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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).

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

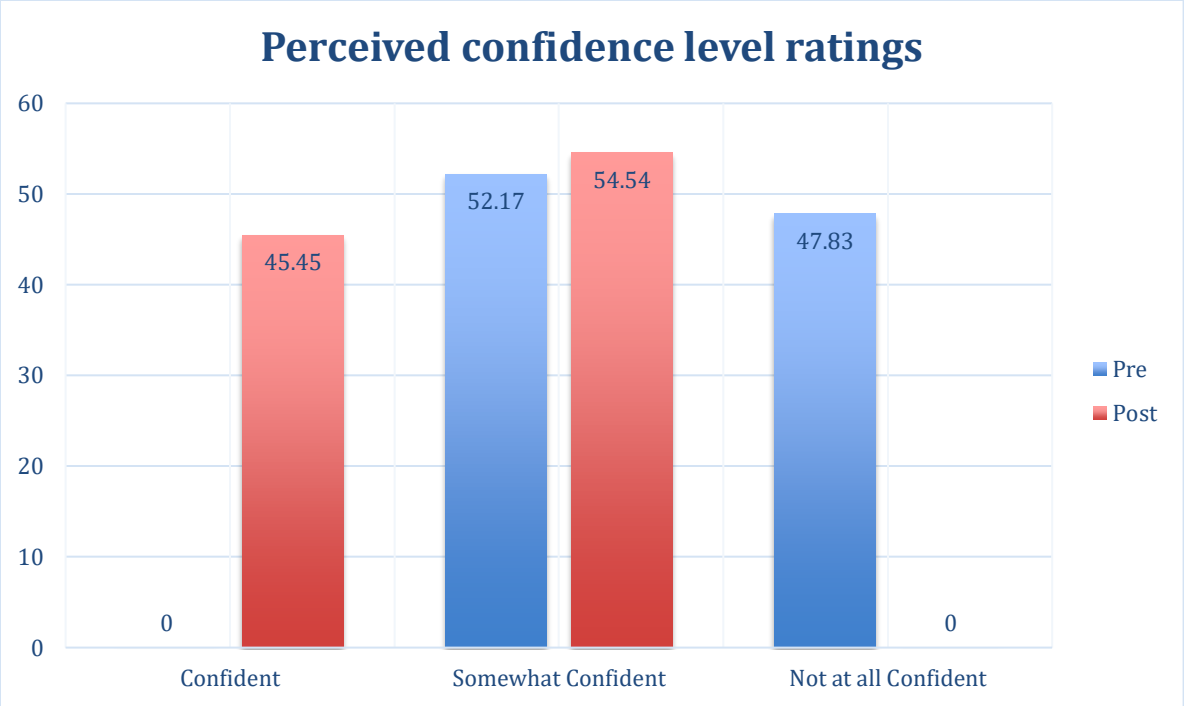


Table 2

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

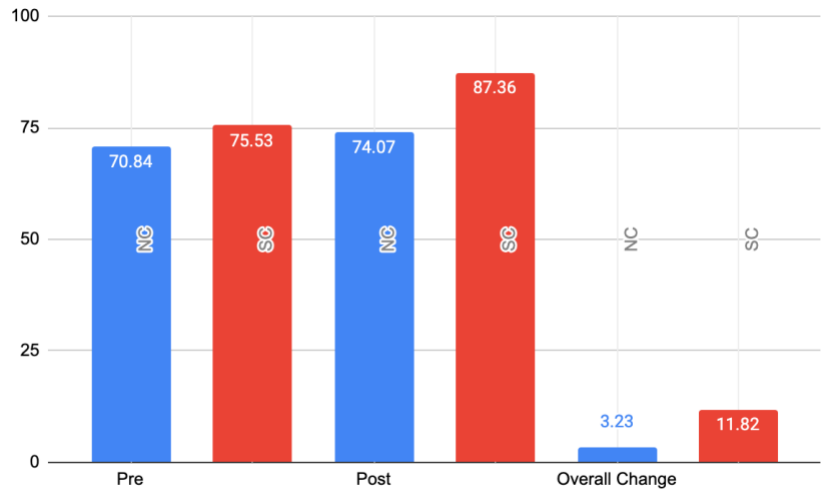
Perceived confidence and science knowledge growth

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.

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