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STEM SMART: Unpacking the Research on Teachers' Beliefs about Essential Life Skills and Dispositions

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ABSTRACT

Success in science and mathematics courses, and later in careers, requires more than disciplinary knowledge and general academic competencies. Students also need proficiency in certain key dispositions and life skills. This article is a systematic review of literature that examines what teachers believe about the non-academic skills necessary for student success in science, technology, engineering, and mathematics (STEM) classes and future careers in STEM fields. We report our results of the literature review and discuss these in terms of *STEM SMART skills* – non-academic skills and dispositions that support students' learning across science and mathematics. These life skills and dispositions are usually not studied as academic skills; nevertheless, they are essential for long-term success in STEM fields. The acronym *STEM SMART* is intended to serve as a mnemonic to help educators and others remember and discuss these life skills and dispositions that support STEM learning.

Keywords: teacher beliefs, STEM education, life skills, learner dispositions, STEM SMART, systematic literature review

Introduction

Classroom teachers understand much more about their students than academic performance. Within the classroom context, teachers observe many non-academic aspects of students' dispositions and character traits. Educational research has long shown that teacher beliefs about students can influence student performance (Hamre & Pianta, 2001; McKown & Weinstein, 2008; Rosenthal & Jacobson, 1968). Most studies about teacher beliefs focus on how teacher beliefs affect teacher behavior toward students or instructional innovation (Bryan, 2012; Brophy & Good, 1986; Wang, Haertel, Walberg, 1993). Similarly, the *Next Generation of Science Standards* (NGSS, 2013), the *Common*

Core State Standards for Mathematics (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010), and the *Principles and Standards for School Mathematics* (National Council of Teachers of Mathematics [NCTM], 2000) focus on practices and skills to specifically promote student academic achievement in the STEM area.

After conducting workshops and family engagement events with science and mathematics teachers over the course of several years (Hoffman, Suh, & Zollman., 2021; Zollman, Hoffman, & Suh, in press), we have heard many classroom teachers discuss their beliefs about the importance of specific life skills required for student success in Science, Technology, Engineering, and Mathematics (STEM) coursework. These conversations with teachers led us to question which non-academic skills teachers see as particularly relevant for student success in STEM courses. For years, teachers have been talking about these skills in general ways, often using terms from outside the education field such as "soft skills" (Berdanier, 2022) or "21st century skills" (Ng, 2019).

Rather than focusing on what teachers believe about students and their achievement, however, this study focuses on teacher beliefs about a particular set of skills. Specifically, we sought to pinpoint what life skills and non-academic character traits teachers believe lead to success in STEM fields in order to help teachers unpack and apply the research behind the body of nonacademic skills students need to be successful. This is not an exhaustive search of the literature on all life skills that support STEM, but instead an analysis of how teachers' perceptions of these needed skills and their efforts to support these skills are discussed in the literature. Because we value teachers' experience, observations, insights, and knowledge about what non-academic skills correlate with students' learning and performance, we grounded our research on teacher beliefs about this aspect of student development. The present study was guided by the following research questions: How are teacher beliefs about life skills relevant to STEM learning characterized in the literature? And what recommendations do teachers make to support the development of these skills?

In this article, we report on the examination of the research and ultimately present an acronym, STEM SMART, which we intend to serve as a mnemonic to help educators and others remember and foster the life skills and dispositions that support STEM learning (Hoffman et al., 2021; Figure 1). Based on the major discrete skill categories which emerged from our analysis of the published research, the acronym refers to S for struggle (promoting persistence as productive struggle), M for mistakes (embracing mistakes as learning opportunities), A for STEM's relevance for all people (making STEM interdisciplinary and accessible for all), R for risk taking (encouraging academic risk taking), and T for critical and divergent thinking (supporting critical thinking). It is our hope that this acronym not only succinctly presents the existing literature but, more importantly, helps teachers unpack and apply the research on teacher beliefs about the nonacademic life skills students must develop to be successful in their STEM classes and beyond.

Figure 1

STEM SMART

Struggle (promoting persistence as productive struggle)
Mistakes (embracing mistakes as learning opportunities)
All are Relevant (making STEM interdisciplinary and accessible for all)
Risk Taking (encouraging academic risk-taking)
Thinking (engaging in critical and divergent thinking)

Guiding Literature

Given the fast pace of innovation in STEM careers, educators and industry experts emphasize the importance of individuals' adaptability and soft skills development for long term STEM success (Schulz, 2008; Wats & Wats, 2009; White, 2020). For many years, researchers across many fields have studied the role of non-academic skills in academic success and career readiness. These human-focused competencies (Berdanier, 2021) have been called life skills, soft skills, twenty-first century skills, transversal skills, and nontechnical skills (Succi & Canovi, 2020). Such skills have been cited as critical to graduates' employability (Claxton et al., 2016) and have even been added as required student outcomes for engineering programs by the Accreditation Board of Engineering and Technology (ABET, 2016; Hirudayaraj et al., 2021). Still, scholars have not come to a consensus on a list of skills needed for employability (Griffiths, Brady, Riley, Alsip, Trine, & Gomez, 2018). In recent years, some scholars have advocated for retiring the term "soft skills" (Berdanier, 2021; Parlamis & Monnot, 2019), in part because choices in terminology can connote certain domains or skills being less professional and therefore less important than "hard" or technical skills.

In business, soft skills often refer to interpersonal skills that characterize a person's relationships with other people. In the workplace, soft skills are a complement to hard skills, which refer to a person's knowledge and occupational skills. Soft skills have more to do with how people operate rather than what they know. As such, they encompass the character traits that decide how well one interacts with others (Majid, Liming, Tong, & Raihana, 2012). In the business world, employees acquire hard skills through formal education or training programs. Hard skills can be learned and perfected over time, but soft skills are more difficult to acquire and change (Mitchell, Skinner, & White, 2010). Some in education use the term soft skills to describe a person's social/emotional intellectual skills as opposed to knowledge/intellectual skills (Cohen & Sandy, 2007; Kenton, 2021; Scheerens, van der Werf, & de Boer, 2020). Given these differences in meaning across disciplines, we suggest the term "soft skills" is not an accurate description of the skills educators want to foster in their students. The term "21st century skills" is also problematic, as it is not clearly defined and seems a curious choice for current students who were born into the 21st century. Instead, we introduce the term "STEM SMART skills" to describe the necessary skill set which emerged from our systematic review of the literature.

Methodology

Systematic reviews of the literature apply detailed, comprehensive analysis to identify, appraise, and synthesize studies and reduce bias (Davis, Mengersen, Bennett, & Mazerolle, 2014; Denyer & Tranfield, 2009; Uman, 2011). Systematic reviews can communicate the current state of research, determine themes across studies, and guide future investigations. The purpose of this systematic review was to collect and analyze the current research conducted on teachers' beliefs about student nonacademic skills necessary for students' success in the STEM area.

Data Collection

This study was conducted using a university library database supplemented by Google Scholar to search for the keywords "teachers," "beliefs," "STEM," "student," and "success" in a ten-year range from 2011 to 2021. Our inclusion criteria were peer-reviewed articles addressing teachers' beliefs and perceptions about students' life skills to succeed in STEM. We included articles from different countries and a range of levels from kindergarten to college and graduate school. Google Scholar was used to supplement this review of the literature because is the largest database of educational research.

It also overlaps with most other large educational databases. Our first search yielded about 20,200 results. From this initial result, the first fifteen pages (150 items) were manually reviewed to select peer-reviewed articles matching our search criteria. Thus, articles that lacked one of the key terms within the summary or the paper were eliminated. For instance, a paper by De Angelis (2011) on teachers' beliefs about the role of prior language knowledge lacked discussion of STEM topics and, therefore, was discarded. To increase the sample size and relevance of included articles, other papers that used synonyms of our key words were added. For example, Nadelson, Callahan, Pyke, Hay, Dance, & Pfiester's, (2013) "Teacher STEM Perception and Preparation: Inquiry-Based STEM Professional Development for Elementary Teachers" used the word "perceptions" instead of "beliefs" and was added to the article corpus.

After eliminating articles outside of our search criteria, we obtained twenty-four articles that fulfilled our research criteria and were included in this literature review. The articles were first read to identify the focus and were subsequently categorized as: "Teacher Practices," "Literature Review" "Teacher Beliefs about Student Backgrounds" and "Learning Outcomes." An individual article could be identified as falling within multiple categories. For example, Chrysostomou and Philippou's (2010) article "Teachers' Epistemological Beliefs and Efficacy Beliefs about Mathematics" was coded as both "Teacher Practices" and "Teacher Beliefs about Student Backgrounds." Seventeen articles were identified as "Teacher Practices," one article was classified as "Literature Review," five articles discussed "Teacher Beliefs about Student Backgrounds," and one paper was classified as "Learning Outcomes" (Appendix).

Data Analysis

Articles matching the focus of the literature review were analyzed qualitatively to identify common themes across the literature related to what is currently known about STEM teachers' beliefs about the dispositions necessary for students' STEM learning. The authors applied thematic analysis (Braun & Clarke, 2012), which is a rigorous qualitative method involving the establishment of analytic categories and their provisional definitions in six phases: (a) familiarization through multiple readings of the data; (b) formulation of initial codes by identifying common themes and novel trends; (c) search for themes by reviewing coded segments and generalizability to a larger section of the data; (d) review potential themes by comparing across coded segments; (e) definition and naming of themes; and (f) establishing theme boundaries.

After multiple reads of the corpus to familiarize ourselves with the data, we began identifying common themes and trends across articles which allowed us to create our initial codes. For example, several articles mentioned the importance of teaching STEM in and for a variety of contexts, which we initially identified as part of the emerging theme "Multiple Contexts." We then identified this theme within several texts, noting the appropriate coded segment with MaxQDA, a qualitative data analysis software. The first author developed the initial codebook and was joined by the research team in applying the codebook in our subsequent analysis. After our initial coding of the data, we confirmed the code categories by assessing generalizable relationships and connections between coded segments within a code category.

We also sought to identify broader themes by identifying connections between different code categories. For instance, coded segments from the emerging theme "Multiple Contexts" were combined with another emerging theme "Social/Cultural Contexts of STEM" to form a broader theme which was later named "All Types of STEM" (the letter A in the SMART acronym. Once each coded segment within this theme was reviewed, the theme was defined as STEM contexts beyond traditional or theoretical applications. The theme boundaries were established to include school-based and extracurricular applications of STEM, including social and cultural contexts for STEM learning at school. However, the theme boundaries excluded STEM learning that occurred outside of school.

Instead, these outside-of-school based STEM references became part of the theme "All Types of Learning Environments." Both "All Types of STEM" and "All Types of Learning Environments" became child codes within the larger theme of "Making STEM Accessible for All" and "Viewing STEM as Interdisciplinary."

After defining and naming the themes, we calculated the number of utterances (or times the theme was referenced in the literature) and selected a quote from the literature to represent that particular belief about necessary dispositions. In our calculations of the count data, a single phrase could be counted multiple times if it related to multiple codes. For example, "All three teachers...believe that problem solving plays an important role in integrating engineering into science and mathematics" (Wang, Moore, Roehrig, & Park, 2011, p. 10) was coded as both "STEM for All" and "Promoting Persistence." In this way, this single quote yielded two instances to be coded.

Findings

The analysis yielded six overarching themes related to teachers' beliefs about necessary dispositions for STEM learning. We used such themes to build the SMART acronym, **S** is for struggle (promoting persistence as productive struggle), **M** is for mistakes (embracing mistakes as learning opportunities), **A** is for STEM's relevance for all people (making STEM interdisciplinary and accessible for all), **R** is for risk taking (encouraging academic risk taking), and **T** is for critical and divergent thinking (supporting critical thinking). Below we present qualitative and frequency count data from each of the emerging themes.

Promoting Persistence through Productive Struggle

Persistence was also an important skill that teachers identified for success in STEM (35 instances). Most frequently, teachers and teacher educators referred to persistence in reference to a mindset that was open to challenges and the benefits of productive struggle." Such theme represented the letter S in the SMART acronym because of the used of the struggle to foster students' persistence. The literature also reported the importance of setting high expectations for students, for instance, a teacher who continuously pushed her students to struggle in the classroom while solving STEM-related problems (Dare, Ellis, & Roehrig, 2014). The teacher claimed that the more students face problems, the more they get used to them and enhance their learning in problem-solving. Such a mentality is related to improving persistence as the teacher used productive struggle to increase her students' perseverance while solving problems. Table 1 summarizes the three dominant themes related to persistence.

Table 1

Examples of Persistence Themes from the Literature

Subtheme	Example Quote
"Mindset" (15)	"[Teachers] seemed to hold more growth mindsets, agreeing that hard work and effort could lead to success in mathematics" (Copur-Gencturk et al., 2020, p. 1264)
"Communicating High Expectations" (10)	"When teachers had high expectations for students, however, these students typically met the higher expectations of performance" (Nathan et al., 2010, p. 410)
"Productive Struggle"	"Effective schools have been found to embrace and promote a strong common

(10)	mission and vision, fostered by focused school leaders, that articulates high expectations for minority student success" (Dare et al., 2014, p. 10)

"Mindset" emerged as the dominant subtheme with 15 examples in the data. This subtheme referred to taking advantage of learners' enthusiasm, intrinsic and extrinsic motivations, interests, positive attitudes, and self-regulation to explore STEM concepts. Also, the subtheme of mindset was related to teachers who believed that mentality can be modeled and nurtured. Many teachers agreed that students that showed hard work and effort could succeed in STEM areas. For instance, Copur-Gencturk, Cimpian, Lubienski, & Thacker (2020) showed their results after studying teachers' beliefs about students' mathematical aptitudes. They found that the teachers in their sample had growth mindsets. This way of thinking means that the teachers believe students can modify their mindset through hard work and effort. This type of belief is related to the mindset subtheme because it shows a conviction in which the students' mentality can be sculpted and developed.

Encouraging Academic Risk Taking

In the literature, "Academic Risk Taking," which represents the letter R in the SMART acronym, was the most frequently referenced skill (60 instances) in relation to students' success in STEM. Overall, risk taking in the literature included encouraging students to become self-directed and to solve problems through inquiry. Teachers also believed that it was important to encourage cooperative and intrinsically motivated learning. For example, Van Haneghan, Pruet, Neal-Waltman, & Harlan (2015) found that teachers believe students must develop the skills to analyze, interpret data, identify, formulate, solve problems, and become self-directed learners. This belief about necessary skills for students to learn STEM-related topics is under the umbrella of risk-taking because it contains ideas or beliefs of students becoming self-directed and solving problems. Another example was found in Stohlmann, Moore, & Roehrig (2012) which included the results of a model for teaching integrated STEM education. They found that the teachers involved in the research believed in the importance of having students work together and develop their ideas. This teaching style is related to the view of risk-taking as an essential factor in encouraging cooperative and intrinsically motivated learning.

Table 2

Examples of Encouraging Academic Risk Taking in the Literature

Subtheme	Example Quote
"Give Time and Space" (37)	"His view that scientific inquiry in the classroom can occur only if the students are fully in charge of designing and implementing an investigation" (Park Rogers et al., 2010, p. 906)
"Encourage Questioning" (14)	"The purpose of the motivating and engaging context provides students with real problems that require them to draw from multiple disciplines in order to solve a given problem or challenge" (Dare et al., 2014, p. 2)
"Support Wonder" (9)	"Opportunities include capitalizing on the enthusiasm of young learners and their desire to explore STEM concepts, the development of student foundational STEM knowledge, and flexibility in the elementary curriculum that can more readily support innovative approaches for teaching STEM content" (Nadelson et al., 2013, p. 157)

The overall theme of Academic Risk Taking encompassed three subthemes (Table 2). Within the larger theme of "Academic Risk-Taking," the most frequently occurring subtheme was "Give Time and Space." This subtheme referred to giving students the freedom to explore, think creatively, identify and formulate problems, design their work, and allow the development of independent learning. Additionally, it conveyed respect for each student's learning process and gave numerous opportunities to learn, such as demonstrated by Park Rogers, Cross, Gresalfi, Trauth-Nare, & Buck (2010; Table 2). The researchers described a teacher's belief that "scientific inquiry in the classroom can occur only if the students are fully in charge of designing and implementing an investigation" (Park Rogers et al., 2010, p. 906). Such a view demonstrates the subtheme of giving time and space by acknowledging that students need space to be in control of their learning.

Making STEM Accessible for All and Viewing STEM as Interdisciplinary

We conceptualized the theme "STEM for All and All Things as STEM" (44 instances) as emphasizing the interdisciplinary nature of STEM as learning that can occur in multiple environments and can be accessible for every learner. Such theme represents the letter A in the SMART acronym. An example of the code "STEM for all" in the literature is when Nathan, Tran, Atwood, Prevost, & Phelps (2010) cited Lewis' (2007) calling to expand engineering education accessibility for all students. Nathan et al. describe the tension in teacher beliefs between those who view K-12 engineering as a pathway to postsecondary engineering studies and those who believe all students benefit from engineering education to support their technological literacy. The theme also related to our growing understanding of STEM as including the social and cultural contexts of school-based and extracurricular applications of STEM. Nathan et al., 2010, for example, found that teachers believe engineering preparation occurs in multiple contexts, including students' homes and communities as well as school and workplace settings. While these examples come particularly from engineering education studies, overall, this theme included explicit references to interdisciplinarity more than to the discrete disciplines of science, technology, engineering, or mathematics (Table 3).

Table 3

Examples of STEM for All and All Things as STEM in the Literature

Subtheme	Example Quote
"All Types of STEM (Integrated Disciplines)" (25)	"All three teachers believed that science, mathematics, and engineering are related in a very natural way, either by content or problem solving processes" (Wang et al., 2011, p. 10)
"All Types of Students" (16)	"[Teachers held the epistemological belief that] If a student is *not* naturally gifted in mathematics, they can still learn the class materials well" (Chrysostomou & Philippou, 2010, p. 1512)
"All Types of Learning Environments" (3)	"Connection between in-school and out-of-school learning" (Nathan et al., 2010, p. 14)

With 25 instances in the corpus, the most frequent subtheme, "All Types of STEM", referred not just to the integration of science, technology, engineering, and mathematics but also to non-traditional or applied instructional foci. For example, Dare and colleagues (2014) cited Moore, Stohlmann, Wang, Tank, Glancy, & Roehrig's (2014) claim that the purpose of engaging instructional contexts is to provide students with real problems that require knowledge from multiple disciplines to solve. This theme emphasized teachers' beliefs about the importance of students' understanding of STEM as relevant to all people and in all areas of life. The theme illuminated teachers' beliefs that students can increase their interest in STEM through a range of experiences. It also supports STEM learning's relevance to other types of learning and all learners. Although not explicitly stated within any of the reviewed articles, we conceptualized the relevant life skill teachers referenced within this theme as students' awareness of and openness to STEM as a connective force to the world around them.

Embracing Mistakes as Problem Solving Opportunities

The literature contained several references to how STEM teachers believed mistakes should be seen as opportunities to learn (Table 4; 44 instances). Such code represents the letter M in the SMART acronym. Teachers were most likely to emphasize the complexity of problems and students' self-image as problem-solvers (Table 3). For instance, in their case study of middle school teachers integrating STEM across multiple disciplines, Wang and collaborators (2011) noted how teachers "believe that STEM integration helps their students to not be afraid to make mistakes and to think that they are able to accomplish something they could not do before" (p. 11).

The emphasis on embracing mistakes was a key finding from Wang et al. (2011) and alluded to another core aspect of problem solving as an integral part of the value of making mistakes. This mindset also reinforced students' views of themselves as problem solvers–a key aspect of their willingness to make mistakes. An example of this was reported by Dare et al. (2014), whose literature review discussed providing students with real problems that require using knowledge from multiple disciplines to find a solution as a way to help students engage in the class context. This way of thinking of thinking is related to the idea that complex problems require complex solutions and that mistakes are a natural part of seeking such solutions.

Table 4

Examples of Encouraging Mistakes as Problem Solving Opportunities from the Literature

Subtheme	Example Quote
"Complex Problems have Complex Solutions" (21)	"There isn't always one right answer. You know, there's lots of different ways you can approach a problem and there's lots of different results you can get. In a way that's kind of how the real world goes" (Dare et al., 2014, p. 7)
"Promoting Positive Self-Image as Problem-Solvers" (20)	"She believed STEM integration helped her students to think independently and to become more confident in learning, to learn how to communicate with each other, and to become skilled at teamwork" (Wang et al., 2011, p. 10)
"Avoiding Perfectionism" (3)	"James was careful in talking about his students' hesitation to begin work with the wind turbines, almost being afraid to touch the equipment because they were afraid that they would do something wrong" (Dare et al., 2014, p. 10)

The most frequently occurring subtheme under the theme of "Embracing Mistakes as Learning" moments was "Complex Problems have Complex Solutions." This belief reflected the importance of helping students think creatively, work collectively, and use interdisciplinary knowledge. It also includes the idea that a problem can be approached in different ways. For instance, Dare et al. (2014) described a teacher who thought that the best way to teach students was by giving them problems with multiple correct answers. The teacher said, "There's lots of different ways you can approach a problem and there's lots of different results you can get" (Dare et al., 2014, p. 7). Such a mindset illustrates the subtheme of "Complex Problems have Complex Solutions" by acknowledging that real world situations do not always have only one correct answer and that creative thinking is a necessary life skill for approaching complex problems.

Supporting Critical Thinking

"Supporting Critical Thinking" was the final theme we uncovered with 11 instances. Although the theme was numerically less substantial than the other thematic categories, the theme's representation in eight different articles indicates its significance in discussions of teacher beliefs about life skills and dispositions essential to STEM learning. STEM educators and professionals typically define critical thinking as an important application of the scientific method to formulate and solve problems using inquisitiveness and multidisciplinary knowledge. This involves encouraging students to think outside of the box and learn through their own experiences to become self-directed learners. The corpus contained both these subthemes, with explicit references to critical thinking being more common (Table 5). For instance, Radloff and Guzey (2016) found that preservice teachers believed that creative and critical thinking were essential for student success in STEM areas. The subtheme "Thinking Outside of the Box" also included the importance of creativity, such as Chriostomou and Philippou's (2010) factor analysis of teachers' epistemological beliefs of mathematics in which the authors described the importance of teachers' belief that "doing mathematics involves exploration and creativity" (p. 1512).

Table 5

Examples of Supporting Critical Thinking Themes from the Literature

Subtheme	**Example Quote**
"Critical Thinking" (8)	"[Preservice Teachers' instructional conceptions included] real-world application and context, creative and critical thinking, discovery or hands-on learning" (Radloff & Guzey, 2016, p. 766)
"Thinking Outside of the Box" (3)	"His goal as a teacher is to make a difference in the world through teaching, challenging students to think outside-the-box and not always give them the answer right away" (Dare et al., 2014, p. 7)

Building Skills for the Future

A final theme, which was not directly accounted for in our original SMART acronym related to skills for the future. The literature also included 27 references to "Building Skills for the Future" to prepare students for success beyond high school and in their future as productive citizens and workers (Table 5). Such skills included citizen and ethical behaviors, technological skills, interdisciplinary knowledge connected to the real world, and communication skills. For instance, O'Neal, Gibson, Cotten, (2017) summarized the beliefs of a teacher who argued that students need to develop technical skills such as the skill to communicate online. The teacher claimed that this type of communication is becoming an essential component of our modern society. As these examples show, such skills are not traditionally or explicitly taught. However, there is a growing interest in technological skills-in STEM disciplines. Another essential skill mentioned was problem-solving related to real-world contexts.

Teachers specify that students must have the skills to find socio-scientific connections while making decisions and problem solving. In other words, students should consider a technological or scientific issue's economic, social, ethical, geographical, cultural, historical, and political context.

Table 6 includes the three most dominant themes for "Skills for the Future." The need to define non-academic life skills more specifically is, in fact, a major reason for undertaking our research. We report on teacher discussions of these "Skills for the Future" as a discrete set of findings as this theme have historically appeared in the literature within the context of "21st Century Skills." However, the term "21st Century Skills" is difficult to define. As such, some readers will see a connection between these skills and the other skills discussed in our STEM SMART framework. We sought to distinguish the other skills as explicitly connecting to our framework.

Table 6

Examples of Skills for the Future

Subtheme	**Example Quote**
"Seeing Real World Applications" (10)	"Student should… focus on the [hypothetical] client (the one who would keep the chair) to find answers to their questions" (Wang et al., 2011, p. 9)
"Making Connections to the Broader World" (8)	"Give students more meaningful learning experiences by connecting disciplinary knowledge with personal and real world experiences" (Wang et al., 2011, p. 3)
"Understanding Problems in New Ways" (6)	"Students can function effectively as a part of a multidisciplinary team" (Van Haneghan et al., 2015, p. 2)

Conclusions, Limitations, and Implications

In exploring the implications of this systematic review of the literature, we begin by addressing the study's limitations and delimitations.

Delimitations and Limitations

A possible limitation of our study is that we limited our work to research in a university library database supplemented with a Google Scholar search without cross referencing the articles in our corpus with other databases such as EBSCOhost. As noted in our methods, our choice to use Google Scholar was an intentional delimit of the research design. Our study's delimitations were informed by conversations with STEM teachers during which they discussed the non-academic life skills students needed in addition to the curriculum they were teaching. As such, we focused on analysis on non-academic and non-discipline specific skills.

Although previous research indicates that teacher beliefs are important and connect to classroom practice in meaningful ways, there are several limitations and challenges in identifying teachers' beliefs and attitudes. First, there is the limitation involved in all data analyses drawing from data which include only a single instance of the central phenomenon. For instance, some authors mentioned teacher beliefs only one time in an article, thereby limiting the depth of their discussion of those beliefs. Because so few studies focus explicitly on teacher beliefs about non-academic life skills, we included even these single mentions in order to expand our corpus. Another limitation of this study is that we focused on teachers' beliefs and perceptions rather than on what investigations have shown are the essential life skills to reach success in the STEM area. Therefore, further, correlations are not evidence of causation. A teacher's infusion of these skills in their teaching does not automatically result in student learning. The process of learning is a complicated undertaking, involving a multitude of factors. Simply put, these life skills and dispositions, in teachers' opinions, are necessary but not sufficient for student success in STEM education. Future research should explore how teachers make sense of the STEM SMART acronym for conceptualizing the life skills necessary for succeeding in STEM and beyond. Additional research can explore the impact of various interventions addressing a particular aspect of the STEM SMART framework.

Implications

Although there are many studies about the relevance of "soft skills" or "21st century skills" to STEM learning, this review of the literature is delimited to teachers' perceptions of which skills and dispositions benefit students across STEM disciplines or for the purpose of developing a STEM disposition. This literature review identified these six major themes, summarized here in descending order of frequency as encouraging academic risk taking; making STEM accessible for all and viewing STEM as interdisciplinary; embracing mistakes as problem-solving opportunities; building non-academic life skills; promoting persistence as productive struggle; and supporting critical thinking.

Of the six themes uncovered in the literature review, five refer to life skills and dispositions that teachers believe students need to master to be successful in STEM classes. One of the themes, Building Life Skills for the Future, is not its own set of skills but rather encompasses a broad array of life skills and dispositions learned outside of formal curriculum (such as those encompassed by the terms soft skills and 21st century skills, as discussed previously.). In order to aid further discussion of these important topics, we reworked the categories of skills and dispositions into an acronym, STEM SMART. The acronym is intended to serve as a mnemonic to help educators and others remember and discuss these life skills and dispositions that support STEM learning (Hoffman et al., 2021). Using the SMART acronym, **S** is for struggle (promoting persistence as productive struggle), **M** is for mistakes (embracing mistakes as learning opportunities), **A** is for STEM's relevance for all people (making STEM interdisciplinary and accessible for all), **R** is for risk taking (encouraging academic risk taking), and **T** is for critical and divergent thinking (supporting critical thinking).

STEM SMART skills include "commonsense" life skills, separate from explicit content skills and knowledge, that are typically not taught explicitly in schools. Yet our literature review demonstrates that teachers believe these skills and dispositions to be instrumental in students' success in STEM disciplines. We know from prior research that teachers' beliefs often directly affect their actions and therefore are an important influence on student learning outcomes (Fenstermacher, 1994; Richardson, 1994). Teachers support of STEM SMART skills aligns with Darling-Hammond and Cook-Harvey's (2018) research brief on educating the whole child; this work focuses on developing students' wellbeing in academic, cognitive, social-emotional, physical, mental, and self-identity contexts. In particular, STEM SMART skills and dispositions target self-identity and social-emotional development in ways not always addressed in school (Hoffman et al., 2021; Suh et al., 2022). For all these reasons, we encourage teacher educators to address and discuss these life skills and dispositions explicitly when discussing STEM learning.

To teacher educators, our research is not implying that teacher educators teach STEM SMART skills as part of a separate curriculum. Rather, teachers can model and emphasize the value of STEM SMART skills and dispositions across the existing academic curriculum. By normalizing STEM SMART skills, teachers strengthen students' abilities to see STEM all around them and to see themselves as being successful in the STEM classroom – and beyond.

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Appendix

Review of Literature

	Author Last Name (Year)	*Discipline*	*Grade Level*	*Teacher Practices*	*Literature Review*	*Teachers' Beliefs on Students' Background*	*Learning Outcomes*
1	Archambault et al. (2012)	Mathematics	Secondary	X			
2	Barak (2014)	STEM	Pre-Service Teachers	X			
3	Blanchard et al. (2016)	Technology	Middle School	X			
4	Chrysostomou & Philippou (2010)	Mathematics	Primary School	X		X	
5	Copur-Gencturk et al. (2019)	Mathematics	K-8			X	
6	Dare et al. (2014)	Engineering & Physics	K-12	X		X	
7	Ebert-May et al. (2015)	STEM	College/ Graduate	X			
8	Edmondson (2019)	STEM	High School			X	
9	Lazarides & Watt (2015)	Mathematics	Grade 10			X	
10	Margot & Kettler (2019)	STEM	K-12		X	X	

11	Miranda & Russell (2012)	Technology	Elementary	X			
12	Nadelson et al. (2013)	STEM	Elementary	X			
13	Nathan et al. (2010)	Engineering	High School	X		X	
14	O' Neal et al. (2017)	Technology	K-12			X	
15	Park et al. (2017)	STEM	Early Childhood	X		X	
16	Park Rogers et al. (2011)	Mathematics & Science	K-12	X			
17	Pizdrowski et al. (2012)	Mathematics	High School	X		X	
18	Pryor et al. (2016)	STEM	Elementary, Middle, and High School	X			
19	Radloff & Guzey (2016)	STEM	College	X			
20	Smith et al, (2015)	STEM	Secondary	X			
21	Stohlmann et al. (2012)	STEM	Middle School	X			
22	Tofel-Grelh & Callahan (2017)	STEM	High School			X	
23	Van Haneghan et al. (215)	Engineering	Middle School				X
24	Wang et al. (2011)	STEM	Middle School	X			

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Curriculum and Pedagogy in STEM Teacher Education: Developing Case Studies Focusing on Socio-scientific Issues and Differentiated Instruction

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ABSTRACT

Differentiated instruction (DI) is a teaching approach that aims to achieve learning for students of diverse backgrounds, abilities, and interests. This study explores STEM teacher candidates' (TCs') development of DI-focused curriculum using case studies of socio-scientific issues (SSI). The paper addresses the following research question: How well suited are case studies of socio-scientific issues to incorporate differentiated instruction? The paper adopts a qualitative method approach utilizing document analysis, in which the authors present the analysis of seven case studies of SSI developed by 18 TCs. Overall, the results convey that TCs showed very good integration of DI principles and practices in the case studies. TCs differentiated the process of teaching most followed by the product of learning; yet showing a need for more training in content differentiation to attend to students' needs, backgrounds, and academic levels. Furthermore, the research highlights the compatibility between DI and case studies of SSI, rendering them as promising tools to differentiate instruction. This research equips science teachers and curriculum designers with practical resources and strategies to implement DI, to ensure equitable education for all students. Implications for STEM teacher education research and practice are also highlighted.

Keywords: differentiated instruction, STEM education, teacher education, case studies, socio-scientific issues

Introduction

Classrooms are hubs for students from diverse cultural backgrounds, socioeconomic status (SES), gender, and race. Students' various academic achievement levels, interests, and needs add another layer to this diversity in student body. This matter is of unique importance in science, technology, engineering, and mathematics (STEM) disciplines. Yet, research still documents lack of equitable representation of women and racial minorities in STEM (Butler-Barnes et al., 2021; Salmon, 2022; Zuo et al., 2020). Accordingly, calls have been rampant to implement equity, diversity, and inclusion (EDI) measures in academic institutions, especially in STEM classrooms (Hernandez et al., 2013; Mark et al., 2020; Meyer & Crawford, 2011; Smith et al., 2022; Zuo et al., 2020). At a classroom level, examples of inclusive pedagogical strategies include differentiated instruction (DI) (Tomlinson, 2001) and universal design for learning (UDL) (Center for Applied Special Technology [CAST], 2022).

Correspondingly, recent science curriculum development efforts emphasize the importance of active learning and problem-based strategies (Gorghiu et al., 2015; Nguyen et al., 2021). One example of these strategies in science classrooms is developing case studies of socio-scientific issues (SSI) (DeCoito & Fazio, 2017). This research aims to support STEM teacher candidates (TCs) in curriculum development that is focused on inclusive instructional approaches such as DI. In this study, TCs develop curriculum using case studies of SSI in a STEM curriculum and pedagogy course in the teacher education program at a Canadian university, in an attempt to promote the incorporation of EDI strategies in their future teaching practices.

Research Rationale and Questions

The integration of SSI in STEM curricula is crucial for promoting students' socio-scientific awareness of the social, political, and economic dimensions to science and situating science as accessible to various underprivileged groups (Chowdhury, 2016; Cook & Buck, 2013). Johnson et al. (2020) highlighted how SSI can promote learners' argumentation skills including reasoning, supporting claims, and the ability to question the sources of information. Hence, it is recommended that teacher education programs make explicit efforts to develop these skills by providing TCs a variety of experiences to develop their repertoire of SSI contexts and teaching strategies (Johnson et al., 2020) as well as SSI-related assessments (Stouthart et al., 2023). In line with these pedagogical recommendations, case studies allow for multiple levels of analysis and interpretation (Levin, 1995) and present various perspectives of different stakeholders. This is one of the main reasons case studies are adequate strategies to teach about SSI (DeCoito & Fazio, 2017).

Correspondingly, there are many benefits of DI, including enhancing students' appreciation, recognition, acceptance, understanding, and respect for individual differences among each other (Watts-Taffe et al., 2012). Thus, the benefits of DI provide a strong rationale for using case studies of SSI as vehicles to highlight diversity and differentiate instruction. However, two of the main challenges that hinder teachers' implementation of DI are limited curriculum resources and perceived complexity due to insufficient or ineffective training programs (de Jager, 2017; Turner & Solis, 2017; Wan, 2017). These reported challenges call for better teacher preparation in DI, with a focus on developing relevant instructional resources that can facilitate implementing DI in the classroom.

Accordingly, this research explores the compatibility of case studies of SSI and DI. It presents STEM TCs' development of science curriculum using case studies of SSI, with a focus on DI as a teaching approach. Therefore, this research aimed to address the following research question: How well suited are case studies of socio-scientific issues to incorporate differentiated instruction?

Literature Review

Case Studies as a Teaching Strategy

A case study is a description of a real-life situation that usually involves a decision, a challenge, an opportunity, a problem, or an issue faced by a person or an organization (Ching 2014; Leenders et al., 2001). The practice of using cases as a pedagogical tool is widespread in several fields such as law, business, medicine, and education. Case studies are used in a flexible manner that involves learning by doing, and hence engages students in active learning (Popil, 2011). In addition to teaching science content, case studies develop higher order thinking skills, critical thinking, collaborative work, communication skills, and decision making (Farashahi & Tajeddin, 2018; Mahaffey, 2019).

The effective use of case studies in teacher education has been documented (e.g., Ching, 2014; Hemphill et al., 2015; Koehler et al., 2019; Lengyel & Vernon-Dotson, 2010). Ching (2014) indicated that case studies are an important pedagogy in the training of TCs as it promotes critical thinking, decision making, and motivation. Hemphill et al. (2015) highlighted how case studies contribute to TCs' engagement and cognitive growth as they consider multiple sources of knowledge. Koehler et al.

(2019) also explored how case study discussions promote TCs' problem-solving skills and cognitive levels. Furthermore, DeCoito and Fazio (2017) maintained the importance of TCs designing and enacting case studies while they assume dual roles of curriculum developers and co-constructors of knowledge. Yet, to attain these benefits, teachers using case studies must consider the following: 1) contextualizing the case in real-life scenarios to make it memorable for students (Ching, 2014); 2) promoting peer interaction to internalize cognitive processes and gain new perspectives (Levin, 1995); and 3) facilitating and supporting the scaffold process by providing feedback and guidance (DeCoito & Fazio, 2017). These considerations were incorporated within the instructions provided to the TCs as they developed their case studies in this research.

Case Studies of SSI

Socio-scientific issues are science issues that have a significant effect on society (e.g., nuclear energy, biotechnology, human genetics, global warming) (Sibiç & Topçu, 2020). Socio-scientific issues involve societal dilemmas with conceptual, procedural, or technological links to science (Sadler & Zeidler, 2004). Socio-scientific issues also acknowledge the contextual setting in which science is embedded, hence, they can provide a rich medium for argumentation due to their societal, political, and ethical implications (Bächtold et al., 2022; Hancock et al., 2019; Sadler, 2009; Zeidler et al., 2009).

DeCoito and Fazio (2017) emphasized the suitability of case studies as a pedagogical tool to specifically address SSI in science education. Case studies allow learners to debate about the nature of science topics (McComas, 2020), and to teach about the history and philosophy of science (HPS) (Höttecke & Riess, 2009; Stinner et al., 2003). Moreover, Höttecke and Riess (2009) note the importance of teaching about HPS via case studies as they include student perspectives as well as creative, open-ended, and student-centered activities like experimenting, making observations, discussing, and role-playing.

Levinson (2006) argue that teaching SSI requires a strong theoretical and conceptual basis and presents a model for teaching these topics. Levison's model includes three categories: 1) reasonable disagreement which includes evidence-based discussions and high level of critical thinking; 2) communicative virtues that include tolerance, respecting differences, thoughtful listening, equality, and freedom of expression among many other elements; and 3) modes of thought that include narrative modes and logico-scientific modes based on scientific evidence. These assertions justify the alignment between SSI and the philosophy behind DI; thus, providing a strong rationale for using case studies of SSI in diverse classrooms, and specifically for incorporating DI as an inclusive pedagogical practice.

On the other hand, Mostert (2007) highlights some of the challenges that TCs may face when teaching using case studies, including pedagogical ones, such as their unfamiliarity with the strategy and difficulty matching case problems to course content. Additionally, Şen Akbulut and Hill (2020) shed light on another pedagogical challenge especially in the context of using case studies to teach SSI. The authors highlight the difficulty of tackling controversial issues and the importance of being careful, well-prepared, and considerate about students' backgrounds upon bringing these issues into the classroom. Mostert (2007) adds practical challenges that TCs face upon teaching using case studies such as time, physical setting for the discussion, lack of experience, and lack of modeling skills (Mostert, 2007). Sibic and Topcu (2020) indicate that TCs generally do not have enough self-efficacy beliefs to integrate SSI into their curriculum, hence their call for incorporating SSI in teacher education programs. Hancock et al. (2019) maintain that several factors affect teachers' choice of SSI such as their passion and existing resources. Moreover, Chang and Park (2020) highlight the importance of professional development that aims at specifically advancing teachers' pedagogical content knowledge to teach SSI. Thus, including these topics in teacher education programs is crucial in preparing STEM teachers to incorporate them in their future practices.

Therefore, given the aforementioned affordances and challenges of developing case studies of SSI, this research aimed to provide TCs with a first-hand experience in developing case studies of SSI and simultaneously incorporating DI as an inclusive pedagogical practice in their curriculum.

Theoretical Framework

Differentiated Instruction

Differentiated instruction is a constructivist-based teaching approach that aims to achieve learning for all students by meeting their personal learning needs (Valiandes & Tarman, 2011). Deunk et al. (2015) explained differentiation as a combination of teachers' attitudes, knowledge, practices, and professional skills needed to provide adaptive instruction to address student differences. Tomlinson (2001) simplified the areas that teachers need to differentiate as three main categories: 1) content- what is taught, 2) process- teaching strategies, and 3) product- assessment strategies.

Although DI is extensively researched and theorized (e.g., Tobin & Tippett, 2014; Tomlinson et al., 2003), Maeng (2017) documented the need to explore the applicability of DI in STEM subjects at the secondary school level. Moreover, one of the significant gaps is research on DI in a Canadian context, despite student diversity in Canadian classrooms. In Ontario specifically, minimal research is dedicated to teachers' understanding and implementation of DI, as well as their preparation to implement it. For instance, D'Intino and Wang (2021) indicated that teachers in Canadian classrooms need more support to be able to differentiate their instruction. Specht et al. (2016) reiterated the specific need of secondary school level TCs to be trained on inclusive teaching strategies such as DI. Therefore, this research is warranted as it addresses the gaps related to secondary STEM teachers' preparation focusing on DI, including TCs' DI-focused curriculum development.

The DI Matrix

To analyze how TCs incorporate DI in case studies, the authors adopted the Differentiated Instruction Implementation Matrix-Modified (DIIM-M) (Maeng, 2011) after obtaining the permission from the author. The DIIM-M is a validated instrument that evaluates teachers' proficiency and their performance levels in DI (Downes, 2006, as cited in Maeng, 2011). Since the instrument was initially designed to assess the implementation of DI in a classroom, several modifications were made to address the uniqueness of the planned case studies, and hence named DIIM-M2. The resultant matrix is composed of six domains and 20 sub-criteria. See Table 1 for details pertaining to the modifications of the original matrix are explained in the "Data Analysis" section. This matrix will be referred to as the DI Matrix for simplicity.

Table 1

Short Version of the DI Matrix (DIIM-M2)

Domains	Criteria	Criteria Description
1: Quality Curriculum and Lesson Design	1. Quality and clarity of the lesson objectives: What students should know, understand, and be able to do	Objectives are informed by national or state standards and the important ideas, issues, or problems specific and meaningful to the content area. Objectives extend learning in authentic ways.

Domains	Criteria	Criteria Description
	2. Alignment of lesson objectives and lesson activities throughout the case study	The activities of the lessons are clearly and strongly related to the objectives.
2: Response to Learner Needs	1. Preassessment and Proactive Preparation	The case study demonstrates that the TC used multiple sources of preassessment data and student learning profiles in advance of the lessons to plan for the needs of the students.
	2. Scaffolding for Struggling Learners; Special Ed., ELL, etc.	Struggling learners are given tasks of high-quality and thoughtfulness with appropriate scaffolding to reach the same learning goals as other students. Multiple indicators are used when grouping students so that struggling learners experience a variety of grouping strategies.
	3. Challenging Advanced Students	Academically advanced students are appropriately challenged at higher levels of complexity and quality, not quantity. Experiences as an academic anchor in a flexible group enhance their understanding. Options are available for compacting into independent study on the topic.
3: Planned Instructional Practices	1. Lesson Organization	The lessons are organized in a coherent (organized, unified, and sensible) manner, producing a unified whole.
	2. Modes and Strategies of Instruction	The lessons use multiple modes of instruction that require active learning and the exploration of the lessons' understandings. It intentionally matches the learning profiles and the learning needs of the students. The strategies and activities reflect best practices in that content area.
	3. Engagement Capacity of Activities	Lesson components are stimulating, motivating, and engaging to learners, linked to students' prior learning or experiences, and clearly connect to their lives and/or goals. Students explicate connections between lesson content, practical applications, current events, the real world, or other aspects of the content area.
	4. Intellectual Development	Each student works at levels of readiness, interest, and/or learning profile that are appropriately challenging. The lessons are designed so that all students are compelled to do their best and complete high-quality work. The strategies and activities are planned to promote higher order thinking for all students.
	5. Flexible Grouping	Lessons use various student groupings: individual, pairs, small groups. Students are grouped for a great variety of reasons to differentiate content, process, and/or product by readiness, interest, and/or learning profile. The lessons may combine grouping rationales (i.e., readiness and interest). Flexibility in grouping strategies is in response to a clear analysis of student needs.
	6. Teacher's Planned Role, Learner Independence, and Student Choice	Teacher's overall planned role is primarily that of coach or facilitator in learning. Both students and teacher will have consistent input into lesson content. Students take on increasing responsibility for their own learning. There is a perfect balance of student and teacher choice.
	7. Technology Integration	The TC plans an excellent use of digital material. The lessons can be fully implemented in an online environment.
4: Student Assessment	1. Formative Assessment	TC plans to regularly use formative assessments throughout the lessons. Data from these lessons is used to: make modifications to instruction within a lesson, to gauge student understanding, and to plan future instruction for individuals and groups.

Domains	Criteria	Criteria Description
	2. Existence and Quality of Rubrics and Guidelines	Rubrics and guidelines of clearly articulated assessment criteria and standards are developed. Students have the ability to participate in the creation of the rubric and guidelines and can actively plan next steps for learning.
5: Positive, Supportive, and Inclusive Learning Environment	1. Principles of Equity, Diversity, and Inclusion (EDI) as stated in Ontario's Education Equity Action Plan (Ontario's Education Equity Action Plan, 2017)	The case study demonstrates a sophisticated understanding of EDI principles. The case study excellently implements inclusive and culturally responsive pedagogy. Planned lessons fully reflect and attend to diversity in students' identities.
	2. Respectful Behavior Toward and Among Students	The lessons' structure fosters active participation and questions from all students. Awareness of students' strengths, successes, and contributions are cultivated and celebrated.
	3. Sense of Community and Collaboration	Students and teacher can consistently focus on both individual and group excellence and growth. Students can consistently engage and support one another in learning. They are supported to work with any other student in the class.
Domain 6: Evidence of Differentiation	1. Content: adapting what is taught and modifying how students are given access to the information (Tomlinson, 2001)	Lessons are highly concept-based and makes use of diverse materials at various levels of readability, complexity, and/or interest. Lessons include, but are not limited to, one or more of the following strategies: multiple ways to access and organize information, learning contracts, curriculum compacting, flex-group mini-lessons, and varied support systems such as audio/video recorders, note-taking organizers, highlighted print materials, digests of key ideas, peer/adult mentors.
	2. Process: the sense-making… without it, students either lose the ideas or confuse them (Tomlinson, 2001)	Most of the instructional time is spent on small groups of students or individuals working with various sense-making activities that represent a diversity of approaches at varied degrees of sophistication to be completed in varying time spans with various levels of scaffolding. All sense-making activities use essential skills and essential information to understand the big idea or understanding of the lesson. The lesson's sense-making activities may differentiate in one or more of the following ways: readiness by matching complexity of task to student's current level of understanding; interest by giving students choices and linking to personal interests and/or goals; learning profile by making sense of ideas in the students' preferred way of learning.
	3. Product: helps students rethink, use, and extend what they have learned… [and] represent understandings (Tomlinson, 2001)	Case study provides several product options that are designed to foster deeper and richer understandings of the unit's goals. Products may differ due to curriculum requirements or student readiness, interest, or learning profile. Guidelines provide the perfect balance between structure needed to focus and guide students and freedom to support innovation and thought. Students collaborate with the teacher to design the project requirements, timeline for completion, and assessment criteria. Teacher works as a coach to facilitate, scaffold, and expand the students' thinking through flexible study groups, mini-lessons, and conferencing.

Methodology

This research explores TCs' development of DI-focused curriculum in a STEM curriculum and pedagogy course in a teacher education program at a Canadian university. In this paper, the authors adopted a qualitative method approach (Creswell & Creswell, 2018) utilizing document analysis (Stake, 2000), to capture the complexity and the richness of how STEM TCs developed curriculum to be inclusive of DI using case studies of SSI.

In this paper, the authors present the analysis of one course assignment – case studies of SSI developed by TCs. Document and artefact analysis produces rich descriptions of a single phenomenon, event, organization, or program (Stake, 2000). Yet, few limitations may decrease its authenticity and accuracy. First, the chosen documents may be personal (written by the teachers themselves) and biased/self-selected; hence they may not be representative or trustworthy. Moreover, the information presented by the participants for analysis may be insufficient, incomplete, irrelevant, or un-understandable (Merriam & Tisdell, 2015). To avoid these limitations, all TCs' course work related to this assignment, including lesson plans, supplementary teaching and assessment resources, and peer presentations were analyzed as part of the collected evidence.

Participants

In total, 18 TCs participated in the study. Participants were enrolled in a *STEM Curriculum and Pedagogy* course in the second year of the teacher education program at a university in Ontario, Canada. In year one of the teacher education program, TCs had enrolled in 10 courses. Among these courses are those directly related to general teaching methods: one course on special education and inclusion, one course on Aboriginal education, two teaching methods courses (each related to one of their future teachable subjects), and one course entitled Year 1- Introduction to STEM education. In year two of the program, TCs were enrolled in seven courses. Among these courses are those directly related to general teaching methods: one course on supporting English language learners, one course on multiliteracies, and one course entitled Year 2- Curriculum and pedagogy in STEM education, in which this study was conducted. Accordingly, TCs have had background knowledge in curriculum development (lesson and unit planning), SSI and their importance in science curriculum, and inclusive education. All TCs in the study were eligible to teach STEM subjects in the intermediate-senior divisions (Grades 9, 10, 11, and/or 12). TCs' teachable subjects included general sciences, biology, mathematics, physics, chemistry, health and physical education, and computer studies.

Overview of the Course Procedures

This 12-week course is one of two STEM courses offered to TCs enrolled in the STEM Specialty Focus in the teacher education program. The course was enriched with DI resources and training. In the first two weeks of the course, the researcher coordinated with the course instructor and provided a seminar on DI and EDI in the context of STEM education. Throughout the course, the instructor addressed DI in an explicit and reflective approach (Abd-El-Khalick & Lederman, 2000). The instructor provided the TCs with DI resources and required the TCs' to integrate DI principles and strategies in their assignments as one of the success criteria. Hence, TCs were requested to explicitly address DI in their coursework (Estaiteyeh & DeCoito, 2023b, 2023c).

Additionally, the instructor provided feedback on TCs' work and recommendations on how to improve or maintain certain aspects of their assignments. For example, in class discussions the feedback took the form of guiding questions to draw TCs' attention to the inclusion of DI practices. The instructor would ask TCs how they plan to include DI in a specific lesson plan or how plan to include more culturally relevant pedagogies in their content and strategies. When TCs submitted a draft of their work, the instructor would include links to articles or resources that TCs could consult and incorporate as they see fit. As such, the ongoing feedback was eye-opening and generic to enhance the quality of the work. Moreover, TCs were constantly reflecting on their progress and hence advancing their knowledge and skills in DI implementation throughout the course.

Data Sources

In groups of four, TCs designed a case study, assuming dual roles – curriculum developers and students (DeCoito & Fazio, 2017). This assignment was the first major task for TCs in the course. Over a five-week period, a team of four TCs collaborated to develop a case study that is interactive and based on SSI (e.g., environmental sustainability, healthcare, social issues, etc.), for Grades 9-12. At the beginning of the five-week period, the instructor explained the theoretical and conceptual backgrounds related to case studies of SSI and discussed what comprises this task. In addressing the SSI, TCs were required to complete several activities that involve the research and development of the case study including lesson plans, scenario, stakeholders, graphic organizers, note-taking framework, consequence map, cost-benefit analysis, and a presentation to lay audience. The task was also accompanied with progress reports, peer feedback, and a final reflection. A sample cover page of this assignment is illustrated in Figure 1.

Figure 1

Sample Cover Page of a Case Study about Light Pollution

A total of seven case study packages were completed and comprised the data set analyzed. The data set included 18 lesson plans, supplementary teaching and assessment resources, and peer presentations. Each team of TCs submitted all those artefacts and documents as a case study package, which was the unit of analysis in this research.

Data Analysis

Data analysis adopted a deductive approach in which the DI Matrix shown in Table 1 was utilized for the content analysis of the case studies. The deductive analysis looks back at the data from pre-determined themes (Creswell & Creswell, 2018). The data analysis process included three steps.

First Step: Developing the DI Matrix

As introduced earlier, the DIIM-M (Maeng, 2011) was adapted then used to analyze how TCs integrated DI in their case studies. First, some of the criteria that are unique to in-class observations were removed since our analysis is restricted to what the TCs planned but did not implement in the classroom. Second, due to the COVID-19 pandemic, TCs in this research were expected to conduct their practicum in an online environment as they may be teaching online in the future. To highlight the importance of this aspect, a specific criterion was added regarding integrating technology and the ability to implement the case study in an online environment.

Furthermore, one of the major amendments to the matrix was the explicit incorporation of EDI principles within the framework. This amendment was done by adding a criterion entitled "Principles of EDI", as stated in Ontario's Education Equity Action Plan (2017) within Domain 5, which entails implementing inclusive and culturally responsive and relevant teaching, curriculum, assessment, and resources. This action was to ensure that students consider Ontario's Education Equity Action Plan (2017), which promotes classes that are inclusive and reflect student diversity. This change takes into consideration the recommendation by Valiandes et al. (2018) calling for the blending of intercultural education and DI in practice by deploying the strategy of interculturally differentiated teaching. Moreover, since the STEM TCs are most likely going to teach in Ontario schools, Ontario's Education Equity Action Plan was the most relevant framework to integrate in the matrix. Therefore, the resulting DI Matrix- composed of six domains and 20 sub-criteria, is a composite model adapted by the researchers to analyze the case studies specifically with an attention to DI integration and Ontario's equity policies.

Second Step: Deductive Analysis Using the DI Matrix

The case studies were analyzed in a descriptive manner to explain the level of integration of different DI components. To ensure the reliability and validity, the authors conducted an iterative and collaborative analysis process (Creswell & Creswell, 2018). The first author conducted the analysis of the case studies as per the criteria in the matrix, and the second author reviewed it by providing comments and corrections. The two authors met afterwards to discuss and finalize the findings.

Third Step: Quantification

The qualitative analysis was quantified to further explore the holistic incorporation of DI across all case studies. Quantitizing (Sandelowski et al., 2009) was done by providing scores for each case study on each of the DI Matrix criteria and domains to attain a deeper understanding of TCs' successes, and the areas of improvement with respect to their utilization of DI in their curriculum development.

A score out of four was allocated to each of the 20 criteria in the DI Matrix, where (1) indicates "Novice", (2) indicates "Apprentice", (3) indicates "Practitioner", and (4) indicates "Expert". This score allocation was followed by the following calculations:

1) The total score of each case study on the DI Matrix (score out of 80) is the sum of the scores obtained by the case study on all the 20 criteria in the matrix.
2) Average score of the case studies on each criterion (score out of four) is calculated by dividing the sum of the scores of all seven case studies on an individual criterion by seven (the total number of case studies)
3) Average score of the case studies on each domain (score out of four) is the average score of the criteria within each domain. For example, the average score of the case studies on Domain 1 is obtained by calculating the average of the scores on its two criteria (explained in step 2 above).
4) Average score of the case studies on each domain in percentage is the number obtained in step 3 converted to percentages (dividing by four and multiplying by 100).
5) The count of case studies scoring a specific level on each of the DI Matrix criteria, that is, how many of the seven case studies scored 1=Novice, 2=Apprentice, 3=Practitioner, and 4=Expert on a given criterion.

Results

A General Analysis of Groups' Performance

Table 2 describes the case studies created by TCs, including a brief and general analysis listing the major positive points and missing elements, as well as the total score obtained on the DI Matrix.

Table 2

Case Studies' Details and Brief Analysis

Case Study Title	Class and Subject	Case Summary	Brief Analysis
Health and Medicine			
Case Study A: COVID-19 and the Vaccine Race	Grade 12: Science	Explore the implications of producing and distributing a COVID-19 vaccine in Canada from the perspectives of four key stakeholders: pharmaceutical companies (for), medical ethics advisory board (against), parents (against), and public health officials (for).	The case study scored 59 out of 80 on the DI Matrix. TCs did well on integrating multimodalities and using flexible grouping. TCs also related their topic to EDI principles by including equity issues in relation to vaccine distribution, as well as Indigenous ways of knowledge when discussing Western science. On the other hand, the case study did not scaffold learning for struggling learners or challenge advanced students. More variety in assessment strategies and clarity about assessment criteria are also recommended. Thus, differentiation of content and product components needed improvement.
Space Science			
Case Study B: Starlink	Grade 9: Earth & Space Science	The pro-Starlink and anti-Starlink groups assemble and plan out a case for debate. The stakeholders are SpaceX (satellite manufacturer), consumers (rural and under-serviced communities), professional astronomers, and space explorers.	The case study scored 58 out of 80 on the DI Matrix. TCs did well on their lessons' organization and aligning objectives with instructional activities. They incorporated rubrics in their assessment. Moreover, they encouraged collaboration and respectful behavior among students. On the other hand, the case study did not highlight topics related to EDI principles. Their differentiation strategies in content, process, and product aspects were limited.

Case Study Title	**Class and Subject**	**Case Summary**	**Brief Analysis**
Environment			
Case Study C: Water Crisis in Canadian Indigenous Communities	Grade 10: Science	The decision of whether to upgrade the existing water treatment facility in Grassy Narrows First Nation Community is decided after a debate between various stakeholders at a town hall. The stakeholders are government, environmentalists, utility companies, and the Indigenous community.	The case study scored 65 out of 80 on the DI Matrix. TCs did well on diagnostic assessment of their students at the beginning of the case; varying the modes and strategies of teaching; using flexible grouping; proficiently integrating technology in their teaching; and using formative assessment. Moreover, the chosen topic relates to equity practices in Indigenous communities. This content would catalyze many discussions on topics related to EDI principles. The case study did not scaffold learning for struggling learners or challenge advanced students. Furthermore, the case study could have been more consistent in implementing the aforementioned positive strategies throughout all lessons.
Case Study D: Microplastics	Grade 11: Biology	The costs and benefits of plastic use are investigated, based on perspectives of four stakeholders: plastic manufacturer, consumers of plastics, scientific researchers, and ocean protection groups.	The case study scored 70 out of 80 on the DI Matrix. TCs did well on diagnostic assessment of their students; varying the modes and strategies of teaching; using flexible grouping; and using formative assessment. TCs did not scaffold learning for struggling learners or challenge advanced students. Furthermore, EDI principles were not consistently incorporated in all lessons.
Case Study E: Light Pollution – The Effects of Artificial Light Use	Grade 10: Science	The case explored the social-scientific issue relating to artificial light use and the effects of light pollution, from a variety of stakeholder perspectives, taking on a social, economic, and environmental views.	The case study scored 74 out of 80 on the DI Matrix. TCs effectively addressed all three aspects of DI: content, process, and product. The case study could be improved by enhancing technology integration and being more consistent in challenging advanced learners and scaffolding learning.
Case Study F: Three Gorges Dam	Grade 9: Science	Discuss the implications of the Three Gorges Dam. The stakeholders are: The Chinese government, dam builders/hydro power companies, farmers forced to relocate, and environmentalists	The case study scored 76 out of 80 on the DI Matrix. TCs effectively differentiated all the aspects in their lessons. TCs could better align the objectives with the instructional activities, and challenge advanced learners.
Case Study G: Societal Impacts of Nuclear Energy – Building a Nuclear Power Plant	Grade 11; Physics	Decide on whether constructing a nuclear power plant in Innergee, a little-known Ontario town, would impact on the community. The town hall involves speakers representing major stakeholders in this decision.	The case study scored 66 out of 80 on the DI Matrix. TCs addressed differentiating the process of the lessons by using a variety of engaging activities. TCs neglected to clarify the objectives, differentiate the content, ensure more student agency, and provide clarity on assessment criteria and rubrics.

A Detailed Analysis of the Case Studies

Seven case studies were analyzed according to the DI Matrix and included accompanying lesson plans, presentation, supporting documents and resources. This section details how TCs addressed each of the criteria in the DI Matrix, with a focus on best practices.

Domain 1: Quality Curriculum and Lesson Design

The first criterion in this domain includes what students should know, understand, and be able to do. To attain the expert level, the case studies' lesson objectives should comply with the written curriculum standards (Ontario Ministry of Education, 2008), and the important ideas, issues, or problems specific and meaningful to the content area. The objectives need to extend learning in authentic ways. TCs showed excellent implementation of this criterion with three case studies reflecting scores at an expert level and four case studies at a practitioner level. With respect to the second criterion, the activities of the lessons within the case study need to be clearly linked to the objectives. TCs also showed excellent implementation of this criterion with four case studies showing an expert level and three case studies showing a practitioner level.

In general, TCs showed a mastery of this domain. Most TCs were able to address the case study-related skills as well as the learning goals and science content objectives. For many case studies, the four required lessons provided opportunities to address many objectives, hence offering rich science content. Yet, few TCs focused more on the case study requirements such as note-taking, KWL charts, consequence maps, and cost-benefit analysis, rather than the science content. Most TCs were able to smoothly integrate the case study components within the lessons, and thereby use the case study as a tool to teach the science content.

Domain 2: Response to Learner Needs

First, to attain the expert level on the first criterion- preassessment, the case study should reflect multiple sources of preassessment data and student learning profiles in advance of the lesson to address and plan for student needs. In general, TCs showed a good level of implementation of this criterion with three case studies scoring at an expert level, three case studies at a practitioner level, and one case study at an apprenticeship level. For example, TCs frequently used pre-assessment and proactive assessment within formative assessment. They included brainstorming activities and referred to students' prior knowledge in their lesson plans, which demonstrates awareness of the importance of tackling students' prior knowledge and misconceptions through diagnostic assessments before introducing new concepts. On the other hand, some groups relied on graphic organizers (e.g., KWL charts) to explore students' prior knowledge. One group did not include a diagnostic assessment. Several groups did not show consistency in tackling students' prior knowledge throughout the whole case study and included this aspect in only one or two lessons. Samples of diagnostic assessment include the following statements:

> Find out what students know about clean drinking water in First Nations communities. Find out why a boil water advisory would be in effect. (Group C, lesson plan)

> To recap information from the preceding day's class, a "mind-on" activity must ensure the students understand earlier concepts before moving on to the next topic. (Group D, lesson plan)

The second criterion in this domain is scaffolding, specifically for struggling learners. To attain the expert level on this criterion, the case study must be inclusive, for example for special education students, English language learners (ELLs), and students with low reading abilities. Struggling learners need to engage with high-quality tasks, with appropriate scaffolding to attain the same learning goals as other students. In certain cases, individual educational plans (IEPs) need to be provided to certain students. Multiple indicators are used when grouping students so that struggling learners experience a variety of grouping strategies. Four case studies scored at an apprenticeship level, two at a practitioner level, and one at an expert level. Most case studies did not indicate any special arrangements in this regard. This criterion was superficially addressed through flexible grouping and the use of multimodalities. For example, one group included:

> Students are given the opportunity to read the case study on their own or have a PDF read out loud with their Chromebooks. This helps accommodate ELL students, who may have a difficult time with written material. The teacher can also provide students with the option to use a translator extension if they require one to read the case study. (Group F, lesson plan)

One group also included a voice-over option along with the provided text to students in a presentation, demonstrating more inclusivity to specific groups of students with special needs. Yet, TCs demonstrated a lack of awareness and consistency in addressing various student needs. Several groups referred to ELLs in their lesson plans which reflects an accepted level of awareness. Yet, there were no practical strategies planned to cater for their needs. An example of an incomplete adaptation is:

> Ask students with IEPs and ELLs how they find the lesson if they feel they need to go to resource or would like additional materials. (Group D, lesson plan)

In general, this criterion requires improvement. For example, none of the groups mentioned modifying the pace of learning for different groups of students or modifying the learning objectives at certain learning stages. Moreover, the adaptations were inconsistent throughout the same case study and thereby needing much reinforcement.

Finally, to attain the expert level on the third criterion- challenging advanced students, the case study must challenge high-achieving students at higher levels of complexity and quality, not quantity. Five case studies reflected scores at an apprenticeship level, two at a practitioner level, and none of the case studies scored at an expert level. The average score on this criterion was the lowest among all 20 criteria indicating that most case studies did not include special arrangements for challenging advanced students. Furthermore, most case studies did not mention this group of students. The arrangements included flexible grouping and independent research by students to reach a more in-depth understanding, yet worksheets, rubrics, and class activities did not address this category of students explicitly. While certain tasks enable students to work independently, and others require critical thinking, high achievers in general were not provided with multiple options to expand their knowledge. Thus, this is one criterion that needs to be further developed in the future.

Domain 3: Planned Instructional Practices

For the first criterion – lesson organization – to attain the expert level, the case study lessons and elements need to be organized in a coherent (organized, unified, and sensible) manner, producing a unified whole. TCs showed an excellent implementation of this criterion with six case studies scoring at an expert level and one at a practitioner level. In all case studies, lesson plans were clear and comprehensive, well-organized, and easy to follow. As well, all lessons and activities were linked and connected appropriately.

For the second criterion – modes and strategies of instruction – to attain the expert level, the case study lessons and elements should utilize multiple modes of instruction that require active learning and exploration of student understandings. The lessons should intentionally match the learning profiles and the learning needs of students. As well, the strategies and activities should reflect best practices in that content area. TCs showed very good implementation of this criterion, with four case studies scoring an expert level and three at a practitioner level. For example, Group C used think-pair-share, a map visualization and analysis activity, video and picture analysis, note-taking activities, class discussions, online game activity, independent and group research, and a debate throughout their four lessons. Activities of Group B included videos, jigsaw, hands-on activities, drawing graffiti activity, class discussions, and group activities. Group D included labs, Kahoot activities, table group discussions, infographic analysis, debates, article analysis, and hands-on activities such as extracting microbeads. Thus, there was an evident utilization of multimodalities especially digital resources, a variety of student-centered activities, and inquiry-based instruction by all groups. On the other hand, two main points of improvement are consistency in integrating multiple tools throughout all lessons and avoiding long phases of direct instruction. One possible reason for prolonged direct instruction is the variety of new case study elements which TCs chose to introduce through teacher explanation.

For the third criterion – engagement capacity of activities – to attain the expert level, the case study lessons and elements should be stimulating, motivating, and engaging to learners; link to students' prior learning or experiences; and clearly connect to their lives and/or goals. Students should be able to explicate connections between lesson content, practical applications, current events, the real world, or other aspects of the content area. TCs demonstrated very good implementation of this criterion with four case studies scoring at an expert level and three at a practitioner level. The variety of activities presented in the case studies ensured high levels of student engagement. For example, lessons included hands-on activities, roleplay, demonstrations, digital games, online simulations, videos, mind maps, note-taking activities, infographics, group work, class discussions, think-pair-share, student independent research, debates, and jigsaw activities. Furthermore, the topics tackled by the seven case studies, and the questions raised, are highly linked to students' daily lives and real-world implications.

For the fourth criterion – student intellectual development – to attain the expert level, the case studies should enable each student to work at levels of readiness, interest, and/or learning profile that are appropriately challenging. The lessons should be designed so that all students are encouraged to do their best and complete high-quality work. The strategies and activities should promote higher order thinking for all students. TCs demonstrated very good implementation of this criterion, with three case studies scoring at an expert level and four at a practitioner level. Three major factors contributed to TCs achieving this level. The first factor is the inclusion of a variety of activities and case study components requiring students to engage different levels of thinking in each activity. Some activities require advanced levels of high order thinking skills such as critical thinking and evaluation. For example, Group C planned the following activities:

> Break the fake activity: Students will learn about criteria to assess online resources to determine the validity and reliability of the information. They will learn about two different methods of note taking while researching to help keep the information they find organized.
>
> Cost-Benefit Analysis: Ensure that students are using valid reasoning to create their cost and benefit values on a scale from 1 to 5 and the probability of the result occurring. Where possible, they should include references for the sources of their information.

The second factor contributing to implementation of this criterion is the 5E inquiry model, which requires students to explore content. Finally, the third factor is engagement in discussions and debates about a controversial topic from various opposing perspectives and viewpoints, thus requiring students to be prepared with different arguments that enhance their analytical and critical thinking skills. This argumentation also extends students' personal knowledge to a new context. For example, Group F stated the following in their peer presentation:

> The teacher should encourage students to consider opposing arguments in preparation for the debate during the research period (lesson 3). One way to do this is with a consequence map. If the claimant will open with, for example, a positive economic consequence for the Three Gorges Dam, a member of the opposition can use a negative economic consequence as part of their rebuttal.

Furthermore, student readiness is reflected in the depth of information they research and present to their peers, with higher performing students presenting deeper understandings of the subject matter. Also, students' interests were addressed by most groups who allowed students to choose the stakeholders they want to represent, take a stand, and defend it using their own arguments. This strategy ensures students relate on a more personal level and thereby contribute more so to the ongoing class discussions. On the other hand, the major notable point of improvement in this criterion relates to certain case studies in which students' roles are restricted to the application level rather than encompassing higher order thinking. Moreover, many TCs did not explicitly indicate how they would promote higher order thinking especially for high achievers. This result was discussed earlier in Domain 1.

For the fifth criterion – flexible grouping – to attain the expert level, the case study lessons should include various student groupings such as individual, pairs, and small groups, whenever applicable. Students are grouped for a great variety of reasons to differentiate content, process, and/or product by readiness, interest, and/or learning profile. The lesson may combine grouping rationales (i.e., readiness and interest), and flexibility in grouping strategies is in response to a clear analysis of student needs. TCs showed excellent implementation of this criterion, with six case studies scoring at an expert level and one at a practitioner level. All case studies included a variety of independent work, think-pair-share, group work, and general class discussions across the lessons. The last lesson in all case studies also included a debate (e.g., fishbowl debate) or a townhall between students to discuss and present their viewpoints. Moreover, several groups stated that they would change the group members' composition throughout the case study to ensure more student interaction and exchange of ideas.

For the sixth criterion – teacher and student roles – to attain the expert level, the case studies need to ensure that the teacher's overall planned role is primarily that of coach or facilitator. Both students and teacher need to have consistent input into lesson content, with a balance of student and teacher choice, with students taking on increasing responsibility for their own learning. TCs demonstrated good implementation of this criterion with two case studies scoring at an expert level and five at a practitioner level. The role of the teacher as a facilitator and the prevalence of student choice were evident in most case studies. For example:

> The teacher should circulate the room and support/observe group progress. Once all groups have completed their consequence maps, the teacher can facilitate a discussion where ideas from all groups can be consolidated. (Group A, lesson plan)

While most lessons followed a student-centered approach, some TCs chose direct instruction to introduce certain concepts or case study components such as the cost-benefit analysis and consequence maps. For example, Group C stated:

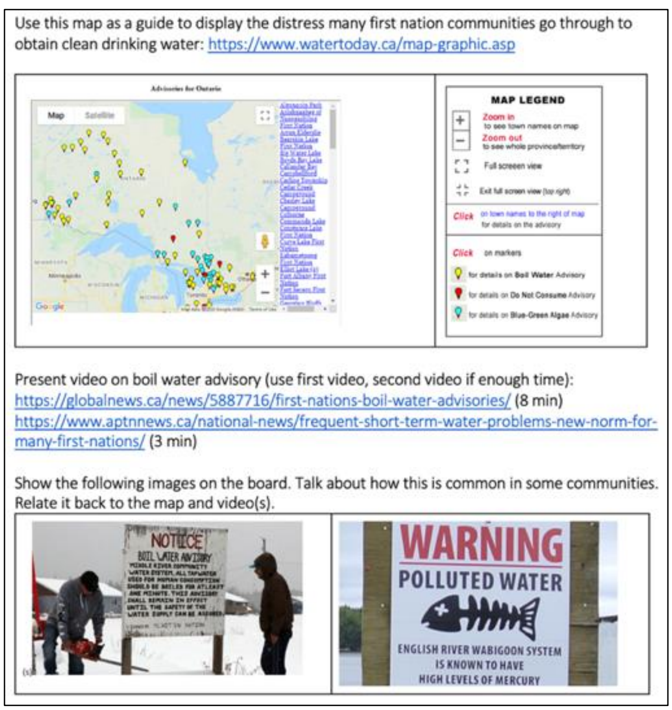
> Introduce students to consequence map and options for how to organize. Provide time for independent research and note taking using three methods. Provide time for group research for 'stakeholders' to amalgamate their research and formulate a stance. (Lesson plan)

Moreover, some TCs' excessive reliance on showing videos to explain certain concepts posed a few challenges in terms of the level of inquiry and student agency in the classroom. While videos and other audio-visuals are engaging, they may situate students as passive recipients of knowledge. Accordingly, TCs were advised to substitute those with other activities that enable students to lead and understand the content on their own. Furthermore, some TCs showed hesitation when providing students will full autonomy. This hesitation is expected from novice teachers who may not have the confidence to provide this agency to their students. For example, Group G stated: "Students will be assigned a stakeholder- they can also choose depending on class dynamics." (Lesson plan)

For the seventh criterion – technology integration – to attain the expert level, the case study should exhibit exemplary and proficient use of digital material. This action would render the lesson fully implementable in an online environment. TCs showed a good implementation of this criterion, with one case study scored at an expert level and six at a practitioner level. TCs included a vast array of digital resources such as Kahoot activities, simulations, digital maps, digital games, online articles, internet research, and audio-visuals. See Figure 2 for an example.

Figure 2

Sample Digital Activities, Group C – Water in Indigenous Communities, Supplementary Teaching Resources



Since the data was collected during the COVID-19 pandemic, TCs took into consideration the fact that they may use these case studies either in-person or in an online teaching environment and succeeded in this adaptation. Several groups were advised to maintain consistency in integrating digital resources throughout the case study lessons, and not only in some of them.

Domain 4: Student Assessment

For the first criterion, formative assessment, to attain the expert level TCs should plan to regularly use formative assessments throughout the lessons. Information from these lessons should be utilized in modifying instruction within a lesson, gauging student understanding, and planning future instruction for individuals and groups. TCs showed a very good implementation of this criterion with four case studies scored at an expert level and three at a practitioner level. TCs integrated formative, diagnostic, and summative assessments in their case studies. Several case studies explicitly included assessment for, of, and as learning within the lesson plans. Moreover, multiple tools were included to assess students such as a prior knowledge check, KWL charts, polling, lab sheets, fact sheets, worksheets, note-taking, exit tickets, student reflections, and rubrics for class discussions and debates. TCs' awareness of the importance of a variety of assessment strategies, especially formative assessments, is highlighted in the following excerpts from the lesson plans:

> Ensure that students come prepared with research notes taken from previous classes. Please review the following teacher instructions for Day 1 and Day 2 of the activity and read the student task to all students at the beginning of class. (Group C, lesson plan)
>
> Constant check-ins with the class to see if we are moving too fast or if they understand concepts. (Group D, lesson plan)

Furthermore, TCs provided students multiple ways to present their understanding, especially at the end of the case study. This strategy offers students multiple options to express and convey their understanding in ways that match their levels of readiness and interest. Major points of improvement in this criterion include: 1) integrating more variety in the assessment methods throughout the case study rather than relying only on the case study note-taking sheets; and 2) making the assessment section more explicit in the lesson plan, and not only in the lesson closure section, to highlight its importance and to reinforce the importance of ongoing assessment during the lesson rather than only at the end.

To attain the expert level on the second criterion, assessment rubrics and guidelines, TCs should clearly articulate the rubrics and guidelines through specific assessment criteria and standards. Students should have the ability to participate in the creation of the rubric/guidelines and actively plan next steps for learning. TCs showed a good implementation of this criterion with five case studies scored at an expert level and two at an apprentice level. Most case studies included clear and comprehensive rubrics for different instructional activities, especially the consolidating debate. Rubrics entailed clear indicators and specifications that measure various components such as students' knowledge, application, thinking, and communication. Two case studies at the apprentice level included assessment criteria such as worksheets but did not include rubrics for the final class discussion/debate.

Domain 5: Supportive and Inclusive Learning Environments

For the first criterion, EDI principles, to attain the expert level TCs must demonstrate a sophisticated understanding of EDI principles. They need to effectively implement inclusive and culturally responsive pedagogy. Planned lessons should fully reflect and attend to diversity (race, ethnicity, culture, religion, SES, immigration status, Indigenous communities, Indigenous histories and ways of knowing, sexual orientation, gender identity, etc.). TCs demonstrated good implementation of this criterion with three case studies ranked at an expert level, three at a practitioner level, and one at an apprentice level. First, the nature and choice of the case study topics around SSI made it easier for TCs to relate their cases to EDI principles. For example, Group C tackled water filtration in Indigenous reserves, which directly relates to equity practices and Indigenous communities. Similarly, Group A discussed equity in accessing COVID-19 vaccines. Second, the case study format allows for addressing various backgrounds and perspectives. Student awareness of different perspectives on scientific topics could eventually lead to a more inclusive and respectful approach when discussing those topics, as illustrated in Table 2 in which the key stakeholders pertaining to each case study are included.

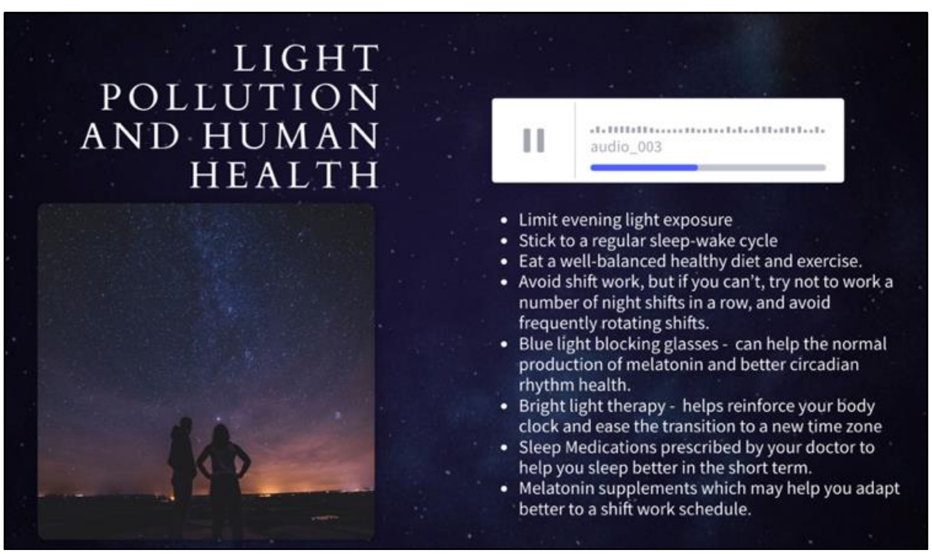
Moreover, TCs were aware of non-Western centric approaches in science. Many of them integrated Indigenous ways of knowledge within their teaching, as shown in the excerpt below.

> While vaccines are largely a product of modern and "Western" science, teachers should take care not to ignore or undermine other ways of knowing such as Indigenous ways of knowing. In the case of the prevention and treatment of communicable diseases, Indigenous science, and contributions to the development of medical treatments and remedies should be included in discussion... Care and consideration should be taken as Indigenous communities have historically experienced viral epidemics…. It is possible students in the class may have ancestors that experienced these epidemics... Below are some resources that can support both teacher's and student's understanding of Indigenous people, viral epidemics, and vaccines … (Group A, lesson plan and supplementary teaching resources)

Third, most TCs dedicated a part of their lesson plans to explicitly discuss EDI-related principles and teaching methods. TCs highlighted how they would address different student backgrounds and differentiate their instruction. For example, Group F planned for engaging parents as per Ontario's Equity Plan, providing accommodations and multimodal presentations, and addressing different backgrounds and perspectives. Group G included multimodal presentations, addressing different backgrounds and perspectives, and integrating Indigenous ways of knowledge. This finding shows that TCs were able to link DI to EDI principles. Finally, some TCs provided accessibility accommodations for students with different needs (e.g., visually impaired, ELLs, low reading proficiency) as shown in Figure 3.

Figure 3

Voice-over Option Provided by Group E as an Accommodation Strategy



For the second criterion, respectful behavior toward and among students, to attain the expert level the case study should foster active participation and questions from all students. Awareness of students' strengths, successes, and contributions are to be cultivated and celebrated. TCs demonstrated exemplary implementation of this criterion with six case studies ranked at an expert level and one at a practitioner level. For instance, TCs situated their roles as facilitators in the classroom, thus respecting student choices and discussions. On the other hand, Group C stressed respectful behavior among students in their instructions and assessment guidelines.

For the third criterion, sense of community and collaboration, to attain the expert level, the case study should enable students and teacher to consistently focus on both individual and group excellence and growth. Students should consistently engage and support one another in learning and be supported to work with any student in the class. TCs showed very good implementation of this criterion, with five case studies at an expert level and two at a practitioner level.

Domain 6: Evidence of Differentiation

The first criterion, content differentiation, refers to adapting what is taught and modifying how students are given access to the information and understandings (Tomlinson, 2001). The planned lessons need to be highly concept-based and make use of diverse materials at various levels of readability, complexity, and/or interest. Lessons shall include, but are not limited to, one or more of the following strategies: multiple ways to access and organize information, learning contracts, curriculum compacting, flex-group mini-lessons, and varied support systems such as audio/video recorders, note-taking organizers, highlighted print materials, digests of key ideas, and peer/adult mentors. TCs showed a novice implementation of this criterion with no case studies scored at an expert level, while five were scored at a practitioner level, and two at an apprentice level. As explained previously, TCs effectively utilized the different note-taking organizers as instructed by the course instructor such as KWL charts, Cornell's note-taking sheet, and consequence map. Yet, the lesson plans of most TCs did not adeptly change the complexity levels and/or the pace of learning for various students. This shortcoming justifies the relatively lower scores on this criterion compared to others.

The second criterion, process differentiation, refers to the instructional activities that represent a diversity of approaches at varying degrees of sophistication, with several levels of scaffolding, and completed in different time spans (Tomlinson, 2001). Process differentiation can happen in one or more of the following ways: readiness by matching complexity of task to student's current level of understanding; interest by giving students choices and linking to personal interests and/or goals; and learning profile by making sense of ideas reflected in the students' preferred way of learning. TCs demonstrated good implementation of this criterion, with three case studies rated at an expert level, three at a practitioner level, and one at an apprentice level. In addition to the previously included samples, the following samples reiterate the findings:

> This lesson includes multimodal representations of information (text, videos with audio, visual diagrams/descriptions etc.) ... The consequence map activity encourages inclusion of all student voices in group work and allows students to organize and express their thinking in a way which is not heavily reliant on writing skills. (Group A, lesson plan)

> For the research and Cornell note-taking activities, both videos and text-based learning is offered, in addition to oral discussion. Also, the arguments made during the debate do not need to strictly be verbal. Share text, images, and short videos if they can assist a student in making their point. (Group F, lesson plan)

The third criterion, product differentiation, refers to providing several product options that are designed to foster deeper and richer understandings of the unit's goals. Products may differ due to curriculum requirements or student readiness, interest, or learning profile (Tomlinson, 2001). Guidelines provide the perfect balance between structure needed to focus and guide students, and the freedom to support innovation and thought. Students collaborate with the teacher to design the project requirements, timeline for completion, and assessment criteria. The teacher works as a coach to facilitate, scaffold, and expand the students' thinking through flexible study groups, mini-lessons, and conferencing. TCs showed good implementation of this criterion with three case studies scoring an expert level, two at a practitioner level, and two at an apprentice level. Several groups provided a wide array of different assessment strategies for students to demonstrate their understanding. Nevertheless, additional options would provide more choice for students. TCs stated:

> Several opportunities to individualize and differentiate the assessment are available:
> - No more than two debates per day to give each student time to meaningfully participate. Following the debate, students will complete a cost benefit analysis of the Three Gorges Dam issue, along with the learned section of the KWL chart.
> - Brainstorm, discuss, then present (mind map, infographic, skit, etc.) different ways how technologies have made a change with our energy consumption. (Group F, lesson plan)
>
> - Students have the chance to communicate orally and in writing.
> - Digital, Differentiated Instruction - In lieu of writing a paper, teachers can also consider presenting students with the option of presenting their discussion and analysis in a pre-recorded video.
> - Students can then use visual graphics to support their arguments. This method may also remove some essay-writing anxiety. (Group G, lesson plan)

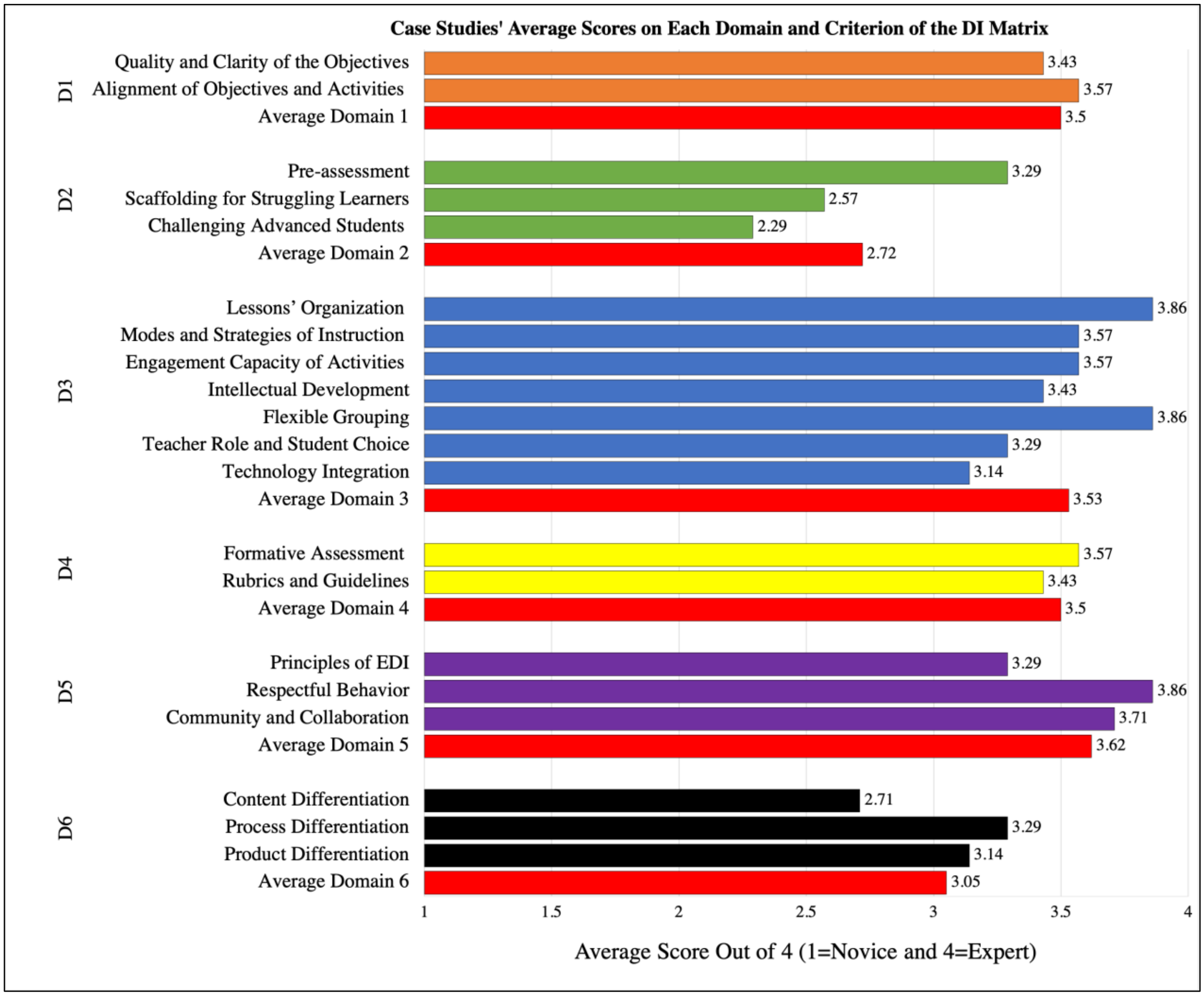
Quantifying Case Studies' Analysis

A score out of four was allocated to each case study in each of the 20 criteria in the DI Matrix, where (1) indicates "Novice", (2) indicates "Apprentice", (3) indicates "Practitioner", and (4) indicates "Expert". Figure 4 highlights the average scores of the seven case studies on each of the 20 criteria. In general, the average score on each criterion shows that the DI seminar and subsequent training had a positive impact on TCs' conceptions and implementation of DI. The average score of TCs' case studies between 1 and 2 was not recorded on any of the criteria, between 2 and 3 was recorded on three of the 20 criteria, and between 3 and 4 on 17 of the 20 criteria. This result shows that TCs showed practitioner to expert level on most criteria, which reflects good understanding and implementation of DI in the case studies. The highest scores were recorded on aligning the objectives with the activities (3.57), lesson organization (3.86), modes and strategies of instruction (3.57), engagement capacity of activities (3.57), flexible grouping (3.86), formative assessment (3.57), encouraging respectful behavior (3.86), and ensuring a sense of community and collaboration (3.71). These criteria scored between 3.5 and 4 which reflects an expert level.

On the other hand, other indicators reflecting a score between 3 and 3.5 show very good performance indicative of a practitioner level. These are quality and clarity of the objectives (3.43), pre-assessment and proactive preparation (3.29), working on students' intellectual development by addressing different thinking levels as per Bloom's taxonomy (3.43), teacher's planned role, learner independence, and student choice (3.29), technology integration (3.14), using rubrics and assessment guidelines (3.43), integrating the principles of EDI (3.29), differentiating the process (3.29), and differentiating the product (3.14). The three indicators that need improvement, indicative of apprenticeship level, are scaffolding for struggling learners (2.57) with four case studies showing apprenticeship level, challenging advanced students (2.29) with five case studies showing apprenticeship level, and differentiating the content (2.71) with two case studies showing apprenticeship level, five case studies showing practitioner level, and none of the case studies showing expertise level.

Figure 4

The Average Score (out of 4) of the Seven Case Studies Per Domain (D1-D6) and Constituent Criteria



To obtain a general and holistic overview of TCs' implementation of DI in their case studies, the average score on each domain was calculated for all case studies by calculating the average score of the criteria in each domain (also shown in Figure 4). Additionally, the average scores on each domain were converted to percentages. TCs demonstrated exemplary performance on four of the six domains: Domain 1 – quality curriculum and lesson design (7 out of 8: 87.5%); Domain 3 – planned instructional practices (24.71 out of 28: 88.25%); Domain 4 – student assessment (7 out of 8: 87.5%); and Domain 5 – positive, supportive, and inclusive learning environment (10.86 out of 12: 90.5%). On the other hand, the averages on Domain 6 – evidence of differentiation was 9.14 out of 12 or 76.16%; Domain 2 – response to learner needs scored the lowest average of 8.14 out of 12 or 67.83%. The relatively low scores on Domain 2 are further reinforced on the content differentiation component in Domain

6. TCs showed relatively low implementation in terms of adapting the lessons to various academic achievement levels.

Discussion and Conclusion

Based on the findings, TCs were successful to a high extent in developing differentiated curriculum using the case studies of SSI. TCs showed excellent performance on four of the six domains: quality curriculum and lesson design, planned instructional practices, student assessment, and positive, supportive, and inclusive learning environments. However, the domains related to responding to learner needs and content differentiation showed relatively low levels. TCs demonstrated proficient integration of strategies related to differentiating the process most, followed by the product of learning yet showing a need for more training in content differentiation to attend to students' needs, backgrounds, and academic levels.

In terms of TCs' detailed DI skills, the relatively high scores on the assessment domain in the DI Matrix contradicts what is documented in the literature related to teachers facing difficulties in differentiating their assessment strategies (Rollins, 2010; Wan, 2017). However, a major area of improvement that this study highlighted is TCs' ability to differentiate the content component. TCs needed more guidance on how to scaffold learning for struggling students, attend to special need students, cater their teaching for various linguistic abilities, and challenge advanced students. This finding parallels the conclusion documented in other studies that teachers usually understand the differentiation of the content the least compared to other components (Estaiteyeh & DeCoito, 2023a, 2024; Turner & Solis, 2017). This finding is also in harmony with de Jager (2017) who maintained that most teachers find it difficult to adopt a flexible curriculum and provide extra time for their students. This challenge has also been documented by Wan (2017) who maintains that teachers believe that the great diversity among students in the same classroom poses difficulty in their ability to attend to all learner needs. Furthermore, it is important to note that while this analysis focuses on the ability of TCs to integrate DI strategies in their curriculum, DI was not the only focus of this assignment. For instance, this was the first experience for TCs developing case studies of SSI in the teacher education program despite their prior knowledge of case studies and SSI as stand-alone concepts/strategies. Thus, TCs had to address several criteria which may have hindered their full incorporation of DI.

TCs' work on DI-focused case studies also addresses two major challenges that typically hinder teachers' implementation of DI in their classes, i.e., limited curriculum resources and insufficient training (de Jager, 2017; Turner & Solis, 2017; Wan, 2017). Concurrently, this research addresses some of the pedagogical challenges that teachers face when teaching using case studies of SSI, including unfamiliarity with the strategy and difficulty matching case problems to course content (Mostert, 2007); tackling controversial issues and considering students' backgrounds (Şen Akbulut & Hill, 2020); self-efficacy beliefs to integrate SSI into the curriculum (Sibic & Topcu, 2020); availability of teaching resources (Hancock et al., 2019); and lack of training (Chang & Park, 2020).

In terms of the compatibility of case studies of SSI and DI, the overall analyses of the assignment design and requirements as well as TCs' coursework indicate that case studies of SSI are well suited to incorporate DI. This compatibility renders case studies of SSI as promising tools to differentiate instruction in STEM classrooms. This is mainly because case studies present multiple perspectives and opposing arguments on debatable topics (Hemphill et al., 2015) and enable multiple levels of analysis and interpretation (Levin, 1995), which is in accordance with the philosophy behind DI as an equitable and inclusive pedagogy in diverse classrooms (Estaiteyeh & DeCoito, 2023b; Tomlinson, 2021, 2022). Hughes (2000) maintains that SSI promote students' socioscientific awareness of the various dimensions to science and presents science as accessible to various underprivileged groups. Furthermore, since SSI advances students' reflective judgement and argumentation (Sadler & Zeidler, 2004; Zeidler et al., 2009), this assignment proved to be adequate for differentiating instruction, as exemplified in TCs' coursework. This result was specifically facilitated by several components of the SSI case studies such as: 1) multiple stakeholders involved; 2) several sequenced lessons enabling the use of variety of teaching and assessment strategies; 3) multiple graphic organizers, note-taking frameworks, and sheets required in the analysis of the case; 4) presenting to different audiences; and 5) the debatable SSI topics that require attending to the rights and living conditions of minorities and underprivileged communities. Teachers can therefore capitalize on these components to embed DI practices within case studies of SSI, and thereby attain potential positive outcomes of both.

Limitations and Implications

One of the study limitations is the potential disconnect between TCs' curriculum development work and their classroom instruction. Due to the COVID-19 pandemic and the scope of the study, the researchers were not able to observe TCs while implementing their case studies in a classroom setting. As such, future research for teacher educators and researchers in the field can follow-up with TCs or in-service teachers on the implementation of case studies in their classes to attain the full picture of the impact, real-life successes, and challenges of the developed DI-focused curriculum. Additionally, given that the instructor provided TCs with feedback that guided their work, future research can explore the various levels of support and scaffolding that need to be provided to TCs so that they can engage in curriculum development proficiently. Moreover, further research for educators and curriculum designers can focus on how to develop strategies related to content differentiation specifically, which was noted as a significant challenge for TCs in this study.

This research advances knowledge about DI as a pedagogical practice in STEM education utilizing case studies of SSI. This is a unique study that presents case studies of SSI as an avenue to facilitate DI. STEM TCs in this study were provided with rich opportunities to engage with DI as a form of professional development. The explicit, reflective, collaborative, and interdisciplinary training model, showcased in this study, is of benefit to STEM teacher education programs. Adopting this training approach addresses significant gaps in the literature and the practice related to integrating equitable and inclusive pedagogies in STEM curriculum as well as creating teaching materials relevant to case studies of SSI. Overall, this work offers a foundation for a multi-year effort, providing important data for STEM researchers regarding 1) prior preparation needed by TCs as an entry point to this field; 2) multiple experiences that may enable TCs to navigate this complex landscape in meaningful ways; and 3) various classroom-based and/or online experiences that may enable TCs to experience how the theory plays out in actual classroom contexts.

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Preservice Mathematics Teachers' Dispositions Regarding Tasks in a Computer-mediated Learning Environment

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ABSTRACT

The aim of this research is to examine preservice mathematics teachers' dispositions toward drawing geometric patterns in tasks and find out their perspectives on using these tasks for their future students. Sixty preservice mathematics teachers who enrolled in a methods course for 14 weeks participated in the research. The responses to the written questionnaire were evaluated through document analysis. As a result, two perspectives — I as a learner position and I as a teacher position — were used to group the preservice teachers' dispositions. Under the headings of the socio-psychological approach, cognitive conditions of sensorimotor skill acquisition, and epistemological approach, the perspective of a learner was investigated. The perspective of being a future teacher was examined under the vocational and pragmatic approaches. From learner and teacher perspectives, the participants support GeoGebra's use in mathematics classes, even though they initially knew nothing about GeoGebra in the learning process. The participants mentioned that learning GeoGebra and the use of the application in the learning process, such as dragging, copying, easily rotating shapes, and getting their symmetries, contributed to learning geometry as well as developing positive feelings towards mathematics.

Keywords: tasks, geometric patterns, preservice mathematics teachers, computer-mediated learning environment, I-positions

Introduction

Technology has become indispensable in today's world. In the field of mathematics education, it not only serves a basic need but also acts as a catalyst for transformation. Such technologies are known as Information Communication Technologies (ICTs) and include a variety of tools such as calculators, virtual reality applications, computer algebra systems, and dynamic geometry software. However, the impact of technology on mathematics teaching and learning, as well as its integration, has long been the focus of mathematics education research. The existing literature presents findings indicating that technology use affects mathematics achievement positively (Özçakır & Çakıroğlu, 2019; Turk & Akyuz, 2016) and contributes to the development of a positive attitude towards geometry and the mitigation of anxiety (Wittman et al., 1998). Numerous studies have investigated the roles of students' and teachers in Computer-mediated Learning Environments (CLEs) (Bartolini Bussi & Mariotti, 2008; Drijvers & Trouche, 2008). These studies offer detailed insights into the learning process. Indeed, the integration of technology into mathematics lessons has the potential to improve achievement and disposition. However, the success of this integration largely depends on teachers' perspectives. Their views on using technologies, along with their own experiences in computer-mediated lessons, play a crucial role. Research has shown that teachers' attitudes toward a subject (in our case, employing technology to teach mathematics) and their personal educational experiences have an impact on how they manage the teaching and learning process (Baumert et al., 2010; Campbell et al., 2014). Therefore, it is important for preservice mathematics teachers (PTs) to participate in methods courses that incorporate technology. Computer-mediated courses also encourage PTs to reflect on their experiences and include a review of this reflection process. Teacher education programs are specifically designed to facilitate a transformative process in students, enabling them to adopt the perspective and role of a teacher. The courses offered within these programs play a crucial role in fostering the development of teacher identity among students. Examining the efficacy of computer-mediated courses is important for the professional identity growth of teachers and PTs (Lai & Jin, 2021; Ye & Wang, 2023). The aim is to prepare them to become future teachers who are adept at utilizing technology.

Dynamic geometry software such as Cabri, Sketchpad, and GeoGebra have become essential for mathematics education. They allow teachers to create specific tasks for instruction (Ndlovu et al., 2013). According to findings from research, teachers' development of computer-mediated tasks can enhance cognitive and affective gains for students (Aruvee & Vintere, 2023; Turk & Akyuz, 2016; Wangid et al., 2020; Wittman et al., 1998). Such studies present findings indicating that the use of ICTs in lessons decreases mathematics anxiety and develops a positive disposition. In their study, Turk and Akyuz (2016) emphasized that students in computer-mediated classes displayed higher levels of excitement and curiosity. These authors reported an enhanced enjoyment of learning geometry through GeoGebra tools, which contributed to a positive disposition towards geometry within the experimental group where GeoGebra was implemented.

Furner and Duffy (2002) emphasized the profound influence of mathematics anxiety on students' attitudes and dispositions towards the subject and highlight the essential role of teachers in shaping students' experiences. A teacher's level of knowledge, and the manner in which they employ such knowledge, influence students' disposition and achievement (Baumert et al., 2010; Campbell et al., 2014). Teacher's types of knowledge, particularly pedagogical content knowledge (PCK) and knowledge of integrating technology into the lessons (Technological Pedagogical Content Knowledge-TPACK), are crucial factors in helping them become successful instructors (Guerrero, 2010; Hill et al., 2008). Mathematics teachers should be supported regarding technology integration into lessons and thereby teach the efficient and effective use of technology.

Furthermore, it is imperative for PTs to participate in CLEs in mathematics teaching courses to acquire valuable learning and teaching experiences, as well as engage in computer-mediated tasks as learners. Consequently, PTs will acquire a deeper understanding of students' perspectives on computer-mediated tasks within their instructional settings, enabling them to proactively identify and resolve any potential challenges. Therefore, an investigation into PTs' thoughts and feelings regarding computer-mediated lessons is crucial for establishing their attitude and understanding towards conducting such lessons in the future. In this area, even though the early studies (e.g., Çakıroğlu et al., 2008) found negative beliefs regarding the use of technology while teaching mathematics, recent studies (Akkaya, 2016; Bingölbali et al., 2012) showed that PTs have positive opinions about employing technology in their upcoming mathematics teaching and they considered technology as a helpful tool, especially for geometry lessons when they are provided with CLE tasks.

Research indicates that mathematics in CLEs is more effective than traditional methods (Özçakır & Çakıroğlu, 2019; Sokolowski et al., 2015). This effectiveness is not limited to the cognitive domain but also extends to affective and psychomotor domains. Sokolowski et al. (2015) conducted a meta-analysis and found that CLEs produced a moderate effect size when compared to traditional instruction methods. The study conducted by Ndlovu et al. (2020) investigated the beliefs held by PTs regarding their intentions to incorporate technologies into their future mathematics classrooms. The feelings and thoughts of PTs about the utilization of technology constitute a determinant that will exert an impact on their future students. Therefore, the examination of PTs' present proficiency in technology utilization and their intentions towards integrating it into their future instructional methodologies are significant areas of investigation for the researchers.

The educational experiences of PTs have a significant impact on their future pedagogical approaches. It is crucial to examine students' learning experiences and their reflections on their learning (Ferguson, 2023). Therefore, PTs will gain practical knowledge not only in finding personalized ways to effectively integrate technology into educational settings, but also in crafting instructional tasks. PTs who lack hands-on training in CLE are bound to have their career paths affected by their orientations. As a result, this research aims to contribute to the field by offering insights into PTs' perspectives before they implement technology in their profession. In light of this information, the research questions are as follows:

- What are the experiences of the PTs in a methods course supported with tasks employed in CLEs?
- How do these experiences influence PTs' thoughts on teaching mathematics to their future students?

Theoretical Framework

Teacher education programs have a fundamental function in equipping PTs with essential professional knowledge and skills. Navigating the complexities inherent in their profession, PTs must concurrently develop a distinct professional identity. This identity involves a transformative journey from being a student to becoming a qualified teacher. To better understand and facilitate this transformation, our study employs two complementary theoretical frameworks aimed at enhancing the professional identity development of PTs: Wenger's (1998, 2010) sociocultural theory and Montaigne's insights with Herman's I-positions (Hermans, 2014). Wenger's framework provides a lens through which we can examine how the social environment shapes professional identity, while Herman's I-positions adds an introspective dimension to this discourse.

Wenger's Theory on Identity Development

Drawing on Wenger's (1998, 2010) theoretical framework on identity development, which emphasizes the importance of social interactions, one can derive valuable insights into the process by which individuals transition from being students to assuming the role of teachers. According to Wenger (1998), the formation of an individual's identity within a community is shaped by their actions and beliefs. More specifically, Wenger (2010) underscores the notion that one's identity is formed by a combination of past and future experiences, ultimately shaping one's present state. This process involves accumulating memories, skills, notable events, narratives, and social connections. Additionally, identity has a crucial role in shaping an individual's trajectory, as it establishes a framework for guidance, offering directions, aspirations, and self-images (Wenger, 2010, p. 185).

In Wenger's (2010) conceptualization, the process of establishing an identity is grounded in the *identification* and *negotiation* of meaning processes. Identification can be facilitated by three key factors: *engagement, imagination*, and *alignment*. Engagement refers to active participation within a community of practice, where individuals become involved and immersed in shared activities and goals. Imagination involves the ability to connect oneself to the broader world outside of the immediate community of practice, allowing for a broader perspective and understanding. Lastly, alignment pertains to the process of aligning one's own practices and actions with the established norms and values of the community of practice, ensuring coherence and integration within the collective endeavor. This process involves not only the construction of an identity but also the negotiation of meanings and practices. To examine the aspect of *identification* within the identity formation process, we have adopted the perspective of "being a learner," while the perspective of "being a future teacher" is employed to observe the *negotiation* aspect. In this current research, identification of the meaning process connects to the learner position through the aforementioned factors (engagement, imagination, and alignment) from the following perspective. For engagement, PTs were immersed in a method course where the CLE was introduced. Within this course, PTs actively participated in various tasks, both individually and as a class. In terms of imagination, during tasks, PTs envisioned themselves as students, either imagining current mathematical and educational scenarios, or hypothesizing potential challenges and reflecting on how such situations might pose problems for them as students. For alignment, the PTs, while performing their tasks, underwent a process of ensuring consistency and integration of their practices and actions, aligning them with a student's perspective in a collective endeavor.

According to Wenger (1998), it is also posited that *negotiations* have a crucial role in determining the level of active participation and influence individuals have in the practices they engage in. In the current research, PTs negotiate their future teacher's perspective to develop appropriate CLE tasks and employ these tasks by considering their prospective students. Hence, the development of one's identity is a continuous and dynamic process influenced not just by personal actions and thoughts, but also by the larger societal community in which the individual is situated. For example, in their study, Nguyen and Yang (2018) investigated the acquisition of teaching skills by PTs during their practicum and the subsequent impact of this educational experience on their professional identities as educators. The researchers drew upon Wenger's (1998, 2010) theory to gain insights into this process. Their research revealed that the formation of PTs' identities is an ongoing and evolving process, significantly influenced by collective activities stemming from their interactions with coordinating teachers, mentors, and students. Drawing from this understanding, Wenger's theoretical framework pertaining to identity formation provides a useful perspective for analyzing the evolution of teacher identity throughout the initial phases of their professional trajectory, particularly in the context of a methods course that integrates the notion of CLE.

Montaigne's Insights and Herman's I-positions

Transitioning to another theoretical insight, Montaigne's comprehensive exploration of self (as cited in Hermans, 2014) reveals the dual facets of "being a learner" and "being a future teacher." By employing Hermans' (2014) *I-position* technique, PTs can explore various facets of their identities, specifically those pertaining to their roles as teachers and learners. This exploration enables them to gain a deeper comprehension of these components. PTs can utilize this technique to actively engage in dialogue regarding their opinions and personal characteristics (Hermans & Herman-Konopka, 2010). For instance, Assen et al. (2018) conducted a study utilizing *I-positions* to investigate the growth of teachers' professional identities. Their findings indicated that engaging in dialogues in which teachers share boundary experiences and *I-positions* enables them to critically evaluate their teaching practices from a meta-position. Concurrently, these dialogues assist them in reconciling their myriad *I-positions*. Thus, it serves as a catalyst for educators to enhance their teaching practices and cultivate a stronger professional identity. Stenberg et al. (2014) performed a study to investigate the concept of *I-position* among first-year PTs, with the aim of gaining a deeper understanding of teacher identity. This study revealed that the majority of PTs' initial teaching responsibilities involved inspiring and encouraging students to engage in studying and acquiring knowledge. The identities of first-year PTs sometimes lacked consideration for contextual aspects pertaining to the classroom, society, and curriculum-related issues. These results highlight the crucial importance of teacher education in enhancing the process of teacher identity development. The *I-position* technique provides a scaffold for teachers and preservice teachers in crystallizing their identities.

By enrolling in holistic programs, spanning theoretical lectures to hands-on practicums, PTs carve their identities. The orientation of PTs towards the teaching-learning continuum plays a crucial role in the process of integrating knowledge and experiences throughout their educational journey. Therefore, the current research aims to investigate the self-perceptions of PTs about their professional potential as students and future teachers. This research seeks to gain a deeper understanding of PTs' professional identities and their engagement with the process of CLE, which encompasses both theoretical and practical aspects.

Method

The current research is characterized as a qualitative study, utilizing a case study approach to provide a comprehensive analysis of the topic at hand. Within the scope of a case study, which requires extensive investigation and analysis of a specific group or instance (Merriam, 2009), this research design enables an in-depth exploration of the complex dynamics affecting PTs in CLEs that employ task-based approaches. The primary goal of this research is to gain a deeper understanding of the experiences of PTs attending CLEs that employ task-based approaches in the methods course. In alignment with this primary aim, this research explores PTs' dispositions regarding the use of tasks within a CLE, aiming to foster critical reflection on their identities as both learners and teachers in future.

Participants

This research was conducted at a prominent Turkish university during the autumn semester of the academic year 2019-2020. A total of sixty PTs, consisting of thirty-one sophomores and twenty-nine seniors, who were enrolled in the mathematics education program, willingly participated in the research. These volunteers were primarily selected because they were enrolled in a course that utilized computers for mathematics instruction. None of the volunteers had previous experience with GeoGebra or any other type of computer-assisted learning environment. This research exclusively examined the utilization of GeoGebra, which was chosen for its dual advantages: being a publicly accessible dynamic geometry software and providing support for the Turkish language. The particularity of GeoGebra has permitted its integration into a higher education methodological course offered in the Turkish language, while simultaneously constraining the focus of the research to exclusively encompass experiences related to GeoGebra. In the educational environment, PTs in their sophomore year completed courses in mathematics, yet they did not engage in any formal pedagogical training. In contrast, senior PTs undertook a comprehensive curriculum that not only encompassed advanced mathematics courses but also included courses with a pedagogical focus. To maintain confidentiality, the participants were assigned numbers ranging from 1 to 60.

Data Collection Tools

The research employed a written questionnaire comprising four open-ended questions to ascertain the thoughts of PTs about the tasks employed in CLE for the teaching of mathematics. Additionally, a decision was made to verify the claims of the PTs by examining the drawings created using GeoGebra and the tasks assigned by the PTs. The participants were presented with the following series of open-ended questions:

(1) What did you gain as a learner while studying with CLE tasks? Please explain.
(2) What do you think about using tasks in mathematics teaching?
(3) If you think that these tasks are useful for students in mathematics teaching, in what way could the students benefit from them?
(4) If you think that these tasks are not useful for students in mathematics teaching, could you please explain why you think so?

The initial question delves into the perceptions of PTs regarding their own experiences with drawing-based learning as learners. The second question focuses on the perspective of PTs about the usage of tasks within mathematics teaching settings, considering both the perspectives of teachers and students. The third question is to ascertain the intentions of the PTs who replied positively to the previous question regarding their utilization of this instructional setting in their teaching career. The fourth question specifically targeted the PTs who gave unfavorable responses to the second question. It seeks to understand the reasons behind PTs' beliefs that engaging in such tasks would not be advantageous in their future careers as teachers.

Procedures and Data Collection

During a 14-week math teaching course in CLE, PTs received weekly in-person training sessions lasting three hours each, focused on the utilization of the GeoGebra software, which is freely available and can be used offline. During this procedure, the primary author ran instructional applications on the main computer, whilst the PTs typically operated the applications on their assigned computers. The PTs were provided with comprehensive information regarding the objectives and structure of the tasks, considering both the viewpoints of the teacher and student. Additionally, they were made aware of the potential outcomes, practical application, and instructional strategies for incorporating these tasks into the classroom setting. Initially, PTs were provided with a comprehensive introduction to GeoGebra and its significance within the educational setting. Next, PTs acquired proficiency in utilizing the toolbars of GeoGebra to manipulate and represent a diverse range of mathematical items, concepts, principles, and prepositions. Finally, PTs actively participated in tasks aimed at determining the most effective ways of representing those ideas, including algebraic, verbal, symbolic, and graphical approaches. When designing the tasks, the instructor considered two factors: 1) The development of certain classroom tasks was initiated by utilizing GeoGebra toolbars. As a teacher identity, PTs were asked to think about the GeoGebra toolbar that would be most advantageous for the present instructional task; 2) The PTs in the class were assigned tasks that required them to engage in critical thinking, considering situations where concepts and topics were presented from the perspectives of both a teacher and a learner.

Throughout the duration of the course, a total of 40 distinct tasks were carried out by the PTs over a span of 14 weeks. The primary focus of the 40 distinct tasks was to educate students on K-12 subjects, with a specific emphasis on the manipulation of geometrical transformations in an educational context. To explore the practical applications of geometric transformations, specific examples of geometric patterns were created on the coordinate plane, illustrating their relevance in real-world contexts. During instruction, PTs worked individually on their computers but also used collaborative classroom settings with groups of two to three PTs depending on the specific content and characteristics of certain activities.

After the 14 weeks of training, PTs were given two tasks to complete. The first of these was for the PTs to design a task involving GeoGebra that matches a learning goal they selected from the mathematics teaching curriculum (Ministry of National Education [MoNE], 2018). The second task was to employ GeoGebra to create a geometric pattern inspired by Bourgoin (1879). Throughout the

14-week instruction period, every PT completed two pattern drawings: one self-designed pattern and another pattern assigned by the instructor. This opportunity afforded researchers the ability to gain insights into the perspectives and dispositions of future teachers.

The primary data source for this research consists of the responses provided to the four open-ended questions mentioned previously. In light of these four questions, PTs were requested to meticulously write down their thoughts with the greatest detail. PTs were also asked to provide their names on the written questionnaire paper, as their GeoGebra drawings will be assessed in accordance with their responses.

Data Analysis

Hermans et al.'s (1992) framework of how a teacher's identity develops from a "multi-voiced", or "dialectic" self was used to analyze the qualitative data in this research. Using the *I-positions* points of view, such as "I as a teacher" and "I as a learner" (Hermans, 1996), a document analysis was conducted to address research questions about the experiences and dispositions of PTs who engage in task-based CLEs (Cornett, 1990). The researchers separately conducted a thorough analysis of the written responses provided by the PTs within the established framework. This analysis was performed multiple times, and the perspectives of both the teacher and learner identities were subsequently incorporated into the coding process using open coding, as outlined by Patton (2002). The researchers then proceeded to research and interpret the encoded texts while also engaging in the process of refining the codes during two distinct 2-hour video conferences conducted online. Themes were developed to classify the codes into coherent and meaningful units. The primary focus of the analysis was on the words used by the PTs to express their feelings and experiences regarding the utilization of CLE-related tasks in their own instructional practices and in their professional development as future teachers. The themes and codes are detailed in Table 1.

Table 1

Themes and Codes Clarifications in the Light of PTs' Role

The Role of PTs	Themes	Codes	Clarifications of the codes
I as a learner	Cognitive conditions of acquisition of sensorimotor skills	The context of using GeoGebra	-Being capable of mastering GeoGebra -Being aware of the practical use of GeoGebra -Being able to draw with GeoGebra
		The context of creating patterns	-Knowing specifications on how to make a pattern -Being able to draw easily
		The context of drawing	-Learning to draw better -Having ability to easily draw a pattern -Knowing the distinction between digital and hand-drawn techniques
	Epistemological approach	The context of technology and geometry relation	-Discovering GeoGebra's many facets -Being capable of using GeoGebra for geometric analysis
		The context of topics	-Learning to recognize shapes conceptually -Using GeoGebra to improve algebra and numbers -Using GeoGebra to improve geometry
		The context of thinking skills	-Having spatial thinking -Having geometrical thinking -Having analytical thinking -Having reasoning ability -Encouraging thinking differently

The Role of PTs	Themes	Codes	Clarifications of the codes
		The context of learning geometry	-Competence in identifying geometrical relations -Being able to use mathematical language -Being aware of different perspectives of mathematics -Learning during drawing
	Socio-psychological approach	Interest and curiosity	-Inciting interest and curiosity
		Motivation	-Providing motivation
		Enjoyable lesson	-Learning to enjoy the process of learning
		Struggle	-Having hard time
		Being patient	-Learning to wait patiently
		Overcome mathematics anxiety	-Getting over learner's fear of math
		Attention	-Improving learner's ability to focus
		Admirance / Respect	-Having a sense of admiration and respect
		Positive attitude	-Enhancing positive attitude
I as a teacher	Vocational approach	Learning environment	-Pondering interactive, individualized learning environments with the aid of CLE-related tasks
		Measurement and evaluation	-Having thoughts on utilizing CLE-related tasks to provide instant feedback, prevent misconceptions, and comprehend students' conceptions during and after instruction
		Teaching methods	-Pondering many instructional strategies to facilitate student learning
		Skill acquisition	-Considering the impact of CLE-related tasks in enhancing learners' skill acquisition
		Teaching process	-Considering about the contribution of CLE-related tasks to the teaching process
	Pragmatic approach	Technological perspective	-Highlighting concerns related to hardware and software
		Social interaction perspective	-Emphasizing concerns about the social development
		Professional perspective	-Highlighting issues regarding operating the task, managing time, and using GeoGebra as a manipulative
		Learning acquisition perspective	-Emphasizing concerns about the gains and losses in cognitive, affective domains

The analysis yielded five prominent themes that were evident in the perspectives of both the teacher and student identities. The cognitive conditions of the acquisition of sensorimotor skills, the epistemological approach, and the socio-psychological approach were assessed by analyzing the statements of PTs in their roles as students or learners. The issues of drawing, pattern creation using GeoGebra, and cognitive gains are all topics of interest that reflect the perspective of PTs when they perform the roles of typical learners and students in various tasks. To exemplify the cognitive conditions of the acquisition of sensorimotor skills, this research examined the improvements in the coordination between mental processes and physical actions, as reported by PTs or directly observed. The PTs addressed this procedure by considering the aspects of drawing, pattern construction, and the utilization of GeoGebra. The epistemological approach also elucidates the enhancement of cognitive abilities, such as thinking, learning, analytical proficiency, and similar skills. PTs reported that they noticed improvements in areas such as values, personality, and aesthetics; however, these transformations are not easily observable. This is where the socio-psychological approach comes in.

In contrast, both the vocational approach and the pragmatic approach were used to discuss the inner perspectives of PTs in their role as teachers. These overarching themes illustrate the perspectives of the PTs as teachers about CLE-related tasks. As an illustrative example, the pragmatic approach brings together the explanations provided by PTs on the advantages and disadvantages associated with technology within the educational setting. Additionally, it encompasses their concerns pertaining to classroom management and the challenges encountered with hardware and software.

The vocational approach represents the benefits of the PTs and could support their efforts in enhancing their mathematics instruction. Consequently, PTs participated in discussions regarding their perspectives on professional competence pertaining to teaching processes, classroom dynamics, assessment, skill acquisition, and instructional strategies.

The validity and reliability of the research were assessed by several methods. The researchers' long-term interactions with the PTs, their collection of data in the PTs' natural context, and their use of various data sources all improved the research's validity and reliability. Furthermore, the entirety of the data was subjected to independent analysis by two researchers, resulting in a 95 percent concurrence between their respective analyses. After a period of three weeks, a collaborative endeavor led to the achievement of complete synchronization with the agreed-upon protocols (Miles & Huberman, 1994). After a period of one month, the codes and themes that were obtained were reviewed and modified. The intent was to achieve reliability by considering the time gap and conducting a subsequent re-evaluation of the codes. To ensure the validity of the research, a comprehensive explanation of all stages was provided, as recommended by Maxwell (1992). The codes and themes that emerged were introduced using direct quotations from the remarks made by the PTs.

Ethical Considerations

Various strategies were implemented to address a power disparity between the course instructor and the research PTs. Initially, PTs were informed that their participation in the research was voluntary and that they had the freedom to leave at any point without incurring any negative repercussions. The PTs received a description of the research's objectives and assurances that their participation wouldn't have an impact on their academic performance. Researchers assured the PTs that confidentiality would be maintained in all written reports from the research, acknowledging the significance of these aspects in relation to the power issue.

Results

The findings are provided in the result section using two primary lenses: *I as a learner* and *I as a teacher*. The present research provides a comprehensive analysis of the findings, organized according to thematic categories (cognitive conditions of the acquisition of sensorimotor skills, the epistemological approach, the socio-psychological approach, vocational approach, and pragmatic approach) and incorporating direct statements from the participants.

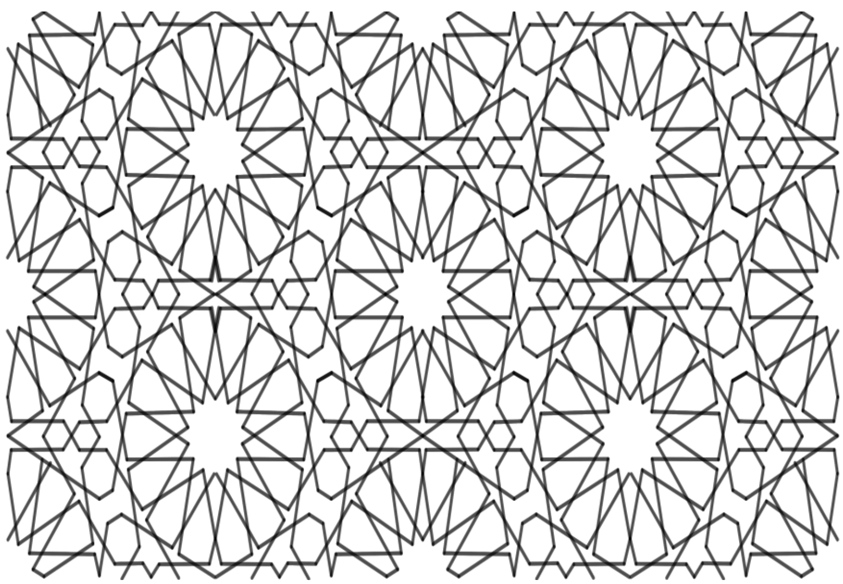
I as a Learner

Cognitive Conditions of Acquisition of Sensory-motor Skills

Through the lens of *I as a learner*, PTs discussed the impact of CLE on the growth of their sensory-motor abilities. Within this setting, it was seen that the PTs had a progressive improvement in their ability to execute drawings that were initially challenging. As the process unfolded, their drawing skills exhibited noticeable enhancement. PTs pointed out the differences between technological and manual drawings. PT16 provided a concise overview of the PTs' approach at the commencement and culmination of the academic term, stating, "...I gained an in-depth understanding that the act of drawing was not as hard as I had initially perceived." Several PTs remarked that they found it to be a straightforward task to create 2D and 3D figures as well as curved graphics, which are typically considered challenging to create. For instance, PT55 reported that the utilization of a program to facilitate the creation of accurate and comprehensible 3D figures would be beneficial for students, as it can alleviate the inherent challenges associated with manual drawing. Despite drawing in a CLE, several PTs reported an enhancement in their dexterity skills. PTs also emphasized the differentiation between technological and hand-drawn drawings, as exemplified by PT4's statement: "Drawing geometric patterns using GeoGebra software versus manually drawing them on paper are fundamentally dissimilar activities. GeoGebra enables us to examine certain attributes of a cube which are not readily observable on a surface such as paper." Initially, PTs experienced apprehension about the idea of drawing geometric patterns. However, they discovered that the task was not as challenging as anticipated. Figure 1 displays the pattern developed by PT27 who had no prior experience with GeoGebra, by the end of the semester.

Figure 1

The Pattern Constructed by PT27



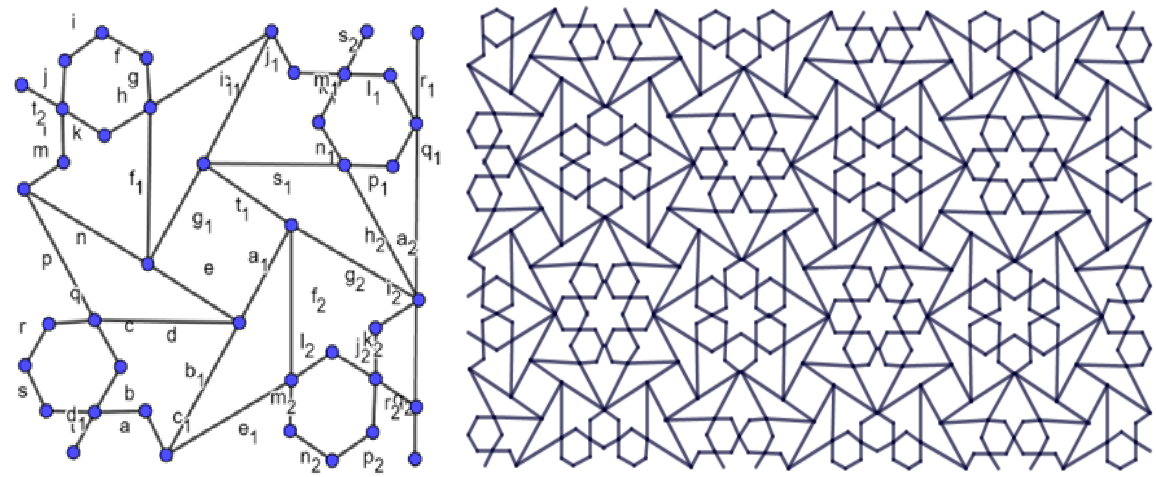
Aside from the convenience of drawing, PTs shared information regarding the process of generating a pattern based on the techniques they acquired or devised throughout their professional journey. In this regard, they performed pattern analysis utilizing the concept of ratio, and enhanced practicality by attempting to discern the unit pattern during the construction of geometric patterns. For instance, PT20 emphasized the importance of conducting pattern analysis before commencing the drawing process, stating, "I acquired the skill of pattern analysis. I gained expertise in the initial steps involved in drawing a pattern." PT37 indicated that they primarily considered which geometric transformation to employ, stating, "I've discovered that utilizing procedures such as reflection and translation when designing patterns allows me to complete the task even more quickly." The objective of the analysis was to partition recurrent patterns into sub-components and formulate the requisite procedures for their construction. However, PT26 highlighted the significance of ratio in the creation of geometric patterns by acknowledging that "I saw how important the ratio is between figures while constructing our patterns."

In contrast, PT58 elucidated their approach to speeding up sketching geometric patterns by identifying the unit pattern: "I gained practicality in visualizing the pattern as a result of drawing geometric patterns with GeoGebra. When I see a pattern, it becomes more convenient to identify its unit pattern and which procedures were used." Figure 2 displays the unit and geometric pattern that PT32 made in 3480 steps.

Figure 2

The Unit Pattern and Completed One by PT32

Unit Pattern Geometric Pattern



Additionally, PTs emphasized that they gained proficiency in utilizing GeoGebra as they were acquiring the skill of drawing with this software. This provided PTs with practical exposure to the utilization of GeoGebra in real-world scenarios. Several participants indicated that engaging in the task of drawing geometric patterns facilitated their familiarity with the toolbars in GeoGebra. Conversely, other PTs expressed the belief that acquiring proficiency in GeoGebra would enhance their performance in the given task. PT3 and PT21 expressed their opinions on these situations. PT3 stated that it would be more beneficial to teach, like in their lesson, with toolbars. PT21 mentioned that they became more familiar with the toolbars while constructing patterns.

Epistemological Approach

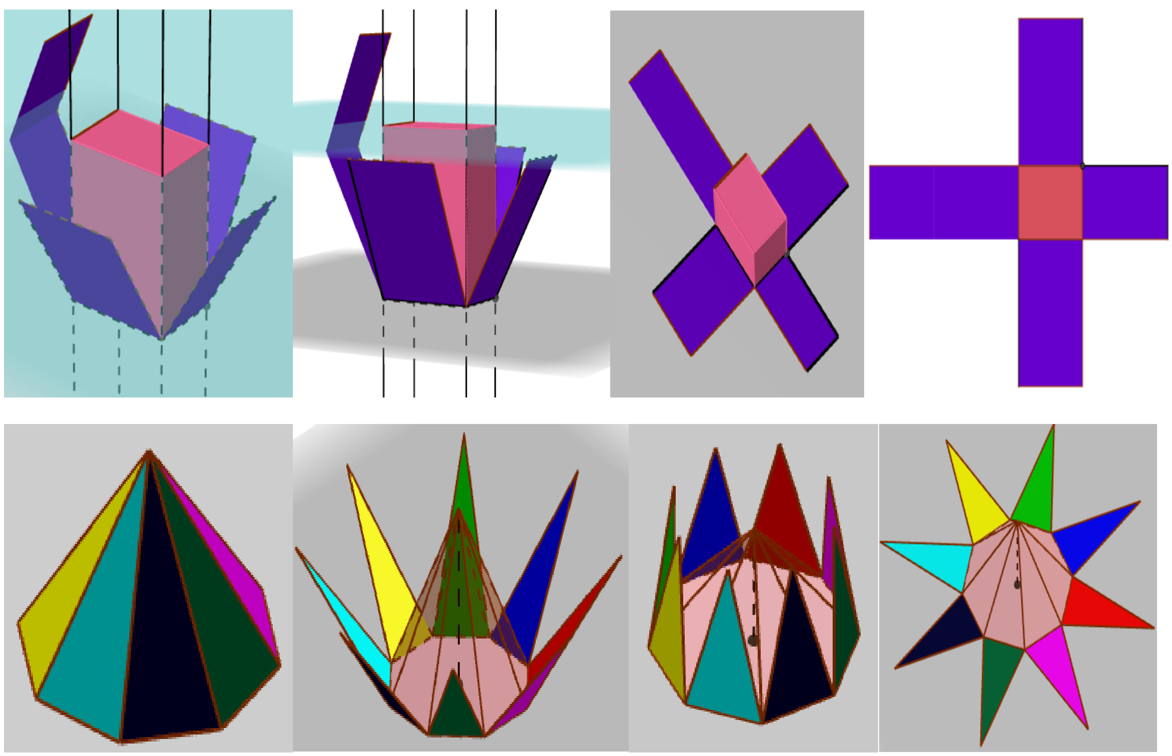
Using the *I as a learner* point of view, PTs discussed their knowledge regarding the relationship between technology and geometry. PTs deliberated on the areas in which they could employ these tasks, the thinking skills they acquired, and their personal learning experiences. Within this setting, PTs expressed statements indicating that predominantly geometry topics and concepts, ultimately connecting to algebra and numbers, could potentially be acquired and that the understanding of shapes could be achieved through the utilization of various tasks. For instance, PT44 posited that students could potentially benefit from intuiting concepts on their own. According to PT44, students' comprehension could be enhanced by visually demonstrating the infinite extension of both sides of a line through drawing. This approach is not limited to a single concept; rather, it encompasses multiple concepts such as line segments, rays, and reflections.

Several PTs indicated that it is possible to acquire knowledge in transformation geometry, encompassing concepts, and subjects pertaining to reflection, rotation, and translation. Nevertheless, proficiency in these areas is essential for accurately drawing geometric patterns. PT37 highlighted the importance of reflection and translation, stating that these tasks can be accomplished by performing procedures, such as reflection and translation, while drawing. PT29 emphasized the significance of reflection and rotation, stating that individuals possess the ability to comprehend and use these cognitive processes.

The PTs additionally reported that the tasks have educational value in the study of solid geometric shapes such as prisms and pyramids, with their corresponding nets, spatial perspectives from various angles, surface areas, volumes, and related concepts. For instance, PT6 placed a strong emphasis on the acquisition of knowledge pertaining to nets of solids. However, PT9 highlighted the potential usefulness of the tasks' advantage that it would enable the observation of 3D objects from several perspectives. This capability could yield significant conceptual advantages. Likewise, PT27 noted the potential to learn objects' surface areas, and volumes of things, stating that it offers a practical means of elucidating these properties. Figure 3 shows the tasks performed by the participants in the CLE.

Figure 3

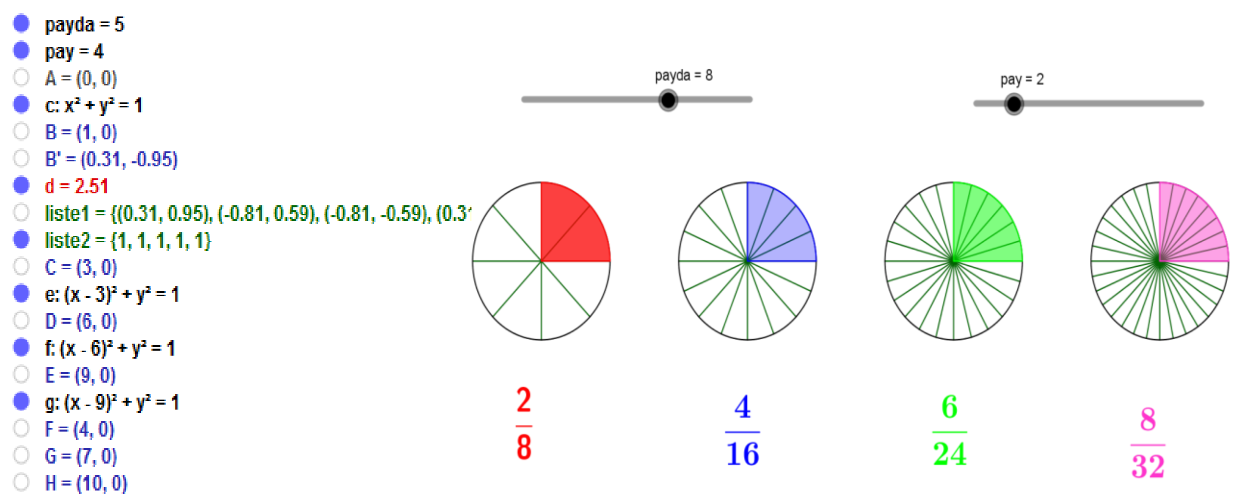
Construction of Prisms and Their Nets



The PTs who placed importance on the analysis of shapes and the acquisition of concepts argued that by focusing on conceptual understanding, students would develop a more enduring grasp of these concepts, thereby discouraging rote memorization. This approach was supported by PT22, which suggested that through this program, students can internalize the definitions of geometric concepts in a deep and lasting manner. The PTs also deliberated on the topic of algebra and numbers, discussing potential learning of various concepts including algebraic patterns, operations, equations, the coordinate system, ellipses, parabolas, hyperbolas, and the perception of infinity. PT10 provided an illustration of their ability to monitor algebraic operations by utilizing the various stages incorporated within the algebra window of GeoGebra. As depicted in Figure 4, students were able to visually comprehend the mathematical operations and sequential procedures involved in the construction of geometrical shapes.

Figure 4

A Task on Fractions

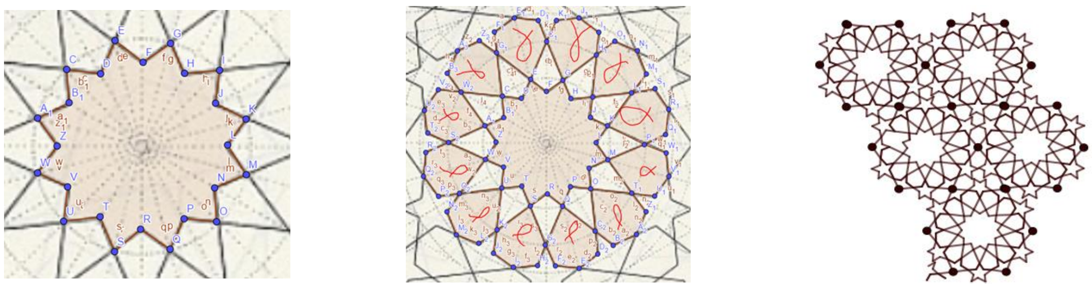


The PTs asserted that the tasks had a positive impact on individuals' thinking skills, specifically enhancing their reasoning, analytical thinking, geometric thinking, and spatial thinking capabilities, while also promoting divergent thinking. For instance, PT21 articulated their opinion on the cognitive ability of reasoning by stating, "It facilitates the adoption of a cognitive approach similar to that of a mathematician, enabling the formulation of mathematical conclusions, generalizations, and the cultivation of a distinct cognitive framework." Only PT49 mentioned the task's ability to improve analytical thinking skills. With respect to spatial thinking skills, the PTs stated that students encountered challenges in perceiving geometric patterns and successfully surmounted this issue through engagement in tasks that incorporated GeoGebra. The participants clarified that the tasks fostered divergent thinking by the utilization of the terms "creative thinking," "multi-dimensional thinking," and "improved imagination." In this respect, the PTs indicated that individuals' perspectives would be improved. PT41 argued that there was no single way of drawing a geometric pattern, emphasizing the need for alternative approaches. PTs highlighted the usefulness of employing GeoGebra to explore geometric shapes from various perspectives. This approach involved analyzing patterns and determining the appropriate geometric procedure and additional toolbars required to construct a given shape.

The PTs emphasized the use of GeoGebra as a tool for learning geometry. They observed that the tasks facilitated the recognition of geometrical relationships, the exploration of various facets of mathematics, the acquisition of mathematical knowledge through drawing, and the development of proficiency in employing mathematical language. PT3 expressed that they now possess the capacity to comprehend the constituent elements of a drawing, thus greatly benefiting from this newfound knowledge. Additionally, PT23 emphasized that this understanding of geometrical relations aids in facilitating the comprehension of mathematical connections for students. As depicted in Figure 5, PT43 who placed significant emphasis on the relationship between mathematics and art, incorporated the mathematical underpinnings of the patterns into their independent task. Furthermore, PT43 expounded upon the relationship between mathematics and art, highlighting the step-by-step construction process involved. Through this approach, PT43 gained a fresh perspective on mathematics, recognizing its role in the aesthetic realm of artistic expression.

Figure 5

The Construction for Representing an Artwork of PT43

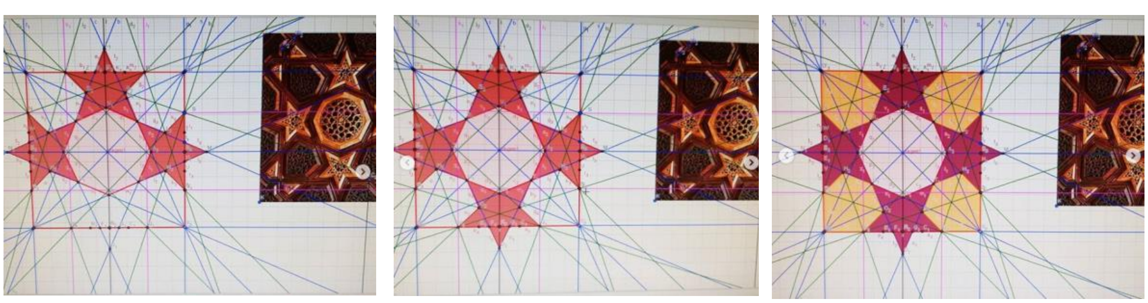


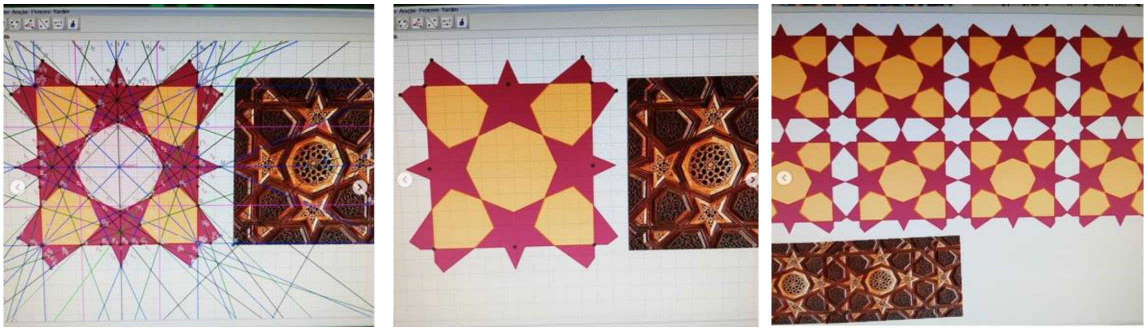
Socio-psychological Approach

Through the prism of *I as a learner,* the PTs engaged in an explanation of the social and psychological advantages they had experienced from performing CLE-related tasks. Within this context, the PTs asserted that incorporating tasks into the class would facilitate an enjoyable learning experience, with a particular focus on the pleasant qualities of these tasks. PT12's observation indicated that conducting a lesson in a traditional manner on a board can be monotonous. PT12 proposed that utilizing this program could potentially inject an element of enjoyment into the learning process. The PTs indicated that tasks had a motivating effect on students. Additionally, the PTs emphasized that tasks elicited qualities such as interest, curiosity, and attention, aiding individuals in fostering positive attitudes. The PTs appreciated the task of recreating the geometric pattern on the minbar of İzmir Birgi Grand Mosque (Ödemiş) in the class. This was accomplished by transferring the real-life pattern onto a coordinate plane using the stages outlined in Figure 6.

Figure 6

The Steps of Constructing a Pattern





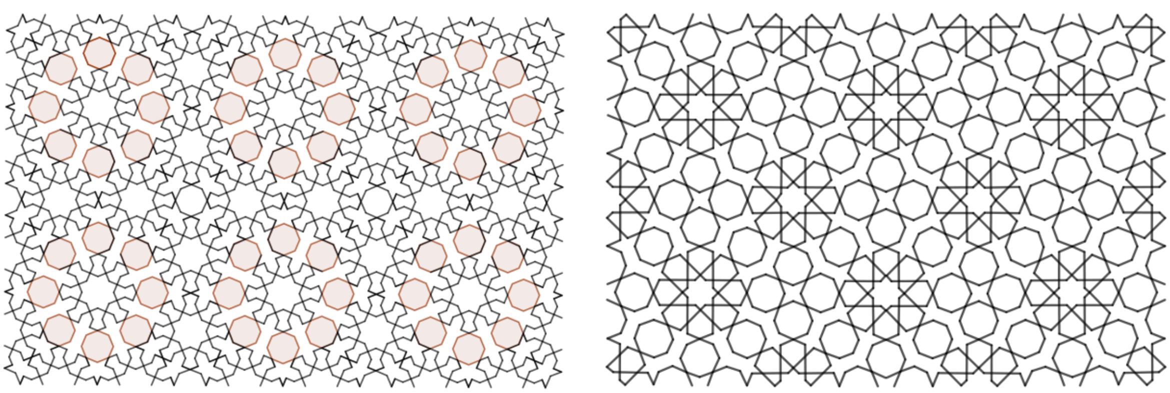
PTs recognized that engaging in the process of drawing geometric patterns fostered a deeper respect for everyday works of art and a greater understanding of the role mathematics plays in daily life, particularly in the effortless creation of intricate patterns. PT15 expressed their appreciation for the use of mathematics in everyday life and highlighted how the tool effortlessly identifies patterns. PT15 further remarked, "Actually, my perspective on historical ceramic art has undergone a transformation. The patterns exhibit a high level of complexity and necessitate diligent effort."

Another benefit indicated by the PTs was the ability to overcome math anxiety. According to PT7, it was possible to effectively challenge students' preconceived notions that mathematics is excessively abstract and beyond their ability to comprehend. Furthermore, the PTs stated that the tasks they experienced in CLEs provided them with valuable skills in problem-solving and cultivating patience.

The PTs asserted that they obtained these two important benefits by creating patterns during class. The construction procedures, particularly those pertaining to the formation of geometric patterns by the participants, were regarded as the decisive component. Figure 7 displays the geometric patterns of PT3 and PT47, which were constructed using 7421 and 2811 steps, respectively.

Figure 7

Patterns Constructed by PT3 and PT47



PT3 discovered the virtue of patience through drawing geometric patterns using GeoGebra, as they mentioned that it was the most significant benefit, and a prominent level of patience was required. PT59 also mentioned that tasks helped the development of the ability to struggle; "...students can learn to cultivate patience and confront the challenges they encounter."

I as a Teacher

Vocational Approach

Through the lens of *I as a teacher,* the PTs recognized that CLE-related tasks offered certain advantages. These advantages include the ability to introduce a fresh perspective to teaching, optimize time utilization, give comprehensive and explanatory demonstrations, facilitate teaching, deliver long-lasting, effective, and relevant instruction, and ensure continuity in the teaching process. The PTs stated that the incorporation of tasks altered their perspective on mathematics instruction. This was attributed to the tasks' ability to communicate lesson content in diverse formats, hence catering to multiple senses and appealing to a wider range of students. For example, PT52 asserted that "It helps the learning process by engaging multiple senses." Several PTs, for instance PT42, contended that the inclusion of such tasks in CLEs facilitated the efficient utilization of teaching time. They posited that by eliminating the need for teachers to manually draw on the board, more time could be allocated to instructional tasks." In contrast, comprehensive and explanatory demonstrations focused on providing real-world examples of mathematical applications in daily life, presenting comprehensible and proper drawings, and offering in-depth explanations of relevant concepts. For example, PT15 stated, "When students ask where they would use [mathematics], we might show them it is in works of art."

The PTs underlined that tasks in CLEs were effective in promoting comprehension of mathematical subjects, enhancing teachers' instructional methods, and ultimately improving students' understanding of the lesson. PT44's perspective on this issue was that by using GeoGebra to create patterns, they realized the potential to teach their students more effectively in the future. PT44 also noted that this application could facilitate the explanation of geometry terms. The PTs who voiced their opinions on the instructional process contended that tasks also provided permanent and effective teaching, therefore enhancing the comprehension of geometric shapes. For example, PT49 hinted at more effective teaching. In particular, PT49 proposed that a shape that a teacher drew on a plane at random might not coincide with a child's imaginary schemes but might share a common geometric basis. Consequently, they advised that teachers should implement strategies that minimize the child's exposure to such discrepancies. Certain PTs stressed that including tasks in the teaching process directs meaningful learning experiences for students.

Although multiple PTs emphasized using tasks in geometry classes from a teaching perspective, only a single PT mentioned skill acquisition. The PTs posited that the tasks may be employed as a pedagogical tool to facilitate comprehension of students' cognitive processes, offer immediate feedback, mitigate the occurrence of misconceptions, and serve as a means of assessment-evaluation during and following instruction. Furthermore, PT56 expressed their intention to incorporate the use of GeoGebra for the purpose of drawing shapes in upcoming examinations. PT56 said that it would be more beneficial for students to take geometry exams that are prepared using this application, rather than solely relying on training with the program. However, PT43 expressed the notion of eliminating misconceptions in the teaching process. They highlighted that conventional instructional approaches provide challenges in effectively conveying mathematical objects and avoiding misunderstandings. Consequently, PT43 asserted that the implementation of this application is indispensable and endorsed its utilization. PT25 briefly addressed the final component of the measurement-evaluation element, suggesting the possibility of assigning tasks to students and observing their performance and thought processes.

When asked regarding pedagogical approaches, the PTs acknowledged that the utilization of tasks can provide a framework for instructional guidance. In this respect, the participants believed that tasks facilitated student learning through active engagement, exploration, and visualization of mathematical ideas within the instructional context. PT4 stressed that GeoGebra has the power to promote learning through exploration, as it is an application designed to assist students in this process. Finally, the PTs indicated that engaging in these tasks could improve students' ability to visualize or embody mathematical concepts, with a focus on preparing them to teach these concepts to future students.

The PTs highlighted the utilization of technology in mathematics instruction, considering the unique characteristics of each student, and fostering an engaging and participatory educational setting. The participants mostly mentioned the instructional value of GeoGebra and the advantages it offers to students. For instance, PT28's emphasis was on an interactive learning environment, stating, "I think that students would learn in an interactive manner." PT2 mentioned an individualized learning environment where it is possible to offer an educational atmosphere that aligns with the students' specific level of learning.

Pragmatic Approach

Through the lens of *I as a teacher*, PTs focused on the advantages of the CLE-related tasks for their future professional careers. This professional perspective was commonly expressed when discussing the implementation of CLE-related tasks within the educational setting, as well as strategies for effective time management during these tasks. In these explanations, the PTs put forth the contention that tasks might potentially result in adverse professional consequences for teachers in terms of their instructional practices, time management, and lesson planning. As future teachers, the PTs indicated that students were unable to perform mathematical inquiries while utilizing the software, and the use of concrete materials yielded more favorable outcomes. For example, PT20 asserted that the utilization of concrete materials serves as a pedagogical instrument for facilitating inquiry-based instruction, hence fostering permanent learning outcomes:

> I believe that engaging in hands-on learning experiences with tangible tools such as a compass or ruler, as opposed to relying solely on computer-based methods, may provide more enduring educational outcomes. The act of adjusting on a computer automatically, compared to manually, implies that a student is inclined to take shortcuts rather than engage in the process of learning.

The inability to create appropriate tasks or manage them effectively was another professional perspective that the PTs highlighted, according to PT25. This PT emphasized that if tasks cannot be created and managed adequately, they may not yield favorable outcomes for the children. One of the primary considerations regarding the professional perspective was the inability to effectively utilize GeoGebra in practical situations. For example, PT56 underscored the importance of ensuring equal access to education, which necessitates the consideration of all educational institutions and students nationwide. In the assessment context, PT56 underscored the limitation that not all schools have incorporated GeoGebra into their curriculum, restricting the potential benefits of this tool to certain students or schools while excluding others.

The social interaction perspective was another way in which the PTs conveyed their opinions. They emphasized that CLE-related tasks may exert a detrimental impact on students' social development, particularly for younger children who may find these tasks excessively challenging. For instance, PT52 highlighted their apprehension over social development, claiming that it will intensify the challenges faced by students who are already experiencing setbacks in this way.

From the technological perspective, the PTs placed significant emphasis on the hardware and software concerns that align with the prevailing economic conditions. The PTs highlighted the insufficiency of hardware in schools and classrooms, asserting that CLE-related tasks would be unsuccessful without the establishment of appropriate technical and technological infrastructure. The PTs clarified that these hardships give rise to psychological aspects in students, such as a sense of inadequacy and the erosion of their enthusiasm. One example of a challenge highlighted by PT13 was the difficulties encountered by students in transferring 3D drawings observed on GeoGebra onto their notebooks. The potential disparity between visual perception and visual representation might lead individuals to experience feelings of inadequacy. The learning acquisition perspective encompasses PTs' thoughts on psychomotor, physiological, and cognitive gains and losses, as elucidated by these types of explanations. Finally, the PTs addressed the cognitive aspects and posited that the acquisition of application proficiency posed significant challenges and consumed substantial amounts of time for students.

Conclusion and Discussion

Results of the research profoundly explored the comprehension of PTs' dispositions with respect to the utilization of tasks within a CLE. By drawing from Wenger's (1998, 2010) and Herman's (2014) theoretical framework, the research emphasized the dynamic process of PTs' development of identity as they navigated the realms of *I as a learner* and *I as a teacher*. The utilization of tasks derived from CLEs inside the methods course played a crucial role in shaping the experiences of the PTs, consequently impacting their future perceptions of the pedagogy of mathematics instruction. As PTs transition from their roles as students to future educators, comprehending their experiences and viewpoints becomes crucial. Thus, the present investigation contributes valuable insights into the ongoing discourse on teacher education, highlighting the potential of tasks within CLEs to shape future educational practices in the domain of mathematics.

In addition, this research offers evidence demonstrating the substantial influence of GeoGebra on the psychomotor, cognitive, affective, and pedagogical development of PTs, emphasizing its innovative potential in mathematics instruction when positioned at the core of the learner's experience (*I as a learner*). In contrast to conventional wisdom that minimizes the essential role of psychomotor skills in the educational impact of digital technology, our research emphasizes the transformative effect of GeoGebra on visual representation and understanding of mathematical concepts. This highlights the importance of psychomotor skills in CLEs. Initially, the PTs perceived the task of manually creating geometric patterns as challenging, but eventually recognized the capabilities of GeoGebra and highlighted the advantages it provided. This phenomenon reflects a more extensive change in the mindset enabled by digital tools, like GeoGebra, which transforms the way PTs perceive and interact with mathematical subjects. In particular, the integration of cultural aspects into geometric patterns, enabled by the use of GeoGebra, has a significant role in promoting cognitive and psychomotor development in PTs. In addition to its practical applications, GeoGebra enhances individuals' intellectual frameworks, fosters deeper comprehension, and refines pedagogical approaches (Drijvers & Trouche, 2008; Trouche, 2004).

Although the natural attraction of a manual geometric drawing cannot be disregarded, the capabilities of GeoGebra present a strong argument for its inclusion in the classroom as a dynamic alternative to the traditional pencil and paper environment (Kokol-Voljc, 2007). This study also emphasizes the benefits gained from attaining practicality in psychomotor action, which are closely interconnected with cognitive processes. Illustrative instances of such tasks encompass the acquisition of fundamental technical terminology associated with GeoGebra, a widely employed tool. Students derive advantages from acquiring familiarity with visual aids such as graphics, drawings, and technical plans. Furthermore, it is advisable for individuals to actively participate in tasks that include the analysis of structures and the acquisition of practical knowledge, such as the ability to associate an element with its corresponding function. Additionally, it is imperative for students to cultivate the ability to utilize tools and hardware in a logical and systematic manner. This viewpoint is consistent with the research results of Trouche (2005) and Vérillon (2000).

The power of technology in educational settings extends beyond the facilitation of work, as it engenders a more profound comprehension and interrelation of concepts. This research emphasizes the cognitive processes that are routinely engaged in the scrutiny of the patterns employed during the act of drawing. These methods also include evaluating the mathematics involved in the drawing. The PTs who effectively leveraged technological advantages were able to uncover the relationships between the unit pattern, and the completed pattern, by identifying specific mathematical characteristics inherent in those patterns. In this process, the PTs endeavored to choose appropriate geometric components and concepts from GeoGebra. The PTs applied these elements proficiently and efficiently while constructing a geometrical structure. As a result, the PTs acquired a comprehensive understanding of these concepts, encompassing both their definition and visual representation. The findings of this study support the assertion made by Escuder and Furner (2012), Çağlayan (2015), and Azizah and Kumala (2023) that learners demonstrated the ability to make connections between visual representations, mathematical concepts, and symbolic representations through the utilization of GeoGebra as a technology.

As we navigate the future of mathematics education, understanding the intersection of technology, pedagogy, and student disposition is vital. Examining PTs' dispositions and experiences with GeoGebra during a task is an important assessment for future research and computer-mediated programs, especially with the increasing active and effective use of technology in mathematics classrooms. One of the most intriguing discoveries of this research pertains to the acquisition of patience and challenges encountered by PTs during their engagement with tasks in CLEs. In the *I as a learner* position, the PTs exhibited a strong interest and curiosity towards challenging tasks, demonstrating high motivation and perseverance in their efforts to successfully complete them. In this context, the inclinations of motivation, curiosity, and persistence can be seen as a mechanism for maximizing the utilization of GeoGebra.

However, achieving this was not straightforward. PTs faced unexpected challenges such as instability and interruption of the application, which hindered the advancement of the PTs during their utilization of different methods and specific tools within GeoGebra. In such cases, it is imperative for instructors and learners to create a conducive atmosphere. Instructors should aim to cultivate and internalize effective pedagogical and instructional strategies. As Rivera (2007) suggests, the efficacy and significance of such tools are contingent upon the presence of favorable social conditions that facilitate the development of appropriate representations, applications, and language. PTs will enhance their capacity to serve as mentors to their students by acquiring a comprehensive understanding of effective strategies to assist students in navigating and surmounting classroom problems with persistence and reasonableness. This is consistent with our initial focus on the crucial interaction of technology, pedagogy, and student disposition in the future context of mathematics education. The influence of emotions on students' classroom experiences was noteworthy, particularly when engaging with geometric patterns in the CLE. The tasks involving the creation of geometric patterns elicited different emotions among PTs. Engaging in the assigned tasks evoked a profound sense of worth, appreciation, and esteem that mathematics teachers aspire to instill in their students. This was achieved through the examination of manually crafted geometric patterns from the Seljuk and Ottoman periods, devoid of technological aids. The presence of positive tendencies in teaching and learning processes is likely to have a significant impact on the success of students in mathematics lessons.

The presence of math anxiety is a significant barrier to the acquisition of mathematical knowledge, presenting a formidable challenge to overcome. According to the Organisation for Economic Co-operation and Development (2016, p.117), students' positive opinions towards mathematics are linked to increasing their motivation, reducing their anxiety and prompting them to invest time and effort, consequently resulting in academic success. From the viewpoint of PTs as learners, research suggests that specific tasks can serve as a potential strategy for overcoming anxiety connected to mathematics (Horzum & Ünlü, 2017). The integration of historical patterns with contemporary instruments in these tasks serves to enhance comprehension and establish a connection between the past and the present. The implementation of this integrated methodology has the potential to effectively mitigate math anxiety through enhancing the subject's relevance and fostering active participation. Research has indicated that mathematics anxiety tends to be more prevalent in mathematics classes that employ traditional teaching methods, whereas it is comparatively lower in classes which encourage active student participation, incorporate enjoyable tasks, and value the opinions of the students (Hackworth, 1992; National Council of Teachers of Mathematics, 2000).

The integration of cultural history with modern technological tools offers a unique avenue for pedagogical innovation. This integration not only enhances the educational encounter but also holds the capacity to mitigate mathematical anxiety by establishing a stronger connection between mathematics and real-life situations, thereby fostering greater interest and involvement. Building on existing research, several methods can foster a positive disposition towards mathematics lessons (Furner & Duffy, 2002), one of which is the focus of this research. Specifically, one method that can be employed to foster interdisciplinary learning is the utilization of geometric patterns, which serve as a means to connect individuals with their history and culture. This is exemplified in the present research through the cultural motif generated by GeoGebra. The advancement of technical tools such as GeoGebra not only presents a novel instructional approach but also signifies a fundamental shift in the comprehension of geometric patterns. Implementing this technological advancement is notably advantageous for mitigating math anxiety. Moreover, it not only facilitates a more participatory and experiential pedagogical approach but also fosters heightened student engagement while alleviating sentiments of fear or dissatisfaction. In line with Tennant's (2004) observations, geometric patterns serve as stimulating, captivating, motivating, and multifaceted educational tools for students.

The initial experiences acquired by PTs during their educational trajectory, concomitant with their roles as future teachers, play a pivotal role in shaping and nurturing their prospective professional identities. In the *I as a teacher* position, the PTs who were enthusiastic about mathematics teaching in the CLE showed a tendency for collaboratively creating practical CLE tasks that would be beneficial to their teaching careers. Thurm and Barzel (2020) emphasize that a teachers' beliefs and epistemological stance about how mathematics should be taught and learned, significantly influence their teaching skills. In alignment with the findings of Ndlovu et al. (2020), our research discovered that PTs commonly demonstrated positive dispositions towards incorporating technology in mathematics education. Similarly, Bingölbali et al. (2012) remarked that teachers effortlessly integrated technological tools and displayed a positive disposition towards the use of technology when they interacted with those tools they intended to employ. Through the CLE process, PTs, as learners who become aware of this situation shaped their learning perspective to take on instructional responsibilities from the outset. This aligns with Stenberg et al.'s (2014) findings, with a primary focus on inspiring and motivating students to engage in study and knowledge acquisition.

Although technology holds the potential to significantly revolutionize mathematics education, its pragmatic limitations and ensuing pedagogical challenges underscore the intricate interplay between tool, teacher, and task. For the PTs in the *I as a teacher* position, tasks in the CLE presented certain limitations. These limitations highlighted the pragmatic and functional roles of technology. In this respect, Cellerier (1979, as cited in Verillon & Rabardel, 1995) argues that identification and resolution of problems that arise during the interaction of the tool with the environment are part of the pragmatic approach. Accordingly, in the current research, certain problems were identified regarding the interaction of the technological materials with users and the environment during lessons. It was determined that some of these problems were caused by users and that these might lead to pedagogical problems in the teaching process. According to Ndlovu et al. (2020), the significance of a teacher's adaptability in pedagogy is emphasized. Therefore, the projections made by the PTs could potentially be interpreted as tasks conducted in the CLE with the intention of facilitating the incorporation of technology into mathematics lessons. Consistent with the research conducted by Akkaya (2016) and Ndlovu et al. (2020), the current research highlights the perspective of the PTs occupying the *I as a* *teacher* position regarding the challenges they faced in conducting tasks due to hardware limitations. Specifically, the lack of technological infrastructure for learning tools in educational settings hindered the efficient execution of these tasks. PTs are aware that these interruptions could make it challenging for the teacher to properly complete the lesson. Managing the computer-mediated mathematics classroom is one of the components of TPACK (Guerrero, 2010), which requires the ability to manage technical infrastructure. According to Mishra and Kohler (2006), a teacher who uses technology effectively should have knowledge distinct from that of a disciplinary expert (such as a mathematician), a technology expert (such as a computer scientist), and a pedagogical expert (an experienced educator).

The aspiration to seamlessly weave technology into the fabric of mathematics education confronts a sobering reality: the teacher's proficiency in utilizing hardware can significantly impact the intricate equilibrium of TPACK. In this research, the user-related problems stem from the PTs' insufficient prior knowledge of hardware. This suggests that the effective incorporation of technology, content knowledge, and pedagogy requires a strong foundation in TPACK (Mishra & Koehler, 2006). Ultimately, proficiency in information communication technologies (ICT) has a crucial role in shaping the intentions of both teachers' and PTs' intentions to integrate ICT into mathematics classes (Ndlovu et al., 2020; Thurm & Barzel 2020).

The cornerstone of mathematical education relies not solely on the teacher's subject-matter expertise but also on their refined pedagogical abilities, enhanced by the use of digital resources. The research findings illuminate the complex relationship between these factors and their potential impact on the evolution of mathematics instruction. Therefore, it is imperative for PTs to comfortably navigate these stages if they have aspirations of teaching mathematics in the future. The influence of teachers' knowledge and its implementation on students' dispositions and success has been well-documented (Baumert et al., 2010; Campbell et al., 2014). Additionally, research has shown that the use of digital tools in mathematics education has a positive impact on students' learning and achievement (Turk & Akyuz, 2016). Insufficient proficiency in the practical use of programs may cause complications for teachers while engaging in mathematical inquiries and formulating suitable tasks. Researchers can gain insights into PTs' awareness of and expectations for PCK by observing their responses while they are in the *I as a teacher* position. This underscores the recurring importance of teacher education. The present research seeks to validate this importance by examining the perspectives of PT's regarding tasks, both as learners and as future teachers.

The digital transformation of the classroom goes beyond a simple adoption of digital tools; it necessitates a reassessment of educational methodologies. The present research illuminates crucial factors that practitioners must take into account in the vanguard of this educational paradigm shift. Based on the findings, specific recommendations may be posited to researchers and teachers utilizing tasks within the CLE. Researchers and teachers involved in CLEs might benefit from exploring these proposed approaches. Conducting research on the influence of pedagogical approaches on technology utilization may provide valuable insights that can help educational practitioners cultivate a more positive disposition towards implementing tasks in future educational settings.

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Pre-service Teachers' Subject Matter Knowledge about Normal Distribution

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ABSTRACT

Many countries do not include the normal distribution concept in their middle school mathematics curriculum, but on the grounds that middle school mathematics teachers need to know more than just mathematics, researchers argue that preservice teachers (PTs) ought to have knowledge and skills in this area. This study was aimed to investigate PTs' subject matter knowledge (SMK) about the normal distribution. Data was collected from 120 PTs attending a state university through a questionnaire. PTs were asked to evaluate a variety of examples of the normal distribution. The data were analyzed using descriptive statistics and item-based analysis. It was found that the PTs were more knowledgeable about the features of the normal distribution than about standard deviation. Real-life situations made it difficult for them to interpret the concepts associated with normal distributions. Normal distribution curves were more easily interpreted by the PTs. It was determined that their mistakes were the result of their not establishing connections between statistical concepts, and their operational evaluation of concepts. Additionally, PT errors were caused by failure to establish a relationship between probability values and the area covered by the curve and making errors in operation.

Keywords: Normal distribution, pre-service middle school mathematics teachers, subject matter knowledge

Introduction

The topic of what mathematics teachers should know is an up-to-date area of research attracting a great deal of attention (Ponte & Chapman, 2016; Sullivan & Wood, 2008) because the knowledge and skills of the teacher have a direct effect on students' learning (Ball, 2003; National Council of Teachers of Mathematics [NCTM], 2000; Walshaw, 2012). Teachers should have much more than the knowledge they teach to their students (Ball et al., 2008; Hill et al., 2008). The strength of this knowledge not only triggers the development of pedagogical content knowledge, but also has the potential to support student achievement (Baumert et al., 2010; Rivkin et al., 2005; Shulman 1986). In addition, the fact that subject matter knowledge directly affects the teacher's pedagogical preferences (e.g., Even et al., 1996) indicates the need to investigate this knowledge in more depth. However, research (e.g., Hill et al., 2007; Mewborn, 2003) shows that teachers/pre-service teachers have various difficulties in gaining a deep and rich understanding of the concepts they will teach. A similar situation draws attention in statistics (e.g., Canada, 2008; Groth, 2007; Makar & Confrey, 2005; Mooney et al., 2014), where subject matter knowledge is important. Statistics is important (Konold & Higgins, 2003) because students today need to have a strong understanding of this learning area in order to evaluate and analyze statistical data (e.g., TV news, research results) correctly (Baillargeon 2005; Vermette & Savard, 2019). This makes the knowledge of teachers who directly affect students' learning important

(Franklin et al. 2015). Teachers' subject matter knowledge plays a critical role both in using effective teaching strategies about statistics in the classroom environment and in the development of students' understanding of big ideas related to statistics (Burgess, 2011; Groth, 2013). The normal distribution is an important concept that relies on this knowledge (Batanero et al., 2004) because the normal distribution plays a critical role in representing and understanding data in real-life (Watkins et al., 2008). The normal distribution appears to be a very complex concept that involves the integration and relationship of many different statistical concepts and ideas (Batanero et al., 2004). The normal distribution allows the modelling of many physical, biological, and psychological conditions such as physical measurements, test scores, and measurement errors and is a prerequisite for statistical analyses to be conducted (Batanero et al., 2004). However, research has revealed that there are various difficulties regarding the normal distribution (e.g., Bansilal, 2014). In the current study, it is aimed to reveal the subject matter knowledge (SMK) of preservice teachers (PTs) about the normal distribution.

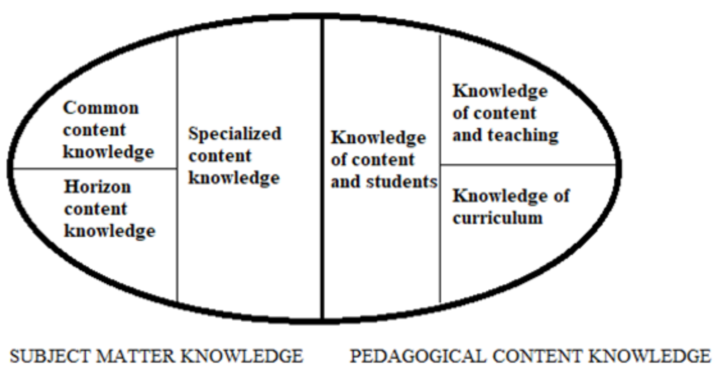
Theoretical Framework

Teacher Subject Matter Knowledge

There has been a significant increase in studies focusing on the knowledge of teachers in recent years and different classifications of this knowledge have been proposed (Tchoshanov et al., 2017). One of the common results of these studies is that the teacher's SMK is of vital importance for the teacher (Ball et. al., 2008; Grossman, 1990; Shulman, 1986, 1987). Shulman (1986) defined the teacher's SMK as "the amount and organization of knowledge per se in the mind of teachers" (p. 9). On the basis of the teacher knowledge proposed by Shulman (1986), Ball et al. (2008) drew attention to the necessity of having SMK and pedagogical content knowledge in order for a teacher to be able to teach mathematics. Ball and colleagues (2008) analyzed SMK by defining it in more depth. See Figure 1 for this information.

Figure 1

Mathematical Knowledge for Teaching (Ball et al., 2008)



Ball et al. (2008) examined SMK by dividing it into three components: common, horizon and specialized content knowledge. While common content knowledge is defined as the knowledge that the teacher should know outside the teaching environment, specialized content knowledge is considered as the knowledge required by the specialization in the field of mathematics teaching. Horizon content knowledge, on the other hand, requires the teacher to be aware of how the subject to be taught is related to other subjects. All these definitions show that both the effectiveness of the teaching process and the development of students' knowledge are directly related to the teacher's SMK

(Hill et al., 2005; Ma, 1999). In order for the teacher to carry out an effective teaching process, they must be able to make in-depth associations about the focused mathematical concepts (Bair & Rich, 2011). Statistics is one of the areas that include such concepts (Groth, 2007).

Individuals have to make evaluations and decisions based on the statistical data surrounding all areas of life. This requires individuals to have knowledge and skills related to statistics (Bargagliotti et al., 2020). Clearly, teacher competence plays a very important role in ensuring students acquire these skills and knowledge. One of these competences is SMK about statistics (Franklin et al., 2015). SMK should be present in the teacher's knowledge of many statistical concepts, one of which is the normal distribution (Batanero et al., 2004). The normal distribution forms the basis for other distributions and provides important clues to the reader at the point of making sense of the data. Many situations in real-life (e.g., biological, psychological) can be modelled using a normal distribution. Different distributions (e.g., Poisson) can be approximated to a normal distribution. Even when the datasets are not normally distributed, it can be assumed that the sample means are normally distributed based on the central limit theorem and analyses can be made based on this (Batanero et al., 2004). The normal distribution is defined as follows: If the probability density function of the continuous random variable X is

$$f(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-(x-\mu)^2/2\sigma^2}, \quad -\infty < x < \infty$$

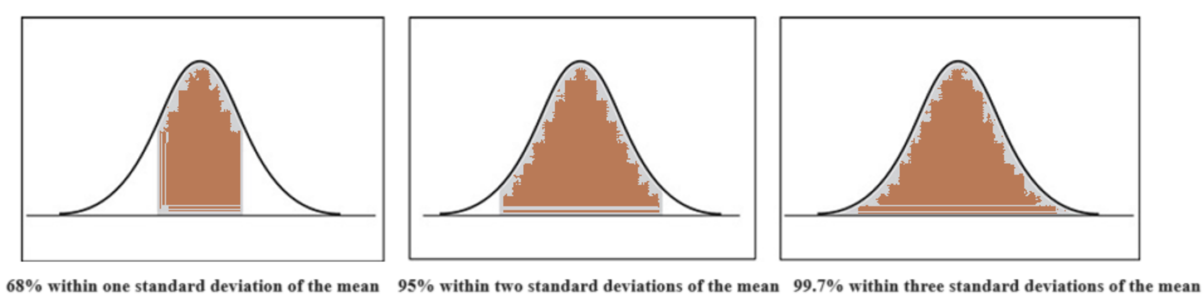
Then the random variable X has a normal distribution. The probability density function f(x) of the normal distribution has the following properties.

i. For each x, $f(x) \geq 0$.
ii. The area under the curve $f(x)$ and bounded by the x-axis is equal to 1.
iii. The curve of $f(x)$ is symmetrical according to $x = \mu$.
iv. The two ends (tails) of the curve go to infinity.

In addition, in a normally distributed dataset, 68% of the data are within one standard deviation of the mean, 95% of the data are within two standard deviations of the mean, and 99.7% of the data are within three standard deviations of the mean. This is called the empirical rule or the 68-95-99.7 rule. See Figure 2 for visuals of this rule.

Figure 2.

Empirical rule or 68-95-99.7 rule (Hinders, 2010, p.75)



The standard normal distribution is a special case of a normal distribution. In other words, a normal distribution with a mean of $\mu = 0$ and a standard deviation of $\sigma = 1$ is called a standard normal distribution.

Although the concept of a normal distribution are not directly included in the middle school mathematics curriculum in many countries and Türkiye (e.g. Bansilal, 2014; Ministry of National Education [MoNE, 2018]), mathematics teachers should possess a broad knowledge and skill set regarding this subject matter, as opposed to merely knowing what their students will learn in class. Despite the importance of a normal distribution, few studies have examined individuals' knowledge of it (Batanero et al., 2004; Pfannkuch & Reading, 2006). These studies revealed deficiencies in the knowledge of teachers/PTs about the normal distribution (Bansilal, 2014; Batanero, et al., 2004; Chaput, et al., 2021; Huck, et al., 1986).

For example, Huck et al. (1986) discovered two erroneous conceptions of normal standard scores in their study of university students. The first is that some students thought that standard scores always vary between –3 and +3. In addition, some students thought that there is no restriction on the maximum and minimum values in these scores. It was concluded that the reasons for these misunderstandings of the students were related to a normal distribution. The students who thought that z-scores always vary between -3 and +3 often used a picture or a table of the standard normal curve with this range of variation. Similarly, the students who thought that there were no maximum and minimum limits for z-scores made an incorrect generalization, thinking that the tails of the normal curve were asymptotic for the abscissa because they did not notice that no finite distribution is exactly normal.

In their study on university students, Batanero et al. (2004) revealed that students had various difficulties regarding normal distribution and many related concepts. Students had difficulties in calculating probabilities under the curve and the graphical representations of the areas under the normal curve. In addition, students misinterpreted the skewness coefficient and assumed that the equities of the mean, median, and mode were sufficient to show the symmetry of the distribution. Some students, on the other hand, were unaware of the effect of range widths on the frequency represented by the area under the histogram. In addition, some students were insufficient in relating other statistical measures (e.g., mode, median) to each other while interpreting the scatter plots.

Bansilal (2014) focused on teachers' knowledge of the concept of a normal distribution in her study conducted with the participation of 290 teachers. The teachers were given two tasks that required the application of the properties of the standard normal distribution curve, and their knowledge was examined based on these tasks. The teachers' success rates for the tasks were 27% and 14%, respectively. When the difficulties they experienced were examined, it was found that they could not establish a connection between the probability values and the area covered by the curve.

Chaput et al. (2021) examined how undergraduate students studying in various departments (statistics, physics, finance) name the vertical axis of a normal distribution and found that only 27 (18.2%) of 148 students could name the vertical axis of a normal distribution correctly and that only five students (3.4%) were able to explain their naming. Students with various misconceptions named the vertical axis as "probability," "count," or "frequency". Few of the students used the correct name as "probability density". These results show the difficulties of both university students and teachers / PTs regarding the concept of normal distribution.

Rationale of the Study

The concept of a normal distribution in statistics education is not part of the middle school mathematics curriculum in many countries (e.g., MoNE, 2018). However, researchers argue that PTs should have knowledge and skills related to this concept (Bansisal, 2014) because of the argument that middle school mathematics teachers should have in-depth knowledge of mathematical concepts (Ball et al., 2008). The normal distribution has an important role in reasoning about real-life situations as well as in understanding other statistical concepts and the relationships between these concepts (Batanero et al., 2004).

Moreover, middle school education plays an important role in developing students' understanding of statistical concepts, because students learn statistical concepts during the middle school years that serve as a foundation for advanced statistical concepts in the later grades. Developing a positive attitude towards statistics and critically evaluating statistical situations begins when students understand the why and how of statistical concepts in the early grades. For them to understand higher-order statistical concepts, they must have a thorough understanding of the underlying statistical concepts. The effectiveness of teaching processes depends on the teachers' ability to establish connections between statistical concepts and allow students to experience higher-order statistical concepts informally, even if not formally (Makar, 2018). Having a limited understanding of the normal distribution by mathematics teachers can negatively impact the teaching process. In this situation, students may only perceive other statistical concepts that shape normal distributions as operations without considering their meaning. As a result, teachers' ability to teach the normal distribution and related concepts are directly related to their subject knowledge. It is therefore important that PTs have the necessary knowledge and skills in the subjects they will teach (Baştürk 2009, 2011). The knowledge and skills PTs possess regarding the normal distribution may provide important clues about what they know about many other statistics concepts as well. Moreover, as teacher education is important for all societies, (Aslan, 2003), teacher training programs should be carefully organized. Accordingly, the results from this study may contribute to the regulation of the content of elementary education mathematics teaching undergraduate courses (e.g., statistics, probability, teaching of statistics and probability). Further, little research has been conducted on normal distributions in the literature (Batanero et al., 2004; Pfannkuch & Reading, 2006). Teachers also have difficulties with these concepts (Bansilal, 2014; Batanero et al., 2004; Chaput et al., 2021; Huck et al., 1986) pointing out the need to reveal PTs' knowledge of the normal distribution. Thus, answers to the following research questions were sought in the current study:

1) What is the knowledge of PTs about normal distribution?
2) What are the reasons for PTs to misinterpret the situations related to normal distribution?

Method

Design of the Study and Participants

Qualitative survey research design allows the researcher to reveal what individuals know about the concept in focus (Fraenkel & Wallen, 2006; Jansen, 2010). This design has been adopted in the current study, as it aimed to reveal the knowledge of PTs regarding the normal distribution. The participants were determined by using the convenience sampling method as it was more suitable for the research design (Fraenkel & Wallen, 2006). The participants of the study were third graders enrolled in the Elementary Education Mathematics Teaching program at a state university located in the Central Anatolia region of Türkiye. Participants' ages vary between 22 and 24, and 86 (71.7%) were female and 34 (28.3%) were male. PTs study normal distribution and related concepts in the probability and statistics courses in their undergraduate curriculum. The PTs took the probability course in the second term of their second year and the statistics course in the first term of their third year. The letter grades of the PTs in these courses are presented in Table 1. As seen in Table 1, nearly half of the PTs (45%) had a grade of 70 or less in the probability course. In the statistics course, half of the PTs (50%) were more successful and had grades in the range of 85-100.

Table 1

Grades of the PTs from the Probability and Statistics Courses

Course	Probability		Statistics	
Letter Grade	n	%	n	%
E	32	26	18	15
D	22	19	22	19
C	22	19	20	16
B	26	21	30	25
A	18	15	30	25

Note: 60-69-E, 70-74-D, 75-84-C, 85-89-B, 90-100-A

Data Collection Instrument and Process

In this study, the focus was on the common content and specialized content knowledge of the PTs. In order to reveal the PTs' content knowledge about the normal distribution, questions under four main skills were created. These skills are shown in Table 2.

Table 2

Skills and Questions on Normal Distribution

Skills	Types of SMK (Question number)	
	Common content	Specialized content
Knowing properties of normal distribution and related concepts	1,2	-
Interpreting concepts related to normal distribution on the basis of datasets	4,5	3
Interpreting the concept of normal distribution on the basis of real-life situations	7,9	-
Interpreting normal distribution curves	8	10a, 10b

Two questions were asked to the PTs under the skill of "Knowing properties of normal distribution and related concepts". See Figure 3 for this information.

Figure 3

Questions Regarding the Properties of the Normal Distribution and Related Concepts

1)Which of the following are properties of the standard deviation? Explain your answer.

1. The interval ± 2s contains 50% of the data in the distribution.
2. It's resistant to extreme values.
3. If you added 20 to every value in the dataset, the standard deviation wouldn't change.
4. If we subtract 5 from each value in the dataset, the standard deviation will decrease.
5. It's independent of the number of terms in the distribution.
6. It's the square root of the average squared deviation from the mean.

2)Which of the following are properties of the normal distribution? Explain your answer.

1. It has a mean of 0 and a standard deviation of 1.
2. Its mean = median = mode.
3. All terms in the distribution lie within four standard deviations of the mean.
4. It is bell-shaped.
5. The total area under the curve and above the horizontal axis is 1.

Hinders (2010) created the questions and an option was added to the first question (item 4). In the first question, it was aimed to reveal the knowledge of the PTs about the properties of standard deviation, and in the second question about the properties of the normal distribution. Under the second skill, three questions were asked to the PTs to reveal their knowledge and skills on "interpreting concepts related to the normal distribution on the basis of data sets" (Hinders, 2010,). The third question was arranged in a way to reveal the specialized content knowledge of the PTs about the normal distribution. In the other two questions, which to reveal the common content knowledge of the PTs, the phrase "Explain your answer" was added to better reveal the thoughts of the PTs.

In the third question, the PTs were asked to interpret the mean, the standard deviation, and the shape of the distribution. The fourth and fifth questions focused on calculating the concepts related to movement (z score, mean, standard deviation) from a normally distributed dataset (Hinders, 2010). Under the third skill, two questions (Hinders, 2010; Watkins et al., 2008) were asked to the PTs to reveal their knowledge and skills on "interpreting the concept of normal distribution on the basis of real-life situations" (See Figure 4).

Figure 4

Questions Regarding the Interpretation of Concepts Related to the Normal Distribution on the Basis of Datasets

3) Suppose that you are dealing with the subject of normal distribution in your class. You ask following question; "The mean and standard deviation of a normally distributed dataset are 19 anc respectively. 19 is subtracted from each term in the dataset and the result is divided by 4. Which of following best describes the resulting distribution?" You see that the following answers are given your students.
S1. It has a mean of 0 and a standard deviation of 1.
S2. It has a mean of 0 and a standard deviation of 4 and its shape is normal.
S3. It has a mean of 1 and a standard deviation of 0.
S4. It has a mean of 0 and a standard deviation of 1 and its shape is normal.
S5. It has a mean of 0 and a standard deviation of 4 and its shape is not known.
Which of these answer(s) can be an answer to the given question? Explain your answers.

4) One of the values in a normal distribution is 43 and its z-score is 1.65. If the mean of distribution is 40, what is the standard deviation of the distribution? Explain your answer.
a. 3
b. –1.82
c. 0.55
d. 1.82
e. –0.55

5) A college readiness exam scores are known to be approximately normally distributed with mean and standard deviation 6. To the nearest integer value, how many scores are there between 63 and Explain your answer.
a. 0.6247
b. 4,115
c. 3,650
d. 3,123
e. 3,227

Figure 5

Questions Regarding the Interpretation of the Concept of Normal Distribution on the Basis of Real-life Situations

7) Merve wonders how the size of her beagle Boncuk compares with other beagles. Boncuk is 40.6 cm tall. Merve learned on the internet that beagles heights are approximately normally distributed with a mean of 38.5 cm and a standard deviation of 1.25 cm. Interpret the height of Boncuk.

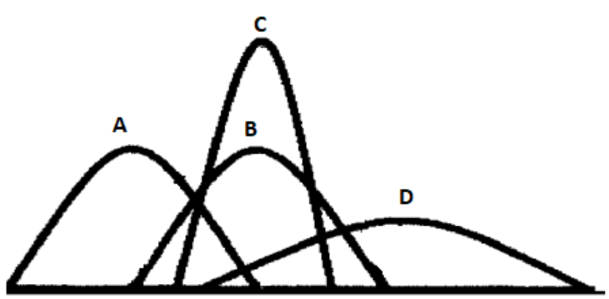
9) Alperen got 70 points from a statistics test whose mean is 60 and standard deviation is 10. He got 50 from a physics test whose mean is 50 and standard deviation is 5. It is known that the scores of the both test are normally distributed. Interpret and compare Alperen's test scores.

In both questions (see Figure 5), it was aimed to reveal the knowledge and skills of the PTs on interpreting real-life situations by associating them with the normal distribution. Under the fourth skill, two questions were asked to reveal the knowledge and skills of the PTs on "interpreting normal distribution curves"(See Figure 6).

Figure 6

Questions Regarding the Interpretation of the Normal Distribution Curves

8) The populations to which the parameters given below belong show a normal distribution. Match these parameters with the normal distribution curves that you think are appropriate (A, B, C, D). Explain your answer.



μ=12 σ=1

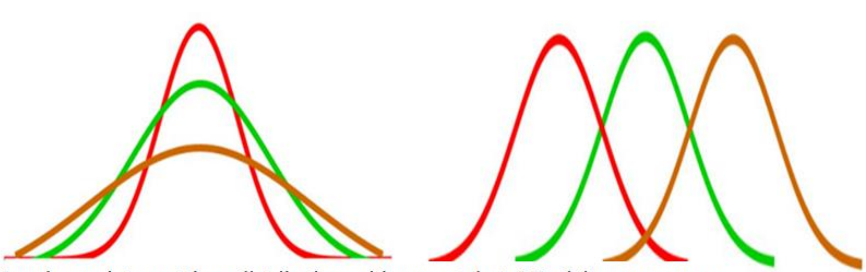
μ=12 σ=0.5

μ=8 σ=1

μ=16 σ=2

10) Imagine a lesson in which you talk about distributions. How do you interpret these distributions with your students?

a) b)



How do you interpret these distributions with your students? Explain your answers.

The eighth question was created based on the study by Özmen (2015). The PTs were asked to explain their answers to examine their thoughts in more detail. The tenth question, which was created by the researcher, and was prepared to reveal the specialized content knowledge of the PTs.

Translations of the original English questions into Turkish were verified by language experts. Following the correction of words or phrases that might cause semantic shifts or misunderstandings, the final forms of the questions were created. Three experts working in statistics education were asked to review the questions for relevance to the objectives and evaluate content validity. A pilot study was conducted with the PTs at the end of the third year, followed by the actual study. Thirty third-year students from a small, state university in Central Anatolia were recruited to participate in the pilot study. Following the pilot study, the actual study was carried out and the PTs were surveyed. It took the PTs 30-45 minutes to complete the questions.

Data Analysis

Descriptive statistics and item-based analysis were performed. Each question was assessed using an evaluation rubric. Each of the PT's answers to each question was categorized as correct and incorrect, then the reasons for each answer were presented as frequencies and percentages. An expert examined 25% of the data for validity and reliability, and the level of agreement between the expert and the study was determined. A 90% inter-coder reliability was found between the researcher (author) and the expert. As a result of discussions, a consensus coding was reached after a number of differences were identified. A description of how the research was conducted was also provided. The results obtained were further supported by several direct quotations. Accordingly, the study's validity and reliability were established (Miles & Huberman, 1994).

Research Ethics

This study adhered to all ethical procedures. Ethical compliance approval was obtained for this research in accordance with the decision of the Scientific Research and Publication Ethics Committee in the field of Social and Human Sciences of Karamanoğlu Mehmetbey University Ethics Committee dated on 17.05.2022 and numbered with 04-2022/80

Findings

The PTs' SMKs concerning the normal distribution was classified under four headings. As a first step, information about PTs' understanding of the normal distribution properties is given, as well as samples of their responses. Secondly, PTs' interpretations of concepts related to the normal distribution are presented along with samples from the PT responses. The third heading presents the PTs' interpretation of the normal distributions based on real-life situations. The last heading presents the interpretations of PTs about normal distribution curves.

PTs' Knowledge on "Properties of Normal Distribution and Related Concepts"

The PTs were asked to answer two questions in the context of the properties of normal distribution and related concepts. The evaluation rubric given in Table 3 was prepared. Answers given to the first and second questions by the PTs were analyzed and the results are presented in Table 4. A review of the PTs' responses to the first question revealed that 11.9% were able to accurately identify all the properties of standard deviation. One property of standard deviation was misidentified by 20%

of participants, two by 36.9%, and three by 23.3%. A mere 6% of PTs could identify only one property correctly, and 1.9% could not identify any of them.

Table 3

Evaluation rubric for the first and second questions

Correctness of the answers	Codes
All the items are correct	5
1 item is incorrect	4
2 items are incorrect	3
3 items are incorrect	2
4 items are incorrect	1
All the items are incorrect	0

Table 4

Answers Given to the First and Second Questions by the PTs

Codes	First Question Frequency/Percentage	Second Question Frequency/Percentage
5	14 (11.9%)	24 (20.0%)
4	24 (20.0%)	60 (50.0%)
3	44 (36.9%)	36 (30.0%)
2	28 (23.3%)	-
1	8 (6.0%)	-
0	2 (1.9%)	-

In the study, 81.6% of PTs misunderstood the statement "The standard deviation is independent of the number of terms in the distribution" when it was examined which statements related to the standard deviation the PTs tended to misidentify. Upon being asked to explain why this statement is incorrect, all of the PTs who made mistakes considered the standard deviation from an operational perspective. PT2 justified their answer by saying "the standard deviation cannot be considered independently of the number of data because we also use the number of data in the formula" and didn't explain what the standard deviation means.

The following statement was misinterpreted by 68.3% of the PTs; “The standard deviation is equal to the square root of the average squared deviation from the mean.” The PTs were observed to evaluate the standard deviation operationally when examining how they justified their answers. Taking PT8, for example, it was only the formula of the standard deviation that was discussed: “There is division by the number of data in the formula. So this statement is wrong.”

There were 20% of PTs who misunderstood the statement, "if we subtract 5 from each value in the dataset, the standard deviation will decrease". PT41 stated that “if we subtract 5 from each value, the arithmetic mean decreases by 5. Therefore, the standard deviation decreases." Thus, it was apparent that they believed the decrease in the arithmetic mean had a direct impact on the standard deviation. The standard deviation, however, offers information about how the data are distributed, as opposed to the arithmetic mean, which is a measure of central tendency.

About 15% of respondents misinterpreted another statement, "The standard deviation won't change if you add 20 to every value in the dataset". As an example, PT2 replied, “Adding 20 to each value will increase the standard deviation because it will increase the arithmetic mean.” The PTs followed the same logic and made a direct connection between the arithmetic mean and the standard deviation, disregarding the fact that the arithmetic mean indicates where the dataset is centered, whereas standard deviations indicate where the dataset is distributed.

According to the results, 13.3% of the PTs misinterpreted the following statement; "The standard deviation is resistant to extreme values." As with other wrong reasons, the association between standard deviation and the arithmetic mean in operational terms emerged when the answers of the PTs were evaluated. In evidence of this, PT27 explained: "The standard deviation depends on the extreme values since the extreme values change the arithmetic mean and the standard deviation depends on the arithmetic mean". There was only one PT who misinterpreted the statement "The interval ± 2s contains 50% of the data in the distribution". This misinterpretation can be attributed to the inability to establish a relationship between distribution and standard deviation.

According to the results of the second question in which the PTs were quizzed about their knowledge of the normal distribution, 20% of them were able to evaluate all normal distribution statements correctly. Among the PTs, 50% misinterpreted one statement and 30% misinterpreted two statements. Upon evaluating which statement(s) the PTs interpreted incorrectly, it was observed that the majority (68.3%) misinterpreted the following statement: "It has a mean of zero and a standard deviation of one." A possible explanation for why this statement was evaluated incorrectly is that the PTs were confused between the normal distribution and standard normal distribution concepts.

The following statement was misinterpreted by 30% of the PTs; "All terms in the distribution lie within four standard deviations of the mean." PT30, for example, responded, "Yes, all data are within four standard deviations of the mean." Based on the theory, it is known that almost all data are within four standard deviations of the mean, however some data are further from it. Another misinterpreted statement is "The total area under the curve and above the horizontal axis is 1". There were 18.3% of PTs who misinterpreted this statement. PT26, for example, stated, "The area under the normal curve is 1, but the area above the curve is greater than 1." Due to a misunderstanding of the normal distribution curve, the PT gave the wrong answer. Normal distributions have this property, which makes them useful for calculating probability density curves. It is clear from evaluating the PTs' answers to the two questions that they have a better understanding of normal distribution properties than standard deviation properties.

PTs' Knowledge on "Interpreting Concepts Related to the Normal Distribution on the Basis of Datasets"

PTs were asked to answer three questions related to interpreting the normal distribution concepts using the datasets. There were two questions (4, 5) that aimed to expose common content knowledge, and one (3) that aimed to expose specialized content knowledge. The evaluation rubric in Table 5 was developed for this purpose.

Table 5

Evaluation Rubric for the Third, Fourth and Fifth Questions

Correctness of the answers	Codes
Correct answer & correct justification	3
Correct answer & wrong/incomplete justification	2
Wrong answer	1
No answer	0

On the basis of the evaluation rubric prepared, the answers given by the PTs to the third questions are shown in Table 6. Nearly half of the PTs (48.1%) answered the third question correctly. However, when asked to justify their answers, approximately one-third (27%) of the PTs who gave correct answers could not justify their answers.

Table 6

PTs' Answers to the Third Question

Codes	Answers	Frequency/Percentage
3	Option D	42 (35%)
2	Option D	16 (13.3%)
1	Option B	38 (31.7%)
	Option E	16 (13.3%)
	Option A	8 (6.7%)

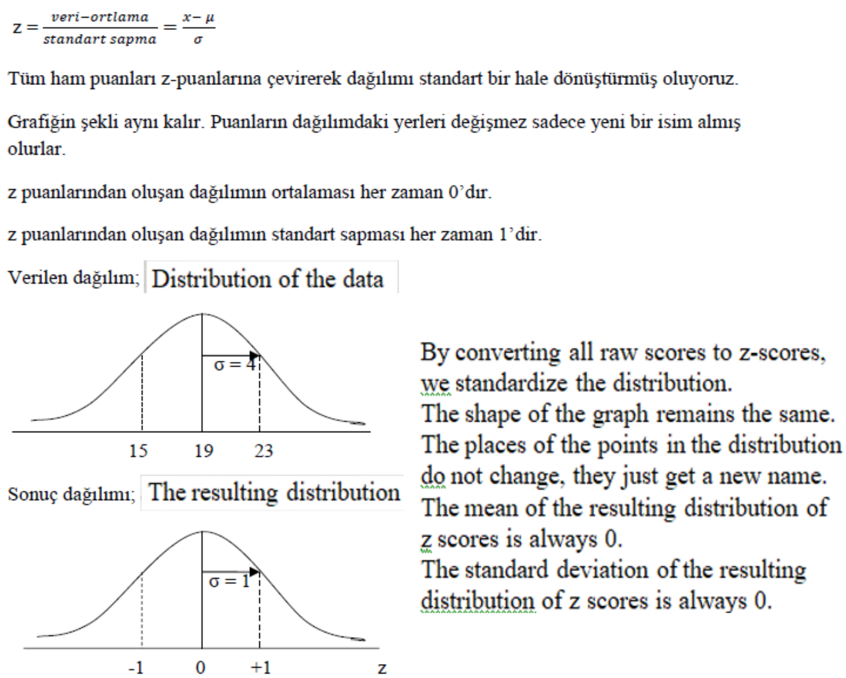
According to PT4 who gave the correct answer and justified it correctly:

> The student who chose option D chose the right answer because subtracting the same value from the mean of a dataset as the mean is to reduce the old mean by the same amount. The first mean was 19, and when 19 is subtracted from each term, the new mean becomes zero. The effect of dividing each term by the same value on the standard deviation of a dataset is to divide the standard deviation by that value. The first standard deviation is four, a new standard deviation of one is obtained when each term is divided by four. If we look at the z-score, its mean is zero and its standard deviation is one. Since the previous distribution is a normal distribution, this distribution will be normal, too.

Another PT who gave the correct answer and correctly justified his/her answer was PT43. See Figure 7 for their response.

Figure 7

PT43's Answer



A good example of a PT who gave the wrong justification despite giving the correct answer is PT49. According to this PT, the student who chose option D gave the correct answer because even when a small sample of data is used, it is clear that this option is correct. PTs who gave wrong answers mostly tended to choose statements like: "It has a mean of zero, a standard deviation of four, and a normal shape" (31.7%). PT24 explained, for example, that:

> The answer of the student who chose option B is correct because, starting from the arithmetic mean of the dataset, the sum of the data in the dataset is 76, and when 19 is subtracted from each data and the arithmetic mean is calculated, the new result will be zero. Since it will be calculated by subtracting 19 from each data, the arithmetic mean will also decrease by 19. Since the number of data remains the same, the standard deviation will not change. That is, the standard deviation will remain as four. As the standard deviation does not change, the distribution is still a normal distribution.

Thus while they was able to determine how the mean was affected by the changes to be made in the dataset, they ignored the possible changes in the standard deviation. On the other hand, 13.3% of the PTs chose the following statement: "It has a mean of zero, a standard deviation of four and its shape is unknown." The PT50 giving this answer justified his/her answer as follows in Figure 8:

Figure 8

PT50's Answer

x= veri toplamı	x=sum of data
y= veri sayısı	y=number of data
x/y=19 (ortalama)	x/y=19(mean)
x-19y/y= x/y - 19y/y	x-19y/y=x/y – 19y/y
= 19 -19	=19-19
=0 (ortalama)	=0 (mean)
Standart sapmanın değişmeyeceğini düşünüyoruz. Dağılımın şekli hakkında ise yorum yapamayız.	We think that the standard deviation will not change. Do not make any comment on the shape of distribution

Here, in relation to the previous answer (option B), although they took into account how changes in the data set affect the arithmetic mean, they ignored the standard deviation and how the shape of the distribution would change. Although they were able to determine the standard deviation and mean correctly, the students who could not determine the shape of the distribution and gave wrong answers constituting 6.7% of all the students. For example, PT33 made the following explanation:

> If we assume that all four samples are 19 and subtract 19 from each, we see that the mean is zero. We see that the standard deviation is one. So the standard deviation also becomes one. When tested with other samples, it is easily concluded that the arithmetic mean is zero.

The answers of the PTs given to the fourth question, which is another question in which the PTs are required to interpret the concepts related to the normal distribution on the basis of the datasets, are shown in Table 7.

Table 7

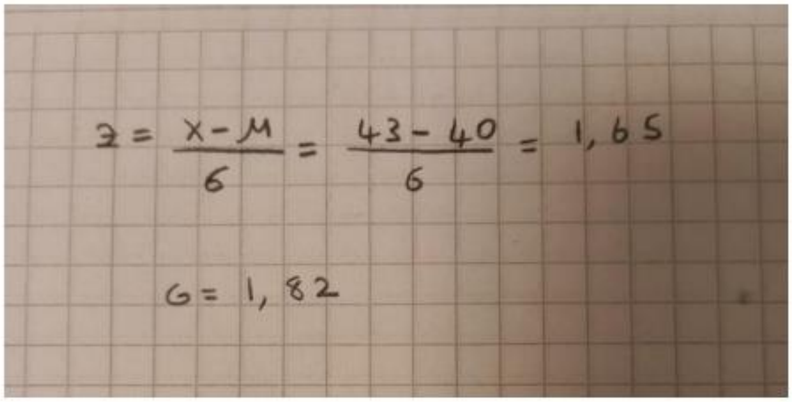
Answers Given to the Fourth Question by the PTs

Codes	Answers	Frequency/Percentage
3	Option D	96 (80%)
2	Option D	-
1	Option C	24 (20%)

It has been revealed that all of the PTs who answered this question correctly were able to justify their answers correctly. For example, PT9 was able to correctly calculate the standard deviation of the dataset as shown in Figure 9.

Figure 9

PT9's Answer



It was observed that the PTs who gave wrong answers gave these wrong answers because they made a mistake in the operation. For example, PT19 gave the following answer as shown in Figure 10.

Figure 10

PT19's Answer

Option C.

1.65=43-40/standard deviation

Standard deviation=0.55

When the answer given is examined, it can be said that the PT made an operational mistake. The answers given by the PTs to the fifth question are shown in Table 8.

Table 8

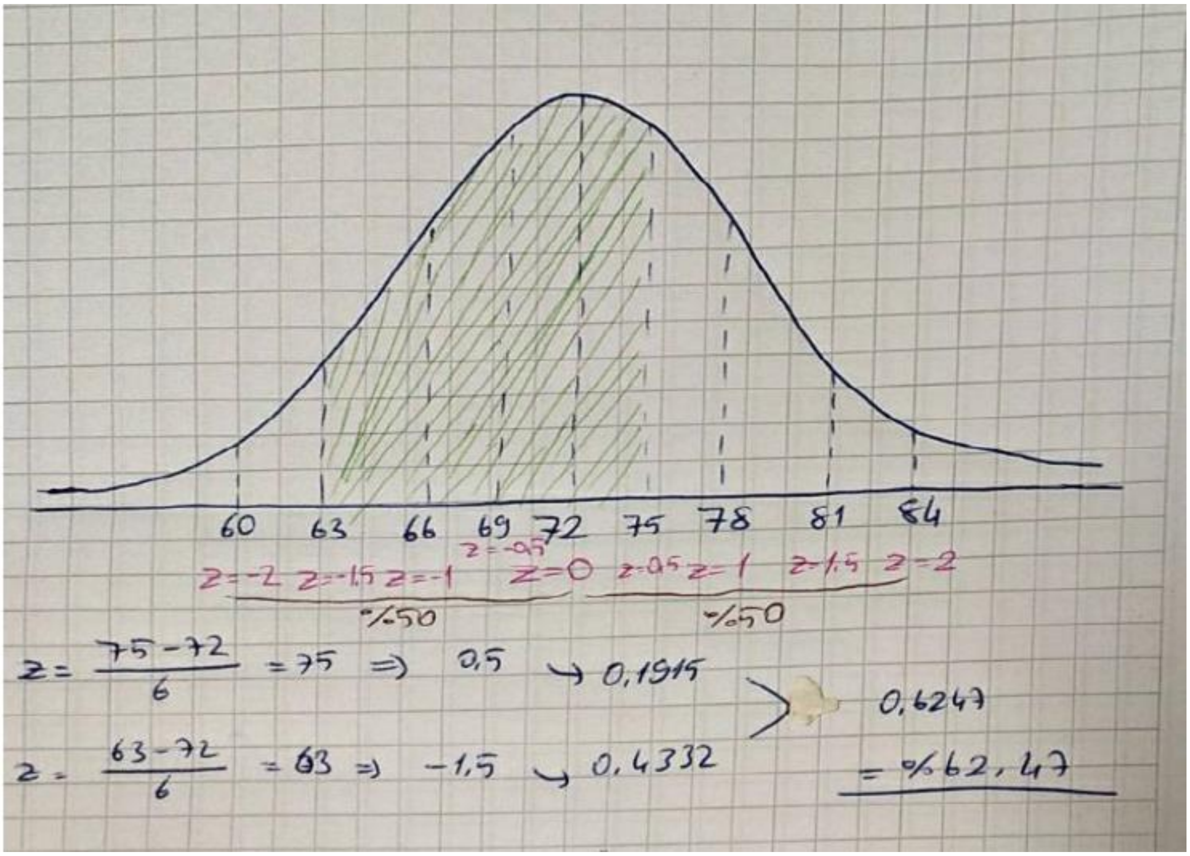
Answers Given to the Fifth Question by the PTs

Codes	Answers	Frequency/Percentage
3	62.47	66 (55%)
2	62.47	-
1	57.95	16 (13.3%)
	57.5	8 (6.65%)
	24.17	16 (13.3%)
	65.86	6 (5%)
	17.5	6 (5%)
	80	2 (1.75%)

For this question, it was revealed that more than half of the students could both give the correct answer and justify their answers. The answer of PT23, one of the PTs who gave both the correct answer and correct justifications, is given in Figure 11.

Figure 11.

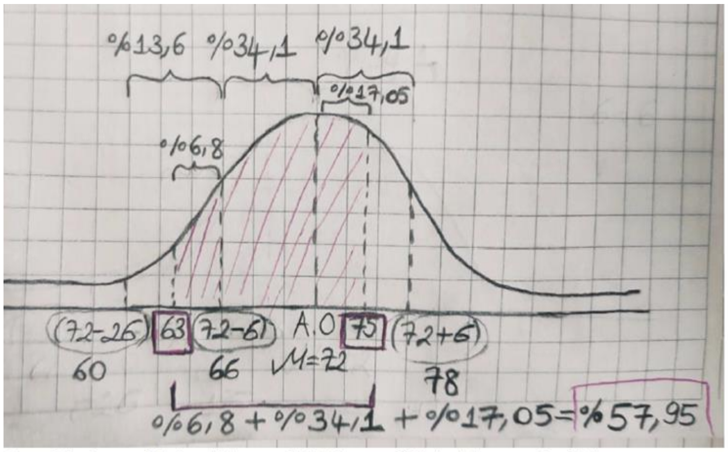
PT23's answer



It was revealed that the wrong answers given by the PTs who gave wrong answers varied. Of the PTs, 13.3% found the answer as 57.95. The answer given by PT1 is as follows in Figure 12

Figure 12

PT1's Answer



Görselde de görüldüğü gibi normal dağılım grafiğini çiziyoruz. Grafiğin tam ortasına verilen aritmetik ortalamayı yazıyoruz yani 72 değerini yazıyoruz. Daha sonra ise standart sapması 6 değeri verildiği için grafiğin sağ tarafına (72+1 standart sapmayı) yazıyoruz. Burada standart sapma 6 verildiği için 72+6 'dan 78 değerine ulaşıyoruz. Bu kısımda 75 değeri aritmetik ortalama ile +1 standart sapmanın tam ortasında kaldığından yani 75 ile 78 değeri arasında bulunduğundan buradaki yüzde değer olan %34,1' i ikiye bölüyoruz ve %17.05 değerine ulaşıyoruz. Şimdi ise grafiğin sol tarafına geçelim. Burada (72 - 1 standart sapmayı) yazıyoruz. Burada standart sapma 6 verildiği için 72 - 6 'dan 66 değerine ulaşıyoruz. Ve devam ediyoruz bu kez (72 - 2 standart sapmayı) yazıyoruz. Burada standart sapma 6 verildiği için 72 - 12 'den 60 değerine ulaşıyoruz.

Böylece 63 değeri -1 standart sapma ile -2 standart sapmanın tam ortasında bulunduğundan buradaki yüzde değer olarak %13,6 'yı ikiye bölüyoruz ve %6,8 değerine ulaşıyoruz. Sonuç olarak 63 ile 75 arasındaki yüzdeleri topluyoruz bu hesaba aritmetik ortalama ile -1 standart sapma arasındaki yüzdelik değeri katmayı unutmuyoruz böylece %6,8 + %34,1 + %13,6 = %57,95 olarak bulmuş oluyoruz. Sonuç olarak verilerin %57,95 'i 63 ile 75 arasındadır diyoruz.

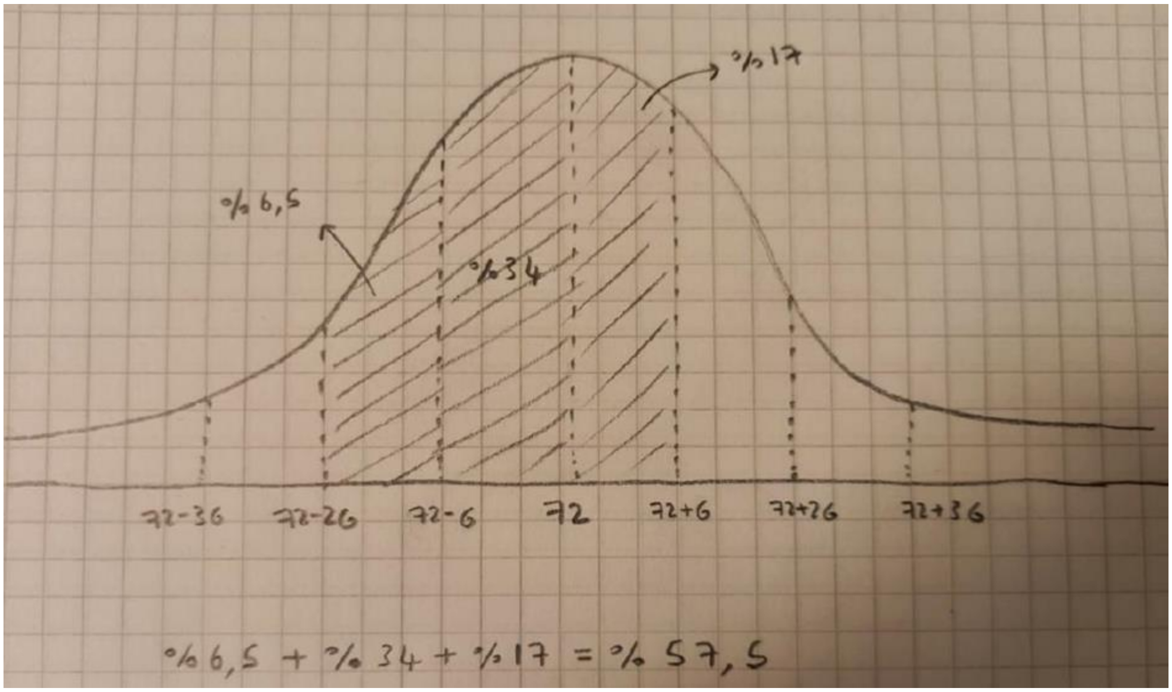
As seen in the figure, we draw the normal distribution graph. We write the arithmetic mean given in the middle of the graph, that is, we write 72. Then, since the value of the standard deviation is given as 6, we reach the value of 78 from 72+6. In this part, since the value of 75 is in the middle of the arithmetic mean and +1 standard deviation (78), that is, it is between the values of 75 and 78, we divide the percentage value here, 34.1%, into two, and we reach the value of 17.05%. Now let's move on to the left side of the graph. Here we write (72 – 1 standard deviation). Since the standard deviation is given as 6 here, we arrive at the value 66 from 72 - 6.

Thus, since the value of 63 is in the middle of -1 standard deviation and -2 standard deviation, we divide 13.6% into two as the percentage value here and we get 6.8%. As a result, we add the percentages between 63 and 75, do not forget to add the percentage value between the arithmetic mean and -1 standard deviation, so we get 6.8% + 34.1% + 13.6% = 57.95%. As a result, we say that 57.95% of the data are between 63 and 75%.

The PTs who gave this answer established a direct relationship with the distances of the data from the arithmetic mean and their areas. They correctly defined the area between 72 and 78, which is one standard deviation (standard deviation six) away from 72, as 0.34. Since the z score of the 75 points is 0.5, they divided the area into two equal parts and found it to be 0.17. A similar situation was observed for 63 points, which were found to be at a distance of -1.5z score. Here, they directly correlated the z score with the area. However, such a relationship is not always the case. For example, the area in the 0.5z score is 0.1925. The PTs who acted with a similar logic and found the answer as 57.5% constituted 6.65% of all the PTs. These PTs acted with similar logic and reached this conclusion because they did not consider the values after the comma.

Figure 13

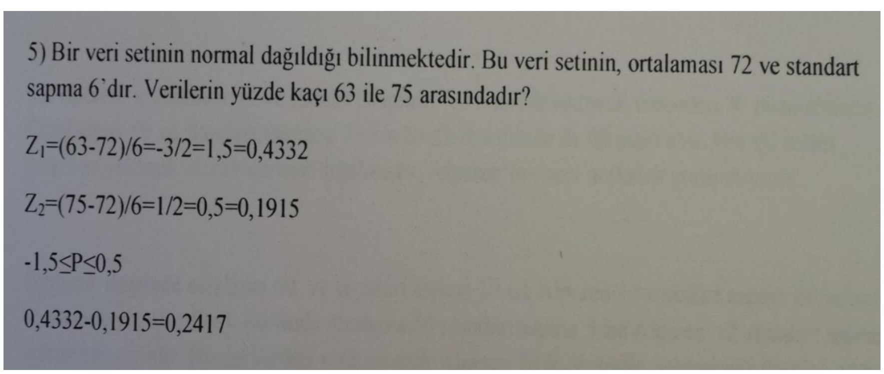
PT34's Answer



The PTs who gave the answer 24.17, which is another wrong answer, constituted 13.3% of all the PTs. The answer given by the PT42 is as follows:

Figure 14

PT42's Answer



5) Bir veri setinin normal dağıldığı bilinmektedir. Bu veri setinin, ortalaması 72 ve standart sapma 6`dır. Verilerin yüzde kaçı 63 ile 75 arasındadır?

Z_1=(63-72)/6=-3/2=1,5=0,4332

Z_2=(75-72)/6=1/2=0,5=0,1915

-1,5≤P≤0,5

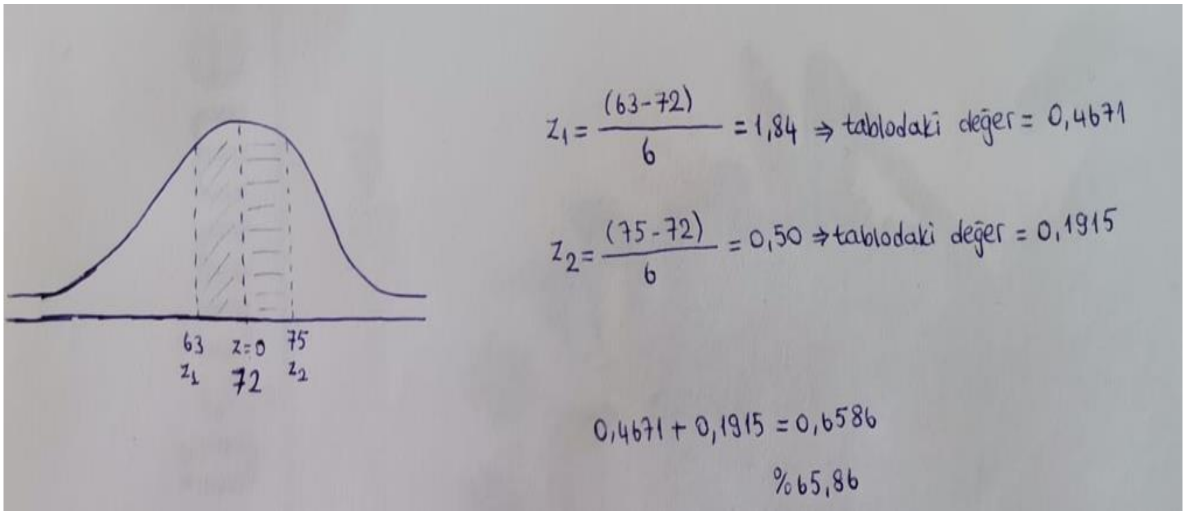
0,4332-0,1915=0,2417

In evaluating the PT's answer, it appears that although she was able to find the z-scores accurately, she was unable to determine how the areas in the distribution were distributed. In spite of the fact that the data were both to the right and left of the arithmetic mean, they acted as if they were only to the right.

Of the total number of PTs, 5% found the answer 65.86. The answer given by PT29 is shown in Figure 15.

Figure 15

PT29's Answer



As a result of an operational mistake, the PT calculated the z-scores incorrectly and found the areas incorrectly. A total of 5% of the PTs found the answer as 17.5% without explaining why. A student also found the answer to be 80 but did not explain why.

In this section, the highest number of PTs answered the fourth question correctly and justified their answers correctly. It was revealed that although this rate decreased, more than half of students gave correct answers and justified their answers in the fifth question. About one-third of the students with the correct answer gave incomplete or incorrect justifications for their answers in the third question. This question was answered incorrectly by more than half of the PTs. Additionally, the third and fifth questions showed a greater degree of variation in the errors made by the PTs.

PTs' Knowledge on "Interpreting the Concept of the Normal Distribution on the Basis of Real-life Situations"

The PTs were asked to answer two questions in order to reveal their knowledge and skills about interpreting the concept of the normal distribution on the basis of real-life situations. The evaluation rubric for these questions is given in Table 9.

Table 9

Evaluation Rubric for the Seventh and Ninth Questions

Correctness of the answers	Codes
Correct answer & correct justification	4
Correct answer & incomplete justification	3
Correct answer & superficial justification	2
Wrong answer	1
No answer	0

Table 10 presents the PTs' responses to the seventh question, as evaluated by the prepared evaluation rubric.

Table 10

Answers to the Seventh Question

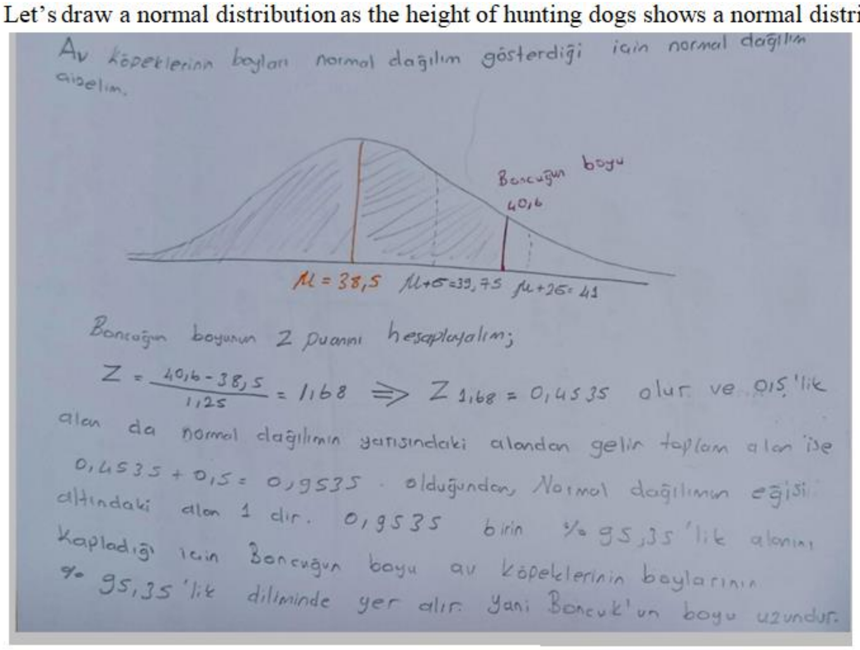
Codes	Answers	Frequency/Percentage
4	%95.35	22 (18.3%)
3	Between the standard deviations of +1 and +2	28 (23.3%)
2	Over the mean	38 (31.7%)
1	In the 45% percentile	14 (11.7%)
	In the 2.28% percentile	8 (6.7%)
	In the +2 standard deviation	8 (6.7%)
0	-	2 (1.6%)

According to the results, almost 75% of the PTs were able to answer the question correctly (73.3%). When asked to justify their correct answers, the PTs were unable to demonstrate the same level of success. It was found that only 25 percent of the PTs who gave correct answers were able to justify their answers in the correct way. Figure 16 shows the answer of PT26, who not only gave the correct answer, but also justified their answer.

Figure 16

PT26's Answer

Let's draw a normal distribution as the height of hunting dogs shows a normal distribution.



Height of Boncuk is 40.6
Let's calculate the z score of the height of Boncuk;

0.5 area comes from the area in the middle of the normal distribution, as the total area is 0.4535 + 0.5 = 0.9535, the area under the curve of normal distribution is 1. As 0.9535 covers 95.35% of 1, the height of Boncuk is in the 95.35% slice of the heights of hunting dogs. That is, Boncuk is tall.

Despite providing accurate solutions, nearly a third of the PTs (32%) failed to provide complete justifications for their answers. PT21 provided the following explanation as shown in Figure 17.

Figure 17

PT21's Answer

Boncuk is quite tall compared to other hunting dogs.

If we were to draw a normal distribution graph showing the height of the dogs;

Mean of the graph 38.5/+1 *standard deviation is 39.75 / +2 standard deviation is 41*

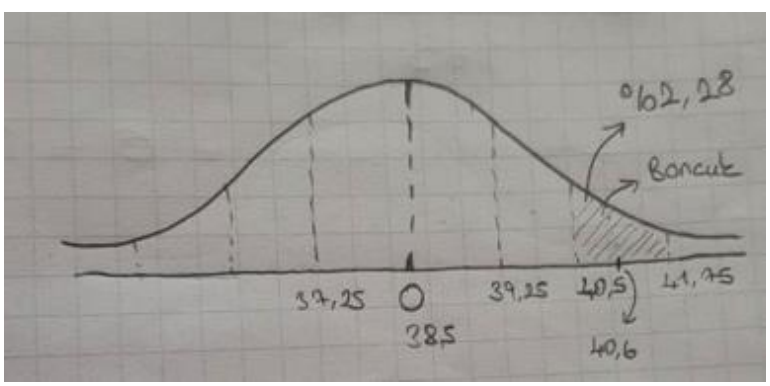
• In this case, we see that the height of Boncuk (40.6) is between +1 standard deviation and +2 standard deviation and is closer to +2 standard deviation. In other words, we can say that Boncuk is taller than 85% of all dogs.

By using correct reasoning, PT21 was able to conclude that the height of Boncuk lies in the range of +1 and +2 standard deviations, and is most likely closer to +2 standard deviations due to the right reasoning they demonstrated. Due to the lack of explanation of the point Boncuk corresponds to on the z score distribution, they justified their answer incompletely. A total of 43% of the PTs who gave the correct answer gave superficial justifications for their answers despite giving the correct answer. Although these PTs attempted to justify Boncuk's height by associating it with the standard deviation, their explanations remained quite superficial. PT56 used a statement such as "Boncuk's height is above the mean according to the standard deviation", but did not explain how this was determined.

The PTs who made mistakes constituted 25.1% of all the PTs. When the types of the mistakes made by these PTs were examined, three different types of mistakes were noticed. PS30, one of the PTs who found the answer as 45%, gave the following answer: "The z-score of the height of Boncuk is 1.68. The percentage of Boncuk among other hunting dogs is in the 45.35% slice". When this answer was evaluated, it was observed that although the PT found the z-score correct, they determined the percentage by only taking into account the upper half of the distribution but not the lower half. The PTs who gave the answer 2.28%, which is another wrong answer, constituted 6.7% of all the PTs. For example, PS13 stated that "When compared to the average height of other hunting dogs, the height of the hunting dog, which Merve named Boncuk, is tall and is in the 2.28% slice." and drew the graph shown in Figure 18.

Figure 18

PT13's Answer



As a result of evaluating the PT's answer, it becomes apparent that they estimated Boncuk's height as between +2 and +3 standard deviations, which constitutes an operational error. There were 6.7% of PTs who determined the answer to be +2 standard deviation. As an example, PT41 explains:

> If hunting dogs have an average height of 38.5 cm and a standard deviation of 1.25 cm, Boncuk's height of 40.6 cm falls within the +2 standard deviation percentile. Because of this, we can say that Boncuk is taller than the average hunting dog.

Here, they made a mistake by saying that the height of Boncuk is within +2 standard deviation. No answers were given by two PTs. Table 11 shows the answers given by PTs to another question designed to reveal their understanding of interpreting the concept of a normal distribution in real-life situations.

Table 11

Answers to the Ninth Question

Code	Answers	Frequency/Percentage
4	Alperen is more successful in the physics test than the statistics test.	84 (70%)
3	Alperen is successful in both the physics and statistics tests	20 (16.6%)
2	-	-
1	Alperen scored 70 in the statistics test and 60 in the physics test. Therefore, he is more successful in the physics test.	14 (11.7%)
0	-	2 (1.7%)

Seventy percent of the PTs answered correctly and justified their answer to the ninth question. According to PT3, the following answer and rationale was given:

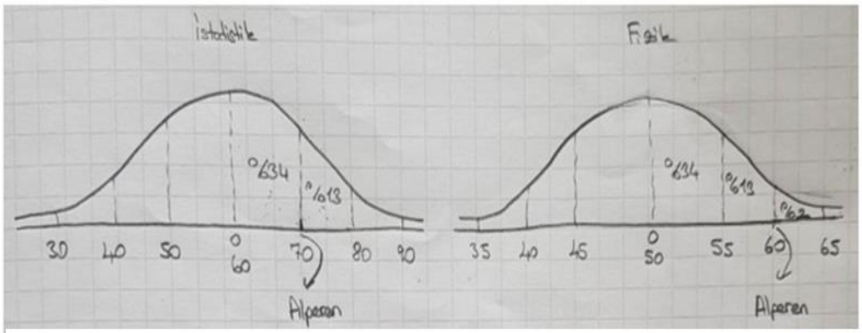
> We look at the normal distributions in both tests. We can say that Alperen is more successful in physics, even though he scored 70 in statistics and 60 in physics. The mean in the statistics test is 60 and the standard deviation is 10. In Alperen's case, the grade is 70. In the physics test, Alperen's grade is 60, with a mean of 50 and a standard deviation of five. Alperen's grade in the statistics test is in the range of +1 standard deviation. Alperen's grade in the physics test is in the range of +2 standard deviation. In physics, Alperen does better because when the standard deviation goes in the positive direction from the mean, this indicates that the student will perform better.

Although some PTs accurately commented on Alperen's state in the two tests separately, it was observed that they did not compare the two tests. For example, PT15 provided the answer shown in Figure 19. It is evident that although PT15 interpreted Alperen's statistics and physics grades, he/she did not compare them. The question was incorrectly answered by approximately one out of ten PTs (11.7%). The PTs failed to consider the standard deviation and arithmetic mean when interpreting the grades. PT50 explained that the student got 70 on the statistics test, thus making him more successful.

According to PT50, the physics test was less successful for him since he only scored 60. Two PTs didn't answer this question. According to the results of the tests, when the PTs were challenged on the basis of their real-life situations to interpret the concept of the normal distribution, the second question proved to be more successful than the first question in terms of interpreting the concept of the normal distribution. There was a greater variation in the mistakes made in the first question.

Figure 19

PT15's Answer



Alperen got 70 points in the statistics test and is in the 18% slice of the successful students. In the physics test, he is in the 2% slice of the successful students as he got 60. In general, we can say that Alperen is successful in both of these tests.

PTs' Knowledge on "Interpreting Normal Distribution Curves"

In order to reveal their understanding and skills about interpreting normal distribution curves, the PTs were asked two questions. They were asked a question to reveal their common content knowledge (Question 8), and a second question to reveal their specialized content knowledge (10a, 10b). These three questions were evaluated according to the rubric in Table 12.

Table 12

Evaluation Rubric for the 8th and 10th Questions

Correctness of the answers	Codes
Correct answer & correct justification	3
Correct answer & incomplete justification	2
Wrong answer	1
No answer	0

By using the evaluation rubric above, the answers to the eighth question by the PTs are listed in Table 13.

Table 13

Answers to the Eighth Question

Codes	Frequency/Percentage
3	94 (78.4%)
2	10 (8%)
1	14 (12%)
0	2 (1.6%)

Most PTs answered the eighth question correctly and justified their answers (78.4%). According to PT38, graphs A and B have different means, but they have the same standard deviations. In their opinion:

Both C and B have the same mean, but C's standard deviation is smaller than B's. Therefore, when the standard deviation of graphs A, B, and C is compared, it is $\sigma_A = \sigma_B > \sigma_C$. When the standard deviation of the graph D is compared to those of the other graphs, it is $\sigma_A = \sigma_B > \sigma_C > \sigma_D$. Based on the means of the graphs A, B, C, and D, we can conclude that $\mu_D > \mu_C = \mu_B > \mu_A$.

Despite the fact that 8% of PTs gave correct answers, they did not justify their answers. Twelve percent of the PTs provided incorrect answers. PT55's response is shown in Figure 20.

Figure 20

PT55's Answer

C $\mu=12$ $\sigma=1$

B $\mu=12$ $\sigma=0.5$

D $\mu=8$ $\sigma=1$

A $\mu=16$ $\sigma=2$

Based on this answer, it can be concluded that the PT had difficulty understanding the standard deviation. A narrower curve (C) is chosen when the standard deviation is large, while a wider curve (B) is chosen when the standard deviation is small. The student was unable to understand the standard deviation and the arithmetic mean, while evaluating the A and D curves. Table 14 shows the answers provided by the PTs to question 10a.

Table 14

Answers to the Tenth Question (10a)

Codes	Frequency/Percentage
3	88 (73.3%)
2	22 (18.3%)
1	8 (6.6%)
0	2 (1.8%)

Many PTs were able to justify their answers and provided correct answers. According to PT21, all three distributions are normal. They stated that *"In all three graphs, the arithmetic mean, mode, and median are the same. The standard deviations are different from each other and the brown graph has the largest standard deviation, while the red graph has the smallest standard deviation."* About one out of every five PTs had the correct answer, but they failed to justify their answer (18.3%). Eight PTs answered the question incorrectly. For example, PT36 explained:

> It is a pointed distribution shown in red because it is compressed into a small area, which gives it a pointed appearance. Therefore, its standard deviation is small, and when its standard deviation is small, the group scores are close to each other, resulting in pointedness. Green indicates the normal distribution, which is characterized by a concentration of measurements at the middle and sparse measurements at the extremities. In addition, it is symmetrical. Due to the wide spread of the distribution, the brown distribution appears flattened. In this way,

we can make sense of it. The scores of the groups differ greatly from each other, and the standard deviation is high.

Here, the PT doesn't know what a normal distribution is. All of the distributions given in the questions are normal distributions, but they are all referred to in a different way. There was no response to this question from two PTs. Table 15 shows the answers of the PTs to the second part of the question.

Table 15

Answers to the Tenth Question (10b)

Codes	Frequency/Percentage
3	110 (91.6%)
2	8 (6.6%)
1	-
0	2 (1.8%)

This question was answered correctly and justified by the vast majority of PTs. According to PT7, their standard deviations are the same since both graphs have the same dispersion and kurtosis. They stated that "However, their arithmetic means differ. Their arithmetic means are as follows, from largest to smallest: brown>green>red because if we think of it like a number line, we can say that the brown distribution has the largest arithmetic mean." Although 6.6% of the PTs gave correct answers, they incompletely justified their answers. There was no PT who gave an incorrect answer to this question. Only one PT did not answer the question. When the PTs are evaluated in general on their ability to interpret normal distribution curves, they are considered successful. PTs generally justified their answers and provided correct answers. There was a minority of PTs who provided incorrect answers.

Conclusion and Discussion

This study aimed to reveal PTs' SMK about the normal distribution and to examine their reasons for making mistakes. According to the results, the PTs were better at identifying the normal distribution properties than standard deviation properties. It was noted in some statements that PTs tend to make more mistakes than others. As examples of these statements, we can give the statements "Standard deviation does not depend on the number of terms in the distribution" and "Standard deviation is the square root of the average squared deviation from the mean". It can be considered that the PTs misinterpreted these statements because they presented their justification on the basis of the standard deviation formula, which meant they made the evaluations only operationally.

Furthermore, it has been reported in the literature that PTs/teachers consider statistical concepts mainly operationally, without considering their meaning (Groth & Bergner, 2006; Ijeh & Onwu, 2012; Salinas-Herrera & Salinas-Hernández, 2022; Savard & Manuel, 2015). For example, Salinas-Herrera and Salinas-Hernández (2022) found that students had difficulty in understanding that the area between the horizontal axis and the curve is equal to one. Additionally, the PTs made errors when attempting to correlate the measures of central tendency and dispersion. As an example, in the statement "When we subtract five from each value in the dataset, the standard deviation decreases", the PTs were unable to determine that the standard deviation did not change, because the centre of the dataset did not change despite the decrease in the arithmetic mean. Thus, the measure of central tendency could not be related to the measure of dispersion. Batanero et. al. (2004) reported that PTs have difficulty relating statistical concepts to each other in the literature. Overgeneralizations can be found in some of the PT's statements. A property of the standard normal distribution, "It has a mean of zero and a standard deviation of one", was generalized into a property of all normal distributions by PTs. There is also evidence that pre-service teachers tend to generalize certain claims in the literature (Burgess, 2002; Kurt, 2015; Sorto, 2004).

When asked about interpreting concepts related to the normal distribution based on datasets, the answers of the PTs varied greatly. When it comes to finding the standard deviation, they are most successful. Eight out of ten students answered this question correctly, and PTs who made mistakes in this question did so because they performed operations incorrectly. A question asking where the data are located in the percentage resulted in nearly half the PTs (45%) making mistakes, and these mistakes showed greater diversity. There were two mistakes that were made the most. PTs were observed to establish a direct relationship between the data distances from the arithmetic mean and their areas in the first study. There is 34% of the data located one standard deviation away from the arithmetic mean, while 19.15% of the data are located 0.5 standard deviations away from it. In spite of this, the PTs believed that when the z score was half, 17% of the data fell into the 0.5 standard deviation range since the data was also halved. A similar overgeneralization can be attributed to the PTs here. There was a belief that there was a similar ratio between z scores and the area under the normal distribution. In their opinion, halving the z score results in halving the area. A possible explanation is that the PTs had difficulty relating probability values to the area covered by the curve. There have been similar difficulties emphasized in the literature (Bansisal, 2014; Batanero et al., 2004). The study conducted by Batanero et al. (2004) revealed that undergraduate students had difficulty calculating probabilities under normal curves and presenting them graphically.

Furthermore, the PTs often made mistakes when evaluating normal distributions. It was found that although the PTs were able to calculate z-scores correctly, they evaluated the data as only being located on the right of the arithmetic mean, despite the fact that the data were located both right and left of it. When extracting values from the dataset and analyzing them, PTs had the greatest difficulty determining the curve shape, standard deviation, and arithmetic mean of the new distribution. Over half of the PTs answered incorrectly (51.7%), and about one third of the PTs who answered correctly justified it incorrectly. We observed that only 35% of the PTs understood what changes to the dataset would mean for the shape of the distribution and other statistical concepts. A common characteristic of those who gave incorrect answers was that they could not relate statistical concepts together. An important aspect of this subject is illustrating the areas under a normal distribution and connecting them to various concepts. In the literature, similar findings have been reported, and students are reported to have difficulty determining probabilities and associating them with other concepts (Batanero et al., 2004).

Analysis of PTs' interpretations of the normal distribution by referring to real-life situations revealed remarkable results. According to the results, both questions asked in different contexts resulted in differing rates of correct answers by the PTs. The PTs who answered the question regarding dogs' height correctly accounted for 73.3% of the correct answers, but only 18.3% were able to justify their answers. Taking the grades related question into account, it was found that 86% of the PTs responded correctly, and 70% of them could justify their responses. As shown here, the PTs evaluated the situations differently depending on the context. The PTs are more familiar with the context of grades from different tests, which may explain their greater success rates. In examining the mistakes made, it was found that the reasons were similar to those in the previous section. These reasons are primarily based on the inability to make associations between concepts and operational evaluation of concepts. Further, PTs may experience epistemological anxiety as a result of their difficulties (Wilensky, 1995, 1997). Epistemological anxiety is described by Wilensky (1995; 1997) as the feeling of indecision and confusion experienced by individuals when faced with normal distribution problems.

In evaluating the PTs' interpretations of normal distribution curves, more than 70% answered all three questions correctly, along with acknowledging that their answers were justified. Two categories can be used to evaluate the reasons for the mistakes made. As a starting point, PTs have trouble associating concepts like standard deviation and arithmetic mean. It may also be due to the prototype perceptions developed by PTs. Different words, such as pointed and flattened, were used by PTs to describe the various representations of the normal distribution. There may have been an emergence of such a result since the PTs only created one prototype for the normal distribution. A literature review revealed that prototype perceptions may prevent individuals from expanding their understanding of related concepts.

PTs responded differently to both questions (three and 10a-10b) in which specialized content knowledge was questioned. Despite being able to interpret the given visual representations more accurately, they were unable to create them themselves with the same success. According to the literature, individuals have difficulty transforming datasets into visual representations (Bruno & Espinel, 2009; Meletiou-Mavrotheris & Lee, 2005).

Researchers recommend using and associating different statistical concepts (e.g., centre, skewness) and evaluating distributions as a whole. It is also important to establish a relationship between real data and distributions (Batanero et al., 2004). PTs were required to evaluate and interpret multiple situations related to normal distributions in the current study. This study concludes that normal distributions, as described in other studies (e.g., Batanero et al., 2004), involve many different statistical concepts and ideas that need to be integrated and interrelated. The main emphasis is not on developing computational skills related to statistical concepts, but rather on making profound associations between concepts and taking into account many concepts at once (Batanero et al., 2004). Prior to studying the normal distribution, students should understand probabilities, density curves, kurtosis and skewness, as well as histograms (Batanero et al., 2004). Lack of knowledge about these concepts may also have contributed to PTs' difficulties.

Suggestions and Limitations

For the SMK, the normal distribution is an important concept that the teacher should be familiar with (Ball et al., 2008). As a result, the findings of this study suggest important implications that are supported by other research findings (e.g., Delport, 2022). Students and PTs who have difficulties understanding the normal distribution may have difficulty understanding other statistical concepts as well. Moreover, Batanero et al. (2004) and McLeod (2019) claim that it can be used to model many natural and psychological phenomena. This concept needs to be supported by applications in order for PTs to gain a deeper understanding. In order to improve their understanding of this concept, it may be helpful to work on different tasks to overcome the difficulties they experience. The current study also did not include any computer aided software due to technical difficulties, which may be considered as a limitation of the study. A comparative study could be conducted in the future to find out how these software programs affect PTs' understanding.

A "no answer" code was applied to PT responses if they failed to answer the question. As for the student's knowledge of the questions, it's unclear if they are aware of them or prefer to not write anything. It is possible to consider this a limitation of the study. The identification of these two situations can be improved by conducting qualitative research in future studies. Further, the study examined the reasons for PTs' mistakes. However, the study was unable to determine the origins of the reasons mentioned. PTs' thinking in depth could be analyzed by conducting semi-structured interviews in future studies as a way to understand the reasons behind their mistakes in relation to these concepts.

Different forms of representations can also help PTs overcome the difficulties they encounter. As Wood et al. (2018, p.299) suggests a transition from "concrete to visual and abstract representations" can help students grasp the concept of the normal distribution better. It is possible for PTs to make more in-depth associations between concepts by connecting datasets and representations of these datasets.

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Bridging Inquiry-Based Science Learning through Children's Literature: A Case Study of an Initial Teacher Certification Program

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ABSTRACT

This case study explores the integration of children's literature in science education, with a focus on engaging preservice teachers in a science methods course to select, locate, design, and implement the integration of children's literature in their instructional practices. Sixty-four elementary preservice teachers in an initial teacher certification program in the central US participated in this study. The comprehensive written and oral reflections captured in this study offer insights into preservice teachers' attitudes towards using children's literature to teach science and the challenges they encounter in book selection and pedagogical decision-making. Our findings highlight a significant contrast between preservice teachers' initial skepticism, marked by questions, concerns, and hesitance, and their positive feedback after engaging in the process of selecting, designing, and implementing science lesson plans incorporated with carefully selected children's literature pieces. Our study confirms the valuable role of children's literature in science teaching, particularly within the context of a science methods course for preservice teachers. It also aligns with Flick and Lederman's (2006) perspective on scientific inquiry as an instructional strategy. The identified gaps in preservice teachers' skills also emphasize the pressing need for professional development, such as workshops or training sessions, which specifically focus on developing their skills in selecting and locating children's literature pieces that could be incorporated in inquiry-based science lesson plans.

Keywords: Inquiry-based science, children's literature integration, preservice teachers' perspectives

Introduction

In the 21st century, what kind of competencies are needed for the new phase of globalization? As educators and teachers, we are facing a pressing problem: how can we better help students develop inquiring minds when they are learning different content knowledge, so that our students can become competent global citizens in the 21st century?

There is an urgent need for integrated STEM education (science, technology, engineering, and mathematics). Many reports issued by influential education, policy, and business groups have emphasized the importance of expanding or improving STEM education for globalization (Honey et al., 2014). In an era of technology development and innovation, a STEM-literate citizenry is not only the future workforce in the globalized market, but also the backbone of a nation's productivity and innovative capacity. In other words, a STEM-literate citizenry is closely linked with a nation's prosperity and competitiveness in the world (Carnegie Corporation Report, 2009; Gonzalez & Kuenzi, 2012; Kuenzi, 2008). However, there is also a growing concern in the US, due to the low math and science achievement of American students in the Program for International Student Assessment (PISA), and the lower proportion of STEM degrees in the US compared with other countries (Kuenzi, 2008).

To scaffold integrated STEM education, the use of children's literature emerges as an effective pedagogical practice. Children's literature, widely recognized for its effectiveness in teaching various content knowledge (Hanuscin et al., 2011; Larson & Rumsey, 2018; Saul & Dieckman, 2005; Spencer & Guillaume, 2011), aligns with the developmental stages of young learners (Heisey & Kucan, 2010; Stadler & Ward, 2005). It sparks interest and curiosity (Sackes et al., 2009; Salehjee, 2020),and plays a crucial role in reducing learning-related anxiety (Furner, 2018; Morrow et al., 1997), and thus cultivates a positive approach to education (Wadham & Young, 2015).

In addition, the value of children's literature in facilitating the understanding of inquiry-based content knowledge has long been emphasized by scholars (Howe, 1993; Zeece, 1999). Scholars and educational organizations, such as the National Council of Teacher of Mathematics (NCTM), National Science Teaching Association (NSTA), the National Council on the Teaching of Social Studies (NCSS), and others, support the integration of children's literature in various subjects (Tunks et al., 2015). For instance, in mathematics education, it not only meets instructional recommendations but also helps children achieve mathematics proficiency (Green et al., 2018). Additionally, quality children's literature in social studies provides students with a holistic perspective of historical events (Manak, 2012) and increases students' understanding of the importance of history (Palmer & Burroughs, 2002). Likewise, in science education, children's literature not only serves as an inquiry tool for active learning but also aids in developing inquiring minds and understanding the nature of science (Ford, 2004; Fredericks, 2008; Hanuscin et al., 2011; Lederman, 2014; May et al., 2020). It facilitates authentic scientific explorations by encouraging students to observe, pose questions, listen to different perspectives, and provide their understanding of phenomena (Hachey et al., 2022). The dynamic nature of science, as emphasized by the National Research Council (2000), necessitates a constructivist model (May et al., 2020), aligning with the 5E approach to science education (Bybee, 2019; Lederman, 2014).

To integrate children's literature in the content area study, teachers first must be familiar with a wide range of literature and be able to make selections suitable for the students (Tunks et al., 2015). Therefore, there is a pressing question: what kind of children's literature qualifies as quality literature and should be selected? Selecting appropriate literature poses a challenge even for experienced teachers because it involves many factors. In addition to genre and content, the physical property such as visual features are crucial elements for consideration (Crowther et al., 2005; Donovan & Smolkin, 2002; Sackes et al., 2009). The selection process could be even more daunting for preservice teachers due to their limited and developing content knowledge. Additionally, preservice teachers are often left with few opportunities to explore the possibility of applying strategies outside their area of specialization (Krajcik & Sutherland, 2010). The selection process is also formidable because it involves considerations related to the accuracy of the scientific content, quality of the writing and organization, age appropriateness of subject matter and explanations, and the diversity of gender and ethnicity.

To explore the challenges which preservice teachers face in their attempts to integrate children's literature in inquiry-based science lessons, this article reports the findings of a qualitative study that examines preservice teachers' reasonings for literature choices. This study was guided by the following research questions:

1. How do elementary preservice teachers locate, select, and use children's literature within their inquiry-based lessons, and what rationales do they use in making their selections?
2. What are the convictions of preservice teachers after their experience with the use of children's literature in inquiry-based science lessons?

Literature Review

The Transformative Influence of Children's Literature on Learning, Motivation, and Futures

Over the years, there is a lasting recognition of the effectiveness of children's books in introducing abstract and challenging concepts, offering captivating storylines and colorful pictures, which is different from traditional textbooks (Butzow & Butzow, 2000; Ford, 2004, 2006; Rice, 2002).

Widely acknowledged for its role in teaching various content knowledge (Hanuscin et al., 2011; Larson & Rumsey, 2018; Morrow, Pressley, Smith, & Smith, 1997; Saul & Dieckman, 2005; Spencer & Guillaume, 2011), children's literature serves as a power tool for teachers to present challenging concepts and content knowledge in engaging narratives. Aligned with the development needs of young minds (Heisey & Kucan, 2010; Stadler & Ward, 2005), children's literature plays a pivotal role in alleviating anxiety about learning (Furner, 2018; Morrow et al., 1997) and consequently, cultivates a positive attitude towards learning (Wadham & Young, 2015). This significance lies in its impact on shaping students' perspectives on learning, closely related to their motivation (García et al., 2016), therefore influencing their academic achievements (Green et al., 2018). Such influence may endure in their higher-level studies and even extend to shaping their future career choices (Hackett & Betz, 1995).

Integration of Children's Literature across Inquiry-Based Content Areas

Enabling teachers to present challenging concepts in engaging narratives, children's literature has long been a powerful tool for enhancing inquiry across diverse content areas, promoting active exploration and understanding (Ansberry & Morgan, 2010; Ford, 2004; Fredericks, 2008; Howe, 1993; Lederman, 2014; Lynch-Brown et al., 2011; Mahzoon-Hagheghi et al., 2018; May et al., 2020).

Children's literature, including non-fiction science books, fiction, and poetry, can be used as a literacy tool to support the inquiry learning of content knowledge (Rice, 2002). This explains why integrating children's literature in inquiry-based content areas such as mathematics, social studies, and science is supported by literacy scholars and professional education organizations, including the NCTM, the National Council of Teachers of English (NCTE) (Tunks et al., 2015), the NCSS, and NSTA.

In mathematics education, children's literature not only meets current instruction recommendations by the National Association for the Education of Young Children (NAEYC) and the NCTM but also helps children achieve mathematics proficiency (Green et al., 2018). The NCTM supports using children's literature to present mathematical concepts because such instruction helps students to see mathematics constructs from a different point of view (Tunks et al., 2015). Furthermore, the NCTM reports that the integration of children's literature within the mathematics class has helped students achieve five goals, including one: students understand the value of mathematics; two: students are confident in their mathematical abilities in their daily dealing with math; three: students develop mathematical problem-solving skills; four: students learn mathematical symbols and ideas to communicate with peers, and five: students acquire reasoning skills (Nesmith, 2008).

Likewise, integrating quality children's literature into the social studies class provides students with a more holistic perspective of historical events (Manak, 2012). Children's literature is a powerful and proven learning tool to stimulate the interest and imagination of young people and foster students' understanding of the importance of history (Palmer & Burroughs, 2002). Additionally, research shows that students' interest in history and their understanding and retention of information increase when literature is integrated as an instructional tool (Palmer & Burroughs, 2002).

Children's Literature as an Inquiry Tool for Science Education

When talking about science education in schools, scholars emphasize the importance of acquiring scientific literacy that is "developmentally appropriate and understandable" (Lederman & Lederman, 2019, p.1) for students at all levels. They assert that this acquisition equips students to make informed decisions regarding scientifically-based issues (Brunner & Abd-El-Khalick, 2020; Lederman et al., 2014; Lederman & Lederman, 2019). In essence, achieving scientific literacy involves more than just knowing the concepts, laws, and theories. Students must also understand the nature of science, recognizing that science is a "human enterprise" (Lederman et al., 2014, p. 288) shaped by human creativity, inference, beliefs, prior experiences, and social and cultural factors, which renders scientific knowledge tentative and evolving (Lederman et al., 2014).

In addition, to be scientifically literate, students also need to develop an understanding of how scientific knowledge is developed through scientific inquiry (Abd-El-Khalick, 2002; Brunner & Abd-El-Khalick, 2020; Lederman et al., 2014; Lederman & Lederman, 2019). Flick and Lederman (2006) explain that scientific inquiry, as mentioned in the National Science Education Standards (National Research Council [NRC], 1996) embodies several dimensions. First, it serves as a foundational principle guiding contemporary scientific practices. Furthermore, it refers to the processes and ways of thinking that facilitate the development of new knowledge. Additionally, scientific inquiry also pertains to an understanding of how to acquire knowledge about the characteristics of science, that is, the nature of science. By emulating, to a reasonable extent, the methods and procedures employed by scientists, students will acquire a deeper understanding of the nature of science and, consequently, a holistic understanding of science (Flick & Lederman, 2006). Beyond these aspects, scientific inquiry serves as an instructional strategy for teaching scientific disciplines. In this sense, scientific inquiry is expected to result in two student outcomes: the capacity to engage in scientific processes and the knowledge of the rationales behind (Flick & Lederman, 2006). This explains why "teaching science as inquiry" is a core principle for science education in the National Science Education Standards (Flick & Lederman, 2006, p.x).

In addition to the National Science Education Standards (NRC, 1996), inquiry-based teaching is also a prominent theme in national science education reform documents such as *Project 2061: Science for All Americans* (Rutherford & Alhgren, 1990), and the Next Generation Science Standards ([NGSS], NGSS Lead States, 2013). The NGSS aims to assure a strong foundation of scientific knowledge embedded in all K-12 curricula, achieved through an integrated focus on science content, practices, and crosscutting concepts. Moreover, the NGSS demonstrates a profound alignment with the English Language Arts (ELA) Common Core Standards, establishing explicit connections between the skills of reading and analyzing texts and the science practices of obtaining, evaluating, and communicating information (Mcginnis, 2020).

Mahzoon-Hagheghi and colleagues (2018) emphasize the potential of trade books to align with science content and NGSS science and engineering practices. They claim that trade books used in inquiry-based science teaching can serve as an engaging supplement to science content, facilitating the integration of NGSS practices into students' learning experience. Carefully chosen trade books not only enhance scientific understanding but also promote the development of students' narrative and analytical skills, contributing to the creation of a cohesive and comprehensive learning experience for students.

Children's literature, as a literacy tool, can also activate a student-centered approach to inquiry-based science teaching, aligning with the national science standards (Ansberry & Morgan, 2010; Mahzoon-Hagheghi et al., 2018). This alignment is further underscored by the continued integration of children's picture books in science teaching. This trend is exemplified by the recommendation of the outstanding children's science trade books each year by the NSTA and The Children's Book Council (CBC) since 1973 (Children's Book Council [CBC], 2020). Specifically, series such as *Picture-Perfect Science* series have been designed to facilitate the creation of engaging and comprehensible science lessons through the integration of picture books (Ansberry & Morgan, 2010).

Children's literature proves particularly valuable in elementary inquiry-based science education, because it can effectively employ the storyline, narrative forms, or colorful illustrations (Feathers & Arya, 2012) to not only communicate scientific knowledge to children in an interesting way but also involve them in inquiry learning (Ansberry & Morgan, 2010). For example, children can be invited to identify the scientific problems that characters in the stories encounter, discuss the ways that characters used to solve the problems, and even take on the roles of the characters and provide their own solutions (Hachey et al., 2022). This approach is especially beneficial in elementary science education, allowing students to actively participate in "developing, researching, and investigating questions of significance that are not easily tested with empirical experiments" (Ford, 2004, p. 286).

In this sense, children's literature functions as an inquiry tool, enhancing students' understanding of science by engaging them in the scientific processes (Ford, 2004). Some scholars have noted that learning science in isolation denied children the opportunity to understand the nature of science and scientific inquiry (Ford, 2006; Lederman, 2014; May et al., 2020). Through the processes of scientific inquiry facilitated by children's literature, children not only learn the science concepts and laws but also develop an understanding of the nature of science and the way of thinking that underlies the scientific knowledge (Abd-El-Khalick, 2002; Flick & Lederman, 2006; Lederman, 2014).

The use of children's literature as an inquiry tool in science education is noteworthy also because it aligns with the active student-centered approach emphasized in the national science standards (Ansberry & Morgan, 2010; Mahzoon-Hagheghi et al., 2018). As previously mentioned, science is a "human endeavor" (National Research Council [NRC], 2000, p. xiii) to understand the natural and material world, characterized by its evolving and subjective nature. Scientific knowledge is crafted through scientists' creativity, inferences, and interpretations based on their observation of the empirical studies (Brunner & Abd-El-Khalick, 2020; Lederman et al., 2014). Therefore, from a pedagogical perspective, the "dynamic nature" of science (May et al., 2020, p. 399) calls for a constructivist model of science education. In a constructivist learning environment supported by children's literature, children actively engaged in the process of exploring and constructing their knowledge about science concepts, the nature of science, and the nature of scientific inquiry (Ford, 2004; Fredericks, 2008; Lederman, 2014; May et al., 2020).

In conclusion, the integration of children's literature as an inquiry tool in elementary science education aligns with the goal of cultivating scientific literacy and promoting the active student-centered approach advocated by national science standards. Through the use of carefully selected trade books, educators not only foster their literacy skills in reading and writing, but also enrich students' scientific understanding. This approach creates a comprehensible and engaging learning experience, facilitating the exploration of science concepts and theories. Consequently, it contributes to the development of an understanding of the dynamic nature of science in the process of scientific inquiry.

Theoretical Framework

In this study, the 5E model (Engage, Explore, Explain, Elaborate, and Evaluate) serves as the guiding instructional framework for the integration of children's literature in science education. This model, rooted in constructivism, is widely acknowledged in the field of science education (Singh & Yaduvanshi, 2015; Taylor et al., 2015; van Garderen et al., 2020). Developed by the Biological Science Curriculum Study (BSCS) led by Rodger Bybee, the 5E model provides teachers with a structured approach to scaffold meaningful learning experiences for students (Bybee, 2014). Adopting a constructivist perspective (Duran & Duran, 2004), the 5E model encourages students to become active agents in their science learning, fostering an environment where they can generate scientific knowledge in an interactive environment, make their predictions, draw inferences, propose hypotheses, and develop their own solutions to scientific problems.

This constructivist pedagogy, centered around the 5E model, positions students as active participants in the process of scientific inquiry. Through engagement in the 5E phases, students move beyond the acquisition of dead facts, gaining a profound understanding of the dynamic nature and development of scientific knowledge (Bybee, 2019; Lederman, 2014). This approach promotes a deeper connection between scientific concepts and real-world applications, emphasizing critical thinking and problem-solving skills in the context of authentic learning experiences (Nesmith & Cooper, 2021; Weng et al., 2022).

Methodology

Research Context and Participants

This case study was conducted in an initial teacher certification program at a private university in the central United States. The principle of purposeful sampling was adopted because all sixty-four elementary preservice teachers in this program participated in this study and the purpose of the study was to examine preservice teachers' text selections (Creswell, 2012). All preservice teachers were in their junior year and were enrolled in their required mathematics and science methods courses: forty were first-semester juniors and twenty-four second-semester juniors who had completed their social studies/English language arts methods and practicum courses in the previous semester. Additionally, the preservice teachers were concurrently enrolled in a field experience course wherein they designed and taught mathematics and science lessons, based on methods course requirements, throughout the semester.

During the science methods course, the preservice teachers were exposed to lessons and strategies which aimed at establishing the connection between science and children's literature, including trade books, and other forms of literature such as poetry. Most trade books used in this course contained short passages, some being narratives while others were more didactic. All literature pieces shared throughout the semester-long course involved science content, either implicitly or explicitly (See Table 1). These trade books also contained a predominance of illustrations.

Table 1

Children's Literature Used, the Related Science Content, and Inquiry Activity Conducted

Preservice teacher	Children's Literature Used	Related Science Content	Inquiry Activity
1	Red Leaf, Yellow Leaf by Lois Ehler	Special characteristics of fall plants	Engage
2	Is your mama a Llama, by Deborah Guarino	Inherited Traits	Engage
3	Whose Feet Are These? By: Wayne Lynch	Animal Adaptations	Engage
4	The Tiny Seed by Eric Carle	The concept that not all plants come from seeds	Engage
6	The Windy Day by G. Brian Karas	Wind power & renewable resources	Engage
7	The Runaway Pumpkin by Kevin Lewis	Rolling	Engage
8	Light: Shadows, Mirrors, and Rainbows by Natalie M. Rosinsky	Light Energy	Engage
9	Gotcha! By Jennifer Dussling. The Remarkable Farkle McBride	Force of Magnetism	Engage
11	When Charlie McButton Lost Power by Suzane Collins	Electricity, more specifically battery voltage	Engage
12	Snowball by Shef Silverstein; Pancakes, Pancakes! By Eric Carle; Water is Water by Miranda Pa	Heat Energy; Water	Elaborate; Engage
13	Chicken Little by Steven Kellogg	Gravity	Engage
14	The Remarkable Farkle McBride by John Lithgow	Sound	Engage
15	If You Find a Rock by Peggy Christian; Let's Go Rock Collecting by Roma Gans	Rocks	Engage; Explain
16	Why Do I Have To Wear Glasses? By Greg Williamson	Refraction	Engage
17	One Bear Lost by Karen Hayles and Jenny Jones; Fiesta! By Katacha Diaz	Movement; How to describe the location of an object	Engage
18	Gotcha! By Jennifer Dussling; Nature's Treasures	Magnets; The Natural World	Engage; Elaborate; Explain

Table 1 (continued)

19	Move It! By Adrienne Mason	Motion and Force	Engage
20	One Bear Lost by Karen Hayles and Jenny Jones	Movement	Engage
21	Dirt, by Steve Tomecek and Spenser; Rocks, by Lawrence F. Lowery	The concept of soil and rocks	Engage
22	Who Sank the Boat; Sheep in a Jeep	Force (push/pull)	Engage
23	Move! By Steve Jenkins and Robin Page	Motion and Movement	Engage
24	Pancake, Pancakes! By Eric Carle as my piece of literature	Physical and Chemical Change	Engage
25	The Magic School Bus; Wet All over by Mike Guillory	The Water Cycle	Engage
26	The Snowflake: A Water Cycle Story by Neil Waldman	The Water Cycle	Engage
27	A Cornfield by Julia Ward; Modern Biomass by Joyce Hemsley	Biomass as an Alternative Source of Energy	Engage
28	Drop Goes Plop: First Look at the Water Cycle: Sam Godwin	Precipitation	Engage
29	The Tiny Seed by Eric Carle	The Four Seasons and how they affect plant life	Engage; Explore; Elaborate
30	Switch On, Switch Off by Melvin Berger	Electrical Circuits; Parallel and Series Circuits	Engage
31	The Giving Tree by Shel Silverstein	Renewable and Non-renewable Resources	Engage
32	Roller Coaster by Marla Frazee	Motion and how incline affects how fast something goes	Engage
33	The Lorax by Dr. Seuss	Recycling and Resources; Helping the environment	Engage
34	When Charlie McButton Lost Power by Suzanne Collins and Mike Lester	Electric Circuits specifically battery voltage	Engage
35	The Magic School Bus: Lost in the Solar System by Joanna Cole	Solar System and individual planets' characteristics	Engage

Table 1 (continued)

36	The Plop Goes Drop: A First Look at the Water Cycle, by Sam Godwin	Patterns in the natural world among objects in the sky; Water Cycle	Engage
37	Aunt Chip and the Triple Creek Dam Affair	Power of Water; Alternative Energy	Engage
38	When Charlie McButton Lost Power; Newton and Me	Battery Voltage and Energy; Push and Pull, Friction and Motion	Engage
39	The Wind Blew by Pat Hutchins	Energy	Engage
40	Wet All Over by Patrick Relf	Steps of the Water Cycle	Engage
41	Is Your Mama a llama by Deborah Guarino	Inherited Traits	Engage
42	What's For Dinner by Katherine Hauth	Producers, Consumers, and Decomposers	Engage
43	This Book just Ate My Dog! by Richard Byrne	Producers, Consumers, and Decomposers	Engage
45	Bear Snores by Karma Wilson	Adaptations	Engage
46	Who Eats What? Food Chains and Food Webs by Patricia Lauber, Illustrated by Holly Keller	Food Chain; Food webs	Elaborate
47	Turtle, Turtle, Watch Out! By April Pulley Sayre	Food Webs	Engage
48	Animals in Winter by Henrietta Bancroft; Louie the Leaf by Jeff VanGetson	Hibernation of animals during the wintertime	Engage; Explain
49	I Wanna Iguana by Karen Kaufman Orloff; Summer Coat, Winter Coat by Doe Boyle	Classification and Characteristics of Animals; Animal Adaptations	Elaborate; Explain
50	From Caterpillar to Butterfly by Deborah Heiligman	The Stages of Complete and Incomplete Metamorphosis of Insects	Engage
51	What Do You Do With a Tail Like This? by Steve Jenkins and Robin Page	Adaptations	Elaborate
52	Growing Frogs by Vivian French	Amphibians, and their life cycle	Explore
53	Is a Camel a Mammal? by Dr. Seuss	Amphibians, and their life cycle	Engage

Table 1 (continued)

54	The Reason For a Flower by Ruth Heller	Organisms and the environment; How pollinators work with their environment to pollinate plants and flowers	Explain
55	Wild & Wooly by Mary Jessie Parker	Organisms and Environments	Engage
56	Pass the Energy, Please. By Barbara Shaw McKinney	Organisms and Environments	Engage
58	Froggy Learns to Swim by Jonathon London	Amphibians, including frogs	Engage
59	Leaf Man by Lois Ehlert; Pumpkin Circle: The Story of a Garden by George Levenson	Amphibians, including frogs; Ecosystem and how humans have an impact and create consequences within the ecosystem	Engage
60	The Lorax, by Dr. Seuss	Ecosystem and how humans have an impact and create consequences within the ecosystem	Explain
61	The Lorax" by Dr. Seuss	Ecosystems	Explain
62	Animal Teachers by Janet Halfmann	Learned behaviors by different animals	Engage
63	Where in the Wild: Camouflage Creatures Concealed and Revealed by David M. Schwartz, Yeal Schy, and Dwight Kuhn	Adaptations of plants and animals	Engage
64	If I had Duck Feet by Dr. Seuss	Adaptations	Elaborate

At the beginning of each semester, there was a presentation that exemplified seven ways of integrating children's literature in science, as revised by Welchman-Tischler (1992) who focused on the use of children's literature in mathematics instruction. The aim of the presentation was to provide preservice teachers with a comprehensive framework for incorporating children's literature into elementary science teaching. These seven ways of integration that were introduced to preservice teachers include: (a) provide a context, (b) introduce tools of science, (c) model a creative experience, (d) pose an interesting problem, (e) prepare for a concept or skill, (f) develop a concept or skill, and (g) provide a context for the review.

Throughout the semester, the methods course professor chose several pieces of children's literature and modeled to the preservice teachers the different ways of integrating them into elementary science instruction. One strategy the professor used was to engage the preservice teachers in science activities inspired by the children's literature so that they would have personal experiences connecting literature with science content. For example, after reading *Who Sank the Boat* (Allen, 1996), the preservice teachers were asked to build and launch aluminum foil boats of different shapes and sizes to build their understanding of the concepts of floating and sinking.

In their field experience course, preservice teachers were given the autonomy to choose whether to integrate children's literature into their lesson plans, and if they chose to do so, they would design the lesson plans accordingly. While the seven integration strategies were presented as valuable tools, preservice teachers were not mandated to use a specific strategy, allowing for flexibility and individualized approach in integrating children's literature into their teaching practices. An example lesson plan in which children's literature was integrated is provided in the Appendix.

Before implementing the teaching plans, a literacy-content specialist provided preservice teachers with resources on graphic organizers and ways to select appropriate literature based on the goals of the lesson. The integration of children's literature occurred in elementary school classrooms where students were enrolled in grades three-five and the time of the integration depended on the semester of the in-service teacher.

It should also be noted that the methods employed in this study are grounded in previous successful implementations of children's literature in similar science methods contexts (Nesmith et al., 2017).

Procedures

The most appropriate design for this investigation was the qualitative, naturalist paradigm because the research method allows for an investigation relative to how individuals react in and to the world around them as they construct a personalized meaning to that particular world. As posited by Lincoln and Guba (1985), only through holistic, contextually situated inquiry emphasizing processes, meanings, and the qualities of entities, can an understanding of those realities be determined with any degree of trustworthiness. The research design used for this article fits the characteristics and the process of naturalistic inquiry. Armstrong (2010) outlined eight basic processes of the naturalistic inquiry which include the following common sequence of steps:

1. Gaining access to and entering the field site
2. Gathering data
3. Ensuring accuracy and trustworthiness (verifying and cross-checking findings)
4. Analyzing data
5. Formulating interpretations
6. Writing up findings
7. Member checking (sharing conclusions and conferring with participants)
8. Leaving the field site (p. 881)

Additionally, we employed inductive analysis, a method characterized by the organic emergence of themes, categories, and patterns through the analysts' interactions with the data. This contrasts with deductive analysis, where data was analyzed based on a pre-existing framework (Patton, 2015).

Data Collection

Written Reflections

In this one-year study, the science methods course included a specific requirement for preservice teachers to incorporate children's literature into at least one science lesson during their elementary field experience. Preservice teachers were given autonomy in deciding whether they would integrate children's literature, and if they chose to do so, they would design their lesson plans accordingly. While the decisions regarding the content of the science lesson and the corresponding piece of children's literature were left to the preservice teachers, a collaborative process was established. The field-based classroom teacher participated by offering feedback and giving final approval to ensure the cohesion of the lesson with both course objectives and the practical requirements of the field experience.

Additionally, the preservice teachers were required to respond to a prescribed set of questions to guide their reflections of the literature integration experience. These questions involved various elements, including the planning and presentation of the literature-based science lesson. These questions were as follows: (a) What piece of literature did you use within the science lesson? (b) What science content did you address with the literature piece/lesson? (c) When did you integrate the literature piece and why was the timing a good choice? and (d) How and why did you choose the literature piece, and why was the literature piece a good choice?

Oral Presentations

At the end of each semester, during a scheduled science methods class, all preservice teachers were asked to discuss their literature experience with their course instructor and fellow preservice teachers. The discussions followed the same protocol for their writing reflections. In other words, the preservice teachers were required to respond to the prescribed four questions guiding their reflections on the literature integration experience. These discussions were facilitated with the same set of questions with the purpose of providing a consistent framework for preservice teachers to articulate their initial and evolving perspectives toward the strategy of literature integration.

The discussions were audio-recorded, transcribed, and verified. During the discussions, the preservice teachers responded to questions concerning their initial and ensuing perspectives toward the strategy of literature integration, possible reasons for changes in perspectives toward the strategy, and future plans for their pedagogical strategy.

Although class attendance was required of all preservice teachers, participation in the discussion was not a course requirement. A separate, distinct discussion occurred during each of two course sections each semester. During the discussions in the Fall semester, thirty three of the thirty-five preservice teachers provided oral reflections, and during the spring semester discussions, twenty one of the twenty-nine preservice teachers provided oral reflections. When examined in terms of first and second-semester juniors, thirty eight of the forty first-semester juniors provided oral reflections and sixteen of the twenty-four second-semester juniors provided oral reflections.

The researchers noted the discrepancy between the number of preservice teachers involved in the study and the number who participated in the discussions. However, the research described herein focused on the study and data components consistent for all sixty four of the preservice teacher participants: (a) all participants were required to plan and teach a science-focused lesson that incorporated a piece of children's literature; (b) all participants were required to reflect upon said lessons utilizing a prescribed set of questions; (c) all participants received instruction and support from the same science methods course professor, and (e) all participants were invited to participate in a discussion that utilized a common protocol.

Additionally, the researchers considered the limited number of data sources and how the credibility of the study may have been strengthened through the triangulation of data with additional sources. However, in consideration of the nature of the participants' field teaching experience and concerning the time constraints of additional data collection points, the researchers felt the reflection data was strong in providing rich, thick descriptions of preservice teachers' thoughts, reflections, and experiences.

Data Analysis and Credibility

Researchers' Positionality

Each of the five researchers brought a unique perspective to the study: (a) elementary literacy methods course professor, (b) elementary science methods course professor, and (c) three curriculum and instruction doctoral students, each with unique experiences in English education. The five researchers are all in the teacher preparation program at the same university, but, as delineated above, only the science and literacy methods course professors had direct interactions with the preservice teacher participants, with the three doctoral students participating in data analysis following the intervention and data collection.

Triangulations and Intercoder Agreement

Data analysis is a process of reduction and condensation (Huberman & Miles, 2002). Numerous chunks of data are organized, coded, and categorized and then themes were generated after the pattern-matching process. The principle of triangulation was followed to ensure the credibility of the study (Stake, 1995; Creswell, 2005; Lincoln & Guba, 1985) because according to Lincoln and Guba (1985), "triangulation of data is crucially important in naturalistic studies" (p. 283). As Denzin (1978) recommended, we used two types of triangulations: method and investigator triangulation. First, in the data collection process, different methods were used, which involved gathering the participants' written reflections and oral presentations. The data collected through those methods were also verified with the participants. Second, there are five investigators for this research, two university professors and three doctoral students. All five investigators have unique perspectives about their academic specialty that enhanced the investigator triangulation during the research process.

Additionally, to mitigate researcher bias, data analysis was deferred until the conclusion of the spring semester. Each of the five researchers received word-processed copies of the oral reflection transcriptions and written reflections from the preservice teachers. To ensure the internal consistency, the researchers followed the procedures of intercoder agreement check recommended by Creswell and Poth (2017). They independently read several transcripts and reflections, individually conducted coding, and extracted verbal or written phrases consistent with the research questions.

Subsequently, the researchers came together to discuss the methodology for further analysis of the salient codes and developed a list of preliminary codes. After this, the researchers worked individually again, following the initial codebook to complete the coding for all data. After assessing the consistency of the codes done by the researchers independently to ensure that the intercoder agreement reached 85% as suggested by Miles, Huberman, and Saldana (2014), the researchers revised the codebook and abstracted codes into larger themes.

The generated themes were checked and matched until the researchers established themes and categories representing the entire data set. This method, incorporating constant comparison (Lincoln

& Guba,1985) and intercoder agreement check, significantly enhanced the reliability of this study (Creswell & Poth, 2017; Miles et al., 2014).

Findings

Driven by the interest in exploring the challenges that preservice teachers face when integrating children's literature into inquiry-based science lessons, the researchers aimed to address questions that could explain preservice teachers' perspectives and reasonings regarding the location, selection, and integration into science lessons. Additionally, the researchers sought to understand preservice teachers' convictions of their current and future application of integrating children's literature into inquiry-based science lessons. After collecting written reflections and oral presentations from the preservice teachers, we analyzed them using the principles of constant comparison (Lincoln & Guba,1985) and intercoder agreement check (Creswell & Poth, 2017; Miles et al., 2014), resulting in the identification of the following themes.

RQ1 Findings

The Impact of Personal Experience on Attitudes Towards Integrating Children's Literature

One of the themes that emerged from this study is the impact of prior learning experiences on preservice teachers' attitudes. The study revealed that the use of children's literature in the science methods course shaped preservice teachers' positive attitudes toward teaching, influencing their future decisions about instructional techniques.

When asked about their initial impressions of the use of children's literature in inquiry-based science lessons, most participants expressed excitement about their experience. Phrases such as "It's cool", "exciting", "interesting" or "a fun way of science" (e.g. in oral presentations of participant 31, 63, and more) were commonly used. The novel experience with the integration of children's literature in science lessons exceeded their expectations. Some participants even conveyed their surprise, saying "I had never thought about doing that before, so I thought that was really cool" (participant 25, oral presentation). Many preservice teachers were captivated by the creativity of this practice. They agreed that "it's a really fun, creative way to get students" and expressed their willingness, and even eagerness, to try using children's literature in their classroom instruction.

However, this study also revealed that, despite the professor's exemplary demonstration of integrating children's books into science teaching, there were still concerns and hesitance among the preservice teachers. The study involved sixty-four participants, all of whom had completed their social studies/English language arts methods and practicum courses in the previous semester. According to the participants' written reflections, five out of the 64 participants (7.81%) did not fulfill the requirement to integrate literature within their inquiry science lesson. However, the majority (92.19%) of participants used at least one piece of literature in their science classroom instruction.

These five preservice teachers either had an unintentional oversight or were possibly overwhelmed with lesson planning, not thinking to include literature within their lesson until reminded by the professor of the reflections being a part of their course requirements. It turns out that the textual content of the book was a primary concern. For example, some preservice teachers expressed concerns about the accuracy of the content. "Oh, fiction books aren't always correct" or questioning the effectiveness of the content knowledge, saying "You know if you think the *Magic School Bus,* they are kind of outdated information" (participant 24, oral presentation).

Concerns were also expressed regarding the pedagogical approach, even after the professor exemplified how to integrate children's literature into science lessons. One preservice teacher admitted, "I was kind of confused." Despite the course instructor providing book suggestions, this preservice teacher still struggled to integrate literature appropriately. Additionally, a few preservice teachers, even if they used children's books in their lesson design, remained skeptical about the idea of integrating children's literature into science lessons. One preservice teacher shared, "I really was terrified and had no idea how to use literature in inquiry-based science because I didn't really think they went together at all, um, reading and inquiry."

However, this study also revealed how attitudes could be changed through personal experiences. Preservice teacher 41 shared how her experience with the use of children's literature changed her attitude toward science, saying, "That was something I was excited to bring into math and science because I think growing up, I didn't really like math and science as much." Preservice teacher 18 shared in the presentation how her initial reluctance was turned into a teachable moment, saying,

> Quite honestly, I thought putting literature in science and math was both kind of crazy, um, I thought it was unnecessary because like you already have learned doing so much hands-on, like I thought the hands-on was more useful than reading a book, but I found kind of an interactive book where the kids had to like look for the hidden animals that were camouflaged into the page and so they responded really well to it and wanted to read it again and it actually contributed a lot to their knowledge on the subject so then I kind of felt bad that I thought it was stupid at first because it worked really well so.

When discussing elementary children's experience in classroom science in the UK, Ward, Donna, and Mcnabb (2016) explored the impacts of children's attitudes on their experience and consequently on their study. They pointed out that affective learning involves feelings toward science, which might be positive, negative, or both. While positive feelings bring enjoyment to learners, negative feelings make them feel anxious and fearful about science. One reason for the popularity of using children's literature in various content knowledge learning is that books can ease anxiety and spark learners' interest and curiosity, not only aiding in the formation of positive attitudes toward learning but also potentially influencing their persistent interest in scientific study and even their future career choices (Furner, 2018; Hackett & Betz, 1995; Shapiro, 1995). Our study echoed these findings and confirmed that in affective learning, positive feelings and negative feelings can coexist (Ward et al., 2016).

Genre and Domain of the Books Selected by Preservice Teachers

Our findings confirmed Bandré's (2005) and Donovan and Smolkin's (2002) notion that genre is one important factor influencing preservice teachers' selection of children's literature. According to our data, a majority (68.12%) of participants used fictional texts, while some (26.09%) opted for non-fiction texts, and a few (5.80%) utilized the poetry genre. No major distinctions were noted between the decisions of the preservice teachers who had and had not previously completed the literacy methods course.

This study identified a disparity in the books selected by preservice teachers across the four domains of science. As presented in Table 2, more than two-thirds of the literature pieces chosen by the preservice teachers were related to Life Science (37%) and Physical Science (33.33%). A little bit less than one-third of the literature pieces chosen by the preservice teachers were related to Earth Science (26.09%), with a minimal proportion (2.90%) related to Space Science. While preservice teachers had considerable autonomy in making literature selections, the classroom teacher typically provided the specific content to be addressed in the lesson. Thus, some domain-specific literature choices were prescribed and outside of the preservice teachers' control.

The study also revealed that most literature pieces chosen by preservice teachers were implicitly related to the content taught in the classroom, except in the domain of Earth Science. In the domain of Life Science, 20.30% of the literature pieces chosen by the preservice teachers were implicitly related to the content taught, while 17.40% were explicitly (directly) related to the content taught. Regarding Physical Science, 26.09% of the literature pieces chosen by the preservice teachers were implicitly related to the content taught, while 7.25% were explicitly (directly) related to the content taught. Specific to Earth Science, the results revealed more direct relationships (17.40%) than implicit relationships (8.70%) between literature pieces chosen by preservice teachers and content taught.

Table 2

The Books in the Four Domains of Science Selected by Preservice Teachers (N=69)

Content Category	Number of Literature Pieces	Relation to Content taught	
		Explicit/Direct	Implicit
Life Science	26 (37.68%)	12 (17.40%)	14 (20.30%)
Earth Science	18 (26.09%)	12 (17.40%)	6 (8.70%)
Physical Science	23 (33.33%)	5 (7.25%)	18 (26.09%)
Space Science	2 (2.90%)	1 (1.45%)	1 (1.45%)

The Rationales Behind the Selection Choices

Entertaining and Engaging Contents

Our study revealed that preservice teachers prioritize the entertainment and engagement of the text when selecting literature for their instruction (See Table 3). Several preservice teachers explained their book selection, highlighting that the chosen literature was described as "very engaging," "a fun read,", and appropriate for their students' comprehension level. Preservice teacher 61 affirmed, "This book was a good choice, because my students were immediately drawn to the interesting pictures, and characters, and the interesting vocabulary of the story". Preservice teacher three shared, "[my students] were all excited, paying attention, and laughing and shocked when mystery animal was different than what they expected." Preservice teacher nine mentioned, "[the students] were able to interact with the story [in the book *Gotcha!*] as they made predictions." Preservice teacher 53 echoed this sentiment, stating, "the kids were actively engaged the whole time and loved looking at the cute illustrations." Additionally, preservice teacher three suggested, "Because it was very engaging, and I knew my students would like the guessing games aspect of the book."

Interesting stories from children's books not only stirred up students' interest but also encouraged their inquiry, as suggested by two preservice teachers. Preservice teacher 58 explained her reasoning:

> because the book definitely grabbed my students' attention and effectively engaged them. As soon as I got out the book, many of my kindergarteners immediately expressed excitement to begin reading and, thus, thinking about frogs. Since the book had a setting that included both water and land, it naturally led into the question of inquiry: Where do frogs and other amphibians live?

Preservice teacher one argued that her selection is a good one "because it would help spark the students' interest and would allow them to begin thinking about all of the different characteristics that each plant has."

Table 3

The Rationales Behind the Selection Choices

	Entertaining and Engaging Contents
Preservice teacher 61	This book was a good choice, because my students were immediately drawn to the interesting pictures, characters, and the interesting vocabulary of the story. Almost all of my students had seen the animated movie and they were familiar with [the] story. Since they had background knowledge of the book, it was interesting to see them engage with the story from a scientific perspective and learn and discuss about the true message of the book. After reading the story for a few minutes, they began to make connections from our discussion to the book and they did a really great job.
Preservice teacher 3	Using this book was a great choice because it got all of my students participating and engaged in my lesson. They were so excited to hear me read the next page of the book and get to guess what animal they thought it was based on the description of the feet. They were all excited, paying attention, and laughing/shocked when the mystery animal was different than what they expected.
Preservice teacher 9	I chose Gotcha! Because it was engaging for the students and also entertaining. They were able to interact with the story as they made predictions. It clearly explained magnetism and provided sidebars to break down difficult concepts.
Preservice teacher 53	This book was on their level and a fun read. The kids were actively engaged the whole time and loved looking at the cute illustrations. Like all Dr. Seuss books, some of the nonsense words went straight over their heads, but all in all they understood the concept and loved the different approach to science.
Preservice teacher 3	I chose this piece of literature after searching for different non-fiction books about adaptations, animal traits, and different animal feet. I ultimately chose this book because it was very engaging, and I knew my students would like the guessing game aspect of the book.
Preservice teacher 58	Because the book definitely grabbed my students' attention and effectively engaged them. As soon as I got out the book, many of my kindergarteners immediately expressed excitement to begin reading and, thus, thinking about frogs. Since the book had a setting that included both water and land, it naturally led into the question of inquiry: Where do frogs and other amphibians live?

Preservice teacher 1	For my science lesson, I would have used the book Red Leaf, Yellow Leaf by Lois Ehlert. This piece of literature would have been a good choice because not only is it a fun story about a little boy who planted a sugar maple tree, but it also allows the students to see the different stages that the tree goes through and the students could see the special characteristics that the tree had inherited and how they were even different from other types of trees. …because it would help spark the students' interest and would allow them to begin thinking about all of the different characteristics that each plant has.

Developmentally Appropriate and Easy-to-Understand Examples

Just as Zeece (1999) stated about choosing quality science-based books, the preservice teachers in this study considered factors such as whether the book provided clear and simple explanations of topics and at the same time made sure that the depth and breadth matched the developmental level of children. Preservice teacher 21 articulated, "there were colorful illustrations and vocabulary that the kids were able to comprehend. [The] books allowed for students' attention to be caught and stimulated their brains for the rest of the lesson." Preservice teacher 12, when discussing her choice of the book *Pancake, Pancake!*, expressed that it was "a good one" because "beautiful illustrations are relatable and entertaining." Similarly, preservice teacher nine elaborated on her selection of *Gotcha!* By stating it was "engaging for the students and also entertaining." Moreover, she detailed how her chosen book clearly explained magnetism and provided sidebars to break down difficult concepts.

The age appropriateness of the text and easy-to-understand examples were factors most often cited by the preservice teachers about their book choices. Some preservice teachers chose children's literature as part of their classroom instruction because they found the books were user-friendly with age-appropriate vocabularies, included interesting stories, and presented appealing and age-appropriate characters (See Table 4). Preservice teacher 23 asserted, "*Move!* was a great book to use because the vocabulary was simple for my second graders to understand, the pictures were easy to interpret, and it was concise." Preservice teacher 51 explained, "I chose this piece based upon the content we were studying as well as the age level appropriateness." Similarly, preservice teacher 15 stated in the written reflection about their book choice, saying "because it is developmentally appropriate for kindergarteners, and my students were able to relate to the story as they reflected on rocks that they have found in their own lives." Notably, preservice teacher 50, who didn't include children's literature in their instruction until they were reminded of the coursework requirement, imagined in her reflection that,

> This book would have been a good choice to use because this book had an interesting storyline with fun pictures and characters, and is filled with key vocabulary and a plot that would have made my students think about the science content.

Additionally, preservice teacher 58, who did use children's literature book, presented their reasons for such a choice, saying that "it was developmentally appropriate for my kindergarteners. The book has fairly simple vocabulary and syntax, and the length was short enough to match their attention spans."

Table 4

The Rationales Behind the Selection Choices

	Easy-to-understand Examples and Developmentally Appropriate
Preservice teacher 21	There were colorful illustrations and vocabulary that the kids were able to comprehend, but also both books allowed for students' attention to be caught and stimulate their brains for the rest of the lesson.
Preservice teacher 12	The book, Pancake, Pancake! was a good choice because the book was a big book, (so all the students could see the pictures), the illustrations were beautiful and engaging, and the book took you through the process of making pancakes. It shows how it is a batter and turns into a pancake. This shows how something can be a liquid and can change to a solid when heat is applied.
Preservice teacher 23	Move! Was a great book to use because the vocabulary was simple for my second graders to understand, the pictures were easy to interpret, and it was concise. The book had a lot of great "motion/action words' that we introduced to the students over the next two weeks of learning movement. There weren't a whole lot of words on every page, so students could easily read along and understand the purpose of the book during the lesson.
Preservice teacher 51	I chose this piece based upon the content we were studying as well as the age level appropriateness. This book was a great choice because it engaged my students and allowed them to really challenge themselves. The book would show a tail or a beak or a foot, etc. and ask who it belonged to. This gave the students an opportunity to take a guess and really think about what animals utilize the particular adaptation. They loved this. It was a game for them as well as a learning experience, and they were so proud of themselves when they would get it right.
Preservice teacher 15	This was a good choice because it is developmentally appropriate for kindergarteners, and my students were able to relate to the story as they reflected on rocks that they have found in their own lives.
Preservice teacher 58	I chose this particular book for a few different reasons. First, it was developmentally appropriate for my kindergarteners. The book has fairly simple vocabulary and syntax, and the length was short enough to match their attention spans. Also, the plot and illustrations would be interesting to them. Most importantly, though, I chose this book because it could lead into the concept I was teaching, which was the amphibian characteristic of living in water and on land. In this book, Froggy spends his time on dry land and in the water learning to swim.

Accurate and Relatable Content

Besides the age-appropriateness and user-friendly vocabularies and illustrations, the accuracy of the content was prioritized by preservice teachers. In this study, some of the preservice teachers picked their children’s literature books because they discovered that those books represented accurate information about the science content knowledge which they were to teach (See Table 5). The preservice teachers assessed the accuracy of the information based on their content knowledge.

Table 5

The Rationales Behind the Selection Choices

	Accurate and Relatable Content
Preservice teacher 17	This book was a good choice because the book was age-appropriate for my kindergarteners, and it provided a fun, colorful introduction to my lesson that got the students wondering how the bears were able to find the lost bear. Plus, I knew that my students loved talking about animals so I knew that this book would pique their interest. Fiesta! This book was a good choice because the books were colorful and very appealing to the students since it was huge and all about how the town was preparing for a party.
Preservice teacher 19	Force was the topic that I was covering that day and so this book was perfect for introducing the lesson. I was working with kindergarteners and I felt that this book was appropriate for their level, and it was also a fun book to read.
Preservice teacher 49	I also chose this book because I knew I would be able to tie in other animals and fully teach the concept of camouflage with this as a starting point for my students to draw from. Also, it was great for my ELL students because the illustrations show the process of camouflage so well.
Preservice teacher 8	I chose this book because I felt that it was a book that covered the topic of light very well. The reading level was at the perfect level for my students. The examples that were used throughout the book my students could relate to. It introduced vocabulary words that my students needed to know, and I liked how throughout the book there was an entire page of fun facts about light.
Preservice teacher 55	I read through it and found that not only are the illustrations cute, but the story is literally about the adaptations of two different sheep and I knew that it was the book I needed.
Preservice teacher 24	I used this particular piece of literature because it had examples of both physical and chemical changes throughout the book. The examples were relatable and a common experience for all students. They were able to connect our science subject to their own lives and apply it.
Preservice teacher 59	I found Leaf Man, with help from Analise, and thought it was perfect. The story was simple and age appropriate for my students, the character of Leaf Man was cute and lovable, and although the story was fictional, it accomplished the goal of my students looking at all types of real leaves (since there were drawings of many leaves in the book) and accessing their prior knowledge and their wonderings about leaves.

Preservice teacher 62 considered a book as a good choice for classroom reading "as it provided accurate information, sparking interest in the students, and a wide variety of content on this one particular topic". She continued to justify her choice of the book, indicating that,

> The book discusses many different examples of animals that have a variety of learned animal traits. The book accurately explains the behaviors these animals exhibit, and the information is communicated in an easily understood manner. The book also utilizes animals the students can relate with which gives room for students' interest to heighten.

The preservice teachers' attention to content accuracy may be specific to their utilization of the texts to build students' science content knowledge. For example, Tunks, Giles, and Rogers (2015) surveyed teachers' selections and uses of children's literature in reading classes. The criteria for the teachers' selections revealed an attention to ethical values and the opportunity for children to broaden their self-understanding and feelings, yet none of these criteria were not found in this study.

Aside from considering the books' developmental appropriateness and accuracy of the scientific content, the preservice teachers also stressed that the content or the topic they were able to teach was somewhat reflected in these literature books. For instance, preservice teacher 58 reasoned with her choice of the literature book,

> I chose this particular book for a few different reasons. First, it was developmentally appropriate for my kindergarteners. The book has fairly simple vocabulary and syntax, and the length was short enough to match their attention spans. Also, the plot and illustrations would be interesting to them. Most importantly, though, I chose this book because it could lead into the concept I was teaching.

Similar comments were made by two other preservice teachers. Preservice teacher 17 elucidated that "[this book] was a good choice because the book was age-appropriate for my kindergarteners, and it provided a colorful introduction to my lesson." Additionally, preservice teacher 19 remarked that "force was the topic that I was covering that day and so this book was perfect for introduction [to] the lesson. I felt that this book was appropriate for their level, and it was also a fun book to read."

After finding the literature whose content was related to the topics in the curriculum, four preservice teachers chose to use literature as a starting point to explain the very topics they were teaching. Preservice teacher 49 explained, "I ... chose this book because I knew I would be able to tie in other animals and fully teach the concept of camouflage with this as a starting point for my students to draw from. Also, it was great for my ELL students because the illustrations show the process of camouflage so well." Preservice teacher eight stated, "I chose this book because I felt that it was a book that covered the topic of light very well. The reading level was at the perfect level for my students."

Additionally, preservice teacher 55 shared, "I found not only are the illustrations cute, but the story is literally about the adaptations of two different sheep and I knew that it was the book I needed" and "like using the book to like move into the like question of inquiry was like super, super, super helpful because you don't just like jump into the inquiry like without any background information." This finding aligned with what Barker (2006) said about using purposeful, whole-class, interactive starters that can hook students' interest and engage them by incorporating the elements of mystery, curiosity, novelty, etc. Literature in our study was found to serve this purpose.

Preservice teachers also prioritized the books whose contents were related to students' prior knowledge or real-life experiences, as expressed by three participants. Preservice teacher 24 expressed, "Because it had examples of both physical and chemical changes throughout the book. The examples were relatable and a common experience for all students. [The students] were able to connect our science subject to their own lives and apply it", stated preservice teacher 24. Additionally, preservice teacher 59 noted, "I found *Leaf Man*, and thought it was perfect. The story was simple and age appropriate for my students, the character of *Leaf Man* was cute and lovable, and although the story was fictional, it accomplished the goal of my students looking at all types of real leaves (since there were drawings of May leaves in the book) and accessing their prior knowledge and their wonderings about leaves." Similarly, preservice teacher 15 articulated, "This [book] was a good choice because it [is] developmentally appropriate for kindergarteners, and my students were able to relate to the story as they reflect on rocks that they have found in their own lives."

Visual Features

Our study confirmed the conclusions drawn by Donovan and Smolkin (2002) and Pringle and Lamme (2005) regarding the impact of visual features of trade books on preservice teachers' choices. Some preservice teachers included children's literature in their science classroom instruction due to the books' appealing design, which included features such as close-up pictures and book size. Preservice teacher 17 explained her choice of the book *One Bear Lost* is "very colorful and very appealing to the students since it was huge and all about how the town was preparing for a party." Preservice teacher 12 reasoned that the book *Pancake, Pancake!* as a good choice because the book [is] "a big book", "so all the students could see the pictures." She continued, "the illustrations were beautiful and engaging, and the book took you through the process of making pancakes." She concluded that the book "has beautiful illustrations and ... is relatable and entertaining. The students enjoyed predicting how water would be portrayed next." In essence, the visually appealing designs of children's literature not only attract students and stimulate their interest but also encourage exploration and reasoning. In this sense, visual features of children's literature contribute to the understanding of scientific knowledge in the inquiry process. Preservice teacher 48 echoed this sentiment in her choice of the book *Animals in Winter*, emphasizing that the book "had multiple animals from different places, which shows students [examples] that many animals hibernate and in different places" and "it also had great illustrations and was the perfect length for engagement purposes."

Other Factors that Influenced Preservice Teachers' Selections

As discussed in Bandré's (2005) study, teachers' selections are influenced by the original publication date of a book. In our study, whether the information in the literature was current was a concern raised by preservice teachers. For example, among the five preservice teachers who did not use literature in their instructions, one expressed this concern, saying, "you know if you think the *Magic School Bus,* they kind of outdated information."

Our study further substantiated Bandré's (2005) finding that in book selection, teachers may tend to choose books which are their personal favorite. In our study, several preservice teachers based their selection on their own experiences with particular books they had read previously. For example, preservice teacher 13 chose her book, stating, "I remember reading this book [*Chicken Little*] when I was in school."

Sources Where Teachers Got Information about the Books

Another theme generated from the data is how the preservice teachers obtained information about the literature they intended to use in the instruction. As discovered by Tunks, Giles, and Rogers (2015), word of mouth is one of the main sources where teachers acquire information about children's literature. In our study, there are two approaches that the participants utilized in choosing their literature piece: seeking advice from others or conducting independent searches. For those seeking advice, the method course instructor was the primary source, followed by other elementary educators.

Some preservice teachers selected their literature based on the course instructor's recommendations or chose to use the same book previously used in the course. Preservice teacher 63 said that "I had trouble finding a good book to use about adaptations so I actually asked Dr. Nancy [pseudonym] for suggestions and she and [another fellow teacher] located this book for me out of some of the resources they had." Another participant observed the instructor using a specific book in a lesson and decided to use the same book, stating, "Dr. Nancy used this book [*When Charlie McButton Lost Power*] in a similar lesson, and I thought it was the most appropriate for the age group I would be teaching." Additionally, five participants explicitly mentioned choosing a particular book based on the course instructor's recommendation.

Preservice teachers also sought advice from other sources. Preservice teacher 36, influenced by her mother, a first-grade teacher. She explained, "I chose this particular piece of literature after doing some search of books that were available at the public liberty that had to do with precipitation, and it was a recommendation of my mother, a first-grade teacher." Another participant, preservice teacher 2, chose her literature piece based on the recommendation of a fellow teacher, stating, "I did a lot of researching on book ideas and it wasn't till I was talking to a fellow teacher that she told me about this book and how much her students loved it. I read through it and thought it was the perfect piece to open up the lesson."

Aside from recommendations by others, most of the preservice teachers chose and located their literature pieces through various means, including searching online, exploring the university's Learning Resource Center (LRC), checking the local library, or using a combination of these approaches. Some explicitly mentioned strategic searches through resources. Preservice teacher three shared that "I chose this piece of literature after searching for different non-fiction books about adaptations, animal traits, and different animal feet." Preservice teacher 16 stated, "I simply googled children's books on glasses and read summaries and chose a few to check out." Additionally, one preservice teacher mentioned that "I chose this piece of literature, because it was the only book I could find in the LRC that was about magnets, but didn't just give away everything I wanted them to discover on their own."

RQ2 Findings

Experience, Reflection, and Perspectives on the Future Plan

Regarding our second research question, this study uncovered that preservice teachers' experiences with literature integration played a vital role in reshaping their perspectives on using children's books for science teaching. These preservice teachers recognized the positive impact of children's books in science lessons, such as strengthening connections between students and content. Preservice teacher 43 shared an instance when using a familiar book not only sparked excitement but also increased engagement when her students found that they had watched a movie related to the book. This positive experience encouraged the preservice teacher to consider introducing more children's literature pieces in future teaching. In her presentation, she said,

> I used a book, obviously literature, in my science lesson and they loved it. They thought it was really exciting. And we used a book that they already knew, so they could, and it was a movie too, so they could have commented that they saw the movie and what's in the book. And I think it was really good to just to, like, get away from, just like, um, doing activities at their tables and becoming a group. And it's just something different than the regular teaching. So they liked...they liked the book, I liked the book and I'm definitely using more books in the

> future. It's just a different kind of engaging activity to use. And they enjoy it because it's not just a paper and pencil thing. It's fun.

Preservice teacher 36 mentioned how the book solidified students' knowledge on the topic, which brought changes to students as well as to the teacher, saying,

> After the use of the video, song, anchor chart, and hands-on learning engagement earlier in the instructional week, the reading of a piece of literature provided another input medium to stimulate students' working memory of prior knowledge and acted as a trigger of the inquiry process for the learning target of the day.

Preservice teacher 59 echoed this sentiment when explaining their choice of the literature book, saying, "my students were able to extend their knowledge of the plant life cycle to pumpkins, and by extension other vegetables, and because of the book I was able to correct some misunderstandings, like decomposition is part of the life cycle and it's important too." Three preservice teachers shared how this experience using children's literature in their instructional activities transformed their perspectives on teaching, inspiring them to adopt a more cross-curricular approach. One specifically emphasized the idea of integrating subjects to foster a more comprehensive exploration of both aspects, saying,

> Like we could only teach science or only teach math or only teach reading so that you could kind of...instead of doing an hour of science and an hour of reading, you could take the full two hours and combine both of them at the same time and you'd still be learning both aspects, but you'd have a longer time to explore instead of all these choppy little sections where it's not connected so. (preservice teacher 40; oral presentation).

Another preservice teacher echoed a similar viewpoint about how the experience using children's literature for science teaching made her recognize parallels between themes in math, science, and literature. This realization also led her to appreciate the engaging and creative attributes of books in presenting problems and fostering critical thinking:

> This semester has kind of taught me to, like, incorporate things in different ways that I just didn't think were possible. And like seeing the similarities between themes and incorporating math and science and literature and stuff like that. And books are just really helpful because they're engaging and, like, they can be really creative. There are so many ways to use them, which I used to think it would just be like direct instruction, like reading kind of, like, a textbook maybe with pictures, but there are so many ways to, like, see the problems within them and, um, So I think it has big impact on kids to, like, think more critically, like, not accept everything, but also get to be more creative in areas that are generally less creative, and then it had an impact on me, because I just see the, like, use of literature. (preservice teacher 2; oral presentation).

Integration Impact on Future Teaching Plans

There is one more preservice teacher who expressed her commitment to shaping future lessons with a cross-curricular approach centered around a selected book. Recognizing the transformative impact of enhancing learning through various connections, she advocated for linking content to other texts, to personal experiences, and to the broader world. This commitment reflects a holistic and integrated teaching strategy, which emphasizes connections beyond individual subjects.

By integrating cross-curricular connections, this preservice teacher aimed to provide students with a comprehensive understanding, aligning with the cross-curricular approach emphasized by her peers:

> I think for the future I want to plan more of my lesson directly around the book like not trying to make it fit if it doesn't fit, but like going through and when you're trying to determine different activities and things to implement into a lesson, picking a book first and maybe connecting some of those ideas directly to parts of the book. I think that would add just another aspect of like learning and a different way of looking at things and then for those like text-to-text connections or text-to-self or text-to-world like I think that would be really good to implement. So, I think I'm going to try to do that for the future. (preservice teacher 8; oral presentation).

Two more preservice teachers expressed in their presentations a shared commitment to implementing this strategy in the future. Preservice teacher 10 said, "I think it's going to be really exciting to get to see what all we can do whenever we get to integrate subjects hopefully next year, but if not when we have our own class two years from now." Preservice teacher 12 was eager to adopt the integration strategy because she recognizes the strategy as a valuable means of differentiation. She recognized. Its potential to cater to individual learning preferences, stating,

> My future plans would probably be to actually use these things because I think it's a great way to differentiate, uh, between your students because some students might do better with you reading them a book about the, uh, the topic that they're on or maybe watching a movie. So that's a great way to differentiate how you're going to teach your students and, um, help them make their learning more authentic to themselves.

Discussion

Villegas and Lucas (2002) assert that for preservice teachers to adopt constructivist views and strategies, they must be actively involved in the knowledge construction process as learners. Building upon the principles of scientific inquiry outlined in the National Research Council (NRC, 1996), our study frames preservice teachers' designing and implementing science lesson plans incorporating children's literature as an opportunity to foster questioning, exploring, experiencing, and understanding of the value of children's literature. The constructivist learning experience challenges the traditional way of teaching facts in direct instruction and shed light on the value of scientific inquiry as an instructional strategy, as emphasized by Flick and Lederman (2006).

Our findings reveal that few preservice teachers in our study have ever encountered using children's literature to teach science. When this teaching strategy was first introduced to them, it prompted initial skepticism, with questions, concerns, and hesitance. The sha contrast between the negative responses before trying this teaching strategy and the positive feedback, as well as the commitment to trying it in their future instructional practices suggests a significant transformation. This shift in attitudes and perspectives aligns with the purpose of cultivating scientific inquiry and reflective teaching practices, as discussed earlier.

In addition, our study showcases how experiential learning with the integration of children's literature allowed the preservice teachers to be open, listening to different perspectives on science teaching and responding to the new teaching strategy, and to display the positive attitudes and commitment to reshaping perspectives (Shephard, 2008). The value of learning through experience, to be exact, is also exemplified in this study. For example, inspired by *Who Sank the Boat* (Allen, 1996), the preservice teachers built foil boats of different sizes and shapes to test the concept of floating and sinking. Such experiences are opportunities to guide the preservice teachers to explore and build a connection between theory and practice. In our study, the preservice teachers' prior experience with children's books constructed their knowledge in this field and after experiencing the use of children's books in science classes, the new knowledge was constructed through the new experience and in the dialogic reflection with the other people in the community. This way of constructing knowledge aligns with a constructive understanding of learning from practice. The importance of learning through experience and hands-on activities has long been emphasized by scholars such as Dewey (1902), Flybjerg (2004), Gutierrez, Rymes, and Larson (1995), Piaget (1970), Pinar, Reynolds, Slattery, and Taubman (1995), and Vygotsky (1978). Dewey's (1902) argument regarding the abstraction of eternal truth resonates with the idea that learning should be grounded in the real-world context of children, emphasizing the need for continuous, practical experiences to construct and reconstruct thinking and knowledge. The feedback given by the preservice teachers indicates that children's literature has the potential to build the connections between content and the broader world. This is especially important because children's children can engage elementary students in "developing, researching, and investigating questions of significance that are not easily tested with empirical experiments" (Ford, 2004, p. 286).

In addition, our study may suggest the potential impact of promoting affective learning in science classrooms through children's literature. As Shephard (2008) indicates, affective learning relates to values, attitudes, and behaviors, engaging learner emotionally. This emphasis on affective learning aligns with the broader goal of fostering positive attitudes toward science during the crucial elementary school years (Shapiro, 1995). Encouraging positive attitudes toward science is not only instrumental in shaping learners' perspectives but also aligns with the purpose of an integrated curriculum approach advocated by The National Science Foundation (NSF, 2000). Based on preservice teachers' feedback, our study affirms the engaging role of children's literature in sparking children's interest and curiosity. This observation suggests the possibility of encouraging a positive attitude toward learning and impacting their motivation and academic achievements, as identified by other scholars (García et al., 2016; Green et al., 2018; Wadham & Young, 2015).

The findings of our study may also add evidence to the existing literature about the value of children's literature in science education, as viewed from the perspective of preservice teachers. As demonstrated in our study, preservice teachers prioritize developmentally-appropriate children's literature pieces that align with curriculum topics. They find that that deliberately selected books can effectively facilitate meaningful discussions, serving as a starting point to explain specific science topics or providing a context that connects these topics to children's prior knowledge or real-life experiences. This recognition is exemplified by a preservice teacher who stated, "[The book] was a good choice because it not only made the children excited to discover how the boy played such crazy tricks but it also gave them an opportunity to see how magnets are not just a science thing they do at class, but how they can take what they learned home and use it."

Limitations

There were a few limitations in this study. First, the numbers of data sources are limited. As stated previously, the study may have been strengthened through additional data such as interview data, field notes, or observations of teaching. However, due to time constraints and impediments related to the participants' field-based teaching experiences, the researchers felt the two sources of reflection data were strong in providing the requisite rich, thick descriptions of preservice teachers' thoughts, reflections, and experiences regarding implementing children's literature within inquiry-based science.

Second, the source of information gathered about the children's literature that was used is limited. In consideration of future studies, a set of options that provide annotated bibliographies for each book could help discover prominent themes regarding the selection of literature and how it is connected to science content. For example, since one goal of using children's literature in science lessons is to help students develop inquiring minds so that they can become socially competent and global citizens in the 21st century, global or multicultural aspects could be covered in the books selected for classroom instruction so that children's views could be broadened.

Implications

While using children's literature to teach science is not a new practice, this study provides valuable insights into understanding preservice teachers' perspectives and attitudes towards this teaching strategy. The participants in our study were not just preservice teachers; they were also new learners in the field of science education. Previous studies have identified that preservice teachers often lack confidence in integrating science into authentic inquiry opportunities (Mumba et al., 2019; Yoon et al., 2012). In addition, according to Kozoll (2020), even elementary teachers who value inquiry express varying levels of confidence and interest in implementing content-specific activities within the curriculum. In our study, to foster preservice teachers' confidence and alleviate their concerns, the course instructor modelled for the preservice teachers how to design and implement elementary science teaching, incorporating carefully selected children's literature pieces. This modelling served as a valuable guide. However, the transformative impact on preservice teachers became evident after they gained hands-on experience using children's literature in their teaching. This experience showcases the potential of inquiry opportunities during which personal experience and hands-on inquiry can effectively dispel misconceptions, addressing a gap noted by Sackes, Trundle, and Flevares (2009) that was not always addressed by teachers.

In addition, our study suggests an effective approach to broaden the pedagogical content knowledge of preservice teachers by providing them with affective experience in inquiry-oriented learning. However, as highlighted by Tunks, Giles, and Rogers (2015), the NGSS, Common Core, and other national science standards advocate for an integrated curriculum that emphasizes content, practices, and crosscutting concepts while maintaining a balanced use of various texts during instruction. This becomes particularly crucial when considering the racial and linguistic diversity in the public education system. Pappas (2006) suggests that the gender or ethnolinguistic background of children might influence their responses to children's literature integrated into science learning. For future studies, the issue of diversity should also be explored, such as, how the integration of children's literature can contribute to mitigating disparities, particularly among different ethnic groups. After all, advocating for multicultural science education becomes imperative (NSTA, 2000).

In conclusion, this study has implications for teachers seeking different methods for science teaching and developing cross-curricular perspective toward science learning. In addition, a nuanced understanding of preservice teachers' perspectives on using children's literature in inquiry-based science lessons may prove especially valuable for teacher educators in teacher preparation programs. The comprehensive reflections captured in this qualitative study offer insights into preservice teachers' attitudes towards using children's literature to teach science and the challenges they encounter in book selection and pedagogical decision-making. Teacher educators may find value in this study to enhance the preparation of preservice teachers, guiding them through and towards inquiry-based practices, fostering critical thinking, and developing cross-curricular perspective.

Conclusion

Building upon the transformative experiences of preservice teachers and the understanding of scientific inquiry suggested by Flick and Lederman (2006), our research views the design and implementation of inquiry-based science lesson plans incorporated with children's literature pieces as an opportunity to engage preservice teachers in an inquiry process. During this process, preservice teachers explore, experience, and develop an appreciation for the significance of children's literature in science education.

Our findings reveal that preservice teachers' initial skepticism and concerns about the effectiveness of using children's literature to teach science were transformed after their exposure to this teaching strategy. Experiences in selecting and implementing strategies to integrate children's literature in the elementary classrooms not only encouraged preservice teachers to develop positive attitudes but also reshaped their perspectives. The study highlights the significance of affective learning through hands-on experience and the construction of knowledge during the inquiry process.

Moreover, our study reveals the notable gaps in preservice teachers' skills in selecting, locating, and effectively using children's literature in their instructional practices. The transformation of preservice teachers resulting from the scientific inquiry process in our study emphasizes the importance and necessity of introducing this instructional strategy in science methods. This practice not only promotes preservice teachers' appreciation for and utilization of integrating children's literature in science teaching but also reshapes their perspectives on the value of children's literature and the potential for cross-curricular learning. The identified gaps signify the need for professional development, such as workshops or training sessions, to hone their skills in literature selection, locating, and implementation that aligns with the curriculum objectives.

In conclusion, this study may contribute to the existing literature in several aspects. Firstly, it addresses preservice teachers' lack of confidence identified in teaching science (Mumba et al., 2019; Yoon et al., 2012), advocating for the use of children's literature as an intervention. Secondly, it elaborates on the factors crucial for the literature selection and pedagogical decision-making process, shedding light on the complexity of selection faced by preservice teachers (Crowther et al., 2005; Donovan & Smolkin, 2002; Sackes et al., 2009). Thirdly, this study reveals the perceived value of children's literature for elementary science teaching, from the perspectives of preservice teachers.

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Appendix

An Example of Teaching Lesson Plan on the Integration of Children's Literature

Name of the preservice teacher: XXX
Subject: 5th Grade Science
Title: Unit 5: Energy Resources

TEKS/Content Standards: 5.2 (D) Analyze and interpret information to construct reasonable explanations form direct (observable) and indirect (inferred) evidence 5.2 (F) communicate valid conclusions in both written and verbal forms 5.4 (A) collect, record, and analyze information using tools, including calculators, microscopes, cameras, computers, hand lenses, metric rules, Celsius thermometers, prisms, mirrors, pan balances, triple beam balances, spring scales, graduated cylinders, beakers, hot plates, meter sticks, magnets, collecting nets, and notebooks; timing devices, including clocks and stopwatches; and materials to support observations of habitats or organisms such as terrariums and aquariums 5.7 (C) Students will identify alternative energy resources such as wind, solar, hydroelectric, geothermal, and biofuels.	
Lesson Objectives: In their study of alternative energy resources, students will be able to give examples of and explain how wind energy, hydroelectricity, geothermal, and solar energy are used, and will share their results through wind energy and alternative energy resource activities, as well as through the lesson's closure (which will revolved around all four alternative energy resources touched upon).	
Content Overview:	

Omitted by the researchers here because of the space limitation.	
Prerequisite Skills: ● SWBAT identify and classify Earth's four main alternative energy sources (solar, wind, geothermal, and hydroelectric power), as well as draw upon prior knowledge of Earth's renewable and nonrenewable resources.	
Materials/ Supplies/ Technology: ● IPads ● Schoolhouse Rock: Energy Blues Video ● Energy 101: Wind Energy Video ● Children's literature: *The Windy Day* by G. Brian Karas ● Pinwheel Supplies: pinwheel template, straw, pushpin, markers, scissors ● Wind Energy KWL Sheet ● Geothermal Energy Video ● Hydroelectric Documentary Video ● Alternative Energy Foldable ● Alternative Energy Town Sheet	
Lesson Instructional Model (Circle appropriate model(s) for the lesson): Inquiry/ 5E: Literacy- Read Aloud, Word Study, Guided Reading., Shared Reading, Literature Circle/ Novel Study, Shared Writing, Writing Workshop Direct Instruction Mathematics- Developmental, Reinforcement, Practice, Problem solving Other: ___________________	
Steps/Sequence of Activities Correlated to Instructional Model: **1) Engage (Tuesday and Wednesday)** ● Once all of the students are ready to begin science, tell students that today's topic deals with alternative energy resources -□ more specifically, wind energy, hydroelectricity, geothermal, and solar energy. ● Ask students if they remember talking about different forms and sources of energy last year. Have them provide examples and explain where the different types of energy come from. ● Encourage students to think about why it is important for them to learn about different forms of energy. ● Since students are now thinking about alternative energy sources, inform them that today and tomorrow's lesson will involve them reviewing and investigating four alternative resources: winder energy, hydroelectricity, geothermal and solar energy. ● "Hook" students into today (Tuesday's) lesson topic by watching "Energy Blues" and "Energy 101: Wind Energy" ● Pose the following questions to students can ask themselves about alternative energy resources and why it's important to learn about them: 1) What four alternative energy resources am I	

learning about in today's activities? 2) Why is it important that I learn about alternative energy resources such as wind energy, hydroelectricity, geothermal, and solar energy? 3) Where can I find these different alternative energy resources? ● As a whole class (Wednesday), have students give a few examples of what we reviewed and learned yesterday in class. o Answers should involve the four types of alternative energy we were discussed (solar energy, geothermal, hydroelectricity, and wind energy). o Have students provide examples of each type of energy that they have either seen in their communities or via other resources (internet, social media, literature, etc.) ● Once students have reviewed Tuesday's lesson and topic- focused on wind energy, inform students that we will be reading *the Windy Day* to help students reflect and answer the following question: o If wind is always blowing somewhere in the world, it must have a lot of force and energy behind it. How could that energy be harnessed and used? ● Once students have answered and shared some of their thoughts and ideas, move into today's (Wednesday's) focus- overall review of four alternative energy resources (solar, wind, geothermal, and hydroelectric power). ● "Hook" students into today activities and topic by watching "Geothermal Energy" and "Hydroelectricity Documentary". ● Once again pose the following questions for students to think about throughout the day's activities: 1) What four alternative energy resources am I learning about in today's activities? 2) Why is it important that I learn about alternative energy resources such as wind energy, hydroelectricity, geothermal, and solar energy? 3) Where can I find these different alternative energy resources? **2) Explore (Tuesday)** ● Before explaining the activity, explain to students that they will be working in groups at their tables. Tell students that we will be working on an activity that focuses on wind energy. o Once every student cleared off their desks and tables, inform the students that we will be making pinwheels and further exploring the concept of wind energy. Provide instructions and expectations for pinwheel activity. o Have other T.A.s in the classroom help distribute pinwheel supplies to each table/ group. Each student should receive: pinwheel template, straw, push pen, scissors. o Check student understanding by asking them: ▪ Discuss the factors that affect how well the turbine works. (Answers: the strength of the wind, direction of the wind and actual construction quality of the wind turbine). Ask them where they think the wind is that strongest. (Answer: low to the ground or high up). Ask the students in what direction they should	

point their pinwheel. (Answer: into the wind, at an angle to the wind or away from the wind). o Inform students that we will be going outside after constructing our pinwheels in order to test the power of wind energy in real-life. After going outside and exploring/testing the power of wind energy, have students to return to the classroom and sit with their groups. Then address the following as a whole class: ▪ Would they (the students) change anything on their wind turbine if they built it again? Can they (the students) think of anything that would improve the design of their wind turbines? ● Things that teacher should understand: o How the process of converting wind into energy works, be about to provide different examples of wind energy seen in our environment, be able to explain why wind energy is a renewable resource. **3) Explain (Tuesday and Wednesday)** ● After the pinwheel activity, I will check my students' understanding of wind energy/wind turbines by asking them: ▪ Discuss the factors that affect how well the turbine works. (Answers: the strength of the wind, direction of the wind and actual construction quality of the wind turbine). Ask them where they think the wind is that strongest. (Answer: low to the ground or high up). Ask the students in what direction they should point their pinwheel. (Answer: into the wind, at an angle to the wind or away from the wind). ● I will ask students questions that will enable student to come to the realization that: o Wind energy and hydroelectricity are renewable resources. And once again review the fact that nonrenewable resources are scarce and cannot be made again (replenished) in a short period of time. Renewable resources are replenished naturally. Nonrenewable resources need to be conserved so that there will be some left for generations to come. ● Additional questions to ask students include: o What did you notice during the pinwheel activity? o What happened to the wind energy as time went on? Did it continue to make the pinwheel spin, or did we run out of wind energy/ did the pinwheel break? o How can we describe the wind energy? How can we describe hydroelectricity energy? o What are some examples of wind and hydroelectric energy? What do you think this activity can tell us about using energy in the real world? ● Have students complete KWL Sheet on Wind Energy	

- After the "engage" portion of Wednesday's lesson, move into "explain" portion of the lesson (alternative energy resources).
    - Check students' understanding on the four main alternative energies discussed (solar, wind, geothermal, and hydroelectric power) by posing the following questions: 1) Why is it important that I learn about alternative energy resources such as wind energy, hydroelectricity, geothermal, and solar energy? 2) Where can I find these different alternative energy resources? 3) Why are the four main alternative energy resources we have discussed in class classified as renewable resources? 4) Have students provide examples of each type of energy that they have either seen in their communities or via other resources (internet, social media, literature, etc.)
- Complete alternative energy resources foldable with class as a whole.

4) Elaborate (Wednesday)

- To develop a better understanding on alternative energy resources, we can discuss why it is important to have nonrenewable such as oil and gas. Some students may think we should try to use appliances that are primarily solar, wind, geothermal, or hydroelectric powered. It would be beneficial to explain that we need some "general" energy-powered appliance (i.e. cars, machines), but we can also work towards making more productive strides to expanding everyday household items and appliances more alternative energy friendly.
- They vocabulary introduced over the two-day lesson will be wind energy, hydroelectricity, solar energy, and geothermal energy. The vocabulary will benefit students because it gives some more examples pertaining to alternative energy appliances and uses.
    - Wind energy- energy conversion in which turbine convert the kinetic energy of wind into mechanical or electrical energy that can be used for power (windmill, wind turbine); considered a renewable resource
    - Hydroelectricity- electricity generated by hydropower; the production of electrical power through the use of the gravitational force of falling or flowing water (dams)
    - Solar energy- energy derived from the sun in the form of solar radiation (solar panels)\
    - Geothermal energy- energy derived from the heat of the earth (hot water springs, heats houses)

Closure

- To relate this lesson to our daily lives, we can talk about the impact that different energy resources have on people around the world and discuss what could happen if we were to switch to only alternative energy resources (solar energy, hydroelectricity, geothermal, and win energy).

○ To go a step further, we could investigate which of the four alternative energies discussed over the past two class days is seen the most in our everyday life; as well as which alternative forms of energy we could more easily integrate into our households and everyday life. **5) Evaluate (Provide the information in the Evaluation section of the lesson plan)**	
Differentiation: (An appropriate differentiation must be provided for each of the below-listed student populations; the information must be provided regardless of whether or not you are working with students in each of these populations.) **Struggling Students**: Students will be allotted extra time to complete activities from lesson. Have them engage in lesson via manipulative or "paired" group work. **G/T Students/ Students who Easily Understand the Content**: Students will be assigned to examine particular states, foreign countries. Students can then research what main forms of alternative energies (if any), those areas produce and what forms they consume. Students can begin by researching the country or continent, or by researching the alternative energies (solar energy, geothermal, hydroelectricity, and wind energy) themselves (using their IPads). **LEP Students:** Utilizing the drawings, models, activities, and videos should allow LEP students to participate successfully. Cards with the lesson vocabulary could be provided to students so they could write their own definition/description of the terms of main ideas in their native language. **LD Students:** Make sure that all elements of the students' IEP are being met. Using alternative energy example cards, remind students about like characteristics of solar energy, wind energy, geothermal, and hydroelectricity; allow students to classify different examples of each type of alternative energy.	
Evaluation: Occurs throughout the day's topic and lessons/activities: **Formative:** During the lesson, the teacher will be constantly monitoring and observing the progress of the groups. It is very important to see how the students are doing and to see if anything regarding alternative energy resources need to be retaught. **Summative:** Once the students have completed the activity and are confident that they know the differences between the four types of alternative energy (solar, wind, geothermal, and hydroelectric), the students will work on the "wind energy" and "alternative energy town" activity sheets as individuals. They will have to explain the differences between the four energies, give examples of each type of alternative energy resource discussed in class, and name different ways some cities conserve energy, and sort them into the correct category.	

Analysis of Assessment(s): Assessment occurred on Tuesday and Wednesday via informal group, whole-class, and individual activities. For instance, when I had my students working in groups, I was able to see which group members were lacking in understanding of alternative energies- which was even more evident when I had my students working individually. Overall, I think both Tuesday and Wednesday's activities helped me gauge the levels of understanding my students had on alternative energy resources, which helped me better modify particular portions of both day's lesson objectivities and activities	
Reflection: I feel that the two days (Tuesday and Wednesday) that I devoted to whole-group teaching of alternative energy resources went fairly well. On Tuesday, I thought that the elements of the 5E lesson plan that I incorporated into the classroom and the activities were engage, explore and explain. Looking back, I would probably have students spend more time working on the KWL wind activity sheet and less time letting students making their pinwheels. Overall, I feel that my lesson and activities that I incorporated into the classroom on Tuesday (which revolved around a brief review of the four alternative energy resources- with an emphasis on wind power) was quite successful. On Wednesday, I started off the class time by engaging my students via *The Windy Day* book (to review Tuesday's topic) and had them use their IPads to watch two videos on geothermal and hydroelectric power. I then had my students explain why it is important to learn about alternative energy resources and have them explain and provide example of each. I ended the lesson by having my students elaborate on and connect their new knowledge and understanding of alternative energy resources to real-world situations. I closed both lessons (Tuesday and Wednesday) with a review of the main objectives for each day's topic. I feel that Wednesday's lesson and activities went very successfully. I think my two days teaching alternative energy resources went pretty well. On both days I was able to successfully keep all of my students engaged and actively participating throughout the class discussions. I feel that I have definitely utilized my time in the classroom when teaching my students, and I also feel that I have learned a lot in the past few days in terms of how to better direct and run a classroom- as well as plan an effective lesson.	