcell et al., 2005; Wilhelm et al., 2000). For example, especially in developed countries such as the UK and the USA, a significant portion of qualified teacher candidates do not complete teacher education programs after enrolling, and about half of those who start teaching leave within the first five years in the profession (Kyriacou & Kunc, 2007; Lunenburg, 2011; Manuel & Hughes, 2006; Struyven & Vanthournout, 2014). It is also reported

that many teachers in the workforce do not plan to remain in the profession for the long term, and some teachers plan to retire earlier than the anticipated retirement age (Lysaght et al., 2018; Peters et al., 2017).

The effects of negative future expectations for the teaching profession are mostly studied in developed countries; but since this problem is not unique to developed countries, it should be considered a global problem. The most important reason these problems are not adequately discussed in other developing or undeveloped countries is the lack of relevant scientific studies and the lack of focus on the effectiveness of teacher education programs (Eren, 2012b). Based on these gaps in the related literature, this study focused on the future career expectations of pre-service science teachers (PSTs) in Turkey.

Science Teacher Recruitment in Turkey

Teacher training in Turkey is carried out in universities under the regulations of the Council of Higher Education (CHE), which is the sole decision-making authority for all Turkish universities. Similar to the other majors, a common science teacher education program prepared by the CHE is used in all Turkish universities.

Turkish student selection for undergraduate programs is based on a centralized exam that is administered annually to high school graduates. Based on their central exam scores, individual preferences, and program quotas, candidates are entitled to enter undergraduate programs. Science teacher education programs in Turkey require completing four-years of coursework. Graduates earn their science teaching degree in 5-8th grade science courses at middle schools. In the first two years, Turkish PSTs take basic science (Biology, Chemistry, Physics) and science laboratory courses. In the third and fourth years of the program, specialized science courses (Anatomy, Astronomy, Ecology, Evolution, Geology, etc.) and science education methods courses are taken concurrently. During the four-year coursework, PSTs also take general education courses such as Introduction to Education, Educational Psychology, Teaching Principles and Methods, Measurement and Evaluation, and Classroom Management. In the fall semester of their senior year, PSTs enroll in the School Experience course to make observations at schools followed by the Teaching Practicum course in their final spring semester, which requires teaching 5-8th grade science courses under the supervision of an experienced middle school science teacher.

Graduates of science teacher education programs become entitled to work in private and state middle schools affiliated with the Turkish Ministry of National Education (MNE). The primary employment area for the majority of the Turkish teacher candidates is state schools. A vast majority of Turkish PSTs primarily prefer state schools over private schools because of better working conditions and long-term job security (Cheema et al., 2025; Ergen & Çokkeser, 2022).

However, Turkish PSTs cannot be directly assigned to state schools. To be assigned to a state school, graduates must be successful in the Public Personnel Selection Exam (PPSE), which consists of two different exams. The first exam of the PPSE consists of educational sciences/general ability topics and the second exam of the PPSE measures content area/teaching methods knowledge covering the whole four-year undergraduate teacher education program coursework. Both PPSE exams are conducted on separate sessions during the summer period, and the candidates earn a combined total PPSE score. The first requirement for continuing the appointment process is a higher PPSE score than the minimum score, which is announced for candidates annually. In the following stage, candidates who satisfy the minimum PPSE scores are interviewed by a group of "experts" selected by the MNE. It is not unusual that even the national champions of the PPSE get very low scores from the interviews, which brings questions about the validity of these interviews (Berk, 2025). With the addition of interview scores, final appointment scores are calculated. Based primarily according to their total PPSE scores and the number of open positions and secondarily on candidate

personal preferences, candidates prepare a preference list for the announced positions in different sites throughout the country (mostly in the poorer eastern regions and rural areas). Teacher appointments are completed centrally by the CHE and MNE. The score superiority for each position is the criterion, and candidates with sufficient scores are appointed to state schools (MNE, 2021, 2022, 2023, 2024).

The Turkish teacher-appointment system has been transformed in recent years, but serious problems are still present, mostly due to imbalance between the high number of graduates from teacher education programs and very-limited available teaching positions. Table 1 shows the number of pre-service teachers (all education majors and science education majors) who applied to the PPSE between 2020 and 2023, as well as the officially announced state quotas in these years, and the percentages of quota values to the total numbers in the relevant years (MNE, 2021, 2022, 2023, 2024).

Table 1

The Distribution of PPSE Applicants and Appointment Quota for Turkish State Schools between 2020 and 2023

Year	# of Applicants (All Majors)	Appoint. Quota (All Majors)	%	# of Applicants (Science)	Appoint. Quota (Science)	%
2020	471 506	19 940	4.2%	19 410	996	5.1%
2021	400 842	19 969	5.0%	17 941	480	2.7%
2022	476 974	44 890	9.4%	18 412	2064	11.2%
2023	572 019	20 000	3.5%	18 345	305	1.7%

As seen in Table 1, the appointment percentages of Turkish pre-service teachers change between 3.5% and 9.4% overall and 1.7% and 11.2% for science education majors. Since this supply-demand imbalance has been continuing for many years, more than 90% of Turkish science teacher candidates cannot be appointed upon graduation. Compared to the growing number of candidates awaiting appointment, the limited quotas for recruitment causes prospective teachers to experience intense anxiety regarding the appointment process (Atav & Sönmez, 2013; Berk, 2025). It is inevitable that experiencing high anxiety in the very early stages of their career will negatively affect both the motivational levels and the future career expectations of Turkish PSTs.

Significance and Purpose of the Study

It is very likely that negative expectations or concerns about the teaching profession can negatively impact an individual's teaching career. One of these concerns is the expectations of pre-service teachers regarding the reality shock when they begin teaching at schools. The *reality shock expectation*, which is defined as the collapse of the ideals created before starting the profession due to the negativities encountered in real classrooms, negatively affects beginning teachers (Mahmood, 2013; McIntush & Garza, 2023; Veenman, 1984). In order to identify these negative effects, it is important to investigate pre-service teachers' beliefs about their future teaching career and determine their reality shock expectations.

However, the sources of these negative beliefs are not considered a priority educational problem in many countries, including Turkey, due to the lack of research related to the problems associated with teacher education programs (Eren, 2012b). Therefore, the effects of future career expectations on Turkish teachers' careers should be investigated in detail (Çetin & Eren, 2019; Eren, 2012a). Furthermore, in most of the previous studies, the teaching major variable is not held constant as a control variable and the problems of teachers and/or teacher candidates in different majors (elementary, history, mathematics, preschool, science, etc.) are studied together. This type of single-group study inevitably results in distorted results because of the impact of the teaching major variable as an extraneous variable. For example, in a study where 397 Turkish pre-service teachers' future expectations were investigated, the general conclusion was that the participants had positive expectations. However, the between-group comparisons indicated that PSTs had more anxiety about their professional future compared to their other major peers (Şahin, 2009). For this reason, when studying the future career expectations of teacher candidates, it is important to focus on specific majors, to be able to spot the problems that are unique to those majors (Smetana & Kushki, 2021; Torsney et al., 2023).

It is also common in previous studies that pre-service teachers' future expectations have been examined mostly by single snapshot studies. In the majority of these studies, participants' expectations are measured at a single point in time, either at the start or graduation stage of the teacher education program. In many of these studies, it was reported that pre-service teachers' pre-college expectations towards the teaching career significantly affected their attitudes towards teaching (Eren, 2012b; Malmberg, 2006; Thomson & McIntyre, 2013). Thus, studies carried out at graduation stage also reveal that limiting the study perspective to merely the program entrance stage does not provide adequate information (Eren, 2012b). It has been reported in several studies that pre-service teachers with unrealistic pre-college expectations, even if these expectations were positive, may experience significant problems during the teacher education program and their future career expectations may change in the negative direction (Lysaght et al., 2018; Rots et al., 2012; Sinclair, 2008). Like all other time-dependent variables, future expectations can change over time as a result of the experiences of an individual (Wall, 2016; Yavuz Tabak et al., 2021). In most countries, multiple-year university-level education is required for a teaching license, so similar to other time-dependent variables, future career expectations may change during teacher education programs. Ideally, it is expected for all teacher candidates to enter teacher education programs with positive expectations and improve those expectations leading up to graduation. This improvement can be considered as an indicator of the quality of the teacher education programs (Lysaght et al., 2018; Plecki et al., 2012; van Rooij et al., 2019; Wake & Bunn, 2016). However, in the relevant literature compared to the single snapshot studies, there is a lack of research on the change of the motivational states of teacher candidates during their university years (Eren, 2012b; Rots et al., 2012; van Rooij et al., 2019). Therefore, it becomes crucial to investigate how pre-service teachers' future career expectations change during their teacher education programs (Çetin & Eren, 2019; van Rijswijk et al., 2018; Wall, 2016).

Based on the research gaps in the related literature, this study aimed to contribute to the literature by focusing on a group of Turkish pre-service science teachers (PSTs), a major that has not been studied in the previous literature as a special group in the area of future career expectations, and also by longitudinally investigating the changes in future expectations during a four-year teacher education program.

This study has been designed to investigate the following research questions:

1. Do Turkish pre-service science teachers' (PSTs') career expectations change during their teacher education program according to their (i) stage (beginning or graduation) in the program, (ii) gender, and (iii) being teaching or other career-oriented?

2. What are the views of Turkish pre-service science teachers (PSTs) about their future teaching career?

Methods

Research Design

This study was designed as an explanatory-sequential mixed-method study, which uses quantitative data to identify situations and then explain the causes of the situations by using qualitative data (Creswell & Plano-Clark, 2011). In the quantitative data collection phase, a panel study, a longitudinal design investigating the time-dependent changes on the same sample, was used. Despite the threat of participant attrition due to the long time it requires, panel studies have the highest validity among other longitudinal research designs because the data is collected from the same participants (Fraenkel & Wallen, 2003).

As part of the panel study, data from the same participants were collected in the first and final semesters of a four-year science teacher education program. In both data collection phases, participation in the study was voluntary through written and verbal consents. In the final semester data collection, participants were asked whether they volunteered for interviews to be held in the continuation of the study. Semi-structured interviews were conducted with a purposively selected group from consenting participants. The qualitative data obtained from the interviews and quantitative data were analyzed comparatively.

Participants

The participants of the study were 86 PSTs enrolled in a four-year undergraduate science teacher education program at a state university in Turkey. As a requirement of the panel design employed, the selection criterion for the participants was participating in both first and final semester data administrations. All participants in both data collection occasions were informed that participation in the study was voluntary and provided a written consent. Initially, there were 105 participants in the first-semester study, whereas 98 PSTs participated in the final-semester data administration.

Among these participants, 86 participated in both administrations due to student mobility during the four-years period of the study. 79% (n=68) of the participants were females and 21% (n=18) were males. Interestingly, mostly due to long-standing problems in Turkish university entrance and teacher appointment systems as well as limited teacher appointment quotas in Turkey, only 37% (n=32) of participants indicated teaching as their ideal pre-college profession, while 63% (n=54) of participants' ideal careers were other than teaching. The distributions of the participants by gender and pre-college career orientations are summarized in Table 2.

Table 2

The Distribution of the Participants by Gender and Pre-College Career Orientation

	Pre-College Career Orientation		**Total**
Gender	**Teaching**	**Other**	
Female	25	43	68
Male	7	11	18
Total	32	54	86

Participants for interviews were selected via the maximum-variation sampling technique (Patton, 2002) using participants' pre- and post-Future Expectations Scale (FES) scores. To satisfy maximum-variation criteria, participants with maximum FES score changes (increments/ decrements) and participants with minimal or no FES score changes were identified. Using these criteria, a total of 14 interview participants were selected. The FES score changes of the interview participants are summarized in Table 3.

Table 3

FES Score Changes of Interview Participants

Change Type	Pre-FES	Post-FES	Id
Positive Change	3.1	3.9	P_{34}
	2.4***	3.0	P_{09}
Negative Change	4.0*	2.6	P_{79}
	4.0*	3.1	P_{05}
	3.5	2.9	P_{39}
No Change/Minimal Change (Positive-Positive)	4.0*	4.0*	P_{28}
	3.9	3.9	P_{29}
	3.7	4.0*	P_{66}
No Change/Minimal Change (Moderate-Moderate)	3.3	3.4	P_{13}
	3.1	3.5	P_{71}
	3.3	3.1	P_{84}
No Change/Minimal Change (Negative-Negative)	2.2**	2.2	P_{43}
	3.0	2.8	P_{58}
	2.4***	2.7	P_{69}

*The maximum score that can be obtained from the FES
** The minimum score obtained among all participants in the pre-FES
*** The second-lowest score among all participants in the pre-FES

Data Collection Tools

In this study, the Future Expectations Scale (FES) developed by Bursal and Buldur (2013) was used in both data-collection administrations, at the beginning (as pre-test) and end of the four-year science teacher education program (as post-test) to investigate the longitudinal change of participants' future career expectations. The FES has a single-factor structure and consists of 10 (6 positive/4 negative) items. FES items can be responded to using a four-point Likert scale (1*: Strongly Disagree, 2: Disagree, 3: Agree, 4: Strongly Agree*). The raw data from the negative FES items were reverse coded and mean FES scores for each participant were calculated by dividing their total scores by the number of items. Thus, FES scores were standardized to vary between 1-4, where a high FES score (close to 4) indicates positive expectations. Bursal and Buldur (2013) reported the Cronbach coefficient for FES as α=.82. In this study, Cronbach α=.80 for the pre-FES data and α=.87 for the post-FES data were calculated. According to the reliability data, it was concluded that both the pre- and post-FES data of the participants were reliable.

Demographic data were collected with a personal information form designed by the researchers. In the second stage of the study, audio-recorded semi-structured interviews, focused on the participants' opinions and expectations about their future teaching career, were conducted by the two authors with 14 volunteer participants.

Data Analysis

The first research question, focused on the longitudinal change of the participants' future expectations in different sub-groups, was investigated using quantitative data analysis techniques. While investigating the first research question, since both between-subject effects (gender, teaching career orientation) and within-subject effects (pre-FES to post-FES score change) should be taken into account, a 2*2*2 Mixed-Effects Repeated-Measures ANOVA model was used. In addition to the main effects of each variable, the second- and third-level interaction-effects of the inter-group factors (gender, teaching career orientation) and the within-subject factor (time) were also included in the mixed-effects model. The statistical significance level was selected as .05, and when a statistical significance was determined, partial eta-square effect size values were also reported to interpret the practical significance of the results.

The data collected through semi-structured interviews for the second research question, the participants' views about their future teaching career, was analyzed using categorical content-analysis (Bilgin, 2006; Patton, 2002). During the analysis process, data was firstly coded and themes and categories were created based on these codes. Secondly, the themes were arranged according to weighted-frequency values and findings were defined. The detailed-description method was used to ensure the credibility of the analysis process and the findings obtained from the interviews were explained with direct quotations from participants. To clarify the original meanings, when needed in the translation of quotes from Turkish to English, explanations by authors are provided in brackets.

Results

Within the scope of the first research question, the pre-, post-, and overall-FES (the mean score of the pre- and post-FES) scores of the participants are given in Table 4. Due to the missing response data of four participants to any FES items in either pre- or post-FES applications, the longitudinal model was analyzed with the data from 82 participants.

Table 4

Participants' Pre-FES and Post-FES Scores

Variable	Category		Pre-FES		Post-FES		Overall-FES	
		n	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s
Gender	Female	65	3.4	0.4	3.4	0.5	3.4	0.4
	Male	17	3.4	0.3	3.1	0.7	3.2	0.4
Career Orientation	Teaching	30	3.5	0.3	3.5	0.4	3.5	0.3
	Other	52	3.3	0.5	3.2	0.6	3.3	0.4
	General	82	3.4	0.4	3.3	0.5	3.3	0.4

As seen in Table 4, compared to possible maximum FES score of 4.00, the mean FES scores of the participants are generally high. Thus, it can be concluded that future expectations of participants in all sub-groups are positive, both at the beginning and at the end of the science teacher education

program. As for the between-group differences, the mean pre-FES scores of the sub-groups are quite close to each other; however, post-FES scores indicated a larger gap between the sub-groups. Post-FES scores of females were slightly higher than males; and similarly, post-FES scores of teaching-oriented participants are found to be slightly higher than those with other career orientation. Longitudinal analysis of the pre- to post-FES scores indicates that the mean FES scores did not increase in any of the sub-groups during the four-year period, and even a slight decrease was observed in some sub-groups. For example, while the agreement rate for the FES item *"Even if I start teaching, I don't think I will stay as a teacher for a long time " (Item 3)* was 92% in the pre-test, the agreement rate decreased to 81% in the post-test. Similarly, compared to the 95% pre-test agreement rate for the FES item of *"I believe, I will love teaching (Item 2)*", the agreement rate for the same item was 91% in the post-test.

The findings from the 2*2*2 Repeated-Measurements ANOVA for Mixed-Measures model, which tests both the longitudinal variation of the participants' FES scores in the overall group and the sub-groups during the four-year period (within-subject effects), as well as compares whether overall-FES scores differ by participants' gender and career orientation (between-subject effects), are shown in Table 5.

Table 5

Test Statistics for the Effects Examined in the Repeated-Measures ANOVA for Mixed-Measures Model

Effect Type	Effect	df	*F*	*p*
Within-subject	Time	1	2.09	.152
	Time*Gender	1	2.24	.139
	Time*Teaching Career Orientation	1	3.54	.064
	Time*Gender*Teaching Career Orientation	1	3.85	.053
Between-subject	Gender	1	2.03	.159
	Teaching Career Orientation	1	7.66	<.01
	Gender*Teaching Career Orientation	1	0.90	.346

Table 5 data indicates that none of the within-subject effects examined in the repeated-measures model were statistically significant. In other words, there was no significant change in participants' FES scores (for all sub-groups) during the four-year science teacher education program. However, it is noteworthy that the "time*gender*teaching career orientation" interaction effect (p=.053) has a borderline trend, which indicates that there may be complex interactions between gender, career orientation, and time in shaping participants' career expectations. Among the investigated between-subject effects, while the main-effect of the gender variable and the interaction-effect of the "gender* teaching career orientation" were not significant, the teaching career orientation variable was found to have a significant main effect on the overall FES scores. Based on this finding, it can be concluded that teaching-oriented participants have significantly higher FES scores than those with other career orientations. The partial eta-square value calculated for this main effect ($\eta^2_{Partial}$=.08) shows that teaching career orientation has a moderate effect on the future career expectations of PSTs.

To investigate the second research question, semi-structured interviews were conducted with 14 participants at the graduation stage. During interviews, participants were asked about their future expectations after graduation from the science teacher education program and their views on their

future teaching life. The interview data were analyzed via categorical content analysis (Ely et al., 1998), where transcripts were read independently by the researchers and meaningful parts of the data were coded according to predetermined concepts as well as new concepts derived from the data. After the coding process, data themes were determined by the consensus of the two researchers and meaning units were placed under the themes. The frequency of each unit was calculated, and direct quotations were used to reflect the findings more convincingly.

Responses of the participants were analyzed and coded under the themes of "Opinions Regarding the Appointment Process" (see Table 6) and "Concerns Regarding the Future Teaching Career" (see Table 7). The categories and sub-categories, related to the opinions of the participants about the science teacher appointment process after graduation are shown in Table 6.

Table 6

Opinions of the Participants about the Appointment Process after Graduation

	f	%	Participant
Hopeful for Appointment in the first year	4	29%	P_{13}, P_{39}, P_{66}, P_{71}
Hopeful for Appointment in the next years	4	29%	P_{29}, P_{43}, P_{79}, P_{84}
Pessimistic for Appointment	6	42%	P_{05}, P_{09}, P_{28}, P_{34}, P_{58}, P_{69}

As can be seen in Table 6, participants' opinions on the science teacher appointment process in Turkey are grouped under the categories of "hope of appointment". When interview participants' statements were examined, nearly 60% (8 of the 14) of them were hopeful for the appointment, while nearly half of them (6 of the 14) stated that they were pessimistic about being appointed as a teacher. It is interesting that among the hopeful participants, only half of them are hopeful for being appointed in the following year after graduation. On the contrary, the other half of those hopeful participants postponed their appointment hope to the next years. Some sample responses for each sub-category are provided below.

> *I want to be hopeful. I don't think anything will change when you become pessimistic. Will the result be with an interview [for being appointed as a teacher] or whatever… (P_{13})*
> *My only dream is to work in state schools. If it doesn't happen this year, I believe it will happen next year. Because I think I have created a good background this year. (P_{29})*
> *I am very pessimistic. The education we receive here isn't enough for the PPSE. (P_{58})*

Based on these findings, the optimism of the majority of the participants for being assigned as science teachers can be considered a positive finding, in terms of their motivation toward teaching. However, it is alarming that almost half (n=6) of the 13 PSTs who are willing to be appointed are pessimistic about being appointed. Moreover, it is noteworthy that half of the participants feel obliged to postpone their hopes to the following years.

During the interviews, 12 of 14 participants explicitly expressed their concerns about their future careers. Thus, the categories and sub-categories within the "Concerns Regarding the Future Teaching Career", which is defined as the second theme regarding the future expectations of the participants, are given in Table 7.

Table 7

Concerns of the Participants about Their Future Teaching Career

		f	%	Participants
Concerns Regarding the Appointment Process	Central exam (PPSE)	3	21%	P_{28}, P_{29}, P_{58}
	Appointment interview	2	14%	P_{28}, P_{29}
	Lack of preparation for the central exam (PPSE)	4	29%	P_{09}, P_{43}, P_{79}, P_{84}
	Inadequacy of teacher education program	2	14%	P_{43}, P_{58}
	Concerns of not being appointed	1	7%	P_{34}
	Uncertainties in the process	2	14%	P_{69}, P_{84}
Concerns Regarding the Teaching Career	Possibility of boredom/disappointment	3	21%	P_{13}, P_{69}, P_{84}
	Generation gap after a while	2	14%	P_{58}, P_{71}
	Failure in the profession	2	14%	P_{29}, P_{43}
	Inability to communicate with students	1	7%	P_{05}
	Experiencing burnout	1	7%	P_{34}

As seen in Table 7, participants' concerns regarding their future are grouped under two categories as "Concerns Regarding the Appointment Process" and "Concerns Regarding the Teaching Career". Participant responses under the "Concerns Regarding the Appointment Process" category indicate that while they hold hopes and they are willing to be appointed as science teachers, the majority of the interview participants have several concerns regarding their future. Some of these concerns are related to the insufficiency of the education they received at the university but many more of them stem from the Turkish state procedures about the teacher-appointment process. For example, compared to the high number of qualified teacher candidates, the limited quotas allocated for teacher appointments, as well as the written exam (PPSE) and the interview requirements, were found to cause many of these concerns. Some sample participant statements clearly explain the sources of Turkish PSTs concerns about their future.

> *I am afraid! Because we didn't receive information about the PPSE for four years. Because the PPSE also includes questions out of our major. We can do the questions from our major, we are not at a sufficient level. (P_{28})*
> *The PPSE and then interview. I think the interview is ridiculous. Because interview means injustice. The questions they ask in the interviews include politics. If you find someone [in charge], you can be appointed that way. Because I would work for four years, for the PPSE day and night. I would get 80; then, they will lower my score in the interview. (P_{29})*
> *The PPSE is a big problem, so I'm very afraid. I don't know what will happen because they also require an interview. I think there will be different things [being asked in the interviews], other than our knowledge. (P_{09})*
> *The education we received here isn't enough for the PPSE. There has to be extra support. (P_{58})*

I work hard and I believe that I will get rewarded for it. But it is possible that appointment process may be long. (P_{34})
There are problems in terms of the appointment and recruitment of teachers in our country. In my last year, I couldn't follow up the teaching practicum, university courses, and the PPSE preparation together. When the PPSE will be my only focus, I think I will succeed. About the appointment, why not when you work with devotion. (P_{84})

As seen in Table 7, other than their concerns about the teacher-appointment process, some participants have some concerns about their future teaching life. The sub-categories under the "Concerns Regarding the Teaching Career" reveal that some of the participants have concerns about being bored or being disappointed with teaching in the future. Some participants were concerned about facing a generation gap between them and their students after a certain time. Another concern was feeling anxious about failing in the profession and/or being unable to communicate with their students. One participant was worried about experiencing professional burnout, a situation she had observed in her teaching practicum teacher. The following interview quotes clarify participants' concerns.

If I get bored too much, I can do other jobs. (P_{13})
People have different interests in the future when there is a marriage or something... I think I won't lose my excitement in the first 5, 10 years. Human nature is suitable for easily getting bored of things. 10 years is a very sufficient time for me. (P_{84})
… after I get older, there will be quite a generation gap between us and the new generation. So we have to do something to fix it. When the retirement age comes, I think we should retire. (P_{58})
[During the teaching practicum] I thought for a moment that I couldn't be very patient with students. I guess it will settle down with time but I suddenly became like this. I became anxious because students don't understand from saying "stop or be quiet". (P_{29})
In terms of student relations, I can communicate easier with someone who is close to my culture. I have difficulty communicating with a person who is distant from my culture. (P_{05})
There were teachers who were in their 10^{th} and 20^{th} years in the job. They got tired of it. They didn't even communicate with the students anymore. They stopped greeting [students]. If I am going to be such a teacher, I definitely don't want to be appointed at all. I think that I will be always excited and like my job. (P_{34})

Based on the Table 7 data and participant quotes, it is clear that almost all of the interview participants have concerns about the appointment process and/or their future teaching career. Among the sources of concerns, it is vastly apparent that the central written exam (PPSE) that is required as the first step of the appointment process and the compulsory interview after the PPSE worry Turkish PSTs. Moreover, many of the participants also experienced concerns about their future teaching career, most of which are about failure in teaching and staying in the job only for a limited period.

Discussion

In the first research question of this study, the longitudinal change during a four-year science teacher education program of a group of Turkish PSTs future career expectations toward the teaching profession was investigated. The research model also included sub-groups formed by gender and participants' career orientation. From the analysis, future career expectations of Turkish PSTs were found to be positive both at the beginning and graduation stages of the teacher education program. No significant change in these expectations was determined in the four-year period. These results are consistent with similar studies conducted in Turkey, where Turkish PSTs were reported to hold positive future career expectations (Aydin & İşlek, 2021; Buldur & Bursal, 2015; Bursal & Buldur,

2016) and positive attitudes towards teaching (Akıllı & Seven, 2010). Having positive expectations both at the beginning and at the end of a teacher education program is desirable since a significant number of teacher candidates with low career expectations are reported to leave the teacher education programs or the teaching profession after appointment (Purcell et al., 2005; Wilhelm et al., 2000). Therefore, having high future career expectations causes the participants of this study to expect that they would enjoy the teaching profession (Ekinci, 2017; Lysaght et al., 2018).

Between-subject comparisons on FES scores indicated that there was no significant difference in future career expectations of Turkish male and female PSTs. On the other hand, compared to their peers, teaching-oriented Turkish PSTs were found to hold more positive future career expectations. Also, while the "time*gender*teaching career orientation" interaction effect was not found as statistically significant, the near-significance result (p=.053) points to a nuanced relationship that might warrant further exploration of these variables in a larger or more diverse sample.

The conclusions about the statistical effect of the career-orientation variable are in line with the results of the majority of related studies since it is normally expected that teacher candidates, who consider teaching as their ideal profession will develop more positive attitudes towards the profession. Consistent with this expectation, researchers from both Turkey (Buldur & Bursal, 2015; Ekinci, 2017) and other countries (Gallant & Riley, 2014; Malmberg, 2006; Thomson & McIntyre, 2013) repeatedly verified that pre-service teachers, who had chosen the teaching profession intrinsically, have more positive attitudes towards their future teaching career than those who choose the teaching profession for extrinsic reasons.

The finding that female and male Turkish PSTs have similar expectations is also consistent with results from relevant studies, reporting that Turkish pre-service teachers' future career expectations (Buldur & Bursal, 2015; Bursal & Buldur, 2013) and attitudes towards the profession (Akıllı & Seven, 2010) do not significantly differ in terms of gender. Accordingly, it can be concluded that Turkish female and male PSTs' future career expectations are at similar levels.

The second research question of the study investigated the future career expectations of the participants after graduation, through semi-structured interviews. Based on the interview data, the majority of interview participants are found to be willing and hopeful to be appointed as a teacher to Turkish state schools after graduation but nearly half of them were pessimistic about being appointed. It is striking that many of the hopeful participants stated they postponed their hopes of appointment (against their own will) to the next years. The possible reason for this unwilling postponement is the employment problem across the Turkish teacher community. Due to the ever-growing supply-demand imbalance between the number of licensed teacher candidates and limited quotas for teacher appointment, there are serious problems with teacher appointment at state schools. Some of the governmental practices (e.g. increasing number of education faculties and certificate programs, insufficient number of state schools) enhance this problem every year. This unwilling postponement of participants is also compatible with formerly-announced data (Table 1). Therefore, it is clear that more than 90% of Turkish PSTs will not have chance to be appointed to state schools in the year after their graduation.

The detailed investigation of the findings of this study reveals that negative future expectations of participants stem from various concerns. These concerns are mostly related to the teacher-appointment process in Turkey (e.g. PPSE central exam, compulsory interview, etc.). Compared to the number of teacher candidates waiting for an appointment, the very limited number of teacher quotas allocated for state schools result in teacher candidates' postponement of their appointment hopes, which is also a major anxiety source for many Turkish teacher candidates.

In many other studies conducted in Turkey, it has been underlined that PSTs have intense concerns about the teacher-appointment process (Atav & Sönmez, 2013; Berk, 2025; Deliveli & Ar, 2021). These concerns can create problems in two ways. Firstly, concerns about the appointment process negatively impact PSTs' motivation during the teacher education program. If they are not

likely to be appointed after graduation, PSTs' commitment to their program and teaching career may decrease, even though they had previously idealized teaching profession. It would not be realistic to expect teacher candidates to be fully committed to a teacher education program when they are aware that the probability of being appointed after graduation is very low. Based on these findings, it can be concluded that these types of anxieties experienced by Turkish PSTs are likely to hurt their commitment to teaching. The findings of Deliveli and Ar (2021), who studied a group of Turkish pre-service teachers, support this conclusion since nearly half of their participants stated that they would do "any job" if they were not appointed after graduation. The findings of this study join others (Atav & Sönmez, 2013; Deliveli & Ar, 2021) that showed Turkish teacher candidates experience high anxiety and several external factors may lead them lose their motivation toward the teaching profession.

The second source of anxiety for the participants of this study was their concerns about their future teaching careers. Participants were found to be worried about experiencing disappointment, not being successful, and not being able to effectively communicate with their future students. Some of them had concerns about experiencing burnout over time and facing generational differences with students. In the related literature, many studies agree that pre-service teachers both in Turkey (Akıllı & Seven, 2010; Şahin, 2009) and in different countries (Bruinsma & Jansen, 2010; Kyriacou & Kunc, 2007; Lunenburg, 2011) have such future concerns. By a detailed investigation of the concerns of the participants of this study, it can be argued that Turkish PSTs anxieties are mostly related to *reality shock*. Veenman (1984) described reality shock for novice teachers as *"*the collapse of the missionary ideals formed during teacher training by the harsh and rude reality of everyday classroom life*"* (p. 143). The findings of this study fit Veenman's definition in that some participants' concerns about their teaching career were related to experiencing reality shock. Reality shock should be taken seriously, and pre-service teachers should be more prepared for it because even the qualified teachers, who experience reality shock in their early careers, are reported to end up leaving the profession (Lunenburg, 2011; Lysaght et al., 2018; McIntush & Garza, 2023).

Conclusion

Based on the findings related to the two research questions of this study, it can be concluded that the future career expectations of Turkish PSTs were generally positive and that these positive expectations did not differ according to PSTs' gender and their stage (first and/or final semester) in the science teacher education program. The pre-college career-orientation variable was found to have a significant impact on participants' expectations, and teaching-oriented Turkish PSTs were found to have more positive future career expectations than their peers. Finally, based on the qualitative data of the study, most of the Turkish PSTs were found willing to be appointed as science teachers at state schools but due to their numerous concerns about the Turkish teacher-appointment system, as well as their concerns about their future teaching career, a significant amount of them were pessimistic about the future.

The results of this study are limited to 86 PSTs from a Turkish state university. As a limitation, this study group does not represent all Turkish PSTs; however, it should also be noted that the participants of this study are very similar to the general PST population in Turkey. Since university entrance in Turkey is conducted by a centralized written exam organized by the CHE, the entrance scores for the majority of Turkish science teacher education programs are very close across the country. Furthermore, the major coursework, excluding the electives, of science teacher education programs in Turkey are centrally determined by CHE. Thus, it can be argued that the participants in this study share similar academic backgrounds with the overall Turkish PST population.

This study contributes to the relevant literature by examining the longitudinal change of Turkish PSTs' future expectations; however, since this study is limited to a Turkish sample, similar studies in different countries are needed to develop a global perspective on the longitudinal change of

PSTs' expectations. Studies from various contexts will provide a deeper perspective to understand the impact of different cultural, regional, and socioeconomic factors on teacher candidates' expectations.

This study was started with 105 PSTs at the pre-test but 19 of them did not take the post-test due to quitting or transferring out of the teacher education program during the four-year period of the study. Therefore, the attrition threat, which is among the most common threats to the validity and reliability of longitudinal studies (Fraenkel & Wallen, 2003), has become another limitation of this study. To overcome this threat, the sample size was kept as large as possible at the planning stage of the study and completed with 86 participants, which is a satisfactory sample-size for a four-year panel study. Based on this experience, it can be suggested for future researchers to start their longitudinal studies with large samples to tolerate the attrition threat.

This study joins many others in showing that teaching career oriented PST's have more positive future expectations than their peers. This would seem a very straightforward finding; however, it indicates some major implications about university entrance and teacher-appointment systems. Also, while the findings of this study are limited to Turkish pre-service science teachers, based on the similarities of university entrance and the teacher appointment processes, the findings could interest the international teacher educator audience too. In countries that use high-stakes centralized exams in university entrance and/or teacher appointment systems, pre-service teachers could experience similar problems as the participants of this study. For example, researchers mostly from the East Asian countries, such as Bangladesh (Mamun et al., 2022), China (Davey et al., 2007; Huang, 2025), India (Srivastava & Dhamija, 2022), Japan (Zeng, 1995), and South Korea (Weidman & Park, 2000) point out that high-stakes testing in national university entrance systems causes serious problems during the selection of students to the appropriate college programs and would result in placing students to college programs that do not fit their ideal career choices. Moreover, it has been reported that harsh university entrance examination systems lead to many psychological problems for students, such as extreme anxiety, learned helplessness, and even suicidal thoughts (Davey et al., 2007, Mamun et al., 2022).

On the other hand, the negative impact of reality shock on beginning teachers seems to be a global problem. Researchers from various countries, such as China (Sun et al., 2024), Germany (Voss & Kunter, 2020), New Zealand (Mahmood, 2013), and United States (McIntush & Garza, 2023) report that present teacher education systems do not efficiently prepare pre-service teachers to handle reality shock when they start teaching in real life contexts.

In light of the findings of this study and the related literature, it is clear that PSTs in Turkey and in many other countries face reality shock even before graduating from the university and appointments systems solely based on high-stakes testing that is not effective (Huang, 2025). Thus, student selection system for Turkish science teacher education programs, as well as countries employing similar national university entrance exams, should utilize entrance criteria other than central exam scores to attract those who choose the teaching profession with realistic intrinsic motivations. For example, besides the central exam scores, additional requirements such as prior involvement in educational settings (e.g. volunteer services as teacher assistants, tutoring at schools or after-school programs, etc.), letters of recommendation indicating the focus of motivation toward teaching career, and structured interviews with educational value-based questions can be used to achieve this goal. Also, since the reality shock problem seems to be an inevitable fact for PSTs all over the world, arrangements should be made in science teacher education programs to provide gaining more experiences (e.g. increasing the number and credit of applied courses, planning school visits to enhance PSTs-student interaction, organizing seminars with supervising teachers, etc.) for PSTs to be able to prepare for the reality shock they may experience during their transition to the professional life.

Conflicts of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

Ethical Declaration

In this study, scientific, ethical and citation rules were followed, and no falsification was made on the collected data.

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Appendix

Future Expectations Scale

The following items contain propositions regarding your teaching career. Please mark one of the options given for each proposition to indicate to what extent you agree/disagree with the situations described in the propositions.

	Strongly Disagree	**Disagree**	**Agree**	**Strongly Agree**
1. I am not sure that teaching would be a suitable profession for me.	☐	☐	☐	☐
2. I believe that I will enjoy teaching.	☐	☐	☐	☐
3. Even if I start working, I don't think I will stay as a teacher for a long time.	☐	☐	☐	☐
4. I believe that I will be a good teacher in the future.	☐	☐	☐	☐
5. I believe that I will communicate very well with my students as a teacher.	☐	☐	☐	☐
6. Even if it is not financially satisfying, I always want to work as a teacher in the future.	☐	☐	☐	☐
7. I am sure that contributing to the development of the society as a teacher will make me happy in the future.	☐	☐	☐	☐
8. If I have the opportunity to switch to another profession with better financial conditions in the future, I will quit teaching.	☐	☐	☐	☐
9. I think I will get bored while teaching.	☐	☐	☐	☐
10. I believe that the longer I teach, the more I will love my job.	☐	☐	☐	☐

ELECTRONIC JOURNAL FOR RESEARCH
IN SCIENCE & MATHEMATICS EDUCATION
VOL. 30, NO. 1, 43-61

Pre-Service Elementary Teachers' Science Content Knowledge and Confidence: Teaching Science Methods with Metacognitive Awareness Activities

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ABSTRACT

Few elementary teachers are confident in teaching science or in their science knowledge. This study sought to address this concern by investigating the impact of a science methods course on confidence and science knowledge for pre-service elementary teachers (PSETs). In this study, 23 participants enrolled in a teacher education program at a Midwest US university participated in a quasi-experimental pretest-posttest design. The participants engaged in course content, including metacognitive awareness activities, for a full semester and qualitatively described their confidence within the pre-post assessment survey. Results were analyzed using an independent samples t-test, mean content assessment scores, and paired samples t-tests to evaluate the effectiveness of the science methods course in improving science content assessment scores for the whole group and each confidence group. Our findings indicate that participation in a methods course that implements metacognitive activities has the potential to influence PSETs' confidence in science knowledge. We found that students with high and low confidence levels improved their science knowledge after completing the course, as measured by the content assessment.

Keywords: science teaching, metacognition, content knowledge, pre-service elementary teachers, teacher education

Introduction

In the context of education, the phrase "science is all around us" resonates prominently within K-12 settings, underscoring the intrinsic value of science in our daily lives (Hoath, 2020; Lempinen, 2004; Switz, 1984). Despite the popularity of this expression, some teachers lack confidence, specifically in their science teaching abilities. Insights from the 2018 National Survey of Science and Mathematics Education (NSSME) report reveal a telling picture: only 31% of surveyed elementary teachers felt suitably equipped to teach science, a notable contrast to the 77% who felt prepared to teach reading (Smith, 2020). This sense of insecurity contributes significantly to difficulties in both teaching and learning specific subjects for elementary teachers, particularly mathematics and science (Bursal & Paznokas, 2006; Stevens & Wenner, 1996).

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Internationally, researchers have long investigated the reluctance of elementary teachers to embrace science education (Appleton, 2008; Appleton & Kindt, 2002; Bursal & Paznokas, 2006; Howitt, 2007; Jarrett, 1999; Murphy & Smith, 2012). Several studies have identified factors that influence teachers' confidence in teaching science. For example, Howitt (2007) found that pre-service teachers identified factors such as practicum experience, teacher educators, pedagogical content knowledge, learning environments, assessment, and reflection as important contributors to their confidence to teach science. Within pedagogical content knowledge, factors such as science pedagogy, science activities, children's views of science, science content knowledge, and investigating scientifically were ranked as important (Howitt, 2007). Similarly, Knaggs and Sondergeld (2015) highlighted the importance of science content knowledge and personal teaching experience in developing confidence in teaching. They emphasized the need for science content courses that address both content and pedagogy to foster the transformation of content knowledge into effective teaching practice (Knaggs & Sondergeld, 2015). This perspective aligns with findings by Murphy and Smith (2012), who identified inadequate science content knowledge as a significant barrier to primary teachers' confidence in teaching science. Additionally, they noted that teachers with limited scientific knowledge or negative prior learning experiences in science often struggled with both confidence and perceived competence in delivering science instruction (Appleton, 2008; Murphy & Smith, 2012).

Researchers have established the importance of exposure to science during one's childhood and early educational years for fostering interest in and confidence in science among pre-service elementary teachers (PSETs) (Jarrett, 1999). If (current or future) elementary teachers have little to no early experience with science, they may find it difficult to see themselves as *science teachers,* even in primary grades (Appleton, 1995; Knaggs & Sondergeld, 2015). Researchers posit that a lack of early science experience in PSETs' formative education may negatively impact confidence in their science teaching abilities and discourage them from teaching it at all (Appleton, 1995; Kazempour, 2014; Knaggs & Sondergeld, 2015). The lack of confidence in science teaching abilities is further confounded by the decreased time allotted to teaching science in elementary classrooms (Griffith & Scharmann, 2008; Milner et al., 2012). As a response to national laws and mandates, such as No Child Left Behind and the adoption of Common Core Standards, little to no instructional time is devoted to science education in elementary classrooms (Arold & Shakeel, 2021; Griffith & Scharmann, 2008; Milner et al., 2012). Reading and mathematics have become the central focus of instruction in many elementary schools (Arold & Shakeel, 2021; Griffith & Scharmann, 2008; Milner et al., 2012). The concern of reduced science instruction time in elementary schools is historical and ongoing, with urban schools that serve underrepresented minorities and low socioeconomic students being particularly affected (Arold & Shakeel, 2021). King et al.'s (2001) study revealed that teachers in urban schools often possess lower-than-anticipated content knowledge, instructional skills, and classroom management competencies. The 2018 NSSME report indicated that only 35% of elementary teachers assigned to grades 4-6 reported teaching science most days of the week (Smith, 2020). However, only 17% of elementary teachers in grades K-3 reported teaching science on most days, every week, which is down from 20% in 2012 (Smith, 2020). Instead, teachers spend almost four times as much instructional time on reading or language arts and up to three times as much on mathematics (Smith, 2020). In addition, once PSETs become licensed teachers, they typically need more administrative support for science instruction or may sometimes receive professional development training with no support for practical application in the classroom (Dan & Gary, 2018; Smith, 2020). This gap in support and practical application leaves a critical question unanswered: How can teachers develop the confidence needed to effectively teach science if they are not encouraged to practice or refine these skills? When teachers are not expected to teach science or develop skills through professional development and practice, how can they exude confidence in their science teaching abilities? The convergence of diminished instructional time and inadequate training has become a substantial challenge for elementary teachers (Dan & Gary, 2018). In addition, the dearth of preparation in science

content knowledge and training in science teaching frequently results in undermining confidence in science teaching abilities (Kazempour, 2014; Singh, 2022). If PSETs lack confidence in science, experience in science, or encouragement to teach science, their inclination to teach the subject may further diminish (Kazempour, 2013; 2014). Therefore, this study aimed to respond to this need and explore the impact of an elementary science methods course on PSETs' science knowledge and confidence.

Theoretical Framework

Definitions of self-belief constructs like self-efficacy, self-esteem, self-concept, and confidence have been debated and often overlapped in the literature (Ferla et al., 2009; Morony et al., 2013). This study focuses on the change in reported confidence and science content knowledge during a science methods course for elementary preservice teachers. According to Morony et al. (2013), confidence is "a self-assessment measure that is closely tied to a cognitive act" (p. 81). Further, confidence is a subjective belief that can determine and influence performance and behavior (Moreno et al., 2022; Stankov et al., 2012) and is measured by asking the test-taker to report how confident they are with a just-provided response to a cognitive item (Morony et al., 2013). According to Stankov et al. (2012), confidence is the best predictor of performance and achievement and is also related to self-efficacy. The metacognitive construct of confidence "captures much of the predictive variance of other self-beliefs" (Stankov et al., 2012, p. 1). In relation to confidence, Bandura's (1977) self-efficacy theory of behavior change is defined as people's beliefs about their capabilities to produce designated levels of performance, which influence events that affect their lives. Self-efficacy beliefs determine how people feel, think, self-motivate, and behave. Self-efficacy in science education has been studied extensively to predict teachers' future performance in the classroom (Enochs & Riggs, 1990; Gunning & Mensah, 2011; Kazempour, 2013, 2014; Riggs & Enoch, 1990; Singh, 2022) and is often conflated with confidence. PSETs' self-efficacy is typically measured through survey instruments such as widely used teacher self-efficacy scales (Enochs & Riggs, 1990; Johnson et al., 2021). However, in Singh's (2022) study of science teaching confidence, measures of self-efficacy with the STEBI-B self-efficacy scale were made. In an earlier study of PSETs in science, Bleicher (2007) also measured self-efficacy with the STEBI-B, but analyzed students' journal reflections and research field notes to measure confidence. Researchers have established that future performance can be predicted by self-efficacy and one's confidence in their beliefs about their ability to achieve specific outcomes (Bandura, 1977; Stankov et al., 2012). Further supporting this connection, Velthuis et al. (2014) conducted a quantitative study with over 290 primary teachers and found that higher levels of confidence in content knowledge and science teaching experience in primary schools both contributed to higher levels of confidence in beliefs about science teaching abilities. Research suggests that PSETs' confidence in teaching science can increase positively with high-quality science instruction and teacher education preparation (Menon & Sadler, 2016; Menon, 2020).

In science education, metacognition is a significant predictor of science achievement and overall achievement and can enable learners to understand concepts by removing barriers to acquiring new concepts (Sandall et al., 2014). Despite its significance, few studies have addressed the role of metacognitive activities in science teachers' science knowledge and confidence. Metacognition is a cognitive process that involves thinking about thinking and encompasses the ability to reflect upon and control other cognitive processes (Vaccaro & Fleming, 2018). It refers to the knowledge about and regulation of one's cognitive activities in learning processes (Veenman et al., 2006). Metacognitive confidence is guided by the premise that one's beliefs in one's cognition can impact task performance (Moreno et al., 2022). Versteeg and Steendijk (2019) suggest that "we cannot expect students to perform as effective learners if they are unaware of their knowledge deficiencies [and that]...being aware of knowledge deficiencies is considered part of one's metacognition" (p. 9). Furthermore, taking

responsibility for one's own cognition involves being aware of cognitive processes [knowledge of cognition] and being able to regulate them [regulation of cognition] (Brown, 1987; Fleur et al., 2021; Harrison & Vallin, 2018). Metacognition ultimately enhances learning, allowing individuals to monitor and adaptively control their cognitive processes (Frith, 2012; Hampton, 2009).

While metacognition and confidence have been explored in science education by others, many of those studies have focused on developing teacher pedagogical knowledge or examining the constructs separately (Abd-El-Khalick & Akerson, 2009; Kinskey, 2018; Johnson et al., 2021; Menon, 2020; Singh, 2022; Sulaiman et al., 2021; Zohar & Barzilai, 2013). Researchers posit that teachers must be aware of their lack of content knowledge to remedy their insufficient content knowledge (Catalono et al., 2019). Researchers recommend that higher education faculty [teacher educators] adopt teaching strategies that encourage the use of metacognitive skills (Abd-El-Khalick & Akerson, 2009; Abdellah, 2015). Regarding content knowledge, Saputri and Corebima (2020) found significant correlations between metacognitive skills and cognitive learning results of over 100 Indonesian Biology teachers. With this exception, few have examined the impact of metacognitive activities with PSETs in the United States. Our work contributes to the field by exploring the potential impact of metacognitive activities in a science methods course aimed at increasing PSETs' science content knowledge as well as confidence in their science teaching abilities. While this work has some limitations, which will be discussed later, it provides a basis for further examining the role of metacognition in preparing elementary teachers to teach science content and other content areas.

Metacognitive Activities

A range of metacognitive strategies and approaches exists and have been studied by researchers in STEM subject areas. Sandall et al. (2014) emphasized metacognitive questioning that addressed identifying the problem, connecting the problem to past experiences, identifying strategies, and evaluating the appropriateness of the solution when teaching mathematics. Abd-El-Khalick and Akerson (2009) explored the impact of metacognitive strategies on the nature of science conceptions among pre-service elementary teachers. They implemented concept mapping, peer interviews, and responses to case studies in the intervention group. Agarwal and Bain (2019), the authors of the popular text–Powerful Teaching–provided four research-based strategies for improving student confidence and cognition, including (1) giving feedback for incorrect and correct answers, (2) giving elaborate feedback to boost transfer, (3) giving feedback immediately or after a delay, and (4) giving feedback while encouraging mistakes. They also identified several activities instructors can implement to build metacognition among learners, including retrieval cards and metacognition sheets (Agarwal & Bain, 2019). Consistent with existing research, we implemented several metacognitive activities, including metacognition sheets, brain dumps, low-stakes quizzing, reflective journaling, and metacognitive feedback strategies to support PSETs' attainment of confidence and science knowledge in the science methods course in which this study takes place.

Purpose

This preliminary study aimed to investigate the role of an elementary science methods course implementing metacognitive strategies on students' confidence and science knowledge in elementary science methods students at a small midwestern US university. The central research questions for this study are:

1. How does participation in a science methods course with metacognitive activities influence PSETs' self-reported confidence in their science knowledge before and after a science methods course?

2. What is the impact, if any, of the implementation of a science methods course with metacognitive activities on the science knowledge of PSETs as measured by pre-test and post-test scores in a science content assessment?

Research Design and Methods

We used a quasi-experimental pretest-posttest design to examine the relationship between the methods course and its impact on PSETs' self-reported confidence in their science knowledge and their scored content knowledge as recorded by a classroom science content assessment. In a pretest-posttest design, measures are taken at the beginning and end of the semester (Price et al., 2015). Data was collected from a convenience sample of PSETs enrolled in a science methods course. Pre- and post-test scores were collected for the classroom science content assessment. Self-reported confidence in their science knowledge was also collected.

Setting and Participants

A total of 23 of 26 PSETs enrolled in an undergraduate course in elementary science methods at a university in the midwestern region of the United States participated in this study, where Institutional Review Board (IRB) approval was obtained. Twenty-one PSETs identified as women, while two identified as men. Before taking the elementary science methods course, all PSETs had completed at least one college-level science course required for their college major of elementary education and one education course on the science of learning, whereby they explored various learning theories like behaviorism, cognitivism, and metacognition. In the science of learning course, participants were introduced to two dimensions of metacognitive awareness, including knowledge about cognition and regulation of cognition (Harrison & Vallin, 2018). The science methods course met in person twice weekly and virtually once weekly during the spring 2021 semester. The PSETs also completed a virtual field experience at a local urban elementary school due to the erratic impact of COVID-19 on regular course schedules.

Course Description

The instructor (first author) of the science methods course sought to prepare PSETs to teach elementary science and health concepts by implementing mini-science inquiry-based content sessions and activities that promote metacognition. The in-class portion of the course was designed to immerse the PSETs in scientific concepts through lectures, hands-on, collaborative investigations, research, and planning. Activities used to help PSETs tap into their metacognition included the ongoing use of a KLEWS journal, where they identified what they **k**now and **l**earned, **e**vidence of the phenomenon, **w**onderings, and **s**cientific terminology. To promote metacognition, PSETs also participated in what Agarwal and Bain (2019) refer to as power tools, which include retrieval practice, spacing, interleaving, and feedback metacognition. The course instructor used specific strategies, such as metacognition sheets, muddiest points, brain dumps, low-stakes quizzing, and reflective [KLEWS] journaling (Table 1). The instructor also provided metacognitive feedback throughout the course to keep learners engaged and focused on their goals. According to Agarwal and Bain (2019), "Without feedback, students' metacognition can remain overconfident and out of sync with their actual learning" (p. 131). Therefore, it was important that the instructor prioritized feedback to students in the course.

The course addressed several major science topics relevant to elementary teaching, including engineering and design, earth science, life science, physical science, and health science. In addition to coursework activities, the PSETs participated in virtual practicums at a local urban elementary school. Each pair of PSETs was assigned to teachers at the local school in kindergarten through fifth grade.

PSETs observed science courses taught at the school and prepared science lessons to teach at the school, with all students completing at least one lesson. It is important to note that the practicum experience was not ideal because the PSETs were virtual, while the elementary students and classroom teachers were in person.

Table 1

Sample metacognitive strategies and in-class activities

Strategy	Description	Example
Retrieval Practice	"Retrieval practice is a no-stakes opportunity when students can experiment, be challenged, and improve over time." (Agarwal & Bain, 2019, p.48)	Brain Dump: What do I know about moon phases? – Students write for 3 minutes and then switch with a partner. – Students share commonalities, differences, consider misinformation, and how they remembered.
Feedback Driven Metacognition	When students reflect on what they know and do not know followed by instructor feedback (Agarwal & Bain, 2019).	In-class formative assessments (i.e., low-stakes quizzing with Nearpod, Kahoot!) followed by the Muddiest Point tasks—What is something you are still struggling with?
Spacing and Interleaving	Retrieval practice multiple times over time (Agarwal & Bain, 2019); "When the gap between presentations is greater than zero" (Carpenter et al., 2012, p. 370)	KLEWS Journal: Students reflect and share what they Know, what they Learned, Evidence of what they learned, what they Wonder, and Scientific concepts or vocabulary

Data Collection and Analysis

Qualitative and quantitative data were collected from participants through a pretest-posttest design to address the research questions. As part of the pre-test, students were required to complete a science content knowledge assessment and describe their confidence level in science content during the first week of the spring semester. Specifically, students were asked, *How confident do you feel about your science knowledge? Do you feel confident that you could answer the questions accurately?* The qualitative survey questions were coded deductively as one of three codes (confident, somewhat confident, or not at all confident) by employing thematic analysis. The responses were coded based on tone, language, and keywords, and then assigned codes. For example, a participant's response that included words like "somewhat" or "some" was coded as *somewhat confident*. Participants' responses that indicated words like "not at all" or "not confident" were coded as *not at all confident*. These codes were used to determine groups for further analysis of science content data.

The content assessment consisted of 18 selected-response (multiple choice, drag-and-drop, etc.) fifth-grade science items based on three main Next Generation Science Standards (NGSS) disciplinary core idea categories. Fifth-grade items were chosen to match the highest level of content knowledge typically assessed by standardized statewide testing in elementary schools. As an expectation of the instructor, PSETs should be proficient in the fundamental concepts at the highest level of elementary school science as measured by the statewide exam. The content assessment consisted of valid and reliable 5th-grade level science items previously published and administered on state-sponsored science standardized testing administrations. The assessment included six earth and space science items, four state-validated physical science items, and eight state-validated life science items. To measure change (or growth), participants were asked to complete the post-test at the end of the semester. The post-test was administered during Week 14, and participants were asked to qualitatively describe their confidence and any contributors to their confidence at this point. Specifically, students were asked, *How confident do you feel about your science knowledge? Do you feel confident that you could answer the questions accurately?* Using the established pre-test coding scheme, post-test responses were coded as *confident, somewhat confident,* and *not at all confident*. Table 2 provides samples of narratives from the pre-and post-tests, along with respective assigned codes. A comparison of confidence codes before and after the course was completed to develop an overall theme for the data. Additionally, open coding was applied to post-test responses to understand the context with which the participants based their level of confidence and if they perceived improvement in their content knowledge. Pre-determined codes of metacognitive awareness, regulation, or both were applied to each of the responses, as well as a code for sense of improvement. Metacognitive awareness referred to what the PSET knew about their own thinking, whereas metacognitive regulation referred to the actions PSETs knew to take to assist with improving their thinking or learning (Akcaoğlu et al., 2023; Stanton et al., 2021). For example, a PSET shared, "I feel pretty confident about my science knowledge, there are definitely some things that I don't completely [understand]. Other than that, I feel as though I answered the questions accurately, but I'm not expecting to get all of them right." This response was coded as metacognitive awareness. Whereas the following example was coding as both awareness and regulation: "I feel pretty confident on the questions, however, there are still some that have to make me think harder than others. I feel like I would feel more confident if I review the content before I teach it to my students." Applying keywords, like "after" allowed us to code for sense of improvement (i.e., "After the course SCI 301, I feel more confident about my science knowledge."). Each participant's statement was coded by both authors and analyzed for agreement.

Participants completed the science content assessment with the same questions as the pre-test but in a different order. Quantitative analysis was conducted with SPSS v.28 software. Using an independent sample t-test, mean content assessment scores were compared by self-reported confidence for pre-test and post-test scores. Using paired sample t-tests, we evaluated the effectiveness of the science methods course in improving science content assessment scores for the whole group and each confidence group.

Findings

This study sought to answer two main research questions: (1) How does participation in a science methods course with metacognitive activities influence PSETs' self-reported confidence in their science knowledge before and after a science methods course? (2) What is the impact, if any, of the implementation of a science methods course with metacognitive activities on the science knowledge of PSETs as measured by pre-test and post-test scores in a science content assessment? The following sections will describe the findings and discuss their implications.

Confidence in Science

First, we analyzed qualitative data from the pre-assessment survey to assess PSET's confidence in their science knowledge at the start and the end of the science methods course. We found that there were various perceptions about science knowledge among PSETs in the study. Eleven participants' responses to the pre-test question on confidence in science knowledge were coded as *not at all confident*, whereas twelve participants' responses were coded as *somewhat confident* (Figure 1). No responses were coded as *confident*. Sample responses from each category can be seen in Table 2. These three codes (confident, somewhat confident, and not at all confident) served as the primary framework for analyzing science content scores in this course.

Figure 1

Perceived Confidence Composition

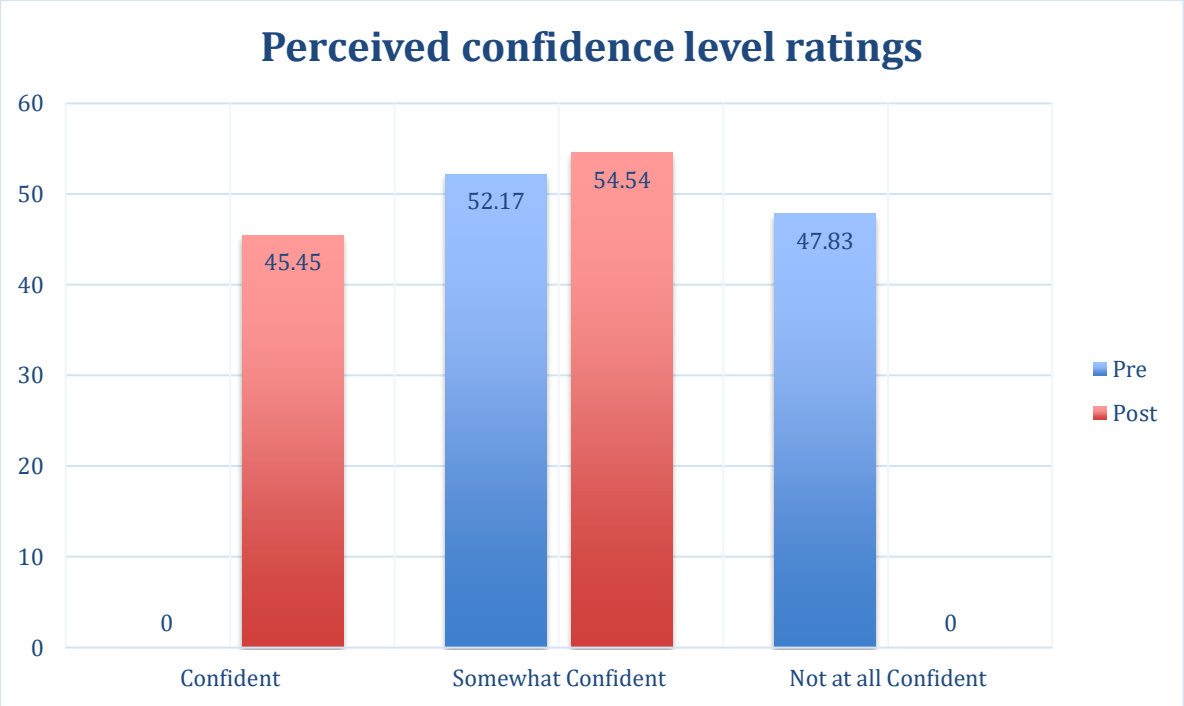


Table 2

PSET sample confidence responses

Science Knowledge Confidence Code	**Sample Statement Pre-test**	**Sample Statement Post-Test**
Confident	N/A	(n=10) *After the course [course number], I feel more confident about my science knowledge. Throughout the course, I was able to refresh my memory and also learn about new material. I feel confident that I would be able to answer most of these questions accurately.* *I felt pretty confident in the answers I provided. Overall I feel that this class prepared me very well to be able to answer these different questions.*
Somewhat Confident	(n=12) *I felt confident for some of [the questions] but not really sure of some of the answers that I put. I hope to learn more this semester. I do like science a lot but not that good at it.* *I feel somewhat confident about my science knowledge. I feel that I could probably use a refresher on some science topics that I have not practiced in years. I did feel pretty confident answering the question accurately today.*	(n=12) *I feel more confident about my science knowledge compared to when we first started. I feel confident enough that I answered most of the questions accurately. I strongly feel though, that there is still a lot of learning I need to do to feel 100% confident in my science knowledge.* *I feel somewhat confident. I think I could use more practice on some of these topics.*
Not At All Confident	(n=11) *Not confident. I think I knew some things but a lot I have not thought about in a while.* *I don't feel confident at all. I barely knew any of the answers, I just tried my best and took a lucky guess.*	N/A

Note. PSETs responded to "How confident do you feel about your science knowledge? Explain."

At the end of the course, the participants' responses to the post-test confidence items suggested that they felt more confident in their science knowledge and their answers to the science content assessment items. Some participants also mentioned feeling comfortable enough to teach science to their future students. When analyzing their statements on the post-test, 10 responses (45.45%) were coded as confident in their science knowledge, and 12 (54.54%) were coded as

somewhat confident. One statement was not coded as it was deemed a non-response. No participants' responses were coded as *not at all confident*.

Qualitative responses were also coded for rationales, and pre-confidence codes were compared to post-confidence codes. Participants were not asked to compare their prior confidence; rather, they indicated confidence from the first assessment to the post-assessment. The theme of sense of improvement can be seen in six of the 22 responses. Rationales for this improvement can be seen in some of the responses, such as the first sample response in Table 2, where the participant relied on their metacognition to explain, *"Throughout the course, I was able to refresh my memory and also learn about new material"*. Here, the PSET is acknowledging their prior knowledge and the acquisition of new knowledge within the course of the semester.

Further, participants' rationales were interpreted as a display of metacognitive awareness, metacognitive regulation, or both. Based upon our analysis, 13 PSETs displayed metacognitive awareness, three displayed regulation, and six displayed both awareness and regulation. This can be seen when some participants discussed their level of comfort with pedagogical content knowledge on the post-test. One PSET commented, "I feel like I would feel more confident if I review the content before I teach it to my students." In this particular example, the PSET has associated their confidence in their ability with a behavior [reviewing content], reflecting on their metacognitive regulation to improve their confidence. One response was coded as a non-response and could not be interpreted. Overall, PSETs perceived themselves as more confident about their science knowledge, ability to teach science, or ability to pass the licensure exam, an indicator of success.

Science Knowledge

To determine whether the course played a role in PSETs' science knowledge, the following inquiries were analyzed using quantitative methods: differences between pre-test and post-test scores for the entire group and between pre-test and post-test scores according to confidence level for each group.

Pre-Post Assessment Growth

The second research question aimed to determine if the science methods courses impacted science content assessment scores for the whole group. To address this question, a paired samples t-test was performed to compare the pre-test and post-test content assessment scores. There was a significant mean difference in content assessment scores between the pre-test ($M = 73.29$, $SD = 12.21$) and post-test ($M = 81.00$, $SD = 12.67$) sessions, $t\,(22) = 2.75$, $p < 0.012$. Specifically, the results showed that post-test scores were significantly higher than pre-test scores. This implies that the science methods course had a positive impact on science content assessment scores, particularly in terms of the metacognitive component of the course.

Table 3

Paired Samples Statistics for the Entire Group

	Mean	N	Std. Deviation	Std. Error Mean
Pre	73.29	23	12.209	2.546
Post	81.00	23	12.673	2.642

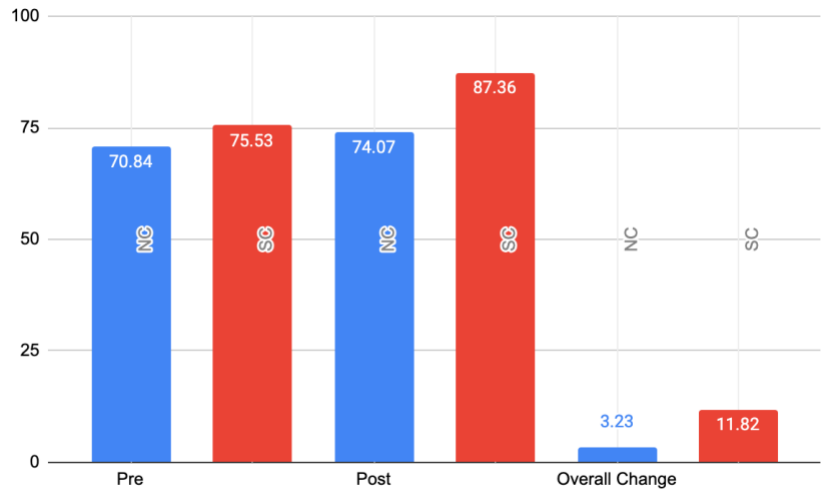
Perceived confidence and science knowledge growth

Based on the first research question analysis (see qualitative results), we identified only two groups (NC= "not at all confident" and SC= "somewhat confident") of PSET confidence levels present in the sample population. Descriptive statistics for each group and each assessment session are represented in Figure 2. To determine if groups demonstrated differences in science knowledge during the pre-test and post-test, paired samples t-tests were the most appropriate inferential statistical analysis because we compared the means of each single group at two different points in time (Ross & Willson, 2017b).

While both groups experienced an increase in mean scores, the pre-test/post-test growth for the NC group was fewer than 4 points. Additionally, the paired samples test revealed no significant difference in pre- and post-test scores among the participants rated as NC (p = .486). On the other hand, participants rated as SC experienced a significantly different increase between their pre-test and post-test scores (p = .004) and grew by more than 11 points between sessions.

Figure 2

Descriptive Statistics comparing NC and SC scores and change



Note: NC represents *not at all confident,* and SC represents *somewhat confident.*

Confidence and Pre-test Performance

Further, we compared PSETs' confidence levels and science knowledge scores at the beginning of the semester (pre-test performance). An independent samples t-test was the appropriate inferential statistic to explore this further because it compares the means of two different groups (Ross & Wilson, 2017a). An independent samples t-test (assuming unequal variance) results showed no significant mean difference in pre-test science content assessment between the group which was not at all confident (M = 70.84, SD = 12.20, n= 11), and the group, which was somewhat confident (M = 75.53, SD = 12.30, n = 12), t (20.86) = -0.92, p = 0.37 (Table 3). Thus, although the pre-test scores were higher for the somewhat confident group than the not at all confident group, the difference was not statistically significant.

Table 4

Independent Samples Test for Pre-test by Perceived Confidence

	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Equal variances assumed	-.918	21	.369	-4.697	5.114
Equal variances not assumed	-.919	20.855	.369	-4.697	5.113

Confidence and Post-Test Performance

This analysis aimed to determine whether there was a significant mean difference in content assessment scores after implementing metacognitive activities in the science methods course. An independent samples t-test (assuming equal variance) showed that there was a significant difference in post-test science content assessment between the group that was initially not at all confident (M = 74.07, SD = 13.42, N = 11) and the group that was initially somewhat confident (M = 87.36, SD = 8.09, N = 12), t (21) = -2.91, $p < 0.01$ (Table 4). In particular, the results revealed that participants who were somewhat confident had significantly higher content assessment scores after the science method course than those who were not at all confident.

Table 5

Independent Samples Test for Post-Test by Perceived Confidence

	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Equal variances assumed	-2.907	21	.008	-13.290	4.572
Equal variances not assumed	-2.845	16.139	.012	-13.290	4.671

Discussion and Implications

With this preliminary study, we aimed to investigate the impact of an elementary science methods course implementing metacognitive awareness activities on teacher confidence and science content knowledge in methods courses at a small midwestern US university. Specifically, we examined two exploratory research questions: (1) How does participation in a science methods course with metacognitive activities influence PSETs' self-reported confidence in their science knowledge before and after a science methods course? (2) What is the impact, if any, of the implementation of a science methods course with metacognitive activities on the science knowledge of PSETs as measured by pre-test and post-test scores in a science content assessment? To determine the impact of the course on PSETs' science content knowledge, we compared PSETs' pre-test and post-test scores on a 5th-grade science assessment. We also sought to preliminarily explore the role of confidence in science content knowledge.

When examining PSETs' initial confidence in science, most participants were apprehensive about being completely confident in their science abilities. PSETs with negative experiences in science can lead to PSETs with negative perceptions of science (Miller et al., 2021). Some participants cited that they had not practiced the science concepts in a while, making them hesitant to express extreme confidence levels and necessitating a 'refresher' in science content. Others lamented that they were not good at science. Therefore, all responses were coded as either somewhat confident or not at all confident. It is worth noting that despite having a mix of confidence levels, all PSETs demonstrated some growth in their content knowledge on the post-test. This growth may be attributed to the course structure, including mini-science content sessions, participating in and preparing inquiry-driven lessons, and completing in-class metacognitive development tasks. The NC group's growth from pre-test to post-test was minimal in this study. While this finding was not surprising, it does speak to the need for additional support that PSETs may need to improve their confidence and performance in science.

While this study did not directly measure the impact of metacognition, we believe metacognitive activities can play a significant role in science learning, enhancing conceptual understanding, problem-solving abilities, and self-regulated learning in science education (Binbasaran Tuysuzoglu & Greene, 2015; Rickey & Stacey, 2000; Zohar & Barzilai, 2013). Moreno et al. (2022), psychology scholars, posit that positive metacognitive confidence can increase performance, and thus,

negative metacognitive confidence can have a detrimental impact. The results suggest that the in-class metacognitive development tasks were particularly effective in helping students develop their confidence. The PSETs in this study were able to articulate their metacognitive awareness and how to regulate it (Frith, 2012; Hampton, 2009). This can be seen in the discussion of the science confidence findings. PSETs were able to articulate their strengths and weaknesses, as well as how to improve them. Whereas before the intervention, some students were aware of their need for a "refresher," but others felt that they were just not good at science. It is vital to address metacognitive confidence in science of pre-service and novice teachers, as it may adversely impact the implementation and efficacy of science education in elementary classrooms (Sulaiman et al., 2021).

Overall, pre-service teachers with higher-rated confidence had the highest potential for growth throughout the course. They also have the highest science content scores despite not showing a significant difference in their pre-test scores from the *not-at-all-confident* group. This finding is an interesting contrast to Catalano et al.'s (2019) study of PSETs' science-teaching self-efficacy and science content knowledge, whereby PSETs with higher science-teaching self-efficacy actually had lower science knowledge. This suggests that PSETs' self-efficacy and knowledge of science content may not be directly linked but may be explained by other factors, such as metacognition, pedagogical interventions, and more experience (Velthuis et al., 2014). Furthermore, it shows that PSETs can develop a high level of science content knowledge regardless of their initial confidence level.

Teacher educators have the potential to support PSETs by thoroughly examining their perceptions in science methods courses to determine what additional supports, including metacognition development, may be beneficial to implement. While pre-service teacher beliefs have primarily been studied through two constructs—confidence and self-efficacy (Dursun, 2019; Howitt, 2007; Pfitzner-Eden, 2016; Slater & Main, 2020; Valtonen et al., 2020), we believe instructors of pre-service methods could support PSETs by implementing science content-specific modules for pre-testing and addressing gaps in knowledge or confidence from the analysis of metacognitive activities and reflections. PSETs at this particular institution were only required to take one science content course from any of the science disciplines. Designing a science survey course to be implemented alongside the methods course would assist students in developing confidence and content knowledge to feel confident and more metacognitively aware of their science knowledge.

Limitations and Next Steps

While our study offers valuable insights, it is important to acknowledge its limitations. This study was based on findings from one semester at one university with one instructor within a single group design with limited diversity and population size. Furthermore, the results of this study are preliminary. To extend this study's findings, we recommend exploring the connection between PSETs' science knowledge, confidence, and metacognitive activities with a larger sample size, an experimental design, or even several comparative samples across multiple sites. In this design, we also asked PSETs to self-report their confidence by responding to a written prompt. Developing or implementing a validated instrument for measuring confidence and metacognitive awareness may be worthwhile in a larger randomized follow-up study.

Conclusion

This preliminary study underscores the critical role of methods courses with metacognitive activities in shaping pre-service elementary teachers' science knowledge and confidence. Our findings shed light on the impact of perceived confidence on increased science content knowledge over the course of a semester, especially for those with higher self-perceptions of confidence. This insight may be useful in bridging the gap in theoretical understanding of metacognition and confidence as it relates

to elementary pre-service teachers learning science. By integrating targeted metacognitive strategies, like KLEWS journaling, brain dumps, and muddiest points, these programs can better equip future educators with subject matter expertise and foster the confidence necessary for effective teaching. While acknowledging the limitations of our study, such as the sample size and participant diversity, the results provide a foundation for further research, potentially exploring broader contexts and diverse educational settings. Ultimately, the study highlights the transformative potential of metacognitive approaches in preparing pre-service teachers to navigate and teach complex scientific concepts, enabling them to teach science more effectively in elementary school.

The authors received no financial support for the research, authorship, and/or publication of this manuscript.

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ELECTRONIC JOURNAL FOR RESEARCH
IN SCIENCE & MATHEMATICS EDUCATION
VOL. 30, NO. 1, 62-84

Effect of Ethnomathematics Approach on Senior High School Students' Achievement in Geometry

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ABSTRACT

This study investigated how ethnomathematics approach influences senior high school students' achievement in geometry. Ethnomathematics approach in this study is conceptualized as a culturally anchored, cognitively scaffolded, historically and socially mediated framework for teaching geometry. Bishop's concept of mathematical enculturation and the sociocultural theory of learning served as the study's foundations. Explanatory sequential mixed approaches were employed in the investigation. This study also employed a quasi-experimental pretest-posttest control group design. We employed a multistage sampling technique to select 140 General Art mathematics teachers and 422 General Arts students from 18 Senior High schools (SHS) to participate in the study. The Geometry Achievement Test (GAT) was used to collect data from the students, while a semi-structured interview guide was used to collect data from both mathematics teachers and students. We analysed the quantitative data using both descriptive and inferential statistics. We used thematic content analysis followed by a narrative discussion to analyse the qualitative data. The study demonstrated that teachers' ethnomathematics approach has a major impact on how they teach geometry. The Ministry of Education should give teachers professional development opportunities to strengthen their knowledge of ethnomathematics approaches and their implications for teaching and learning.

Keywords: efficacy, enhancing, ethnomathematics approach, geometry, senior high schools

Introduction

Mathematics is widely recognized for its role in fostering logical reasoning and problem-solving skills across various fields. Despite its significance, conventional methods of teaching mathematics often fail to engage students, particularly within culturally diverse classrooms. Ethnomathematics, defined by D'Ambrosio (1985) as the study of mathematical practices rooted in cultural contexts, has emerged as a promising pedagogical approach, especially for teaching geometry in senior high schools (SHS). So, emphasizing the connection between culture and mathematics, this approach seeks to make instruction more culturally relevant and meaningful (Davis, 2017a).

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Bishop (1988) identified six universal mathematical activities: measuring, counting, locating, designing, explaining, and playing that offer practical entry points for integrating ethnomathematics into instruction. Geometry, in particular, provides fertile ground for this integration, with its principles evident in architectural designs, artistic patterns, and cultural artefacts (Prahmana & D'Ambrosio, 2020). However, conventional teaching methods often prioritize procedural fluency and rote memorization, overlooking the contextual and cultural dimensions of the subject (Davis, 2017b; Sevgi & Erduran, 2020). This detachment can contribute to student disengagement and underperformance, particularly in multicultural environments like Ghana.

In contrast, the ethnomathematics approach seeks to contextualize geometric concepts, making them more relatable and engaging. Studies have shown that linking geometric ideas such as symmetry, transformations, and tessellations to indigenous African patterns like Adinkra symbols and kente designs enhances students' understanding and retention (Boaler, 2016; Davis, 2010, 2016). Empirical evidence supports the effectiveness of this method in improving student achievement and problem-solving skills (Davis, 2010; Kyeremeh et al., 2023; Rosa & Orey, 2011), with positive outcomes reported in Ghanaian classrooms (Davis, 2017b; Kyeremeh et al., 2023; Opoku-Asare & Agbenatoe, 2016).

Moreover, the ethnomathematics approach fosters critical thinking, creativity, and collaborative learning by encouraging students to explore and analyse cultural experiences through mathematical lenses (Gbormittah, 2022; Gerdes, 1996; D'Ambrosio, 2001). Nevertheless, challenges persist, as teachers often lack the necessary resources and expertise to implement culturally responsive strategies effectively (Davis, 2010; Kyeremeh et al., 2023). Additionally, standardized curricula and assessment systems that favour procedural knowledge over conceptual understanding further hinder the widespread adoption of this innovative approach (Anthony & Walshaw, 2009). Addressing these barriers requires systemic reforms, including culturally responsive teacher training and the development of appropriate instructional materials (Davis, 2016).

Theoretical Framework

Sociocultural Theory of Learning

Sociocultural Theory of Learning, proposed by Lev Vygotsky in 1978, emphasizes the central role of social interaction, cultural tools, and language in the development of human cognition. Vygotsky challenged conventional views that framed learning as an isolated, internal process, arguing instead that knowledge is constructed through engagement with others within a cultural and social context. According to Vygotsky, cognitive development first occurs on the social plane (inter-psychological) before it is internalized within the individual (intra-psychological).

A central construct in Vygotsky's theory is the Zone of Proximal Development (ZPD), which refers to the range of tasks that a learner can perform with the guidance and support of a more knowledgeable other but cannot yet accomplish independently. This concept highlights the importance of scaffolding, wherein teachers or peers provide temporary support structures that are gradually removed as the learner becomes more competent. Through guided participation and dialogue, students internalize strategies and knowledge, leading to deeper and more autonomous learning.

Language plays a particularly vital role in Vygotsky's framework. It is not merely a communication tool but a fundamental mechanism through which thinking and learning are mediated. As students engage in social interactions and verbal exchanges, they appropriate cultural meanings and practices that shape their cognitive processes. In the context of Mathematics Education, Sociocultural Theory suggests that learning should be situated within culturally meaningful activities. Students' understanding of mathematical concepts can be enriched when instruction draws upon their prior

experiences, cultural backgrounds, and collaborative problem-solving activities. Rather than treating mathematics as a culturally neutral or purely abstract discipline, Vygotsky's theory encourages teachers to recognize and harness the diverse cultural resources students bring to the classroom. Thus, Sociocultural Theory of Learning offers a powerful lens for examining how culturally relevant teaching approaches, such as ethnomathematics, can foster deeper mathematical understanding. Therefore, situating learning within familiar cultural frameworks and emphasizing social interaction, educators can bridge gaps between students' everyday experiences and formal mathematical knowledge, leading to enhanced engagement, comprehension, and achievement.

Mathematical Enculturation

Mathematical enculturation, as proposed by Bishop (1988), refers to the process by which individuals are inducted into the practices, values, and modes of thinking associated with mathematics as both a discipline and a cultural phenomenon. Bishop contended that mathematics is not a culturally neutral or purely abstract body of knowledge; rather, it is a human activity deeply embedded in cultural contexts. Learning mathematics, therefore, is not merely about acquiring procedures and formulas but about participating in the broader cultural practices that define mathematical thinking.

Central to Bishop's argument is the idea that every culture engages in certain fundamental mathematical activities. He identified six universal mathematical activities common to all human societies: counting, locating, measuring, designing, playing, and explaining. These activities represent ways in which humans have historically organized and interpreted their world through mathematical reasoning. Therefore, recognizing these universal practices, Bishop emphasized that mathematical ideas are developed and transmitted culturally and that learning mathematics involves adapting to the norms, values, and problem-solving methods that a society associates with mathematics.

Mathematical enculturation has significant implications for education. It suggests that teaching mathematics should not be confined to transmitting decontextualized knowledge but should actively involve students in mathematical practices that are meaningful within their cultural contexts. Through this lens, effective Mathematics Education requires acknowledging and building upon the cultural experiences that students bring to the classroom. Rather than viewing students' cultural backgrounds as obstacles, they are seen as rich resources that can support mathematical learning.

In the context of geometry education, mathematical enculturation implies that students can better grasp abstract concepts when instruction connects to culturally familiar artefacts, patterns, and spatial reasoning contexts. When students engage with geometry through activities rooted in their own cultural environments such as analysing indigenous designs, structures, and symbols they are not only learning mathematical content but also participating in the cultural practices of mathematical thinking. Thus, Bishop's notion of mathematical enculturation supports the argument that Mathematics Education must be both culturally responsive and socially situated. It offers a theoretical basis for approaches like ethnomathematics, which seek to contextualize mathematical learning within students lived cultural realities, promoting deeper understanding, motivation, and achievement.

The Sociocultural Theory of Learning (Vygotsky, 1978) and the concept of Mathematical Enculturation (Bishop, 1988) align closely in their emphasis on the social and cultural foundations of learning. Both perspectives reject the notion of knowledge as fixed and context-free, highlighting instead that learning is a dynamic, socially mediated, and culturally situated process. Vygotsky's emphasis on the role of cultural tools, language, and guided social interaction in cognitive development complements Bishop's view of mathematics as a human cultural activity into which learners must be gradually initiated. In the context of this study, which explores the effect of the ethnomathematics approach on students' achievement in geometry, the two theories provide a coherent and powerful framework. They collectively support the idea that embedding mathematical instruction within students' cultural experiences not only enhances conceptual understanding but also fosters deeper

engagement and motivation. Hence, situating mathematics learning within familiar cultural practices and promoting social interaction, the study leverages both theoretical perspectives to argue for more inclusive, meaningful, and effective geometry education.

Empirical research demonstrates the efficacy of the ethnomathematics approach in enhancing students' geometry proficiency. For example, children who were taught using culturally appropriate examples outperformed those who were taught using conventional techniques in geometry tests (Gay, 2010). Owusu-Mensah et al. (2022) asserted that including cultural artefacts in geometry classes also enhanced students' ability to think spatially and solve problems. These results demonstrate how ethnomathematics can revolutionise geometry education and improve students' academic performances.

Over the years, West African Examinations Council (WAEC) Chief Examiners' reports on Core Mathematics at the senior high school (SHS) level in Ghana have consistently highlighted students' under-achievement in geometry-related concepts (WAEC, 2018, 2020, 2021, 2023). The reports from 2018, 2020, 2021, and 2023 particularly point to persistent difficulties in symmetry, transformations, and tessellations. This pattern of low achievement underscores the need for pedagogical interventions that are both innovative and contextually relevant. One such approach gaining traction within Mathematics Education discourse is ethnomathematics, which integrates learners' cultural backgrounds and lived experiences into the teaching and learning process. The Ghanaian educational landscape is characterised by a strong oral tradition, a rich repository of indigenous knowledge systems, and an abundance of cultural artefacts and practices that inherently embody mathematical ideas. Geometry, in particular, is deeply embedded in Ghanaian cultural expressions such as kente weaving, adinkra symbolism, bead-making, indigenous architecture, and floor patterns. These cultural artefacts offer intuitive and tangible representations of geometric principles, often more relatable to students than abstract textbook illustrations. However, such indigenous knowledge systems are frequently marginalised in mainstream classroom instruction, which tends to rely heavily on expository methods and decontextualised content.

This study draws on the Ghanaian context not only as a backdrop but as a foundational element for reimagining geometry instruction. The ethnomathematics approach adopted involves the deliberate integration of cultural practices and artefacts in the teaching of geometry. For example, lessons on symmetry were connected to adinkra symbols, and studies of tessellations and transformations were based on kente patterns and indigenous floor designs. These culturally relevant resources served as cognitive bridges, helping students visualise and internalise abstract geometric concepts through familiar and meaningful contexts. So, embedding geometry in the cultural realities of Ghanaian students, the study aimed to foster deeper conceptual understanding, greater engagement, and improved academic performance. Preliminary findings suggest that students exposed to instruction infused with cultural elements demonstrated not only enhanced comprehension of geometric ideas but also increased motivation and participation in class activities (Bishop, 1988; D'Ambrosio, 1985, 2001; Davis, 2010, 2016; Davis & Chaiklin, 2015; Gbormittah & Yarkwah, 2025). This points to the value of grounding Mathematics Education in learners' socio-cultural contexts, particularly in areas where achievement has historically been low.

The Ghanaian context, therefore, plays a dual role in this research: it highlights a persistent educational challenge while simultaneously offering rich pedagogical opportunities. The study contributes to the growing body of literature on culturally responsive Mathematics Education and provides a context-sensitive model for improving geometry achievement among SHS students. Through an ethnomathematics lens, the research affirms the potential of culture as a powerful resource for transforming mathematics teaching and learning in Ghana and beyond.

Research Question /Hypotheses

The study was guided by the following research question and hypotheses:

1. How do SHS teachers and students perceive the effectiveness of the ethnomathematics teaching approach in geometry instruction after its implementation?

$H_0$1: There is no statistically significant difference between the achievement of the SHS 2 students in the control and experimental groups in the pretest.

$H_0$2: There is no statistically significant difference between the achievement of the SHS 2 students in the control and experimental groups in the posttest.

$H_0$3: There is no statistically significant difference between the pretest and posttest scores of the control group and the pretest and posttest scores of the experimental group among SHS 2 students in geometry.

Research Methods

This study adopted an explanatory sequential mixed-methods approach, employing a quasi-experimental pretest-posttest design to investigate the research questions (Cohen et al., 2011). The population comprised all Senior High School (SHS) mathematics teachers and their students in Ghana's Savannah Region. A multistage sampling strategy was implemented to ensure representativeness and feasibility. The Savannah Region was selected for convenience, primarily due to the third author's residence in the area, which facilitated access to participants and reduced logistical costs (Davis & Gbormittah, 2023).

Districts within the region were selected using simple random sampling, followed by the identification of 18 SHSs through census sampling. All 140 SHS 2 mathematics teachers and intact General Arts student classrooms in the selected schools were invited to participate. Recruitment emphasized transparency, fairness, and voluntary participation, with clear communication regarding the study's purpose, procedures, and participants' rights, including the freedom to withdraw at any stage without consequences.

Out of 430 students invited, 422 agreed to participate, while eight declined due to health reasons. These decisions were respected without coercion. For the qualitative component, 22 students and 10 teachers from the experimental group were purposefully selected for interviews, considering factors such as teaching experience, gender, and district representation. This purposive sampling ensured a diverse and balanced range of perspectives, enriching the depth and contextual understanding of the qualitative findings.

Experimentation and Data Collection Instruments

We designed this study's experimental procedure to investigate the impact of the ethnomathematics method on the geometry proficiency of senior high school students. This quasi-experimental study design included pre- and post-tests for both the experimental and control groups. This design was selected to assess how well the intervention improved students' geometry comprehension and achievement while accounting for potential outside influences.

We randomly selected the schools to ensure an equal distribution of genders and intellectual aptitudes in the experimental and control groups. Prior to the intervention, we administered a geometry achievement test (GAT) to each participant to assess their baseline geometrical knowledge. This pretest served as a standard by which to measure the efficacy of the ethnomathematics approach in comparison to conventional teaching techniques. The GAT's questions evaluated both procedural and conceptual knowledge of geometry concepts, including symmetry, transformations, and tessellations. The GAT assigned 30 marks to both the pretest and posttest.

In the experimental group, teachers participated in an intensive 12-week professional development program designed to enhance their understanding and application of ethnomathematics in geometry instruction. The training focused on equipping teachers with culturally responsive pedagogical strategies, emphasising the integration of local cultural artefacts such as Adinkra symbols, kente patterns, and indigenous architectural designs into the teaching of geometric concepts. Workshops during the training introduced the foundational principles of ethnomathematics and demonstrated practical approaches to integrating these principles into classroom instruction. Facilitators provided in-depth illustrations on how Adinkra symbols could be used to teach symmetry and reflection, how kente patterns exemplify tessellations and repetitive motifs, and how indigenous Ghanaian architectural designs can be employed to explain geometric transformations such as translation, rotation, and reflection. Participants collaboratively engaged in lesson planning sessions where they developed culturally relevant lesson plans aligned with national curriculum standards. These sessions provided opportunities for teachers to co-construct meaningful learning experiences that resonated with students' cultural backgrounds. In mock teaching segments, teachers practised delivering these lessons and received constructive feedback from peers and facilitators to refine their approaches.

The instructional intervention in the experimental schools was meticulously designed to immerse students in culturally resonant, activity-based geometry lessons that bridged abstract mathematical concepts with tangible elements from their lived environments. Central to the intervention was the use of Ghanaian cultural artefacts (i.e., Adinkra symbols, kente patterns, and indigenous architectural forms) as instructional anchors for exploring core geometry concepts such as symmetry, reflection, tessellation, translation, rotation and area of geometrical shapes. This approach was grounded in the ethnomathematics framework, which emphasizes the integration of students' cultural knowledge systems into formal mathematical learning.

In practice, teachers initiated each lesson by contextualizing a geometric concept within a culturally familiar artefact. For example, during explorations of symmetry, students engaged with the Adinkra symbol 'Nkyinkyim', whose alternating curves and straight lines provided a rich context for identifying lines of symmetry, rotational properties, and reflective balance. Teachers scaffolded this process by guiding students to draw, fold, and trace the symbols, encouraging them to articulate their reasoning and justify the geometric features they identified. These hands-on activities made abstract ideas visually and kinaesthetically accessible, promoting conceptual clarity and retention.

To teach tessellation and spatial patterns, teachers introduced kente cloth as a mathematically rich text. Students examined recurring ideas and patterns in kente designs, mapping translations and identifying congruent shapes and tiling structures. This was followed by guided design tasks in which students created their own tessellation patterns inspired by indigenous weaving principles, applying their understanding of geometric rules in a creative context. These exercises not only deepened spatial reasoning but also fostered cultural appreciation, as students recognized the mathematical sophistication embedded in artisanal practices.

Instruction extended beyond the classroom into the architectural layout of indigenous Ghanaian compounds, which provided authentic models for understanding transformations, scale, and orientation. Through field-based learning and image analyses, students identified examples of reflectional and rotational symmetry in housing layouts, circular designs in courtyards, and proportional reasoning in room arrangements. This situational learning bridged formal geometry with local environmental literacy, enhancing relevance and contextual grounding.

Group projects were an integral component of the intervention, requiring students to either analyse existing artefacts or generate original geometric designs rooted in cultural contexts. These collaborative tasks fostered peer dialogue, cooperative problem-solving, and critical thinking. Teachers served as facilitators, prompting learners to make connections between mathematical vocabulary and cultural symbolism, and encouraging iterative thinking through feedback and peer evaluation. Regular

reflective discussions were held to consolidate learning, allowing students to express their interpretations and insights, thus reinforcing both cognitive and affective dimensions of learning. The instructional sequence was carefully structured to build from recognition to analysis and then to application, ensuring a coherent learning trajectory. Tasks were differentiated to accommodate diverse readiness levels, with formative assessments embedded in the learning cycle to monitor progress and provide timely support. The lessons were not merely illustrative; they were grounded in rigorous mathematical inquiry framed within familiar cultural settings, which enhanced motivation, sense-making, and long-term understanding.

In this study, the ethnomathematics-based instruction was not an additive enrichment but a transformative reorientation of mathematics teaching. It positioned students as active participants in knowledge construction, empowered by the validation of their cultural experiences. The instructional design demonstrated how cultural artefacts can function as authentic mathematical tools, bridging the gap between classroom abstraction and everyday reality, thereby reconfiguring Mathematics Education as a culturally sustaining and intellectually robust endeavour. Figure 1 illustrates geometric elements in Ghanaian cultural artefacts: Adinkra symbols, kente patterns, and indigenous architecture that guided instruction in the experimental group.

Figure 1

Geometry in Ghanian Cultural Designs

In contrast, the control group received instruction through conventional teaching methods that emphasized procedural fluency and rote memorization, in alignment with the Ministry of Education's (MOE, 2010) mathematics curriculum for senior high schools. Teachers in this group introduced geometry to their students mainly by presenting two-dimensional and three-dimensional shapes, etc., prompting students to identify and label them. This approach is repeated for learning other complex geometrical concepts. The instruction focused on demonstrating how to calculate areas and volumes of these shapes, using examples with specified dimensions. The approach lacked contextual or culturally responsive elements and was primarily centred on mechanical repetition and formulaic problem-solving. To maintain the effectiveness of the experimental design, the researchers observed the teaching process during the intervention period. The 12-week intervention involved SHS teachers delivering three geometry lessons per week, each lasting 40–60 minutes, consistent with standard classroom practice in Ghana. Rather than conducting formal lesson observations, the research team employed routine monitoring strategies to track the integration of ethnomathematics. This included regular reviews of lesson materials, teaching aids, and student outputs. The monitoring process confirmed that teachers consistently incorporated relevant cultural artefacts into instruction and that students were meaningfully engaged throughout the program. Teachers participated in biweekly feedback meetings, where they shared challenges, received additional guidance, and discussed strategies for improvement. We developed the Geometry Achievement Test (GAT) based on the Ghanaian national curriculum (MOE, 2010), cultural artefacts in the Ghanaian context (see Figure 1),

and validated international assessment frameworks, such as Trends in International Mathematics Science Study [TIMSS], (2007, 2011) and National Council of Teachers of Mathematics [NCTM], (2007). Conducting a pilot test with a similar group of students to assess the reliability and clarity of the instruments. Few items that were not clear to the students on GAT were reviewed to elicit valid responses. The GAT achieved a Cronbach's alpha of 0.82, indicating high internal consistency. The GAT was designed to assess both procedural and conceptual understanding of geometry topics relevant to the curriculum as shown in appendices C and D.

We also conducted semi-structured interviews (see appendices A and B) for teachers and students from the experimental group to understand the benefits and challenges of implementing the ethnomathematics approach in the classroom. The experiment aimed to comprehensively evaluate the effectiveness of the ethnomathematics approach while adhering to all ethical guidelines. All participants gave their informed consent before the study started, and we upheld confidentiality at all times.

Data collection and analysis procedures

To find out how the ethnomathematics method affected how well students did in geometry, the data collection process for this study was carefully designed to make sure that the data collected was valid and reliable. We used both quantitative and qualitative methodologies to thoroughly understand the effects of the intervention. We carried out the process in stages, beginning with preparation work and concluding with the examination of data from multiple sources. The initial stage of the data-gathering procedure included a pretest for all participants in the experimental and control groups. We created the geometry achievement test (GAT) based on literature (NCTM, 2007; TIMSS, 2007, 2011) to assess students' foundational geometry knowledge and abilities. In line with the national curriculum, the test comprised a combination of procedural and conceptual questions on subjects like symmetry, transformations, and tessellations. We administered the pretest under uniform circumstances to ensure consistency and impartiality.

After the pretest, the experimental group received the intervention. We trained the experimental group's teachers in the use of the ethnomathematics approach, focusing on integrating relevant cultural practices and artefacts into geometry instruction. Throughout the 12-week intervention, researchers maintained close communication with teachers to support implementation, address emerging challenges, and reinforce the consistent use of culturally grounded strategies. This collaborative engagement ensured that the incorporation of ethnomathematical elements remained both contextually relevant and pedagogically effective, contributing to sustained student engagement and alignment with the study's goals. A direct comparison between the two approaches was made possible by the control group's teachers continuing to use conventional teaching techniques, which mirrored those of teachers in the field. The intervention period concluded with a post-test for all participants. Because the posttest and the pretest were identical, the researchers were able to compare the achievement of the experimental and control groups and measure changes in the students' achievement in geometry. To ensure uniformity, the test was administered in the same standard setting as the pretest. The effect of the ethnomathematics method on students' achievement was ascertained using a quantitative analysis of the pretest and posttest data.

To analyze the qualitative data, we employed thematic analysis, following Braun and Clarke's (2006) six-phase framework: familiarization with the data, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the final report. Transcripts from the focus group discussions were read multiple times to ensure immersion and understanding. The first codes were created based on what participants said and then grouped into larger themes that showed common experiences and views about the ethnomathematics approach. We employed several strategies to enhance trustworthiness. Credibility was established through member checking that

selected participants reviewed summarized findings to verify accuracy and resonance with their experiences. We supported transferability by providing detailed descriptions of the context and participants. So, keeping an audit trail of coding decisions and analytical memos, reliability was guaranteed. Confirmability was addressed by triangulating the qualitative data with the quantitative findings and involving multiple researchers in the coding process to minimize bias. These measures collectively contributed to a rigorous and trustworthy analysis of the qualitative data, providing rich insights into how the intervention influenced participants' educational experiences.

Generally, we coded and analysed the collected data using descriptive and inferential statistics specifically, an independent samples *t*-test, a paired samples *t*-test, and a two-way ANOVA test. The biographical data underwent analysis using frequency counts and percentages. Research Question 1 was addressed through thematic content analysis followed by narrative discussion. Hypothesis 1 was tested using an independent samples *t*-test. A one-way ANCOVA was applied for Hypothesis 2 to account for potential covariates. Hypothesis 3 was examined using a paired samples *t*-test. We conducted the inferential analysis at 0.05 error margin, as the presentation of the results will reveal.

Results

The respondents' biographical information is displayed in Table 1.

Table 1

Biographical Data of the Respondents

	Teachers		Students	
Variable		N%		N%
Gender	Male	97 (69.3)	Male	176(41.7)
	Female	43(30.7)	Female	246(58.3)
	Total	140(100.0)	Total	422(100.0)
Age (in years)	18 – 25 years	19(13.6)	Less than 10 years	0(0)
	26 – 33 years	81(57.9)	11 – 18 years	402(95.3)
	Above 33 years	40(28.6)	Above 19 years	20(4.7)
	Total	140(100.0)	Total	422(100.0)
Teaching Experience	Below 5 years	37(26.4)	0	0
	5 – 8years	54(38.6)	0	0
	9 – 12 years	41(29.3)	0	0
	Above 12 years	8(5.7)	0	0
	Total	140(100.0)	0	0
Academic Qualification	Bachelor Degree	117(83.6)	0	0
	Master's Degree	23(16.4)	0	0

	Total	140(100.0)	0	0
Group	Control	81(57.9)	Control	216(51.2)
	Experimental	59(42.1)	Experimental	206(48.8)
	Total		Total	422(100)

Table 1 shows the discrepancy between the gender distribution of the student body (58.3%) and the teacher population (69.3%) may have an effect on classroom dynamics. Students were mostly in the typical high school age range of 11 to 18 years, while teachers were comparatively young, with the majority (57.9%) being between 26 and 33 years old. A balance between early-career and mid-career professionals is suggested by this teacher age profile, which may help to explain a range of teaching philosophies and experiences. With 38.6% having taught for 5–8 years and 29.3% for 9–12 years, the majority of teachers had moderate experience. Only 5.7% of teachers had more than 12 years of experience, and fewer teachers (26.4%) had less than 5 years, suggesting that there aren't many highly experienced teachers. The teaching workforce is highly qualified, as seen by the fact that the majority of teachers (83.6%) had bachelor's degrees and only 16.4% had master's college degrees. Additionally, the participants were split almost equally between the experimental and control groups; 51.2% of students and 57.9% of teachers were in the control group.

$H_0$1: There is no statistically significant difference between the achievement of the SHS 2 students in the control and experimental groups in the pretest.

Table 2 presents the independent samples t-test for equality of means between the experimental and control groups in the pretest.

Table 2

The Independent Samples T-test For Equality of Means for the Control and Experimental Groups in the Pretest

	Levene's Test for Equality of Variances		t-test for Equality of Means			95% confidence interval of the difference	
	F	Sig.	T	Df	Sig. (2-tailed)	Lower	Upper
Equal variances not assumed	15.607	0.00	1.253	406.603	0.21	-0.1298	0.5865

The assumption of homogeneity of variances was broken in Table 2, according to the findings of the independent samples t-test, which focuses on the scenario in which equal variances are not assumed. Levene's Test for Equality of Variances yielded a F value of 15.607 at a significance level of 0.00, $p < 0.05$ which served as the foundation for this conclusion. The *t*-test results must be interpreted under the "Equal variances not assumed" condition since the equal variances assumption cannot be maintained because this significance level is less than the conventional alpha value of 0.05. The independent samples t-test produced a t-value of 1.253 with 406.603 degrees of freedom and a two-tailed significance level of 0.21 under these circumstances. This result means that the achievement of students in geometry did not differ between the control and experimental groups in the pretest.

H_o2: There is no statistically significant difference between the achievement of the SHS 2 students in the control and experimental groups in the posttest.

Table 3 shows one-way ANCOVA test for equality of means for the control and experimental group in the posttest. Preliminary checks confirmed that the assumptions of homogeneity of regression slopes and normality of residuals were met with F value of 4.152 and p = 0.07 (Tabachnick & Fidell, 2013).

Table 3

Test of Between Subject Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	9843.974[a]	2	4921.987	441.303	0.00	.68
Intercept	10396.057	1	10396.057	932.105	0.00	.69
Pretest	22.616	1	22.616	2.028	0.20	.01
Group	9842.362	1	9842.362	882.461	0.00	.68
Error	4673.239	419	11.153			
Total	80730.000	422				
Corrected Total	14517.213	421				

a. R Squared = .678 (Adjusted R Squared = .677)

After adjusting for pretest scores, the analysis in Table 3 showed a significant main impact of group on posttest scores ($F(1, 419) = 882.46$, $p < 0.05$, partial $\eta^2 = .68$), suggesting a substantial effect size. This figure indicates that 68% of the variation in the posttest results was explained by the treatment group, indicating a strong influence on the students' posttest achievement in geometry. $F(1, 419) = 2.03$, $p = 0.20$, and partial $\eta^2 = .01$ indicated that the relationship between the pretest and posttest scores was not statistically significant. This conclusion suggests that the students' posttest scores were not much influenced by their pretest performance. The whole model had a substantial effect size (partial $\eta^2 = .68$) and was significant ($F(2, 419) = 441.30$, $p < .05$). The intercept term, which reflected the baseline difference in scores, was likewise significant, $F(1, 419) = 932.11$, $p < 0.05$. The group factor and other controlled variables accounted for the majority of the variance in posttest scores as shown by the corrected total variance (Total Sum of Squares = 14,517.213). The results demonstrate how well the therapy intervention improved the geometry posttest scores of SHS students. The significant impact of the treatment on learning outcomes is highlighted by the huge effect size for the group component (partial $\eta^2 = .68$). The non-significant contribution of the pretest suggests that prior knowledge, as measured by it, did not substantially predict posttest achievement once the group effect was accounted for.

H_o3: There is no statistically significant difference between the pretest and posttest scores of the control group and the pretest and posttest scores of the experimental group among SHS 2 students in geometry.

Table 4 shows the paired samples test for the control and experimental group.

Table 4

Paired Samples Test for the Control and Experimental Group

		Paired Differences							
					95% Confidence Interval of the Difference				
		M	SD	Std. Error Mean	Lower	Upper	T	df	Sig.(2-tailed)
Pair 1	Exp.	13.40	4.10	0.2834	12.8393	13.9568	47.279	205	.00
Pair 2	Cont.	3.50	3.40	.2285	3.0682	3.9688	15.401	215	.00

The paired samples *t*-test results in Table 4 indicate significant improvements from pretest to posttest for both the experimental and control groups. For the experimental group, the mean difference between posttest and pretest scores was 13.3981, with a standard deviation of 4.0673. The paired samples t-value of 47.279 and a p-value of 0.00, $p < 0.05$ indicate that this improvement is statistically significant with Cohen's d of 3.29. The 95% confidence interval for the mean difference, ranging from 12.8393 to 13.9568, confirming the significance of the result. Similarly, the control group also showed a statistically significant improvement, with a mean difference of 3.5185 and a standard deviation of 3.3577 with Cohen's d of 1.05. The paired samples t-value of 15.401 and a p-value of 0.00, $p < 0.05$ support this conclusion, with the 95% confidence interval for the mean difference (3.0682 to 3.9688) further affirming the result. These findings demonstrate that both groups improved significantly, though the experimental group experienced a much larger mean improvement compared to the control group.

RQ1: How do SHS teachers and students perceive the effectiveness of the ethnomathematics teaching approach in geometry instruction after its implementation?

The ability of the ethnomathematics method to enhance geometry education and learning has been praised by both teachers and students. Both groups acknowledged its benefits, which are consistent with modern pedagogical concepts while also pointing out some implementation-related challenges. Teachers stressed that the ethnomathematics approach was learner-centred and in line with the demands of the new curriculum. A teacher commented, *"This approach shifts the focus from a teacher-dominated instruction model to a student-centred learning process."* One student said, *"I feel like I have more control over my learning because I get to work through the problems myself, with my teacher guiding me only when needed."* Students also experienced empowerment. It adds excitement and enjoyment to the lessons.

The activity-based character of the ethnomathematics approach was another widely acknowledged advantage. *"The practical activities spark students' interest and keep them engaged in ways I've not seen before,"* one teacher said, describing how the hands-on activities created a vibrant classroom environment. One student shared, *"The activities make mathematics feel like play."* Other students agreed. *"I no longer fear making mistakes, and I like fixing issues."* As one teacher put it, *"I've noticed that my students approach geometry problems with less fear and more curiosity."* Teachers also emphasised how this strategy promoted creative thinking while lowering students' anxiety. One student concurred, stating, *"I feel more confidence after doing the actual tasks. "* Understanding how formulas operate is much more important than simply memorising them.

Teachers and students both cited the teaching and learning resources' flexibility as another important strength. Teachers found that employing culturally relevant materials, such Adinkra symbols, greatly improved their students' comprehension of mathematical ideas. A teacher said, *"When I use Adinkra symbols in my lessons, students suddenly understand that mathematics isn't just something in their textbooks but part of their daily lives."* Students found these symbols especially important, as one student put it: *"It was amazing to see mathematics in our* indigenous *icons. I realised that mathematics has applications beyond the confines of the classroom.* Students' understanding of geometry and its practical uses was enhanced by this link between cultural heritage and classroom instruction.

Teachers particularly valued how students were able to connect mathematical ideas to their cultural backgrounds through reflection using the ethnomathematics approach. According to a teacher, "*Students find geometry more relevant and meaningful because they see how it relates to their culture." "I was surprised to learn that mathematics is part of our cultural heritage,"* one student said, echoing this attitude. It has made me proud of my culture and altered my perspective on the matter.

Notwithstanding its many benefits, the ethnomathematics approach presented challenges to both teachers and students. Teachers reported that the hands-on activities frequently took longer than conventional methods, with one teacher explaining, *"While these activities are effective, it's challenging to cover the entire curriculum within the allotted time."* Students also reported difficulties with group activities, with one student sharing, *"Sometimes, not everyone in the group participates equally, which can make it harder for the group to finish the task."* A few students initially had trouble understanding the connections between mathematical concepts and cultural symbols, but these problems were resolved with additional explanations and assistance from the teacher.

To sum up, the ethnomathematics approach has been a transforming teaching and learning strategy for both educators and learners. Geometry teachings are now more interesting, approachable, and significant because of its learner-centred and activity-based methodology, cultural relevance, and utilisation of flexible teaching tools. As summed up by one teacher, *"This approach has brought mathematics alive in my classroom."* One student also asserted that *"mathematics is no longer boring, it's fun and connected to my life."* Even while there are still certain challenges to overcome, the enthusiasm that both teachers and students share shows how the ethnomathematics method has the potential to completely transform mathematics teaching in geometry lessons. Both teachers and students fervently support its broader implementation to improve Mathematics Education in various school settings.

Discussion

When we shifted from conventional, textbook-driven geometry instruction to lessons grounded in students' cultural experiences, the impact was immediate and unmistakable. Students previously disengaged under rote methods began participating more confidently and understanding concepts more deeply. For example, incorporating familiar visual forms such as Adinkra symbols, market layouts, and local architecture made abstract ideas like symmetry and reflection feel accessible and relevant. What once required repeated explanation was now grasped intuitively. This transformation closely mirrors findings by Maryati and Prahmana (2019), whose Indonesian students readily understood geometric transformations through indigenous bamboo-weaving patterns, demonstrating how cultural familiarity can unlock mathematical understanding.

Our ethnomathematics approach followed a clear pedagogical arc; artefact exploration, guided discussion, and abstraction. This structure enabled students to begin with what they knew, articulate insights collaboratively, and then build toward formal understanding. It closely parallels the method used in Munthahana and Budiarto's (2020) study of the Panataran temple in Java, where geometric and probabilistic reasoning emerged from guided exploration of historical reliefs. Their results, like ours, showed that embedding learning in culturally resonant contexts reduces cognitive overload and expands the learner's Zone of Proximal Development.

Ghana-specific research strengthens this picture. For example, Opoku-Asare and Agbenatoe (2016) and Kyeremeh et al (2023) found that lessons using kente and stool geometry improved both performance and mathematical identity. Similarly, Owusu-Mensah, Kwame, and Yeboah (2022) reported gains when clay pot artefacts framed geometry lessons. Students in our experimental group not only achieved higher scores but also showed greater confidence and engagement. Crucially, they exceeded Ghana's TIMSS 2019 Grade 8 geometry average, a benchmark often linked to abstract, teacher-centred instruction (Mullis et al., 2020). These gains were not accidental. Weekly teacher planning clinics were vital for ensuring that cultural connections were explicitly maintained throughout instruction, addressing the caution raised by Nasir, Hand, and Taylor (2008) that without deliberate mediation, cultural knowledge and school mathematics remain disconnected.

In contrast, students in the control group taught through teaching by telling and textbook exercises which reflected the normal practices of teachers in the Ghanaian classroom struggled. Their lessons, lacking meaningful context or differentiation, placed the full cognitive burden on learners, echoing concerns raised by Vygotsky (1978) and Bishop (1988) that learning must not be devoid of the students' cultural, historical and social contexts. Without access to cultural referents or collaborative meaning-making, students failed to internalize concepts effectively. Instruction moved linearly and uniformly, rarely responding to students' emerging understanding, often leaving them bored, frustrated, or both. Misconceptions remained unaddressed, and individual strengths were rarely activated. As Tomlinson (2014) argued, such a lack of differentiation undermines both cognitive and affective dimensions of learning. Mathematical identity suffered, engagement declined, and learning became compliance-based.

The stark contrast in outcomes between the two groups is best understood not as a reflection of student ability, but of pedagogical design. In culturally grounded classrooms, students encountered mathematics as something connected to their world, discussed in community, and abstracted only after deep, shared understanding. These contexts provided what Bishop (1988) calls "enculturation cues," framing students as competent learners within a meaningful mathematical space. Every artefact examined and every conversation had was a mediational tool that scaffolded students' ascent into formal mathematical thought, as Vygotsky (1978) and D'Ambrosio (2001) describe.

Ultimately, our study reinforces a growing consensus that geometry taught through the lens of students lived experiences is not only more engaging but also more effective. What distinguished our work was not just the use of cultural artefacts, but the sustained teacher collaboration that ensured those artefacts remained central throughout instruction. In doing so, we kept the cultural bridge open long enough for deep understanding to form. Where conventional methods presented geometry as a distant abstraction, our approach made it a familiar, shared, and contextually meaningful journey.

Conclusion and Implications

This study affirms the transformative impact of culturally grounded instruction on students' conceptual understanding and achievement in geometry. Ethnomathematics approach enabled students to access mathematical ideas through meaningful and socially mediated experiences within familiar cultural context. The resulting gains in performance, engagement, and confidence highlight the power of pedagogy that bridges learners' informal knowledge systems with formal academic content. In contrast, the conventional method's abstract, decontextualized instruction limited both cognitive development and affective growth, underscoring the limitations of a one-size-fits-all approach to mathematics education.

Educators must reimagine mathematics as a culturally situated practice rather than a neutral set of procedures. Integrating students' cultural experiences into instruction is should not be an optional enhancement but as essential tool for equity, relevance, and deep learning. Teacher preparation programs, curriculum designers, and policymakers must prioritize culturally responsive

methodologies that align with Vygotskian principles of mediation, scaffolding, and enculturation. When mathematics becomes a shared, meaningful practice rooted in the lives of learners, it fosters not only academic success but also enduring identity formation and empowerment learning outcomes that are foundational to long-term participation in STEM and lifelong learning.

The authors received no financial support for the research, authorship, and/or publication of this manuscript

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Appendix A

Interview Protocol for Teachers

Objective: To explore teachers' perceptions of the ethnomathematics approach in improving geometry instruction and learning, focusing on its benefits, challenges, and cultural relevance.

Section A. General Information

1. Participant's role: Teacher
2. How long have you been teaching mathematics?
3. What is your experience with the use of the ethnomathematics approach?

Section B: Teachers' perceptions of the ethnomathematics approach

1. How would you describe your overall experience with the ethnomathematics approach in teaching geometry?
2. In what ways do you think this approach aligns with the current curriculum?
3. Can you describe how the ethnomathematics approach changes your role as a teacher?
4. How does the learner-centred nature of this approach impact student engagement and participation? Can you share an example?
5. What effect do the activity-based components have on students' understanding and enjoyment of geometry?
6. How have culturally appropriate resources (e.g., Adinkra symbols) influenced students' understanding of mathematical concepts?
7. What challenges have you encountered in implementing the ethnomathematics approach?
    a. Time constraints?
    b. Balancing hands-on activities with curriculum coverage?
8. How do you address situations where students struggle to relate cultural symbols to mathematical concepts?
9. Have you observed any difficulties in group activities (e.g., unequal participation)? How have you managed these issues?
10. How do you think the ethnomathematics approach has changed students' attitudes toward mathematics?
11. Would you recommend this approach for wider adoption in Mathematics Education? Why or why not?

Appendix B

Interview Protocol for Students

Objective: To explore students' perceptions of the ethnomathematics approach in improving geometry instruction and learning, focusing on its benefits, challenges, and cultural relevance.

Section A. General Information

4. Participant's role: Student
5. How long have you been learning mathematics?
6. What is your experience with the learning through the ethnomathematics approach?

Section B: Students' perceptions of the ethnomathematics approach

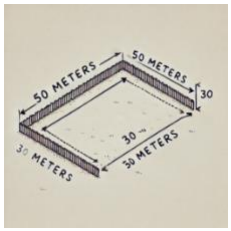
1. How would you describe your experience learning geometry through the ethnomathematics approach?
2. What is different about this method compared to conventional ways of learning math?
3. How has the learner-centred nature of this approach impacted your learning experience?
    a. Do you feel more in control of your learning?
    b. What do you like most about the activity-based lessons?
4. Can you give an example of an activity you enjoyed and why?
5. How do you feel about using cultural resources like Adinkra symbols to learn mathematics?
    a. Did this change how you view math in your everyday life?
6. What challenges have you faced when learning through the ethnomathematics approach?
    a. Were there times when you didn't understand the connection between cultural symbols and mathematics?
7. How do you feel about group activities?
    a. Were there times when some group members didn't participate equally? How did that affect your learning?
8. How has the ethnomathematics approach influenced your attitude toward mathematics?
9. What changes or improvements would you suggest for this approach?
10. Would you like this method to be used more often in your mathematics classes? Why or why not?
11. Is there anything else you'd like to share about your experience with the ethnomathematics approach?
12. Do you have any recommendations for improving how this approach is implemented?

Appendix C

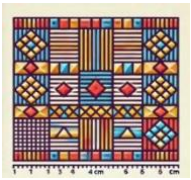
Geometry Achievement Test (GAT)-Pretest

Answer all questions. This is only for research purposes.

1. A farmer wants to fence a rectangular piece of land measuring 50 meters by 30 meters. What is the total length of fencing needed? If fencing costs 20 Ghana cedis per meter, calculate the total cost.

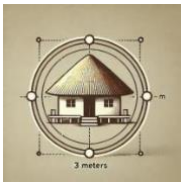


2. A kente cloth pattern has repeated triangles and squares. If the length of one side of the square is 4 cm and the base of the triangle is 6 cm with a height of 5 cm, calculate the total area covered by 3 squares and 2 triangles.



3. The Adinkra symbol 'Eban' represents safety and security. It consists of a circle with a diameter of 8 cm surrounded by a square. Calculate the area of the square if each side is equal to the circle's diameter.

4. In indigenous Ghanaian architecture, some houses have circular bases. If the radius of a house's circular base is 3 meters, calculate the area covered by the base.



5. Identify the type of tessellation shown in this kente cloth pattern. Justify your answer by describing the properties of the shapes used.

6. Using the Adinkra symbol 'Nkyinkyim,' which consists of curved and straight lines, describe how the concept of transformation (translation, reflection, or rotation) is applied to create its repetitive patterns.

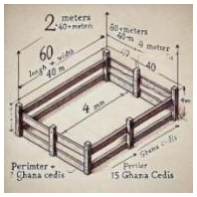
7. Design your own geometric pattern for a piece of kente cloth, using at least two different shapes (e.g., triangles and hexagons). Explain how the shapes fit together without leaving gaps."

Appendix D

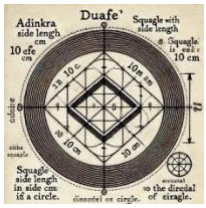
Geometry Achievement Test (GAT)-Posttest

Answer all questions. This is only for research purposes.

1. A decorative floor design includes repeated circles and rectangles. If the radius of each circle is 3 cm and the dimensions of the rectangle are 5 cm by 8 cm, calculate the total area covered by 4 circles and 3 rectangles.



2. The Adinkra symbol 'Duafe' consists of a square with a side length of 10 cm inscribed in a circle. Calculate the area of the circle if its diameter is equal to the square's diagonal.



3. A village water well has a circular opening with a radius of 2.5 meters. Calculate the area of the opening.

4. Identify the type of tessellation shown in a woven basket pattern. Justify your answer by describing the properties of the shapes used (e.g., equilateral triangles, or squares).

5. Using the Adinkra symbol 'Eban,' which consists of straight lines and repeated arcs, describe how the concept of symmetry (reflection, rotation, or translation) is applied to create its repetitive patterns.

6. Create your own design for a floor tile using at least two different shapes (e.g., pentagons and circles). Explain how the shapes fit together seamlessly without leaving gaps.

ELECTRONIC JOURNAL FOR RESEARCH
IN SCIENCE & MATHEMATICS EDUCATION
VOL. 30, NO. 1, 85-111

Catalyzing the Courage to Lead: A Two-Pronged Approach to Empower Mathematics Teachers as Leaders

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ABSTRACT

All students deserve access to high-quality, effective, and impactful mathematics learning experiences. Yet, embodying a collective commitment to high-quality mathematics instruction necessitates a brave willingness of some members to orchestrate the process and provide a vision, working to get everyone on board, shifting away from teaching as a highly individualized activity, and shifting towards teaching as a shared responsibility. In this paper, we broadly ask, how might we facilitate the advancement of K-8 mathematics teachers as leaders? This study, which is part of a larger 5-year project, is focused on analyzing the development of a community of K-8 mathematics teacher leaders, later mentioned as Fellows, involved in an intentional partnership between a large metropolitan research university, one of the largest school districts in the U.S., and an education-focused non-profit. After describing our project's unique two-pronged approach, we share our longitudinal mixed methods approach and broad results from our first two years, which indicated a trend of consistent growth in Fellows' knowledge as well as their ability as leaders to initiate and sustain improvements in mathematics education. We conclude by engaging in a transparent discussion around implications for practice (importance of two-pronged approach, idea that feeling

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valued matters, and intentionality in developing partnerships), implications for research (importance of multi-year district-wide programs for impactful change, the value of longitudinal mixed methods data collection, initial mindsets matter, and the need for further research on classroom teachers as mathematics leaders), and project next steps.

Keywords: doctorate, mathematics teacher leaders, partnerships, professional learning

Introduction

All students deserve access to high-quality, effective, and impactful mathematics learning experiences (National Council of Teachers of Mathematics [NCTM], 2020a; NCTM, 2020b). Embodying a collective commitment to high-quality mathematics instruction does not happen by chance. Instead, it necessitates a brave willingness of some members to orchestrate the process and provide a vision, working to get everyone on board, shifting away from teaching as a highly individualized activity, and shifting towards teaching as a shared responsibility (Bush et al., 2022; Karp et al., 2021; NCTM, 2014). However, mathematics teacher leaders are often left in a seemingly impossible position. Mathematics teacher leaders are equipped with the knowledge, resources, and tools essential for transformative change, yet they are not positioned in their setting, or may not feel comfortable, leading beyond their own classrooms or grade-level teams (Bush et al., 2022). Furthermore, conceptualizations and roles which define teacher leadership vary greatly in the literature (Berg & Zoellick, 2019) and in practice. The project discussed in this paper specifically focuses on mathematics teacher leaders who are still in full-time classroom teaching positions (Rutledge, 2023).

Purpose and Research Questions

The purpose of this paper is to explore how K-8 mathematics teacher leaders are empowered to initiate and sustain improvements in their respective settings. This study explores the following research questions: *How does the launch and implementation of an Ed.D. specialization in K-8 Mathematics Education, together with a Teacher Leader Academy, facilitate the advancement of mathematics teachers as leaders?*

We use data from the first two years of a five-year National Science Foundation (NSF) Noyce program for master teachers involving an intentional partnership between a large metropolitan research university, one of the largest school districts in the U.S., and an education-focused non-profit.

Background Literature

Mathematics leadership structures in school districts differ greatly, with some districts implementing numerous layers of support for mathematics instruction and learning at both the school (e.g. principals, assistant principals, instructional coaches) and district (e.g. curriculum and professional development departments) levels, while others primarily depend on classroom teachers to enhance mathematics instruction and learning within individual schools (e.g. department chair, lead teacher). Regardless of the structure, the flow of information and support for mathematics teachers is often fragmented and disjointed. We contend that classroom teachers, as a universal resource across schools, present a practical solution to this challenge. Leveraging their position and expertise offers a promising avenue to address this need. In fact, NCSM articulates the role of a mathematics teacher leader (a classroom teacher) in their NCSM Essential Actions: Framework for Leadership in Mathematics Education (NCSM, 2020).

As mentioned in the introduction, this study specifically focuses on a program model for teacher leaders who are in full-time classroom teaching positions. Prior research has examined various models of mathematics teacher leadership programs including those delivered through graduate teacher education programs, collaborations between universities and school districts, and those not affiliated with a university. University-based programs are frequently delivered through graduate teacher education programs (Criswell et al., 2018b; Ross et al., 2011; Taylor et al., 2011). Research-to-practice partnerships foster collaborative relationships between research institutions (e.g., universities as the research component) and school districts (e.g., practitioners as the practice component) to develop teacher leaders (Auslander et al., 2022; Borko et al., 2021; Sinha & Hanuscin, 2017; Yow et al., 2021). Numerous professional development-focused models that are not affiliated with universities emphasize both cultivating and supporting teachers in their roles as leaders (Alemdar et al., 2018; Criswell et al., 2018; Green & Kent, 2016; Gul et al., 2019; Gul et al., 2022; Meyer & Slater-Brown, 2020; Rebello, Hanuscin & Sinha, 2011; Reid et al., 2022; Yow & Lotter, 2016).

Prior studies focused on developing teacher leaders suggest program models incorporate both professional learning and mentorship components (Green & Kent, 2016; Gul et.al, 2019). Existing research emphasizes the development of teacher leaders but often overlooks creating opportunities for teachers to simultaneously implement or practice leadership with active support and mentorship. There remains an opportunity to make a meaningful contribution by focusing on both content-specific teacher leadership development and mentorship as teachers enact teacher leadership while fulfilling full-time classroom teacher roles. This current study's design centers on a two-pronged approach that combines the content knowledge development of mathematics teachers with organized opportunities to apply their learning in practice with active guidance and mentorship through a research-to-practice partnership.

Inclusion of professional learning and mentorship components in a teacher leadership development program is supported by the Teacher Leadership Exploratory Consortium's (TLEC) Teacher Leader Model (TLM) Standards (2011) and NCSM's Framework for Mathematics Leadership Guiding Principles (2020). The TLM standards include (a) fostering a collaborative culture to support educator development and student learning, (b) accessing and using research to improve practice and student learning, (c) promoting professional learning for continuous improvement, (d) facilitating improvements in instruction and student learning, (e) promoting the use of assessments and data for school and district improvement, (f) improving outreach and collaboration with families and community, and (g) advocating for student learning and the profession (TLEC, 2011). NCSM's (2020) Framework for Leadership in Mathematics Education provides four guidelines to establish the "bold" work of the mathematics teacher leader focused on empowering teachers as professionals, incorporating structures that support teacher professional development, fostering teacher agency to improve student learning, and positioning teachers to advocate for high-quality mathematics instruction. These components and connected research also informed our project design. In a case study examining the development of master teachers as classroom-based mathematics teacher leaders, Rutledge (2023) found that master teachers positioned in this way were empowered to catalyze change in school systems from a unique *within-the-classroom* perspective. This positioning of mathematics teacher leaders offers viable pathways to sustained organizational improvement as these teacher leaders are uniquely positioned to lead, model, and coach their peers in the area of mathematics content knowledge and pedagogy and high-quality teaching practices from within the classroom (Rutledge, 2023).

Hence, this study emphasizes both strengthening classroom-based mathematics teachers' content knowledge and positioning the developing teacher leaders to engage in mathematics education leadership activities as essential components for effective and impactful mathematics teacher leadership development. This study further leans on the existing research of incorporating both professional learning and mentorship (Green & Kent, 2016; Gul et.al, 2019) into programs focused

on harnessing the growth of mathematics teacher leaders. By prioritizing these areas, the study aims to empower classroom-based teachers as on-the-ground leaders to enhance mathematics teaching and learning in their classrooms and at their schools, to advocate for high-quality mathematics instruction from a classroom-based lens, to lead professional development efforts from appropriate and applicable perspectives, and to use their experience to take on broader leadership roles in the education community at large. These goals for classroom-based teachers ensure that they are well-prepared to drive sustainable, meaningful, and lasting improvements in mathematics education.

The broader rationale for this study is grounded in the national literature. NCTM (2014), in their landmark publication *Principles to Actions: Ensuring Mathematical Success for All*, identified Professionalism as one of the six guiding principles for school mathematics. However, in too many schools, professional isolation exists between colleagues within the school, as well as others including teachers from other schools, mathematics educators, and mathematicians (Scholastic and the Bill & Melinda Gates Foundation, 2012). Such professional isolation can hinder continued professional growth, such as the importance of teachers of mathematics at all levels continuing to deepen their mathematics knowledge for teaching (as described in Conference Board of Mathematical Sciences, 2012). Further, such isolation can lead to inconsistencies in practices and negatively impact student learning (NCTM 2020a, 2020b).

Our overall five-year project focuses broadly on the advancement of mathematics teacher leaders including their ability to meet the needs of all learners, mathematical content knowledge for teaching mathematics, mathematical pedagogical knowledge, and leadership capacity. We aim to develop a community of K-8 teachers of mathematics (which we refer to as Fellows) who are mathematics teacher leaders intentionally positioned as classroom-based school and district mathematics education experts. Through our collaborative partnership, we seek to abolish professional isolation, and develop a safe and welcoming space for needed and challenging conversations to happen.

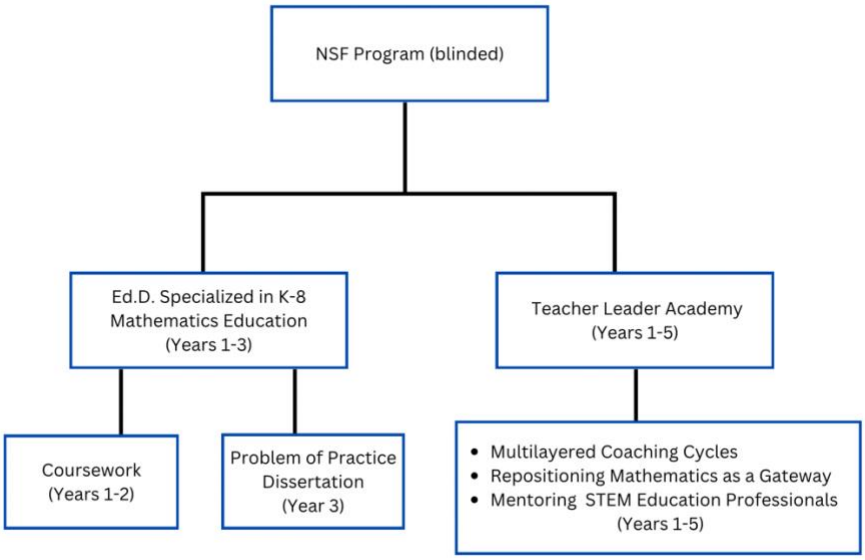
Our Two-Pronged Approach

From the outset of our project, we created and adopted a two-pronged approach. Literature on professional learning effectiveness has long supported an iterative process that oscillates between professional learning and job-embedded components, situated in context (Borko, 2004; Heibert et al., 2005; Lave & Wenger, 1991; Philippou et al., 2015), which led us to this two-pronged approach.

The first prong is to develop mathematics teacher leaders through a new Curriculum and Instruction Ed.D. specialization in K-8 Mathematics Education. The second prong is the launch and implementation of a Teacher Leader Academy (TLA), providing a platform for our Fellows to establish themselves as leaders in their district and enact what they have learned in the Ed.D. program. It is our intent that through our partnership with the district and non-profit, our Fellows, who are K-8 mathematics teacher leaders in classrooms and alongside students and their colleagues every day, once they earn their doctoral degrees will be well-positioned to navigate and contend with the many time, fiscal, policy, and resource barriers that currently exist in K-8 schools. See Figure 1.

Figure 1

Mathematics Teacher Leadership Program Two-Pronged Approach



Ed.D. Specialized in K-8 Mathematics Education (Prong 1)

The Ed.D., specialized in K-8 Mathematics Education, was envisioned as a terminal professional degree program designed for educators working full-time who plan to serve as expert practitioners in their settings following degree completion. This new degree program, launched with our cohort of Fellows, encapsulates direct impact to K-12 schools and districts while elevating the teaching profession. With an Ed.D. program in Curriculum and Instruction already in place at the university, this new program builds from a strong foundation of an existing program but fulfills a needed focus on leadership in K-8 mathematics education. Importantly, a key component of our project is that each Fellow's dissertation targets a current problem of practice (Ma et al., 2018) related to K-8 mathematics in their setting with clear alignment to at least one of the four key recommendations in NCTM's Catalyzing Change framework.

The specialization is designed to be completed in three years and includes 57 credit hours of coursework and dissertation. Fellows were positioned to make a long-term impact in their school and district while supporting administrators, instructional coaches, and teachers in research-informed and effective mathematics teaching which will ultimately lead to improved student learning. This program is dedicated to providing all Fellows with content and pedagogical knowledge for teaching mathematics; tools for guiding, planning, and reflecting on instruction; and skills for conducting research and using data to inform decision-making related to the purposes, structures, and teaching and learning of K-8 mathematics.

Figure 2

Program of Studies: Ed.D. Specialized in K-8 Mathematics Education

Semester	Courses
Fall	**Policies, Practices, and Structures in K-8 Mathematics Education** **Content Knowledge for Teaching K-8 Mathematics I**
Spring	Facilitating Learning, Development & Motivation Data, Assessment & Accountability **Seminar in K-8 Mathematics Education (2 credits)**
Summer	Organizational Theory in Education Identifying Complex Problems of Practice
Semester	Courses
Fall	**Content Knowledge for Teaching K-8 Mathematics II** **Instructional Coaching in K-8 Mathematics**
Spring	Analysis of Complex Problems of Practice Analysis and Synthesis of Educational Literature **Seminar in K-8 Mathematics Education (1 credit)** *Milestone 1: Gap Analysis Paper*
Summer	Research Seminar Advanced Writing Workshop *Milestone 2: Dissertation Prospectus, Annotated Bibliography, Initial Committee* *Milestone 3: Dissertation Proposal*
Semester	Courses
Fall, Spring, and Summer	Dissertation in Practice (18 credit hours)

Note: Mathematics Education courses are designated in bold text and program specific milestones not connected to specific courses are designated in italics.

Becoming an expert practitioner is a complex, multi-layered, ongoing endeavor that involves a unique combination of content knowledge for teaching, pedagogical knowledge, leadership development, advocacy, professionalism, understanding of policy, and a deep understanding of research (NCTM, 2014). The goal is for Fellows to be prepared, positioned, and working to be agents of change in their settings.

Teacher Leader Academy (Prong 2)

The Teacher Leader Academy is designed to engage Fellows as mathematics classroom teachers positioned as leaders through the use of a cognitive apprenticeship system of modeling, coaching, and fading (Collins et al., 1987). This coherent system includes job-embedded support and mentoring (Cobb & Jackson, 2011) using an iterative process so the focus on improving student mathematics learning and achievement is maintained (Boston et al., 2017).

"Teacher leaders must be given opportunities to practice and apply what they learn about leadership" (Katzenmeyer & Moller, 2009, p. 37). This quote encapsulated the purpose of the Teacher Leader Academy we developed with our partner district and non-profit so the Fellows could enact what they learned in the Ed.D. program into practice. The Teacher Leader Academy invests in developing Fellows' agency to implement meaningful change. As a result, these mathematics teacher leaders are the ones thinking critically about the greatest needs in K-8 mathematics education, and they are equipped to approach problems methodologically from their job-embedded perspectives.

The Teacher Leader Academy consists of three interconnected synergistic components: Engaging in Multilayered Coaching Cycles; Repositioning Mathematics as a Gateway; and Mentoring STEM Education Professionals. Engaging in Multilayered Coaching Cycles was intentionally developed as a vehicle through which to build leadership capacity and for Fellows to enact what they have learned in the Ed.D. program beyond their own classroom or grade level team. Repositioning Mathematics as a Gateway leveraged the expertise of the mathematician Co-PI of the project to place an intentional focus on the long-term mathematics journey of Fellows' students. Mentoring STEM professionals specifically recognized the need for multiple layers of mentoring in recruiting, retaining, and elevating the leadership of a high-quality mathematics teaching workforce. We provide details on each component.

Engaging in Multilayered Coaching Cycles

Fellows engage in coaching cycles throughout their experience in the Teacher Leader Academy. The multilayering within the coaching cycles include the Fellows evolving as: Researchers developing expertise and conducting research related to their practice; Catalysts for coherence working with administrators and instructional coaches in guiding their messages regarding best practices for teaching and learning mathematics; and Peer coaches providing mentoring for colleagues and the non-profit partner volunteers. Specifically, this project employs the Affirming Learning Walks approach which is described by Ross, Lamb, and Johnson (2023) as providing "asset-based orientation toward teachers, and teaching, and have [has] the potential to develop trust and collegiality among teachers and teacher leaders" (p. 48). During an Affirming Learning Walk, a 10-15-minute classroom visit occurs and then debriefs between the teacher(s) and visitors takes place which only focuses on productive practices (Ross, Lamb, & Johnson, 2023). This helps to build a space of trust and respect that fosters growth over time. Through the partnership with the non-profit, Fellows have the opportunity to apply their learning and leadership skills with volunteers who work to support K-8 students in Title 1 schools. These volunteers are most often young adults who do not have experience in education, and our Fellows coach them on providing individual and small group mathematics instructional supports to students in the district. There are opportunities for Fellows to interact with five rotations of volunteers (volunteers complete a 1-year commitment) during this five-year project. This allows for modeling, coaching, and fading of support as Fellows learn about, develop, and disseminate information related to best practices for mathematics instruction in a supportive and low-risk environment.

Repositioning Mathematics as a Gateway

Historically, mathematics has been identified as a gatekeeper holding students back from the possibilities of pursuing STEM-related careers (NCTM, 2020b) but should be repositioned as a gateway as advocated for in *Charting a Course for Success: America's Strategy for STEM Education* (National Science and Technology Council, 2018). Teacher leaders have real potential to reposition mathematics as a gateway to those very same career opportunities, as well as, importantly, to develop STEM literacy in all students regardless of whether they ultimately pursue a STEM-related career. Because success in secondary and postsecondary mathematics begins with actualizing K-8 mathematics as a dynamic and creative subject, beyond the memorization and rote application of algorithms, teachers must foster in students the ability to think critically about the information they receive (Bressoud, 2015). This component focuses on:

- Cultivating broad and deep understanding of mathematics, so that students know how and why various approaches work in particular mathematical contexts (Dean & Brookhart, 2013).
- Strengthening problem solving skills, so that students can build solutions to a variety of problems without foreknowledge of the relevant mathematics (Giganti, 2007).
- Developing productive persistence in K-8 students, so they are able to learn from mistakes, without becoming discouraged by minor setbacks (Silva & White, 2013).
- Improving communication skills, so that mathematical ideas may be explored appropriately.

The overall goals of this component are to better understand ways in which mathematics is viewed, develop ways to combat the views that are harmful or counterproductive and promote the views that are beneficial or constructive, and develop practical ways to weave the constructive views into K-8 instruction. With these ends in mind, we aimed to develop in Fellows the tools and techniques necessary to catalyze change and to empower Fellows to serve as agents of change with potential to impact K-12 students' future performance (Barber & Mourshed, 2007).

Programmatic elements towards these goals included the project mathematician engaging Fellows in workshops and activities around this component and the Fellows putting into action new ideas. For example, Fellows engaged in readings and discussions around Francis Su's work (e.g. Su, 2013) and the project mathematician engaged Fellows in topics including sense of belonging in mathematics and joy in mathematics. Further, our project mathematician contributed "Mathematics as Gateway" columns across multiple issues of a Fellow-created newsletter.

Mentoring STEM Education Professionals

Research shows early, consistent, and persistent exposure to role models in STEM fields (particularly ones that students feel they can relate to) is elemental in shaping a sense of belonging and interest (Ong et al., 2011; Weber, 2011). Project Fellows receive intentional support through targeted mentoring. They, in turn, mentor their colleagues, as well as the non-profit volunteers, who are volunteering in our district schools to provide individual and small group mathematics instructional supports to students. Mentoring develops within coaching cycles, with support fading over time, aligned to the cognitive apprenticeship system of modeling (Collins et al., 1987).

Setting and Recruitment of Fellows

Our setting is a large metropolitan area in the southeastern United States. The university is one of the largest universities in the country and designated as a Research I. The partner school district is one of the largest school districts in the United States with more than 200,000 students. At the start of the project, the district's student population was 25% white, 24% Black, 43% Hispanic, 5% Asian, and 2% multi-cultural (as identified by the district). The district has a high population of students on

free or reduced-priced meals. The non-profit partner was initially identified as a potential for this project because they had a long-standing partnership with the district. The non-profit partner had provided support for more than 7,200 students during the past nine years in the district (at the time the project started). The non-profit volunteers partner with classroom teachers across the district to help students cultivate many emotional, social, and academic skills. Our partnership with them specifically focuses on Fellows providing support for the mathematics academic aspects.

Fellows were recruited, selected, and inducted following the university and Ed.D. program admission requirements in addition to the selection criteria identified for our project. Recruitment drew heavily from an existing relationship with the school district. Instrumental to this project was the notion of expanding our existing close collaboration as it relates to our K-8 Mathematics and Science Education Master's program, a program that is centered on improving the quality of mathematics and science teaching and developing teacher leaders, which has been offered for approximately three decades. Since the inception of the Master's program, our partner district has had the greatest enrollment of teachers. Thus, this pre-existing partnership between the university and school district provided a natural pipeline of potential applicants.

Minimum requirements for the Fellows included a Master's degree in their teaching field and a position in the school district as a full-time elementary school teacher and a teacher of mathematics or as a middle school mathematics teacher. Potential applicants were informed of the opportunity through district communications via newsletter, email, information sessions, on-going communications, and through introduction interviews. In addition to a $10,000 per year salary supplement Fellows receive for five years provided by the grant, a strong incentive for applying to the program was that the district provides a permanent pay increase for those in teaching positions with an earned doctorate in specific fields. Fellows had to agree to the five-year teaching service commitment required by NSF. Application materials included transcripts, a goals statement, a resume, three letters of reference, teacher evaluations and an applicant analysis of student data, and an interview with project leaders. An incredibly competitive pool of nearly 40 applicants was reviewed, and 15 applicants were ultimately selected as Fellows (we only had funding for 15).

After the first year of the project, one Fellow decided for personal reasons to leave the field of education (to pursue another career helping children outside of education that was of great passion to them). We have had no other attrition to date. Thirteen are graduates from our K-8 or another one of our Mathematics or Science Education Master's programs, and 11 currently work in Title 1 schools. Of the 14, four are currently middle school mathematics teachers, 10 are elementary teachers with some teaching mathematics or mathematics and science all day, and some working as generalists teaching mathematics and science as well as other subjects. Fellows' years of teaching experience ranged from approximately six to more than 25 years at the start of the program.

Methodology

A longitudinal mixed methods approach was selected for this study, which drew on the strengths and minimized the weaknesses of both quantitative and qualitative approaches (Creswell, 2003; Creswell & Plano Clark, 2007). The research question for this study was as follows: *How does the launch and implementation of an Ed.D. specialization in K-8 Mathematics Education, together with a Teacher Leader Academy, facilitate the advancement of mathematics teachers as leaders?*

Data Sources

Specifically, we grounded our data collection plan in alignment to the two prongs. Figure 3 provides an overview of our data collection timeline for Year 1 and Year 2, with the data sources utilized in this report highlighted in bold text. Although there is overlap, data most closely related to

the Ed.D. program (first prong) consists of: a survey to measure Fellows' use of effective instructional practices (Boston, 2013); the Learning Mathematics for Teaching (LMT) content-knowledge assessments (Hill et al., 2008) which was chosen because of its topic-specific modules and alignment to the two mathematics content courses in the EdD program; and videos of Fellows teaching mathematics lessons in their own classrooms, analyzed with the Instructional Quality Assessment (IQA) in Mathematics Toolkit, which is a set of classroom observation rubrics that specifically targets ambitious mathematics teaching practices (Boston, 2012). The quantitative measures assess Fellows' development in content and pedagogy throughout the program, which are important outcomes and also enable us to examine the relationship between content, pedagogy, and the development of teacher leadership practices. Data related to the Teacher Leader Academy (second prong) consists of focus group interviews with project leaders, Fellows, non-profit volunteers mentored by our mathematics teacher leaders, and school administrators (including instructional coaches); a survey for administrators (including instructional coaches), a task sort and video analysis for instructional leaders (Boston et al., 2017); Fellows self-reporting of leadership engagement; and student deidentified achievement data (with matched control). All Fellows and project leaders completed all data collection activities. Non-profit volunteers and school administrators and instructional leaders at Fellows' schools were encouraged to complete data collection activities but were not required (participation rates for these groups varied but were generally high).

Figure 3

Data Collection Timeline For Year 1 and 2

Year	Target Group	Instruments and Data Sources
Year 1	Fellows	• **Pre Instructional Practices Survey (Prong 1)** • **Pre Pedagogical Content Knowledge LMT (Prong 1)** • **Pre/Post Mathematical Content Knowledge LMT (Prong 1)** • **Interviews/Focus Groups (Prong 2)** • Student Achievement data (Prong 2)
Year 2	Fellows	• **Post Instructional Practices Survey (Prong 1)** • **Post Pedagogical Content Knowledge LMT (Prong 1)** • **Post Mathematical Content Knowledge LMT (middle level only) (Prong 1)** • **Interviews/Focus Groups (Prong 2)** • Student Achievement data (Prong 2) • **Classroom Practice: Pre IQA video (Prong 1)** • Coaching and Mentoring: Pre task sort and video analysis (Prong 2)
	Administrators (including instructional coaches)	• Pre task sort and video analysis (Prong 2) • Survey (Prong 2) • Focus Groups (Prong 2)
	Non-Profit Volunteers	• Focus Groups (Prong 2)

Note: Data sources used in this report are bolded.

Data Analysis

In this section, we share how data have been analyzed for this study (see Figure 3 for data sources). Importantly, our focus is to examine Fellows' growth in the advancement areas in a multi-faceted way with examination both within and across data sources.

For Prong 1, the instructional practices surveys were analyzed quantitatively by our external evaluator, using descriptive statistics and statistical tests such as the Wilcoxon Signed Rank tests (non-parametric t-tests for repeated measures and paired data) to examine Fellows' growth across pre-, post-, and (eventually) post-post administrations. Second, the LMT assessments are a national standardized assessment. Fellows complete a pre, post, and post-post assessment for a set of elementary LMT modules and a set of middle grades LMT modules. After Fellows complete the assessment, the system generates results including a number-of-items-correct score, an item response theory (IRT) score comparing the Fellow's performance to a national database, and an analysis of change over time in IRT scores. Classroom video observations, in which Fellows recorded their own teaching, were analyzed with the IQA Mathematics Toolkit (Boston, 2012). IQA data are analyzed using descriptive statistics, *t*-tests (changes over time in overall IQA lesson scores), and *t*-tests for non-parametric data (changes over time for specific rubrics).

Prong 2 data, the focus group interviews, were analyzed systematically through data reduction and connection, allowing for the identification of common themes across participants, as well as divergent cases (LeCompte et al., 1993). Specifically, the external evaluator and a graduate research associate ([GRA]; doctoral student, not a Noyce participant) analyzed transcripts of the focus group audio-recordings line by line (transcribed by Zoom) to identify Fellow's comments related to each goal of the project (e.g., mathematics content knowledge for teaching, teaching practices, teacher leadership) and/or project activities (e.g., Mathematics as a Gateway, Teacher Leadership Academy). The evaluator and GRA categorized Fellows' comments within each of the project goals and identified two additional main themes, Feeling Valued and Personal Growth. Through consensus and discussion, we then (1) refined the selection of comments and (2) identified subthemes to describe groups comments within each broader goal/theme. In this report, qualitative data are used to provide examples of how Fellows perceive the connections between and support provided by the various project components. While the external evaluator conducted most of the data analysis, she worked closely with the project investigators to help make sense of specifically the qualitative data, and to connect the quantitative and qualitative results.

Our data analysis also includes intentionally examining across data sources. For example, the results of the LMT assessments (which examine Fellows' growth in mathematics content knowledge for teaching and pedagogical content knowledge) are correlated with their instructional practices survey results to explore the relationship between Fellows' beliefs and knowledge. Focus group interview data provide evidence of the extent of Fellows' growth in their confidence to serve as mathematics teacher leaders and agents of high-quality mathematics programmatic structures. We have the ability to compare trends over time to Fellows' instructional practices survey results, as well as to surveys completed by each Fellow's administrator and instructional coach. Additionally, we track leadership engagement of the Fellows throughout the project. This provides an opportunity to document their positive influence within their schools and within the broader mathematics education community. We note changes over time as the Fellows expand their reach from their classroom setting to broader impacts.

Results

Ed.D. Program (Prong 1)

LMT Instrument

Fellows increased or maintained positive outcomes across mathematics content knowledge for teaching, beliefs, and instructional practices. Post-tests for LMT Elementary modules were collected after Fellows' engagement in the first content knowledge for teaching course (Year 1) and post-tests for LMT Middle School modules were collected after Fellows' engagement in the second content knowledge for teaching course (Year 2). Table 1 provides results from the individual LMT modules and overall results in Years 1 and 2 for the group of 14 Fellows who participated in the project throughout Year 2 (one of the original 15 Fellows left the project in Year 2). In Year 1, the individual modules exhibited non-significant positive growth trends, and the overall combined score reflected statistically significant positive growth [t(13) =2.15; *p*(one-tailed) = .026]. In Year 2, 3 of 4 modules and the overall results all indicated statistically significant positive growth.

Table 1

LMT Results by Change in Score (Number Correct), Years 1 and 2

	n	Mean Pre-Test	Mean Post-Test	Change	t	*df*	*p (one-tailed)*
LMT Elementary Tests, Year 1 Pre/Post Comparison							
Number Concepts and Operations	14	18.43	19.07	0.64	0.63	13	0.271
Patterns, Functions, and Algebra	14	19.79	21.00	1.21	1.60	13	0.067
Geometry	14	15.07	16.14	1.07	0.98	13	0.172
Combined results overall	14	53.29	56.22	2.93	2.15	13	**0.026***
LMT Middle Level Tests, Year 2 Pre/Post Comparison							
Number Concepts and Operations	13	13.31	18.54	5.23	4.23	12	**<0.001***
Patterns, Functions, and Algebra	13	14.15	16.15	2.00	1.25	12	0.12
Geometry 4-8	14	16.28	20.28	4.00	4.04	13	**<0.001***
Probability, Data, and Statistics	13	16.08	19.00	2.92	2.15	12	**0.026***
Combined results overall	13	60.23	73.92	13.69	5.05	12	**<0.001***

* Statistically significant at *p*(one-tailed) < .05

Table 2 provides results for changes in IRT scores for Year 1 and 2 LMT data, by module. Year 1 modules did not exhibit significant change. In Year 2, after the second content knowledge course, Fellows' scores on three of the four middle-level LMT modules indicated significant positive growth, with effect sizes ranging from .39 to 1.06, and significantly higher gain scores than those exhibited in the national LMT database.

Table 2

LMT Results by Change in IRT Scores, Years 1 and 2

	Mean IRT Change Score (SD)	t	*df*	*p* (two-tailed)	Effect Size (Cohen's *d*)
LMT Elementary Tests, Year 1 Pre/Post Comparison					
Number Concepts and Operations	0.13 (0.60)	0.80	12	0.44	0.17
Patterns, Functions, and Algebra	0.24 (0.56)	1.55	12	0.15	0.29
Geometry	-0.09 (0.57)	-0.56	12	0.58	-0.10
LMT Middle Level Tests, Year 2 Pre/Post Comparison					
Number Concepts and Operations	0.66 (0.78)	2.95	11	**.01***	0.66
Patterns, Functions, and Algebra	0.39 (0.57)	2.37	11	**.04***	0.39
Geometry 4-8	0.68 (0.55)	4.45	12	**<.001***	1.07
Probability, Data, and Statistics	0.38 (0.62)	2.09	11	**.06***	0.60

*Statistically significant at $p < .10$

Increased content knowledge and pedagogical content knowledge contributes to Fellows' effectiveness as mathematics teacher leaders by enhancing how they are able to identify and support the instructional practices of their colleagues (Cobb & Jackson, 2011; Stein & Nelson, 2003). In order to identify and support high-quality instructional practices, instructional leaders should have expertise in their content area and be knowledgeable about how that content is best taught and learned (Boston et al., 2017; Steele et al., 2015; Stein & Nelson, 2003).

Instructional Strategies Survey

On the instructional strategies survey, Fellows overall tended to agree/strongly agree (mean $\geq$ 3.0) with items expressing a reform-oriented view of mathematics teaching (e.g., multiple representations [pictures, words, symbols, charts, graphs, etc.] should be used in teaching a mathematics topic; mathematical concepts are best retained when learned through investigation and application) and tended to disagree/strongly disagree (mean $\leq$ 2.0) or be neutral toward (mean between 2.0 and 3.0) items expressing a traditional view of mathematics teaching (e.g., students learn mathematical procedures [algorithms] best through repeated practice, rather than by solving problems; tests and quizzes are the best means of assessing student progress in mathematics class). Results were very consistent from Year 1 to 2, with no items having statistically significant changes in means, no

changes in the consensus of agree/strongly agree items (mean > 3.0), and three items changing in consensus of disagree/strongly disagree (mean $\leq$ 2.0). Across the two years, Fellows self-report moderate, frequent or always/daily use of 32 out of 36 teaching practices (mean > 3.0). The four exceptions with means < 3.0 (infrequently used or never used) are all reflective of traditional mathematics teaching practices: (a) Designate time for students to begin homework in class; (b) Begin class by answering questions about homework; (c) Allow students to use calculators to solve exercises or problems; and (d) Introduce content by lecture or demonstration.

Year 1 Video Observations

In Year 1 lesson videos, a majority of lessons featured tasks ($\frac{10}{14}$; 71%) and implementations ($\frac{12}{14}$; 86%) primarily focused on procedures and computations, without connection to deep mathematical understanding. Discussions consisted of presentations of procedural steps, with few explanations provided by students. Though teachers asked questions (How did you get that? How do you know?), the questions more often pertained to mathematical procedures rather than concepts ("how" rather than "why") or resulted in explanations being provided by the teacher. In contrast, half of Year 2 tasks ($\frac{7}{14}, 50\%$) and implementations ($\frac{6}{14}$; 43%) featured students engaged in reasoning and sense-making, with students providing mathematical explanations and overall increased use of manipulatives, visual representations, good questions, and student-voice. Wilcoxon tests (paired-value t-test for ordinal data) for small samples indicated significance growth on the IQA rubrics of Teacher's Questioning (W=29; p(one-tailed) < .05) and Teacher Linking (W=29; p(one-tailed) < .05), indicating Fellows were asking more high-order questions and providing more opportunities for students to connect ideas to one another.

Focus Groups

From the focus group data, which addressed both Prongs 1 and 2, Fellows attributed instructional changes (specific topics and ways of teaching) to their experiences in the project through the mathematics education coursework they had completed and the activities in the Teacher Leader Academy, and specifically mentioned the Mathematics as a Gateway component (led by project co-PI who is a mathematician) of the Teacher Leader Academy. Fellows also noted the consistency in messages from the mathematician and the mathematics education faculty, especially around tasks and questioning. Fellows described how making a task more exploration-based, supportive of play and creativity, and asking questions to support exploration (from the Mathematics as a Gateway component) also increases the task's cognitive demand and aligned with the questioning types and ideas about high-level implementation (from the content courses and Teacher Leadership Academy). These connections and attribution speak to the seamless overlap between the two-pronged approach. Fellows describe specific changes in their instructional practices that they attribute to the project: being more student-centered; changes in how they teach specific content; changes in their instructional practices aligned with tools and ideas shared during the project (e.g., 13 Rules that Expire by Karp et al., 2014), the value of exploration and play, asking "why" and asking rich questions, applying constructs from a classroom observation tool explored in the Teacher Leader Academy).

Themes in Fellows' focus group responses are provided in Table 3, as well as a comment or comments illustrative of the type of responses coded within the theme or subtheme. Subthemes within the project goals of Leadership, Mathematical Content Knowledge, and Mathematics Pedagogy included Fellows' reflections on their own growth and changes in their perspectives or practices. From Year 1 to Year 2, Fellows described their leadership roles as evolving from offering their services and

support to colleagues in Year 1 (primarily informal leadership activities) to becoming the "math go-to person" at their school in Year 2, with teachers seeking them out and generating more organic opportunities to provide support and with more formal requests for serving in leadership roles. Comments within the theme of Feeling Valued (Support and Collaboration) often arose in response to the prompt, "What has been the best part of the project so far?"

The themes and sample comments in Table 3 tie seamlessly to the various key components of our project. For example, in the Mathematical Content Knowledge theme, there was a strong focus on conceptual understanding and the "whys," which align to the focus of the mathematical content knowledge for teaching courses that were part of Fellows' Ed.D. coursework. Several Fellows mentioned the mathematics as a gateway component and that everyone was capable of learning mathematics, which were ideas they worked on with our project mathematician during the Mathematics as Gateway component of the project. The Mathematics Pedagogy theme showcased changes in Fellows' teaching practices, such as through the use of manipulatives, higher-quality tasks, and effective questioning. This growth was also evident in the video observations. The themes of Leadership, Feeling Valued, and Personal Growth all personified Fellows' continued growth as teachers leaders, instructional advocates, as well as their increased confidence. These responses aligned to Fellows finding their voice, giving feedback, leading professional development as well as the value they placed on our project community, and their own surprise at their own personal growth.

Table 3

Themes in Year 1 to Year 2 Focus Groups

Theme	Descriptions or Subthemes	Sample Comments
Mathematical Content Knowledge (CK)*	Own Math Processes/ Conceptual Understanding	• "We are conceptually understanding every aspect within the mathematics, which I did not have full background of." • "I now understand when kids solve it with a different strategy. I can make connections and make sense of their math." • "I'm reflecting back on how I was teaching before the …program, and how we never truly went over the "why" because again, I didn't understand why things worked one hundred percent."
	Changes to Perspectives on Math	• "Being …the Gateway and not the Gatekeeper." • "Everybody is capable of learning math."
Mathematics Pedagogy*	Changes to Teaching Practices	• "A new thing for me is using research to find the activities I'm going to do." • "My teaching was completely revolutionized by her class." • "Struggle productively as they continue to explore and explore and use those manipulative and collaborate with each other." • "To be able to address any misconceptions, asking those higher thinking questions." • "I have literally taken segments of what she's done with us in class and brought it into my classes. There was one lesson where we modeled equations using algebra tiles, and I immediately did that with my class that same week."

		• "I have been intentional about pulling out manipulatives and drawing pictures to help students conceptually understand. And in the past I've always gone straight to the algorithm." • "I've started actually evaluating the tasks that I present to my students. So I look at the potential of the task …and then my implementation of the task." • "Now, when I'm looking at a lesson, I start rethinking what I need to start asking kids because I'm not asking the right questions."
Leadership*	Formal Leadership Activities	• "I'm being asked to deliver more professional development." • "I am supporting the team lead; she comes to me a lot so, and the other team member, if we have new teachers and they still come to me."
	Informal Leadership Activities	• "Teachers are starting to recognize we're in that leadership role, even without being officially in that leadership role." • "I do give them feedback, in the area of mathematics." • "I use as an opportunity to share some of the things that we have learned in the class here with them."
	General Collaboration Within School	• "Trying to collaborate with not just the principal, but other stakeholders in the building." • "Enjoyed the collaboration with other teachers"
Feeling Valued	Collaboration (within the cohort)	• "I love the collaboration that we have as a family of Fellows." • "We have a tight knit support system here."
	Support (by project leaders)	• "I think that the support that we've gotten has definitely helped us grow in that role." • "We feel special to be here." • "Anytime we do voice a concern, we feel heard, and we feel respected in the way that they will do what they can to help us." • "Because we feel trusted, and we feel like we can trust them. Because we have that connection and that bond."
Personal Growth	General Comments on Personal Growth	• "I can't believe how much I did not know." • "I'm still growing, and this program itself has allowed me to reevaluate myself." • "The attributes of a true leader. I am learning that in class." • "My ability to read literature is little bit more refined, and I think that the course work has really helped me develop that side of myself as a student and as a learner, which I think I've seen the most exponential growth."

*Themes that align with Focus Group Prompts and Project Goals

Across Data Sources

Looking across data sources, teachers with high content knowledge for teaching (on the LMT) tended to have higher classroom observation scores (on the IQA). The alignment between Fellows' perceptions of different instructional strategies (as expressed in the survey) and the strategies observed in their own classrooms (from classroom videos) will be interesting to continue to monitor.

From the first two years of data collection related to Prong 1, we have found that Fellows began the project with strong beliefs aligned with high-quality mathematics teaching (which have remained). Regarding their mathematical content knowledge for teaching and pedagogical content knowledge as well as their instructional practices, we have a trend of evidence of growth after the first two years.

Teacher Leader Academy (Prong 2)

Results from interviews with project leadership, Fellows, and school administrators identified the impact of the Teacher Leader Academy (TLA). In particular, TLA assignments and Ed.D. course activities were reported to have intentional positioning, scaffolding, and support of Fellows' development as mathematics teacher leaders. For example, Fellows conducted a Catalyzing Change Needs Assessment assignment and Affirming Learning Walks in their schools. Both of these were incorporated (or engaged in) to position Fellows to build rapport with administration, which provided a platform for Fellows to be recognized and acknowledged as mathematics teacher leaders. While engaging in the Catalyzing Change Needs Assessment and in other activities (particularly, in serving as mentors to interns from the non-profit agency), Fellows initially expressed apprehension in their emerging role as mathematics teacher leaders in Year 1. They described how project leaders developed trust and provided support, particularly around navigating the landscape to promote high-quality mathematics instruction. Project leaders describe how they intentionally planned the Catalyzing Change Needs Assessment and mentoring activities so that Fellows would be recognized by and interact with school administrators as teacher leaders. In Year 1, Fellows describe the following components of their emerging role as teacher leaders: (a) being recognized by their principals as teacher leaders; (b) increased role in mentoring; (c) requests to lead professional learning activities; and 4) developing expertise and confidence.

In Year 2, all 14 Fellows noted the value of the Affirming Learning Walks in being seen as teacher leaders at their school, providing an opportunity to share a new walk-through structure with their principal, and providing an opportunity to lift up their colleagues. Fellows also explored a classroom observation instrument (Boston, 2012) through their TLA engagement, and this instrument was identified as impacting their practice (during focus groups) in ways such as how they analyzed curriculum and instructional tasks and how they provided support to colleagues in their schools. Other tools specific to the project noted by Fellows as impacting their thinking and practice include *Catalyzing Change* (NCTM, 2020), *The Math Pact* (Bush et al., 2021), the Catalyzing Change Needs Assessment assignment and the Milestone 1 Gap Analysis assignment (see Table 1).

Year 2 included new opportunities for leadership activities: attending and presenting at professional conferences and increased opportunities to serve as teacher leaders in their schools. In Year 2, Fellows expressed increased confidence and provided evidence of actions as mathematics teacher leaders including through engaging in the Affirming Learning Walks. Increases in Fellows' self-perceptions as mathematics teacher leaders were identified (e.g., no longer feeling imposter syndrome), recognition by others, and number of leadership activities (self-initiated or requested by administration or teacher colleagues). For example, seven of the 14 Fellows engaged in 32 school-based leadership engagements, such as leading Professional Learning Communities (PLCs), supervising college teacher candidates, mentoring peers, or hosting a community math night. None of

them reported engaging in initiatives at the district level or in the broader mathematics education community. By Year 2, 12 Fellows engaged in a combined 62 school-based initiatives; two of the Fellows engaged in district-level initiatives; and nine of the Fellows engaged in the broader mathematics education community. Collectively, they delivered 21 presentations at both state and national conferences focused on mathematics education and leadership in mathematics education.

In Year 2, Fellows made explicit connections between specific components of the project and their mathematical learning, teaching practice, and role as mathematics teacher leaders. Several Fellows made connections between tools explored in the TLA and instruction modeled during the content classes and Mathematics as a Gateway experiences: (1) the construct of "cognitively challenging tasks" from a classroom observation tool explored in the TLA and the suggestions offered (and modeled) during the Mathematics as a Gateway for making tasks more exploration and play-based; and (b) the questioning types in the classroom observation rubrics and how the professor of the mathematics content courses asked questions of them. In Year 2 focus groups, they connected ideas from Catalyzing Change (shared in Year 1) to the Affirming Learning Walks and gap analysis project. They acknowledged (as did project leaders) how their increased knowledge of content, pedagogy, and research served to enhance their confidence, willingness to act, and actions as instructional leaders.

Some of the most interesting data we collected was the Year 2 focus group interviews (aligning to both Prongs 1 and 2), which provided us with a deeper look at Fellows' perceptions of their own growth since beginning the program, as well as how they are connecting the different components of the project. We share several quotes from Fellows that capture their reflections regarding their growth:

- *"*At my school, a lot of teachers are trying to skip out on the exploration piece because of timing…[and I say], 'Let me tell you this experience we had with (blinded – the mathematician investigator on the project), and how I learned more by exploration than just for us to go straight to the tasks,' … experiencing that with him helped me to talk to teachers more about how exploration is key, because if we take that opportunity away from our students, they might not be able to in-depth conceptualize everything we want them to."

- *"*For me, one of the biggest [changes] I do now is, I now understand when kids solve it with a different strategy. I can make connections and make sense of their math. Because … a lot of it has been previewed with (blinded – one of the mathematics education investigators on the project), and because I can now make the connections, I see my own students making connections and solving in ways that are not necessarily always common.*"*

- *"*I've started actually evaluating the tasks that I present to my students. So I look at the potential of the task…and then my implementation of the task. I look at the students' evidence and teachers' questions to make sure that the quality of the tasks that I'm doing is more level four tasks where there's that justification state."

- That's definitely the kind of leader that I would want to be, is helping teachers understand what they do well, because sometimes we just focus on the negative…or the criticism too much, and that can really bring down a teacher's confidence and morale. So I think that's been really beneficial to me, being a leader that's helping others.*"*

In summary, the results for Prongs 1 and 2 indicate a trend of consistent growth toward the overall goal of empowering K-8 mathematics teachers as leaders to initiate and sustain improvements in our education system. Fellows have been supported as they seek to have positive impacts on their colleagues and the broader community, and they are developing the skills and confidence necessary to enact and disseminate what they have learned in their doctoral program.

Results also support the importance of the longitudinal mixed methods approach. For example, Fellows' exhibited growth in content knowledge for teaching and pedagogical content knowledge on the LMT, and in the focus groups, they describe feeling stronger and more confident in content knowledge based on their coursework experiences and how this new-found confidence has encouraged and empowered them to take more actions as mathematics teacher leaders. Similarly, as Fellows are (a) engaging in ambitious instructional practices as learners in the Mathematics as a Gateway and other courses, and (b) using tools to identify and promote high-quality instructional practices in the Teacher Leader Academy, they are increasing their use of these practices in their own classrooms (as indicated by IQA results), encouraging their peers to implement such practices (e.g., see the quote above about exploration), and using the language from the tools provided in the Teacher Leader Academy to discuss high-quality instruction with their administrators (as reported during focus groups with administrators).

Discussion

Implications for Practice

With the goal to empower K-8 mathematics teachers as leaders to initiate and sustain improvements in our education system consistent with the frameworks that guided this study (NCSM, 2020; TLEC, 2011), we needed to determine both the space for these improvements to occur and the opportunities for Fellows to develop the knowledge and skills necessary to thrive. Our first implication for practice is the importance of a two-pronged approach. We created the space and simultaneously equipped Fellows with the knowledge and skills they needed as they eased into that space (i.e. the Teacher Leader Academy). The knowledge was gained and the skills were developed within coursework and experiences in the Ed.D. program. The link between the two was guided by the cognitive apprenticeship system of modeling, coaching, and fading (Collins et al., 1987). There was an intentional focus on developing Fellows' content knowledge for teaching mathematics and as their voices were elevated, they used their voices to promote mathematics reasoning and sense making in all teachers and students. This promotion of mathematics reasoning and sense making was modeled in their coursework. Fellows were coached through Affirming Learning Walks (Ross et al., 2023) and other activities within the Teacher Leader Academy. Through their work formally in the Teacher Leader Academy, and informally through their school-based leadership experiences, they found their voice with regards to advocating for high-quality mathematics instruction at a more impactful level. The support provided by faculty is now starting to fade as Fellows are positioned as leaders in their schools and districts.

Second, feeling valued matters. As shared in the findings from focus groups (Table 3), Fellows consistently identified support from project leaders and from within their cohort as the best aspect of the project. As Fellows felt valued, their excitement related to the project and their confidence seemed to flourish—and subsequently, their roles as leaders began to flourish as well. This was evident in the focus groups (e.g., multiple quotes aligned with the sample shared herein) and in the number and type of new leadership activities undertaken and initiated by Fellows in Year 2. We propose that the confidence that the feeling of being valued brings, and also because others began to see them as leaders, served as a catalyst for their new role as teacher leaders. This finding is an important implication of our work for administrators in schools and districts, and aligns to one of Berg and Zoellick's (2019) four dimensions of teacher leadership, legitimacy. They share that one way teacher leadership legitimacy has been described is as "something that might emerge as teachers are recognized as leaders by colleagues" (p. 7) even though they might not hold a formal leadership position. Findings by Barth and colleagues (2023) also point to the strong impact the role of recognition plays on teacher leader identity. We ensured Fellows were celebrated in press releases, news articles, and school board

announcements; they were featured on panels, on websites, and through awards; and they were and continue to be sought out by colleagues, coaches, and administrators. Although these efforts take time and mentoring, we have found they are some of the most essential components for numerous reasons including that they critically work to counteract negative stereotypes about teaching and professionalize (to the public) the STEM teaching profession. As Fellows feel more valued, their impact broadens. For example, in Year 2, two Fellows attended a state conference and learned about a fact fluency program that focused on building conceptual understanding to foster fluency (Dixon, 2023), where they saw that senior administrators in their district were also attending the same presentation. They had the courage and confidence to approach the administrators and ask to lead an initiative to implement the program across the district. They worked with one of the project leaders to make a plan for implementation. The project leader gave the first workshop to launch the program with the district (modeling); the project leader helped the Fellows to plan the follow-up workshops (coaching); and moving forward, the Fellows took on leadership in the full implementation of the program, with access to the project leader for support as needed (fading). This level of leadership was new to the Fellows and likely grew from experiences in the program. Efforts to center the Fellows and honor their expertise takes time, energy, and knowledge.

Third, our partnership also took effort and intentionality to develop. Trust needed to be established between the university, the district, and the nonprofit partner. The investment of time and energy in nurturing the partnership should not go unnoticed. It was built by being flexible, open, and transparent. We (the partners) planned well-organized meetings and prioritized attendance and participation in those meetings. The meetings were and continue to be important touch points where information is shared, work is completed, and tasks are assigned. While there were some changes in leadership within the organizations, the clear lines of communication and norms for these interactions have been passed along and upheld. This may have worked so seamlessly because each partner could see value in their involvement.

Related to practice, we want to be forthcoming about obstacles we faced along the way. For example, as Fellows grew in their leadership roles in their school and the district, they were occasionally met with resistance from their colleagues and/or a building administrator. We worked closely with the Fellows to help them navigate these situations. Our project was also situated in one of the largest school districts in the country with more than 100 elementary schools and approximately 40 middle schools. It was challenging to reach district-wide implementation even on initiatives our Fellows were helping to lead at the district level. We imagine this would be less challenging in smaller districts.

Implications for Research

Our work also holds several implications for research and project design. In Year 2, we are beginning to see significant growth in content knowledge (e.g., higher LMT results), positive shifts in instructional practices (e.g., increases in IQA results for half of Fellows), evidence of Fellows' development as teacher leaders (e.g., self-reports of their confidence, increases in the number of leadership activities, and activities self-initiated versus requested by others) and recognition as teacher leaders by colleagues and school administration (e.g., from interviews and requests for teacher leadership activities). Our findings have two implications for project design. First, multi-year, district-wide projects may be necessary to initiate organizational change, particularly those focused on shifting towards more effective structures. Change in individuals and institutions takes time, and based on our work at the end of Year 2, we posit that a minimum of 2–3 years are needed to see the growth necessary for individuals to begin to initiate change in their institutions. As suggested in previous research, single-year projects may not have the time and sustained intentionality necessary to affect universal change in schools (Boston et al., 2017; Cobb & Jackson, 2011).

Second, the longitudinal, mixed methods data collection has been critical in providing a complete picture of Fellows' growth and journey throughout the project. Quantitative measures have identified specific aspects of Fellows' growth, but it is the coordination of quantitative and qualitative data that have truly captured the synergistic aspects of the project. For example, increases in content knowledge in Year 2 (as seen on LMT results) are a factor self-identified by Fellows (during focus groups) as supporting their confidence to act proactively as teacher leaders and as minimizing their feelings of imposter syndrome. While quantitative methods provide evidence of change, we cannot underscore the importance of qualitative methods in describing and understanding how and why that change occurred. Projects need to consider the importance of identifying different evidence markers: statistical significance, practical significance, or both.

Third, we also attribute the capacity for growth of our Fellows to their initial mindsets and motivation to enact change in their school settings, which speaks to the value and importance of the recruitment process. We were incredibly intentional during the interview portion to explore applicants' mindset and beliefs towards teaching. Fellows began the project with the mindset and motivation to be teacher leaders, but needed the platform and confidence. Hence, Fellows were eager to receive the tools and support provided by the Teacher Leader Academy (e.g., Catalyzing Change Needs Assessment, Affirming Learning Walks) to enact change in their schools.

Finally, we suggest the need for additional research on classroom-based mathematics teacher leaders and the role they have in catalyzing change and improving teaching and learning in their schools and districts. Research often focuses on principals as instructional leaders (e.g., Boston et al., 2017) or teacher leadership in content areas other than mathematics (Criswell et al., 2018; Gul et al., 2019). Similarly, additional research is needed on the roles and impacts of stakeholder groups (research institutions, district level administrators, school-based administrators, teachers, and partner organizations) on the success of research-to-practice partnerships in a variety of settings and contexts.

Next Steps for Our Project

As we reflect on this journey so far, we briefly share some of our priorities as we consider next steps. First, in addition to the planned Teacher Leader Academy activities, we will keep our eyes open to individualized avenues to support our Fellows in their mathematics teacher leader growth. Along the same lines as the example we described regarding two Fellows leading a conceptually-based fact fluency initiative in the district, we believe more grassroots organic opportunities will present themselves, and we will be here to encourage and support our Fellows through the modeling, coaching, and fading cycle. By the end of Year 2, Fellows have become quite insightful in thinking broadly beyond the walls of their own school and are starting to identify needs at the district level. Fellows' colleagues, administrators, and district leaders now seek out their advice and expertise as they are becoming the "go-to" experts. The district also started committing funds for Fellows to attend and/or present at state and national conferences. Second, at the time of this writing, our Fellows are in the midst of conducting their dissertation-in-practice research, in which they align to one or more of the recommendations in Catalyzing Change. We simultaneously worked to protect their time so they can stay focused on completing their dissertation while also helping them position themselves for future teacher leader opportunities in their district and through our national and state professional organizations. Third, we have seen a shift from Fellows' spheres of influence being more at their school to becoming more district-level (or multi-school). As we continue to consider how Fellows' impacts can have a more integrated and influential role across their district as well as consider their impacts on a state and national level. Finally, we recognize much of the progress made in Years 1 and 2 had been on improving mathematics learning within existing structures, and we are still working to navigate how some structures might be reimagined and built to ensure all students have access to the mathematics they deserve.

Concluding Thoughts

We believe the two-pronged approach can be adopted and adapted across a wide range of projects and scopes. Simply put, no matter your project, building a strong and caring community focused on learning and doing something meaningful and then providing teachers a space and place to enact it, grow, and flourish with support and encouragement can go a really long way!

To conclude, it is challenging to capture all we have learned about the Fellows, as well as our own immeasurable personal growth as mathematics teacher educators and mathematics education researchers through this journey. We have learned at least as much from our Fellows' strength and resilience; passion for advocating, leading, and teaching; and care for their students as they have learned from us. While the data and results from this project are critical and serve to inform the field in ways we hope are important and impactful, we are most proud of the heart of this work - the Fellows who pour their heart and soul into this work every day and the unwavering dedication of all partners. Mathematics teacher leadership, and STEM teacher leadership more broadly, is not for the faint of heart. It's hard, complicated, complex, exhausting, but absolutely essential work. We join our colleagues in sharing in our project's overall goal and call to action: How do we move beyond improving mathematics learning within existing structures to reimagining and rebuilding to ensure all students have the mathematics learning experiences they deserve?

Funding

National Science Foundation (NSF), Award #2050606 Any opinions, findings, and conclusions or recommendations expressed in this material are those of the project team and do not necessarily reflect the views of the National Science Foundation.

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