Journal of Research in Science, Mathematics and Technology Education

https://jrsmte.com/

The Right Answer for the Wrong Reason: Preservice Science and Mathematics Teacher Preferences and Explanations of Inquiry-Based Teaching

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Abstract: Inquiry in science and mathematics education has a long and established history within the student-centered teaching movement because it can positively impact student learning, retention, and engagement. Yet few teachers have embraced these practices in the classroom. Potential reasons include misalignment of teachers' attitudes about inquiry and a lack of understanding of what inquiry is and how to implement it in the classroom. This mixed-methods study compares these claims by examining preservice teachers' attitudes and knowledge about inquiry-based teaching. Eighty-seven discussion posts were analyzed on preservice science and math teachers' preferences for inquiry-based versus teacher-centered instruction at the beginning and end of their introductory methods course. While the novice science and math preservice teachers in this study overwhelmingly claimed to prefer inquiry-based instruction to teacher-centered, few were able to identify and articulate features specific to inquiry when asked to explain their preference. Most preservice teachers described other student-centered strategies, such as collaboration and active learning, or general teaching strategies, such as questioning, hands-on activities, and creating a fun and engaging environment. Implications and suggestions for the field are discussed.

Keywords: Preservice math and science teachers; Inquiry-based teaching; Student-centered instruction; Misconceptions.
DOI: https://doi.org/10.31756/jrsmte.411SI

Introduction

In 2015, Mike Myers lampooned Saturday Night Live producer Lorne Michaels by mimicking one of his favorite complaints; "It got a laugh, but was it the right laugh?" In essence, Michaels' concern was that the audience was laughing, but did they get the joke?

The same concern can be applied to the field of education and inquiry-based instruction. Historically, there have been two primary teaching pedagogies: *teacher-centered* and *student-centered* instruction (Cuban, 2009). According to Cuban, teacher-centered instruction (often known as direct or traditional instruction) relies on teachers to directly transmit information, skills, and values to their students. Conversely, student-centered instruction empowers students to take greater responsibility for their own learning by actively engaging with the material and collaborating with their peers. In this approach, teachers primarily serve as facilitators or guides, creating an environment that supports independent exploration and deeper understanding.

While there is a reasonably clean dichotomy between teacher-centered and student-centered instruction, the same cannot be said for distinctions in pedagogical approaches within the camps. For example, student-centered teaching goes by many names, such as reform-based teaching, constructivism, active learning, collaborative learning, and inquiry-based instruction, to name but a few (Michael, 2006). On the surface, the aforementioned terms may be easily synonymized; however, there are distinct and subtle differences between the different types of student-centered instruction and conflating them does a disservice to each particular teaching methodology, its aims, purposes, practices, and implementation.

Case in point is inquiry-based learning, one of the most misunderstood pedagogies under student-centered instruction (Minner et al., 2010). Inquiry in science and mathematics education has a long and established history within the student-centered teaching movement, earning the support of prominent scholars and major educational policy organizations both in the United States and internationally for decades (Crawford, 2014; Furtak et al., 2012; National Council of Teachers of Mathematics, 1991; National Research Council, 2000; Organization for Economic Co-Operation and Development, 2005). This support stems from the fact that inquiry-based instruction has been shown to enhance student learning outcomes, improve retention, and foster greater engagement in science, technology, engineering, and mathematics (STEM) fields (Crippen & Archambault, 2012; Minner et al., 2010; Öztürk et al., 2022). Despite these benefits, few teachers have embraced these practices in the classroom (Chin & Lin, 2013; Fitzgerald et al., 2019).

Researchers have proposed many reasons for this disparity, with two of the most prominent being (1) a misalignment between teachers' beliefs and attitudes about inquiry (Cribbs et al., 2020; Wang, 2020) and (2) a lack of understanding of what inquiry is and how to implement it in the classroom (Chinn & Clark, 2013; Rönnebeck et al., 2016). In other words, do teachers not implement inquiry-based practices because they believe they are not the best pedagogical strategies for their students or because they lack the knowledge of inquiry required to execute it effectively in their classroom?

Examining both these assumptions is important because they can lead to different implementation outcomes, starting with preservice teacher (PST) education. The first assumption suggests a need to evaluate PST attitudes, beliefs, and preferences when it comes to inquiry-based instruction because teachers are more likely to teach in styles that align with their beliefs on how students learn best (Choi & Ramsey, 2009). Addressing this issue at the PST level is critical. During this time, preservice teachers are often formulating their teaching philosophies, confronting misconceptions about the profession, and developing preferences for the type of educators they hope to become. (Crawford & Lunetta, 2002; Crawford, 2007; Windschitl, 2003). Therefore, teacher education is a critical period for examining PST attitudes toward inquiry-based and other modes of teaching and determining why these preferences exist.

On the other hand, the second assumption rests on the idea that it is not teacher attitudes about inquiry preventing their implementation, but their knowledge of what inquiry actually is. This second assumption suggests a need to evaluate PSTs' conceptual understanding of inquiry, as well as what misconceptions they possess, particularly in their ability to distinguish between inquiry-based instruction and other student-centered teaching pedagogies (e.g., active and collaborative learning). Evaluating PSTs' understanding of inquiry is important because teachers are more likely to teach in styles they feel knowledgeable about and, therefore, more comfortable utilizing within their classroom (Choi & Ramsey, 2009). Addressing this issue at the PST level is critical because this is where teachers are typically exposed to different theories and pedagogical practices and given instruction and support on how to implement them in the classroom (Darling-Hammond, 2006, 2014). Furthermore, science and math teachers typically receive minimal to no training and guidance on inquiry-based instruction once they enter the field (DiBiase & McDonald, 2015). Therefore, teacher education is an important time to determine PSTs' conceptual knowledge of inquiry and address any misconceptions they may have.

This study compares these two assumptions by examining PSTs' attitudes and knowledge about inquiry-based teaching to answer the following research questions: (1) What are novice math and science PSTs' preferences for inquiry-based versus teacher-centered instruction? (2) What misconceptions do novice math and science PSTs have about inquiry-based instruction compared to other student-centered teaching pedagogies?

Examining these assumptions are important for the field of science and mathematics education to address the longstanding issue of why science and math teachers do not employ inquiry-based teaching practices in their classrooms by determining if the problem stems from teacher preferences, conceptual understanding, or both.

Conceptual Framework

One of the greatest challenges in the field of education is definitions. Terms are often loosely defined (if at all) and used interchangeably (Bybee, 2011; Minner et al., 2010; Ross & Davidson, 2020; Zhang, 2016). The area of student-centered teaching is no exception. Not only are there multiple words and phrases to describe student-centered teaching (e.g., reform-based teaching, constructivism, inquiry-based instruction, active learning), but student-centered teaching itself is used as an umbrella term to describe the many different pedagogical practices that fall under it. While this study does not intend to include all student-centered approaches, the conceptual framework consists of three of the most common: inquiry-based instruction, active learning, and collaborative learning (Chinn & Iordanou, 2023; Goodwin, 2024; Michael, 2006).

Inquiry-Based Instruction

Just as student-centered instruction goes by many names, so too does inquiry-based instruction. Duschl and Grandy (2008) found that science inquiry alone has at least 18 distinct meanings in the literature. Some examples include problem-based learning, project-based learning, and guided discovery (Chinn & Iordanou, 2023; Minner et al., 2010; Ross & Davidson, 2020; Zhang, 2016). The key feature that aligns these pedagogies is that inquiry-based instruction has *students* construct knowledge by discovering and interpreting information and findings for themselves (Chiappetta & Adams, 2004; Chinn & Iordanou, 2023; Zhang, 2016). This pedagogy contrasts direct or teacher-centered instruction, in which the *teacher* provides students with explanations, complete demonstrations, and solutions to problems (Zhang, 2016). In inquiry-based teaching, the teacher does not give the students solutions but instead uses scaffolding, feedback, and various levels of support to assist them in deriving knowledge through engagement with the material (Furtak, 2006).

Inquiry generally displays many of the elements listed above; however, they can vary based on the content being taught and the degree to which they are executed. This variation is because inquiry-based instruction lies on a continuum based on the degree of direction given by the teacher. Open-ended inquiry (also known as discovery learning) is on one end of the continuum, direct instruction is on the other, and teacher-led guided inquiry is in the middle (Bransford et al., 2000). Both proponents and detractors of inquiry-based teaching tend to dismiss fully open-ended inquiry as ineffectual because students need some level of structure and support to promote targeted learning (Chinn & Iordanou, 2023; Kirschner et al., 2006; Zhang, 2016). However, many supporters of inquiry-based instruction embrace various levels of teacher-led guided inquiry as being effective because students are allowed to ponder solutions and construct their own knowledge, but through the support of teacher-provided scaffolding (Kapur, 2016; Kapur & Bielaczyc, 2012; Schwartz et al., 2011).

Teacher scaffolding and support can vary by content area. Science inquiry, for example, often involves identifying research questions, searching for information and patterns, formulating hypotheses, planning, designing, and carrying out investigations, evaluating data, constructing models and explanations, and engaging in argumentation (Bybee, 2011; McDonald, 2016; Rönnebeck et al., 2016). In essence, the purpose of science inquiry is two-faceted: to have students engage both in understanding science and doing science (Levy et al., 2013).

Mathematical inquiry values mathematical practices of exploration, proofs, and investigation of mathematical ideas (Panaoura, 2017). Mathematics inquiry involves “exploring, conjecturing, reasoning logically, and evaluating whether something makes sense or not” (Chinn & Clark, 2013, p. 919). Furthermore, mathematics inquiry encourages students to not only develop a conceptual understanding of mathematical principles but also consider mathematical knowledge as a human endeavor that is developed, not ordained (Ernest, 1991; Savelsbergh et al., 2016). In this way, students can realize the complex and contextual nature of mathematics that goes beyond a single answer found in the back of the book (Panaoura, 2017).

Active Learning

Active learning focuses on students accessing their own understanding through mental or physical engagement in the learning process with the goal of students developing a sense of responsibility for their own learning (Acosta & Slotta, 2018). Active learning has also been linked to promoting metacognitive strategies, such as developing plans, progress checks, and utilizing productive strategies (Chinn & Iordanou, 2023). Elements of active learning include a high level of student investment, collaboration, discussing different perspectives and ideas, solving ill-structured problems, ranking tasks, questioning, students working on problems on their own or in groups, problem-solving, and critical thinking (Acosta & Slotta, 2018; Goodwin, 2024; Nelson & Crow, 2014; Walker, 2003; Wallace et al., 2021).

While active learning can involve inquiry (Ruiz-Primo et al., 2011), the two terms are not synonymous. According to Ruiz-Primo and colleagues, active learning must also include conceptually-oriented tasks, collaborative learning activities, and technology elements. While these features may support or enhance inquiry-based teaching, they are not required elements. For example, inquiry-based teaching can take place in the absence of technology or group work. Moreover, while students may be actively engaged in solving problems and tasks, active learning can still occur without the students discovering scientific or mathematical principles for themselves if the activities are more teacher-focused (Goodwin, 2024).

Collaborative Learning

Collaborative learning involves developing effective groups where students work together to accomplish the learning objective (Chinn & Iordanou, 2023). Collaborative learning relies on multiple students working together because students working alone cannot succeed without the group's assistance (Johnson & Johnson, 1992). To accomplish this, students engage in argumentation, co-construction of knowledge, higher-order thinking (Asterhan & Schwarz, 2016; Webb, 2013), and develop productive norms and mutual respect for their peers (Duncan et al., 2021; Saleh et al., 2021).

Collaborative learning can intersect or diverge with inquiry-based learning depending on the aims of the teacher. For example, inquiry can occur if the goal of the collaborative group work is to generate new knowledge (Chen & Hong, 2016; Kali, 2021). However, if the goal is to summarize, explain, or elucidate on knowledge previously provided by the teacher, then inquiry is not required (i.e., the jigsaw technique where each student summarizes and shares partial information with the group in order for the group to learn the topic as a whole). Even when the aim is new knowledge generation, teachers must be careful to delineate between group work and cooperative group work; otherwise, teachers may simply be outsourcing the role of direct instruction to an individual in each group rather than having the group collectively working on the problem at hand (Cohen, 1994; Cohen et al., 2002).

Teacher-Centered Instruction

Teacher-centered instruction takes a different approach from the aforementioned pedagogies by providing students with explanations, solutions, and answers (Zhang, 2016). Proponents of teacher-centered instruction claim that student-centered approaches are ineffective because they cause confusion, misconceptions, and overburden working memory (Kirschner et al., 2006; Mayer, 2004). Instead, they argue that directly providing students with information eliminates false starts, frustration, and cognitive overload.

Teacher-centered instruction is typically characterized by teacher-led lectures or explanatory texts and videos (Zhang, 2016). For example, in a gradual release of responsibility instructional framework (i.e., *I do, we do, you do* model), the teacher explains the steps of a scientific or mathematical process before the students practice as a class and then on their own or in small groups (Fisher & Frey, 2013).

Common Strategies

While teacher-centered and student-centered instruction may seem like diametric opposites, they do share several practices and strategies (Furtak & Penuel, 2018; Goodwin, 2024; Kirkup et al., 2016; Osborne, 2019; Zhang, 2016). For example, teacher-centered instruction can also incorporate manipulatives, hands-on activities, and experiments. The difference is that in student-centered (particularly inquiry-based instruction), these activities, models, and labs are designed to have the *students* discover new scientific or mathematical concepts and test if their ideas are supported by the data or patterns they observe. In teacher-centered instruction, these hands-on activities (typically known as *cookie-cutter labs*) are used to reinforce or illustrate scientific and mathematical principles the *teacher* has already presented or is about to present to the students (Furtak & Penuel, 2018; McNeil & Jarvin, 2007; Osborne, 2019; Parsons, 2019).

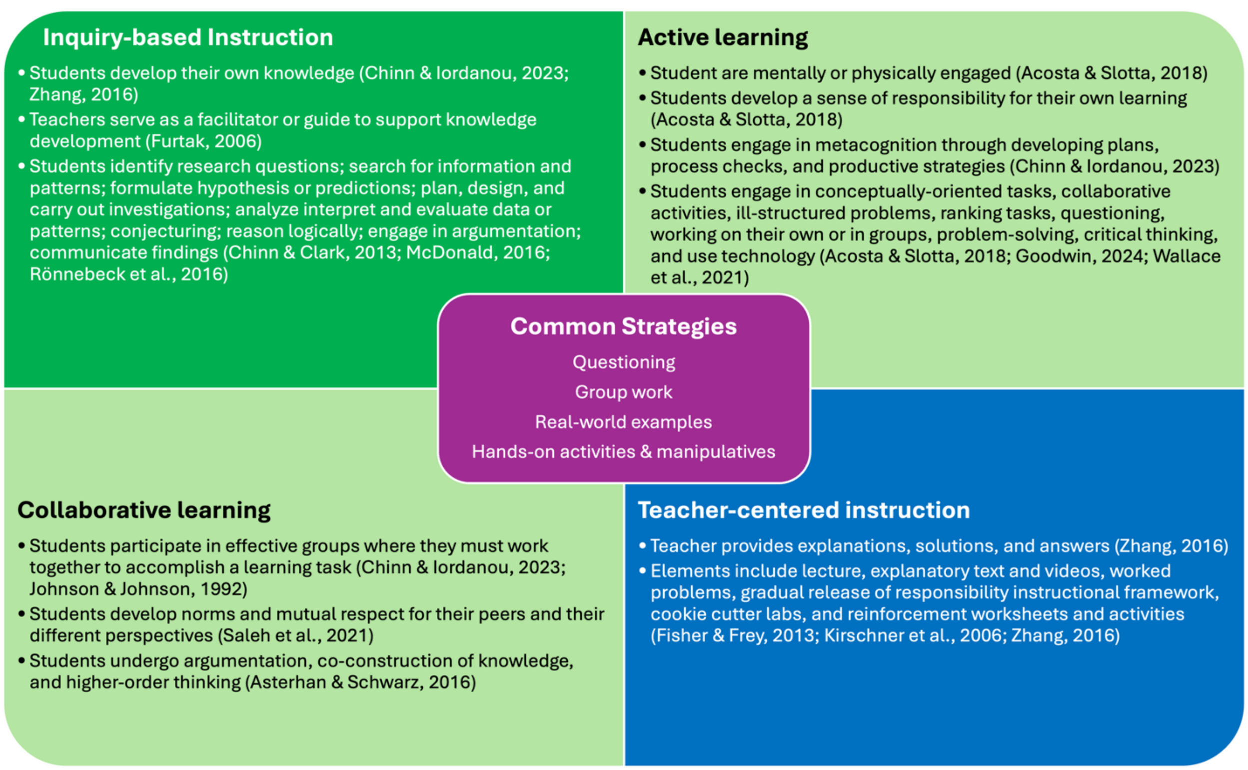
Additionally, both student-centered and teacher-centered instruction can incorporate formative assessment of student learning through questioning and group work. Again, the difference lies in the intent behind these strategies. In student-centered instruction, the teacher uses questions and peer discussion to have the students predict and formulate ideas around the phenomenon they are studying and justify their reasoning utilizing evidence, patterns, and scientific and mathematical principles (Chinn & Iordanou, 2023). In teacher-centered instruction, questions and group discussions are used primarily to determine if the students have correctly understood the concepts previously learned through lectures, readings, or videos (Kim, 2015).

Another example is the use of real-world examples. In teacher-centered instruction, the teacher may provide examples of how the information learned in class can be utilized outside of their school (e.g., a biology teacher explaining insulin absorption in diabetics or a geometry teacher illustrating how right angles are used in architecture). In student-centered instruction, teachers do not merely provide real-world examples but instead have the students attempt to solve real-world problems utilizing scientific and mathematical techniques (Goodwin, 2024).

Thus, teacher-centered and student-centered instruction can, and frequently do, utilize similar teaching strategies. The main distinction is (1) are the strategies being used to reinforce knowledge imparted by the teacher (i.e., teacher-centered instruction) or (2) to guide the students toward their own knowledge development (i.e., inquiry-based instruction). Because many teaching strategies overlap both within and between student-centered and teacher-centered instruction, it is understandable that PSTs may find these distinctions confusing. Therefore, this study will utilize the conceptual framework in Figure 1 to evaluate which strategies PSTs ascribe to inquiry-based teaching versus other student-centered or teacher-centered pedagogies.

Figure 1

Conceptual Framework: Elements of Inquiry-Based Instruction, Active Learning, Collaborative Learning, and Teacher-Centered Instruction



Methods

This study employs a mixed-methods approach to analyze the two research questions: (1) What are novice preservice science and mathematics teachers' preferences for different teaching methods, specifically inquiry-based, teacher-centered, or a combination of both, and (2) What misconceptions do novice preservice math and science teachers have about inquiry-based instruction compared to other student-centered teaching pedagogies? By combining quantitative and qualitative data, this study aims to provide a comprehensive understanding of how these PSTs' preferences changed or stayed the same over their introductory method course and what justifications they offered for their responses. The quantitative analysis, through the McNemar–Bowker statistical test (Agresti, 2018), addresses RQ1 by assessing PST pedagogical preferences and if there were significant changes in their preferences over time. Meanwhile, the qualitative analysis addresses RQ2 by offering deeper insight into the rationale behind these preferences and what misconceptions they may possess. This mixed-methods approach provides a richer, more nuanced perspective that goes beyond merely looking at PST pedagogical preferences to understanding how those preferences are conceptualized and rationalized.

Participants and Data Collection

This study examines data from four semesters of the fall and spring 2022 and 2023 *Inquiry Approaches to Teaching* methods course for secondary mathematics and science PSTs ($n = 87$). This one-credit introductory course is the PSTs' first exposure to teaching and inquiry-based learning. Students completed an online discussion post before and after their field experience. Students were asked to indicate their teaching preference among three categories: inquiry-based teaching, traditional teaching, or both, and explain why they selected that choice. Preferences were recorded at two time points: the beginning of the semester ("Pre") and the end of the semester ("Post").

Before the first post, the students participated in a model science lesson that was taught using both inquiry and teacher-centered approaches so the PSTs could compare the two. The PSTs discussed differences in the two pedagogical approaches in terms of teacher and student behaviors, the use of questioning, how the content was presented, and who did the majority of explaining. Throughout the course, inquiry-based teaching techniques were reinforced through three model lessons that the PSTs participated in and then taught at local elementary schools. Additional inquiry-based model lessons were implemented to demonstrate how collaborative learning and technology can be integrated into inquiry teaching. Finally, active and collaborative learning strategies such as think-pair-share, talking chips, and random calling were modeled throughout the course to showcase high engagement and effective teaching practices.

Quantitative Data Analysis

The pre- and post-teacher discussions were downloaded from the institution's learning management system and organized into pre- and post-columns. From there, the data was coded based on the teachers' indicated teaching preference for inquiry-based, teacher-centered, or both forms of instruction. Next, the frequencies of each category in their pre- and post-discussion teaching preferences were recorded. A McNemar–Bowker statistical test was conducted to evaluate whether there was a significant change in PST teaching preferences from pre- to post-semester. This test is an extension of the McNemar test and is appropriate for analyzing paired categorical data with more than two response categories (Bowker, 1948). Student preferences (inquiry, teacher-centered, or both) were summarized into a 3x3 contingency table (see Table 1), capturing the transitions between categories. After calculating the McNemar–Bowker test statistic, the resulting chi-squared statistic was compared against the chi-squared distribution ($df = 2$), providing the p-value determining statistical significance.

Table 1

3x3 Contingency Table of Pre- and Post-Semester Teaching Preferences

	Inquiry (Post)	**Teacher-centered (Post)**	**Both (Post)**
Inquiry (Pre)	Count of students who stayed in inquiry	Count of students who switched to teacher-centered	Count of students who switched to both
Teacher-centered (Pre)	Count of students who switched to inquiry	Count of students who stayed in teacher-centered	Count of students who switched to both
Both (Pre)	Count of students who switched to inquiry	Count of students who switched to teacher-centered	Count of students who stayed in both

Qualitative Data Analysis

In their discussion posts, students were asked to explain why they preferred inquiry-based teaching, teacher-centered teaching, or a combination of both. The first author performed the initial coding of these responses using in vivo coding (Saldaña, 2020); a method that captures participants' own words to identify key phrases for why they preferred inquiry-based teaching. To ensure the accuracy and reliability of the coding process, the second author reviewed the first author's codes, cross-referencing them with a coding table derived from the literature. Any discrepancies in the coding were discussed and resolved through consensus.

Codes were further disaggregated into inquiry-specific and non-inquiry-specific elements, guided by the conceptual framework, and organized by frequencies. The frequencies were then converted to proportions of the total codes and reported as percentages in the results section. Following the coding, thematic analysis was employed to identify and explore overarching themes within the data (Saldaña, 2020). This process allowed for a deeper understanding of the reasons behind students' preferences and how these preferences reflected their knowledge of the different teaching methods. The qualitative data was used to explore whether students' preferences for inquiry-based teaching aligned with the core elements of inquiry-based instruction or if there were misalignments and gaps in student conceptual understanding of inquiry-based teaching compared to teacher-centered and other forms of student-centered instruction.

Results

This study explores math and science PSTs’ attitudes and knowledge about inquiry-based teaching by addressing two research questions: (1) What are novice math and science PSTs’ preferences for inquiry-based versus teacher-centered instruction? and (2) What misconceptions do novice math and science PSTs have about inquiry-based instruction compared to other student-centered teaching pedagogies? The results are presented in two parts: the quantitative analysis, which examines shifts in preferences between inquiry-based, teacher-centered, and both instructional approaches and the qualitative analysis, which explores the underlying reasons behind these preferences and identifies common misconceptions about inquiry-based teaching. Together, these findings provide a comprehensive view of how PSTs perceive and conceptualize different pedagogical methods during early stages of teacher preparation.

Quantitative Analysis

To address RQ1, the McNemar–Bowker test yielded a significant result with a chi-squared statistic of $\chi2=13.568$ and a corresponding p-value of $p=0.0011$, indicating that there was a statistically significant change in PSTs' preferences between pre- and post-semester time points (see Table 2). While the overall result suggests significant changes, shifts in preferences for each teaching type are described below.

Table 2

Observed Frequencies and Pre-Post Changes in Teaching Preferences

	Inquiry (Post)	Teacher-centered (Post)	Both (Post)	Total (Pre)
Inquiry (Pre)	48	1	1	50
Teacher-centered (Pre)	2	1	1	4
Both (Pre)	16	1	16	33
Total (Post)	66	3	18	87

Inquiry-Based Teaching

The preference for inquiry-based teaching increased from 50 PSTs pre-semester to 66 PSTs post-semester. While most PSTs retained their preference for inquiry-based instruction throughout the semester, there was a shift toward preferring inquiry-based teaching from other categories (particularly the "both" category) after they concluded their field experience. The significant change suggests that the inquiry-based approach gained favor with some students as the semester progressed.

Teacher-Centered Instruction

The preference for teacher-centered instruction slightly decreased from four PSTs pre-semester to three PSTs post-semester. This change is relatively small, suggesting few students preferred teacher-centered instruction both at the beginning and throughout the course.

Both Inquiry and Teacher-Centered Instruction

PSTs were allowed at both the pre-and post- timestamp to indicate if they preferred elements from both inquiry and teacher-centered instruction. The category "both" exhibited a marked decrease, from 33 students pre-semester to 18 students post-semester. This shift likely reflects students' preference from a combined approach that integrates aspects of both inquiry-based and teacher-centered teaching to preferring one specific type of instruction. The decrease in "both" preference suggests that students may have found a particular model more appealing or effective after experiencing both styles in practice.

Interpretation of Statistical Significance

Given the statistically significant result ($p = 0.0011$), the shifts in teaching preferences were probably not due to chance. The McNemar–Bowker test, which accounts for the paired nature of the data (pre- and post-semester for the same students), highlights that students' preferences for inquiry-based, teacher-centered, or both methods significantly changed over the semester.

Qualitative Analysis

To address RQ2, each pre-and post-discussion post was analyzed using in vivo coding for elements of inquiry-specific versus non-inquiry-specific teaching (i.e., other student-centered pedagogies, teacher-centered instruction, or common teaching strategies; see the conceptual framework and Figure 1). The result from the 174 discussion posts was 438 codes (n=208 pre- and n=230 post). See Table 3 for a summary of the themes and select quotes.

Table 3

Preservice Teacher Explanations for Their Preferences for Inquiry-Based Instruction

Explanations	Themes	Select quotes
Explanations align with inquiry	Students teach themselves and develop answers on their own Students justify and explain their decisions Students experiment and analyze data	● "allowing them to have more participation in their own learning process" ● "students teach themselves" ● "in a pro learning environment where they eventually come to find the answers on their own" ● "allows them to really understand the material since they have to defend their answers" ● "it was nice to converse with the kids and see their reasoning for the questions we had such as in the magnet lesson when we asked the students why certain objects were attracted to the magnet and they had many good answers to tell us." ● "trials of an experiment to learn"
Misconceptions and explanations aligned with other student centered or general teaching practices	Lessons are fun and engaging Lessons are interactive and hands-on Lessons involve group work and sharing different perspectives among students The teacher engages in questioning The teacher promotes critical thinking and problem-solving skills The lesson enhances comprehension, critical thinking, and knowledge retention The teacher makes real-world connections Lessons are more inclusive and equitable.	● "I really enjoyed how hands on it was" ● "the lessons helped everyone learn as a group." ● "it makes learning fun" ● "it was very inclusive and requires a lot of teamwork" ● "appealing and easier to learn" ● "it promotes active engagement, critical thinking, and problem solving skills."

Inquiry Specific Codes

Based on the in-vivo coding, several themes emerged. The PSTs' preferences for inquiry-based instruction centered around allowing students to discover answers to phenomena, experimenting and analyzing data, and justifying and explaining their reasoning. For example, one PST shared that they preferred inquiry-based instruction because:

> You allow for the students to learn on their own before the teacher gives answers to the students. It is important for students to attempt to learn on their own because it will enhance their way of learning. If the teacher is only giving answers without allowing the student to learn, then the students are not really getting anything out of the lesson.

Similarly, another PST clarified this point by stating:

> I want students to work for the answer, with themselves and with their groups. I don't want my class to rely on me for the information and knowledge because they won't be learning anything, just memorizing what has been said.

These PSTs saw the fundamental component of inquiry as providing the students with opportunities to construct knowledge for themselves. The PSTs were generally vague about how this process would take place. However, some did provide insight through the use of experimentation, "students use their previous knowledge, and test it out with mini activities," questioning, "the method to make students answer the questions and teach themselves is effective as long as you have the appropriate questions," and discussion, "allows them to really understand the material since they have to defend their answers."

However, inquiry-based explanations comprised only 12% of the in vivo codes. The majority of PST responses (88%) described strategies not specific to inquiry-based teaching based on the conceptual framework. This was the case for both the pre- and post-explanations, with only a slight increase in inquiry-specific codes from 10% to 13% at the end of the semester.

Non-Inquiry Specific Codes

Instead, the vast majority of PSTs explained their preferences for inquiry-based teaching through the following non-inquiry-specific themes: (1) fun and engaging, (2) interactive and hands-on, (3) based on group work and sharing different perspectives among students, (4) questioning, (5) promoting critical thinking and problem-solving skills, (6) enhancing comprehension, thinking, learning, and knowledge retention, (7) making real-world connections, and (8) being more inclusive and equitable.

Many of the PSTs' preferences for inquiry-based instruction rested on it being fun, engaging, and interactive. PSTs frequently wrote statements like, "I really enjoy the inquiry-based lesson as it is very fun for students and very fun to teach," "it helps me stay engaged and actively think about what we are learning for the day," and "inquiry-based lessons created a fun and riveting environment in my class with everyone getting a chance to speak."

What many students found particularly engaging was working with their peers, "I get to engage with other classmates and learn with them" and hands-on activities, "I am more of a hands-on learner. This is what inquiry based lessons mostly revolve around…being able to connect mental information to physical activities."

In addition to being fun, engaging, and interactive, some students claimed they preferred inquiry-based instruction because they felt it promoted higher-order thinking skills, real-world experiences, learning, and retention. "it promotes active engagement, critical thinking, and problem-solving skills," "learning is a slower pace you are able to process the information," "the K-12 students would benefit from inquiry based lessons so they can retain information," and "inquiry-based learning can be more engaging and enjoyable for students, as they are able to connect their learning to real-world experiences and collaborate with their peers."

Finally, several PSTs conflated inquiry-based instruction with building relationships and creating a more inclusive and equitable environment. For example, PSTs reported, "[inquiry is] more inclusive and it requires more teamwork," "students learn and can even be correlated to cultural topics with high engagement to enhance curiosity," "inquiry-based lessons help students to learn how to respect the opinions of others," and "[it] will be a passage to the students' hearts will also make a bond between you both which is very important when teaching."

Discussions

Preservice Teacher Preferences for Inquiry

RQ1 examined the assumption that science and math teachers do not incorporate inquiry because they have negative attitudes about inquiry-based teaching as an effective pedagogy. This assumption was not supported by the analysis of preferences for inquiry among four semesters' worth of novice science and math PSTs. In fact, the opposite pattern was observed. By the end of the methods course, the PSTs overwhelmingly preferred inquiry-based instruction (76%) compared to teacher-centered instruction (3%) or a combination of both teaching pedagogies (21%). Additionally, there was a statistically significant increase in their preference for inquiry as the semester progressed.

These results have been confirmed in the literature in both qualitative and quantitative studies. Science and math teachers and PSTs frequently report that they find inquiry-based instruction to be beneficial for student learning (Brown & Melear, 2006; Choi & Ramsey, 2009; DiBiase & McDonald, 2015; Fazio et al., 2010; Panaoura, 2017). These results are typically stronger in the presence of an intervention (e.g.., methods course for PSTs or professional development for in-service teachers), which suggests that exposure, training, and enacting inquiry-based pedagogies can improve teacher attitudes (Choi & Ramsey, 2009; Cribbs et al., 2020; Fazio et al., 2010). The fact that the PSTs in this study had a greater affinity for inquiry-based instruction at the end of the course after they had completed their field experience aligns with the idea that PSTs have more positive attitudes about inquiry after engaging in inquiry-based teaching experiences.

It is also important to note that in several studies, science and math teachers and PSTs often held teacher-centered or mixed beliefs (Brown & Melear, 2006; Choi & Ramsey, 2009; DiBiase & McDonald, 2015; Yang et al., 2020). Similar results were found for many of the PSTs in this study who preferred both inquiry and teacher-centered instruction, particularly in their pre-discussion posts. Appreciating both teaching methodologies is understandable as

PSTs are often more familiar with teacher-centered instruction from their own schooling (Lortie, 1975), but are also formulating new opinions as they are introduced to the benefits and challenges of alternative pedagogies in their teacher preparation programs (Fazio et al., 2010). The PSTs in this study who selected the “both” category often recognized the benefits of inquiry-based instruction while also acknowledging the challenges of implementing it in certain classes or circumstances.

Preservice Teacher Knowledge of Inquiry

Following the rejection of the first assumption, we began exploring the second assumption: science and math teachers do not incorporate inquiry-based teaching due to a lack of knowledge about inquiry itself. This was tested through RQ2 by examining the reasons novice science and math PSTs gave for why they preferred inquiry-based instruction. Based on the in vivo coding and thematic analysis, this assumption was well supported as the majority of PSTs in this study displayed significant misconceptions about inquiry and other forms of student-centered instruction.

For example, many of the PSTs claimed what they liked about inquiry-based instruction was that it was hands-on, with some students going as far as to say that the hands-on components are what define a lesson as inquiry-based. Conflating inquiry with hands-on activities is a common misconception among science and math teachers (Furtak & Penuel, 2018; Osborne, 2019). However, hands-on activities can be performed in inquiry-based, student-centered, and even teacher-centered classes. This is because hands-on activities do not necessarily promote inquiry, especially so-called cookie-cutter labs that have students follow a prescribed procedure but do not have them critically evaluate information or create new knowledge (Furtak & Penuel, 2018; Kirkup et al., 2016). The prevalence of this misconception among the PSTs in this study could be an artifact of how the methods class was taught. All modeled inquiry-based lessons involved some kind of physical or virtual experimentation or manipulation that the PSTs utilized to explore scientific and mathematical concepts and phenomena. However, inquiry can be accomplished without the aid of hands-on activities, manipulations, or laboratory activities through illustrations, data, thought experiments, or graphics as a means of analyzing and detecting patterns and formulating new knowledge. These methods are referred to in the literature as *minds-on versus hands-on* (Furtak & Penuel, 2018; Osborne, 2019; Parsons, 2019) and *learning by viewing versus learning by doing* (Stull & Mayer, 2007). Because these techniques were not explicitly discussed or modeled for the PSTs, it is understandable that they were not mentioned in their discussion posts.

Another prevalent misconception among the PSTs was conflating inquiry-based learning with collaborative learning. This came in the form of the PSTs claiming that inquiry-based instruction relied on or resulted from group work and discussion with their peers. Like with hands-on activities, collaboration, and group work are often popular features of inquiry-based teaching (Ross & Davidson, 2020; Wale & Bishaw, 2020) and were prominent features of the methods course. This is because students frequently learn better when they can discuss, debate, and build on the ideas of their peers (McDonald, 2016; Sampson & Clark, 2009). However, neither group work nor collaborative learning is a defining feature of inquiry. The reason for this is two-fold. First, inquiry involves students generating knowledge for themselves, not for a group. Therefore, inquiry can be accomplished on the individual student level. Additionally, while collaborative learning can be a means to support inquiry-based instruction, group work and class discussion can just as easily be used to reinforce teacher-centered instruction (i.e., the *we do* component of the *I do, we do, you do* model) instead of new knowledge generation. Because collaborative group work was a frequent feature of the class to complement the inquiry-based instruction, it is understandable that the PSTs would consider this an important component of inquiry-based teaching.

Finally, the PSTs also confused inquiry-based teaching with active learning. The PSTs frequently commented how, with inquiry, they needed to take an active role in their learning through practices such as answering questions, partaking in problem-solving and critical thinking, and staying engaged throughout the lesson. While these certainly can be features of inquiry-based learning, and frequently were within the methods course (we tried to make all the model inquiry-based lessons engaging and interactive for the PSTs), they are not distinct to inquiry-based instruction, nor do these features inherently lead to inquiry. For example, questioning is an excellent way to engage and formatively assess students, but teachers often ask questions to confirm student learning, not generate it (Kim, 2015). Nevertheless, PSTs, both in this study and one by Lee and Shea (2016) considered asking questions and inquiry to be the same. The same issue was found with making lessons interactive, fun, and engaging. Skilled teachers can often retain their students' attention through demos, hooks, interesting facts, engaging stories, real-world examples, and exciting activities. However, despite all these high engagement strategies, inquiry may not be taking place (Moyer, 2001; Wallace et al., 2021). Moreover, students may not realize this is the case. A study by Deslauriers et al. (2019) found that STEM students learned more in active learning classrooms but perceived they learned more with teacher-centered instruction, particularly when taught by engaging professors. The same effect may have occurred with the PSTs in this study, where they confused a fun, interactive, and engaging class environment with inquiry.

In conclusion, while the novice science and math PSTs in this study overwhelmingly claimed to prefer inquiry-based instruction to teacher-centered, few could actually identify and articulate features specific to inquiry when asked to explain their preference. Most PSTs ended up describing other student-centered strategies, such as collaboration and active learning, or general teaching strategies, such as questioning, hands-on activities, and creating a fun and engaging environment. While we acknowledge intersections within these student-centered strategies, there are still distinctions of inquiry-based instruction that the PSTs may not understand. These results suggest that the PSTs had a weak, limited, or erroneous understanding of science and mathematics inquiry-based instruction elements. Similar results were found by Panaoura (2017), who discovered that math teachers in Cyprus had positive views of inquiry but struggled with their implementation due to a weak knowledge of mathematical inquiry. She suggested that teachers need more experience, starting at the preservice level with executing investigations and explorations of mathematical concepts to strengthen this skill. A review of science inquiry professional developments by Capps et al. (2012) found similar results where science teachers reported positive attitudes toward inquiry but had minimal to no change in their actual implementation due to a lack of understanding of inquiry and its components.

These results are unsurprising as there is considerable confusion among the education community, including teacher educators, about what inquiry is and how it should be defined. Therefore, this confusion is often passed on to their PSTs (Levy et al., 2013). Without a clear articulation of what inquiry is and is not, it would be expected that novice math and science PSTs would struggle with the term and what it conveys.

Conclusion and Limitations

Limitations

This study has several limitations, first and foremost, the format of the course and discussion post. The methods course heavily demonstrated and emphasized the importance of inquiry-based versus teacher-centered instruction. While the PSTs were informed that their preferences on the discussion post would not impact their grade or position in the course, students may have been more inclined to select inquiry-based instruction to appease their professors.

Additionally, while inquiry-based practices were the main foci of the course, other student-centered approaches were not. Instead, they were used in a more supportive role and were not discussed in as much detail. This could have contributed to the students considering all student-centered approaches to be inquiry since they did not have other terms and definitions to distinguish between. Furthermore, the prompt simply asked students to express their preference for inquiry versus teacher-centered instruction but did not offer other student-centered teaching strategies as options for the PSTs to choose from.

Finally, the prompt asked the PSTs which pedagogy they preferred, but it did not distinguish if they were responding to which method they preferred as a student or as a teacher. Had this distinction been made, this could have altered the results of some participants who may prefer learning in one method and teaching in another.

Conclusion

As teacher educators, we can pat ourselves on the back that our PSTs embraced the inquiry-based strategies we emphasize in our courses. However, before we prematurely celebrate, it is important to question as Lorne Michaels does, *was it the right laugh?* In other words, what are these PSTs actually embracing? If they have a limited or erroneous understanding of what inquiry and student-centered practices are, then even if they believe in their value, how well will they be able to implement them in practice? In the case of this study, confusion between inquiry-based teaching, active learning, collaborative learning, and other student-centered practices manifested itself in PSTs with very positive attitudes about inquiry but little understanding of what it was or how it should be implemented. Based on these results, this study makes the following recommendations for teacher educators and preparation programs:

First, the study supports the notion that teacher preparation programs need to clarify what inquiry-based strategies are and are not and delve deeper into the nuances between different pedagogical best practices. Through these efforts, teacher preparation programs can not only help develop positive beliefs about inquiry but also the wherewithal for how to bring it into practice.

Second, while exposing PSTs to inquiry-based teaching early and frequently in their methods courses is an excellent start, merely engaging in inquiry is not enough. PSTs must also reflect on those inquiry-based experiences and determine what features truly indicate inquiry-based learning (Karakaya Cirit & Aydemİr, 2020; Levy et al., 2013; Windschitl, 2003). Otherwise, they risk continuing to manifest misconceptions about the distinctions between inquiry-based and other teaching pedagogies and practices.

Third, while this study focused on PST education, we must consider this a beginning, not an end. Conceptual change is a slow, arduous, and often non-linear process (Addido et al., 2022; Duit et al., 2013). Future studies should follow up with the participants to explore if their indicated teaching preference stayed the same or changed after subsequent teaching courses and additional field experience. Teachers would also benefit from professional development into induction and beyond that assists in grappling with what inquiry is compared to other student and teacher-centered approaches and how it should be authentically presented within the classroom (Feiman-Nemser, 2001; Levy et al., 2013).

Finally, it is important to clarify that this study sought to determine math and science PST preferences for inquiry-based instruction. That does not mean that other forms of student-centered instruction, such as collaborative group work, active learning, argumentation, and the like, are not equally important features of a high-quality science or math classroom. Successful teachers should be well versed in a multitude of teaching pedagogies, starting at the PST level, so they can be nimble to best meet the needs of their students (Ball & Forzani, 2009). Additionally, a second-order meta-analysis by Öztürk et al. (2022) found that inquiry-based learning had a medium-level positive effect on learning outcomes. However, a high-level positive effect was achieved when inquiry-based instruction was coupled with other forms of instruction, such as the learning cycle model, conceptual change text models, and the use of mobile devices. The same goes for teacher-centered instruction, which also has a time and place within a robust teaching environment (Chinn & Iordanou, 2023; Kirschner et al., 2006). This study merely suggests that if PSTs have misconceptions about inquiry-based instruction, the same issue may persist among other teaching pedagogies. Therefore, the education research community could be well served by exploring not only teacher attitudes and implementation of these other pedagogies but also what misconceptions teachers have to better understand how they are being perceived and misconstrued.

The results of this study demonstrated that while our math and science PSTs were a receptive audience, they ultimately missed the joke. However, by being more mindful and intentional about teaching inquiry and student-centered approaches, teacher education programs can assist science and math PSTs in improving not only their attitudes but also their understanding of what inquiry is and how it can be successfully implemented in the classroom—that way we get right laugh for the right reason.

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Please cite: Goldberg, E.R. & Dawin, T.K. (2025). The right answer for the wrong reason: Preservice science and mathematics teacher preferences and explanations of inquiry-based teaching. *Journal of Research in Science, Mathematics and Technology Education, 7*(SI), 1-25. DOI: https://doi.org/10.31756/jrsmte.411SI

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Data Availability Statement: Data available upon request

Ethics Statement: This study obtained institutional review board approval prior to conducting any research related to this study.

Author Contributions: All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Received: January 09, 2025 ▪ Accepted: April 18, 2025