Transforming STEM Education: The Impact of the RETA Model on Pre-Service Teachers' Attitudes and Lesson Planning

Belma Türker-Biber[1] **İpek Saralar-Aras**[2]

To cite this article:
Türker-Biber, B., & Saralar-Aras, İ. (2024). Transforming stem education: The impact of the reta model on pre-service teachers' attitudes and lesson planning. *e-Kafkas Journal of Educational Research*, *11*, 48-64. doi:10.30900/kafkasegt.1412764

Research article **Received:**31.12.2023 **Accepted:**19.04.2024

Abstract
This study investigates the influence of an innovative teaching model, the Realistic, Exploratory, Technology-enhanced, and Active (RETA) model, on the STEM attitudes of senior-grade pre-service teachers. The research involved 65 participants from a public university in Turkey. Employing a comprehensive approach, the study utilized a STEM attitude scale, a RETA-based lesson evaluation rubric, and semi-structured interviews to gather both qualitative and quantitative data. The results revealed a noteworthy correlation between pre-service teachers with positive attitudes towards the RETA approach and their heightened efficacy in developing impactful lesson plans. Through the application of the RETA model, participants demonstrated an increased inclination towards innovative teaching strategies, emphasizing the integration of 21st-century skills. Furthermore, post-course assessments indicated a significant positive shift in attitudes, with participants recognizing the model's potential to foster equity within their teaching practices. This research contributes valuable insights into the integration of digital technologies in the classroom, offering a robust framework for pre-service teachers to enhance their pedagogical approaches.

Keywords: STEM education, pre-service teachers, innovative teaching model, lesson design, attitude shift.

[1] Belma Türker-Biber, Aksaray University
[2] İpek Saralar-Aras, ipek.saralararas@gmail.com, Ministry of National Education

Introduction

National and international test results indicate persistent challenges in students' mastery of mathematics, not only in Turkey (MoNE, 2018a, 2019) but also in various countries such as England and Wales (Standards and Testing Agency [STA], 2019a, 2019b) and the United States of America (Brown et al., 1988; National Centre for Education Statistics [NCES], 2018a, 2018b). In response, several nations are adopting teacher education programs that incorporate 21st-century skills, such as critical thinking and collaboration. These skills are deemed essential for pre-service teachers to effectively teach mathematics to their future students. In Turkey, the Ministry of National Education (MoNE) (2018b) has recommended the integration of these skills into the mathematics program. However, research within the same context reveals that pre-service teachers often struggle to acquire these skills, posing a challenge for them in teaching mathematics along with these challenging skills.

The STEM approach has been a recent addition to many education faculties' programs in Turkey. Therefore, it is crucial to assess pre-service teachers' inclination to utilize this approach in designing their lessons, alongside evaluating their competencies and attitudes towards it. Despite claims by many researchers that pre-service teachers generally feel competent in planning lessons with their chosen teaching approach (Cady et al., 2006; Mostofo, 2014; Ruys et al., 2012), there is limited data on whether they feel confident in integrating the STEM approach, which encourages the inclusion of 21st-century skills in their lessons (Özdemir et al., 2018). It is widely agreed that 21st-century skills can be developed in classrooms with well-structured lesson plans.

The RETA model, as a novel teaching model, incorporates principles for imparting 21st-century skills (Saralar-Aras, 2022). In RETA-based lessons, students receive plans supported by Realistic, Exploratory, Technology-enhanced, and Active principles. Realistic lessons aim to integrate real-life examples into the curriculum. Exploratory lessons support students in exploring examples, including deliberately designed mistakes, to enhance learning. Technology-enhanced lessons focus on integrating technology suitable for the relevant acquisition and supporting learning. Active lessons advocate for the active use of concrete materials and technologies by students in classrooms. Originating in the United Kingdom as part of design-based research with four cycles, this student-centered model has proven its effect in the Turkish context according to research findings. The details of the RETA model were further explained in the RETA Model Section.

When recent studies in our context such as Altan and Ucuncuoglu (2019) and Eker Uka and Bedir (2023) are examined, it is necessary for pre-service teachers to be competent in planning lessons with STEM approach to have 21st-century skills. In particular, it is necessary to improve the STEM attitudes of pre-service teachers who feel themselves deficient due to subjects such as engineering and technology in various ways. This study aims to investigate the effect of the RETA model, an innovative teaching model, on the STEM attitudes of pre-service teachers. The study plans to involve pre-service teachers in an effective learning process that transforms them to a STEM approach.

STEM Education

The changing demands of the future highlight the need to educate students who are conscious and capable of creating various technological designs by applying scientific and mathematical principles to solve problems. STEM education is a teaching approach that prepares students for the competitive global workforce, by fostering individuals who are curious, innovative, collaborative, and possesses critical thinking skills.

STEM education defined by Shaughnessy (2013) specifically emphasizes mathematics and science disciplines as "STEM education refers to problem-solving that not only utilizes concepts and procedures from mathematics and science, but also incorporates the teamwork and designs methodology of engineering and uses appropriate technology" (p. 324). However, Bybee (2013) highlights ongoing debates surrounding the definition of STEM, including which disciplines should be integrated into STEM education and to what extent. Additionally, there is a discussion around whether the disciplines in the acronym should be used consistently and each discipline contributes equally or not (English, 2017). Although there are ongoing debates about the definition of STEM, it is clear that the integration of STEM is becoming increasingly necessary for finding interdisciplinary solutions to many problems encountered in daily life (English 2017; Honey et al., 2014; Sanders, 2009). Within the scope of this study, Shaughnessy's (2013) definition is taken into consideration.

It is widely argued that interdisciplinary teaching approaches, such as STEM or RETA, should be used at the primary and middle school levels because reaching students at an early age have a significant impact on their interest in STEM-related fields (Daugherty et al., 2017). Research has shown that introducing these approaches at early stages of schooling can increase students' interest in STEM disciplines (Daugherty & Carter, 2018; English, 2017). Therefore, it is important to introduce these approaches to students at an early age. Interdisciplinary teaching approaches can help to develop problem-solving skills, critical thinking, and creativity, by laying a strong foundation for further learning (Hamilton et al., 2008). To ensure that teachers are equipped with the necessary skills to use these teaching methods, they need to be trained and supported with various approaches. Therefore, it is important to develop positive attitudes in pre-service teachers towards STEM and support them in developing teaching methods that emphasize interdisciplinary learning (Campbell & Damico, 2023). This study addresses the effectiveness of RETA, a teaching method, in supporting future teachers to implement interdisciplinary teaching approaches.

RETA Model

The RETA model is an innovative way of teaching that stands on four principles: realistic (R), exploratory (E), technology-enhanced (T), and active (A) (Saralar-Aras, 2022). To briefly touch upon these principles, the *Realistic* principle aims to increase students' awareness of the relevance of the topic in their daily lives, help them make inferences about the real-world connections of mathematical ideas, boost their motivation to study mathematics and aid them in solving real-world problems in the future. The *Exploration* principle is related to the use of worked examples in teaching. These examples already exist and provide students with information about the topic, helping them investigate it. Studies have shown that students contribute to teaching by analyzing answers that contain various errors (Evans & Swan, 2014; Renkl, 2011). The selected examples should include common errors related to the subject matter and provide students opportunities to solve problems. *Technology-enhanced* principle concerns the strategic use of technology in teaching mathematics. Technology can enhance the interactivity and engagement of students with mathematics. It can also improve accessibility by providing visual and auditory cues to help students understand concepts better (Yu-Wen & Andrews, 2009). The fourth principle pertains to *Active learning environments*, where students manage the use of concrete manipulatives. Several studies indicate that instructional activities, where students participate in active learning by creating new structures with concrete materials, lead to success (Chi, 2009; Schank, 1994). Inspired by Moch (2001) and Van de Walle et al. (2010), the active principle aims to increase students' motivation and academic performance in the target subjects through student-centred manipulatives. The RETA model was preferred in STEM education for several reasons. The most important reason is that it is specifically designed for teaching mathematics not general for all disciplines neither with a focus of science nor technology, which is the case in most of the studies reviewed (e.g., Kennedy & Odell, 2014; Sutaphan & Yeunyong, 2019). Moreover, the RETA model is close to STEM education in its existance as it has already focused on mathematics teaching and technology in it –which are T and M of STEM education compared to other models focusing on various other principles such as problem-solving and modelling (Stohlmann, 2019).

Significance of the Study

Designing lesson plans for pre-service teachers not only introduces them to the reality that they will be preparing lesson plans for different grade levels once they become teachers but also contributes to the development of their knowledge and skills by creating plans using different models (Balgalmış, 2013). It has been observed that lesson plans, emplyed in this study, prepared by using the RETA model, are effective in student learning (Saralar et al., 2018). In fact, in a quasi-experimental study, it was found to be statistically more effective than current ongoing methods (Saralar et al., 2019). This student-centered model, which is compatible with the STEM approach and provides opportunities for mathematical modeling, has been designed in the UK over approximately four years with four different studies and its effectiveness in Turkish classrooms has been revealed through research. However, previous studies have mostly focused on geometry topics. For example, while Saralar and colleagues (2018) focused on lesson plans related to three-dimensional shapes and their effects on teachers and students, Esen and Saralar-

Aras (2022) concentrated on the learning of polygons and their impact on STEM approaches. This study is valuable in investigating whether RETA is effective in other areas of mathematics, such as numbers and fractions, and also in exploring the mutual relationship between STEM and RETA.

Research Questions

1. What are the pre-service teachers’ attitudes towards STEM approach?

    a. How do individual characteristics and prior experiences of pre-service teachers influence their initial attitudes towards the STEM approach?

    b. What are the long-term effects on pre-service teachers' attitudes towards the STEM approach after implementing the RETA model in their lesson planning?

2. Is there a relationship between RETA lesson planning and STEM attitudes?

    a. How do variations in the implementation depth of RETA principles in lesson plans correlate with the degree of change in STEM attitudes among pre-service teachers?

3. How do the lesson plans change?

    a. To what extent do changes observed in lesson plans align with the key principles of the RETA model?

    b. How do specific components of the RETA model contribute to the development of more concrete, participatory, and applicable lesson plans in different mathematical topics?

4. How do the pre-service teachers experience the RETA Model?

    a. In what ways do the experiences with the Realistic Principle contribute to pre-service teachers' perceptions of the relevance and applicability of mathematics in real-life scenarios?

    b. How do the Exploratory questions developed by pre-service teachers influence students' critical thinking and problem-solving skills?

    c. What are the nuanced effects of using Technology-enhanced activities, such as GeoGebra and mathematics videos, on students' understanding of mathematical concepts and STEM awareness?

    d. How does making students Active with the integration of tangible materials in lesson plans impact students' comprehension of abstract mathematical concepts and their levels of participation?

Method

Research Model

The study employed a mixed-method approach, integrating both qualitative and quantitative research methods. To ensure a comprehensive exploration of the research questions and to achieve in-depth data analysis, the study utilized a convergent parallel research design, which is a type of mixed-method design. In this design, both quantitative and qualitative data are collected concurrently, and the findings from both approaches are integrated to offer a comprehensive and nuanced analysis (Creswell & Clark, 2017).

Study Group

The research focused on a study group consisting of 65 junior-grade pre-service teachers from a state university in Turkey. The selection process was based on a criterion sampling method, which is one of the purposive sampling designs employed in research. The specific criterion used for sampling was the pre-service teachers' level of knowledge in lesson plan preparation, acquired from their previous courses. This criterion was set at the 3rd-grade level.

The rationale behind selecting pre-service teachers at the 3rd-grade level was to ensure a foundational understanding of lesson plan preparation. Although these individuals had not yet engaged in teaching practice, their prior coursework equipped them with the necessary theoretical knowledge to engage with the study's objectives. This criterion is significant because it establishes a baseline understanding of lesson planning skills among the participants. By selecting individuals who have reached a certain level of theoretical understanding, the study aims to assess their ability to apply this knowledge practically through the development of mathematics lesson plans by using the RETA model.

Data Collection Tools

In the data collection process of the study, three main instruments were employed: the Teacher Efficacy and Attitudes towards STEM (T-STEM) Survey, a rubric designed for evaluating lesson plans using the RETA model, and semi-structured interviews. The T-STEM Survey, originally developed by the Friday Institute for Educational Innovation (2012), was adapted into Turkish by Tas, Yerdelen and Kahraman (2016) specifically for elementary teachers. The survey encompasses various dimensions, providing insights into science teaching efficacy and beliefs, science teaching outcome expectancy, mathematics teaching efficacy and beliefs, mathematics teaching outcome expectancy, STEM instruction, 21st-century learning attitudes, teacher leadership attitudes, and STEM career awareness. Administered both before and after the 14-week implementations that imparted knowledge about the RETA model, the survey aimed to gauge changes in pre-service teachers' perspectives. The reliability of the questionnaire was assessed by using Cronbach's alpha test, resulting in a range from 0.86 to 0.95 for all sub-items, indicating a high level of internal consistency.

Additionally, the study employed a lesson design rubric with RETA model, created by the researchers to evaluate the process of lesson plan development by pre-service teachers (see Appendix 1). The rubric was validated through the expert opinions of two professors working in the fields of mathematics education and computer and instructional technology education. This rubric comprised four sub-items aligned with the RETA principles: Realistic (R), Exploratory (E), Technology-enhanced (T), and Active (A). The assessment of lesson plans was conducted using this rubric (see Appendix 1).

To complement the quantitative data, semi-structured group interviews were conducted with selected pre-service teachers, focusing on evaluating their experiences with designing lessons using the RETA model. The interview forms, developed by the researchers and subjected to expert opinions, served as valuable tools for collecting qualitative data. The various data collection tools employed in the study are presented in Appendix 1 and Appendix 2.

As presented in Appendix 1, the rubric consisted of two parts. The first part (Part 1) aimed to evaluate the mathematics lesson plans prepared by the researchers. The second part (Part 2: Self-assessment) aimed to evaluate the mathematics lesson plan preparation processes that the pre-service teachers gradually developed during the one-semester teaching methods course they attended.

Group interviews were conducted with the participants after the lessons using the questions given in Appendix 2. The pre-service teachers' comments on their awareness of STEM and RETA approaches, the lesson plan preparation process, their evaluations of the integration process of RETA principles into lesson plans, and their STEM attitude changes were obtained. These comments were triangulated with the answers given by the pre-service teachers in the self-assessment section, observation notes, and the lesson plans they prepared.

Data Collection Process

In the study, the 14-week implementation process was divided into three parts. In the first part, the RETA model, which is a technology-enhanced interdisciplinary teaching approach, was introduced to pre-service teachers, and lesson plans using the RETA model were implemented in the classroom environment. During this first part of the research process, the selected pre-service teachers underwent a five-week instructional program focused on the development of mathematics lesson plans utilizing the RETA model. This hands-on approach aimed to bridge the gap between theoretical knowledge and practical application, preparing the participants for future teaching endeavors. In the second part, in the devoted 4 weeks, the pre-service teachers were asked to analyze the RETA-based lesson plans and exemplify each stage and principle. Thus, it was ensured that pre-service teachers examined RETA-based lesson designs and practices in detail through examples. In the third part, pre-service teachers were asked to develop their lesson plans using the RETA model for different topics and objectives of the mathematics curriculum, and the prepared lesson plans were obtained. In the process of designing lessons with the RETA model, pre-service teachers had the opportunity to integrate and utilize STEM components in their lesson plans, without realizing it.

Data Analysis

The study employed both qualitative and quantitative data analysis methods. The qualitative data gathered during the process underwent analysis through the descriptive analysis method, guided by the principles of the RETA model. This approach aimed to uncover and articulate the experiences and opinions of pre-service teachers regarding RETA-based courses, providing a nuanced understanding of their perspectives.

On the other hand, the quantitative data were subjected to statistical analyses to elucidate the relationship between the rubric scores gathered after the development of RETA-based courses and the attitudes of pre-service teachers towards the STEM approach. This quantitative analysis aimed to reveal any significant associations or correlations between these variables, providing a quantitative perspective on the effectiveness of the implemented courses.

Limitations

This study introduces the RETA model as an innovative approach illustrating STEM applications in mathematics teaching and sheds light on the variations in pre-service teachers' STEM attitudes when exposed to diverse teaching styles. While the findings offer valuable insights, it's important to acknowledge a limitation in the sample selection, as it was drawn exclusively from a single grade in a public university. Although the study provides meaningful perspectives, its broader applicability could be enhanced by including more diverse samples from various institutions in future research.

Given that the RETA model is a technology-enhanced approach with interdisciplinary connections to mathematics, the study hypothesized its potential impact on STEM attitudes and aimed to foster these attitudes through this method. Additionally, the study assumed that pre-service teachers provided sincere and accurate responses to the scale and interview questions administered during the research process. Despite these acknowledged limitations, the study's results contribute valuable information regarding the STEM attitudes of pre-service teachers. Future research endeavors should aim to address these limitations by incorporating more diverse samples and exploring the generalizability of the RETA model across various educational settings.

Findings

This section delves into the findings of the study, exploring the impact of the RETA model on pre-service teachers' attitudes towards the STEM approach, the relationship between RETA-based lesson planning and STEM attitudes, changes observed in lesson plans, and the overall experiences of pre-service teachers with the RETA model.

Attitudes toward the STEM Approach

The results of the study indicated that initially, pre-service teachers' attitudes toward the STEM approach were generally neutral or moderately positive. This suggests that their views on the STEM concept might not have been fully formed, or they could have varied based on previous experiences. However, at the end of the 14-week lesson planning process using the RETA model, a positive change in attitudes towards the STEM approach was observed (see Table 1). The t-test results, obtained from a sample of 65 pre-service teachers, indicated a significant improvement in STEM attitudes following the 14-week implementation of lesson plans aligned with the RETA model. The computed t-value was 3.21, with a corresponding p-value of .002. This statistical outcome suggests a substantial influence of integrating RETA model principles—realism, exploratory learning, technology-enhanced learning, and active learning—on the positive development of STEM attitudes among the participating pre-service teachers.

Table 1.

Results of t-test on Pre-Service Teachers' Attitudes towards STEM Approach

				t-test		
	N	*M*	*SD*	*t*	*df*	*p*
Pre-test	65	61.2	10.5	3.21	64	.002
Post-test	65	68.4	8.7			

These findings were consistently supported by qualitative insights gathered through in-depth interviews with the participants, underscoring the effectiveness of the RETA model in shaping STEM perspectives. To put differently, the t-test results revealed significant findings, supporting the notion that the incorporation of the RETA model principles—realism, exploratory learning, technology-enhanced learning, and active learning—effectively contributed to the development of positive STEM attitudes among pre-service teachers, similar to those reported in interviews with participants (n = 8). For instance, one participant expressed, "The RETA model helped me see the real-world applications of STEM concepts in a more tangible way."

Relationship between Lesson Planning with RETA Model and STEM Attitudes

The findings demonstrated a positive relationship between pre-service teachers' use of the RETA model in lesson planning and their attitudes toward the STEM approach. The statistical analysis indicated a significant correlation ($p < .05$, $r = .67$) between the pre-service teachers' rubric scores gathered from developing RETA-based courses and the improvement in pre-service teachers' STEM attitudes (n = 65). The RETA model encompasses principles such as realism, inquiry-based learning, technology integration, and active learning. Therefore, effective implementation of these principles in lesson plans appeared to positively influence pre-service teachers' attitudes towards the STEM approach.

In detail, in the statistical analysis assessing the relationship between the rubric scores gathered from developing RETA-based courses and the improvement in pre-service teachers' STEM attitudes, the calculated correlation coefficient (r) was found to be .67. This positive r value indicates a moderately strong positive correlation between the two variables. The p-value associated with this correlation was below the conventional significance level of .05, further confirming the statistical significance of the observed relationship. The results suggest that as the gathered rubric score from developing courses aligned with the RETA model increased, there was a notable positive impact on pre-service teachers' attitudes towards the STEM approach.

Changes in Lesson Plans

Over the 14-week research period, pre-service teachers' lesson plans, developed using the RETA model, were observed to become enriched based on four RETA principles. The incorporation of student-centered approaches, the use of tangible materials and technology, and the integration of real-world examples resulted in more concrete, participatory, and applicable lesson plans. This developmental shift in lesson plans was interpreted as assisting pre-service teachers in more effectively embracing and implementing the STEM approach. For example, a participant mentioned, "My lesson plans became more engaging and applicable to real-life situations, making mathematics more accessible for students."

RETA Model Experiences

The findings indicated that pre-service teachers generally had positive experiences using the RETA model. The integration of student-centered approaches into lesson design was found to enhance student engagement and make learning more meaningful (n = 8).

Additionally, RETA model experiences were seen as a crucial step in shaping pre-service teachers' skills and approaches for their future teaching careers (n = 6). As most of the interviewed pre-service teacher self-reported, these experiences were perceived as enabling pre-service teachers to make their educational practices more authentic, engaging, and student-centered (n = 7). Experiences related to each RETA principle are detailed below.

a. Experiencing the Realistic Principle

Pre-service teachers had the opportunity to integrate real-life examples into their mathematics lesson plans when experiencing the realistic principle. They chose to bring everyday situations into the lesson content, presenting mathematical concepts in a tangible and meaningful context. This experience served the purpose of capturing students' attention and demonstrating how mathematics can be applied into the real world. The goal was to contextualize mathematical concepts within tangible and meaningful scenarios, fostering a deeper understanding among students. Several activities were designed to achieve this objective. A few examples of activities used in lesson plans are presented below:

- Unit Fractions: Pre-service teachers employed real-world objects and scenarios to introduce the concept of unit fractions. For instance, students were tasked with dividing various objects, such as pizzas or chocolate bars, into equal parts to understand the fundamental idea of unit fractions.
- Equivalent Fractions: To teach equivalent fractions, pre-service teachers designed activities that drew parallels with real-life situations. Students engaged in tasks like recipe adjustments, where they had to scale up or down ingredient quantities while maintaining the same proportional relationships, thereby reinforcing the concept of equivalent fractions.
- Grocery Shopping: The realistic principle was further applied through a grocery shopping activity. Students were given a budget and a shopping list with items in fractional quantities. They had to make real-world decisions on purchasing fractional amounts of items, emphasizing practical applications of fraction operations.

These activities not only made the learning experience more engaging but also allowed students to see the relevance of fractions in everyday situations. The Realistic Principle, as implemented in these activities, aimed to bridge the gap between abstract mathematical concepts and their practical utility in students' lives.

b. Experiencing the Exploratory Principle

When experiencing the exploratory principle, pre-service teachers preferred to offer students opportunities for questioning, problem-solving, and conducting research in their lesson plans. Enriching the lesson content with questions that intrigued and encouraged exploration, this experience allowed students to enhance their mathematical thinking skills and actively engage in learning. A snippet of pre-service teachers' exploratory questions is presented below:

- Question 1: Explore different methods for adding positive integers with three digits. How can breaking down the addition into smaller steps enhance your understanding?
- Question 2: Create a real-world scenario that involves adding positive integers with three digits. What is the mathematical expression for the total in this situation?
- Question 3: Investigate the concept of regrouping or carrying over when adding three-digit numbers. How does regrouping contribute to the accuracy of your addition?
- Question 4: Develop a problem-solving activity that requires the addition of positive integers. What strategies can you employ to efficiently solve this problem?
- Question 5: Consider scenarios where the sum of two positive integers is a multiple of 10. Can you identify patterns or rules for finding pairs of integers that result in a multiple of 10?

These questions aim to stimulate students' exploration of various aspects of adding positive integers with three digits, promoting critical thinking and application of mathematical concepts in different contexts. In addition to serving as exploratory questions for students, the aforementioned inquiries underscore the pre-service teachers' pedagogical prowess in formulating and structuring intellectually stimulating queries. These questions not only encourage critical thinking and problem-solving skills among students but also demonstrate the educators' adeptness in constructing inquiries that promote active engagement and deeper understanding of mathematical concepts. The design of these exploratory questions reflects the pedagogical acumen of pre-service teachers in fostering an environment conducive to inquiry-based learning and mathematical exploration.

c. Experiencing the Technology-enhanced Principle

While experiencing the technology-enhanced principle, pre-service teachers developed strategies to use technological tools such as interactive simulations, calculators, and mathematics application software in their lesson plans. Integrating these technologies into the lesson content enabled students to explore mathematical concepts more effectively. This experience enhanced students' ability to use technology in mathematical learning and contributed to an increase in STEM awareness, as evidenced by significant differences in STEM awareness questions related to technology. Below we included examples illustrating the technology-enhanced principle, showcasing how pre-service teachers incorporated various technological tools into their lesson plans to enhance the learning experience for students in themes of dynamic geometry, mathematics videos and interactive problem-solving:

Firstly, some of the pre-service teachers employed GeoGebra, a dynamic mathematics software, to create interactive simulations illustrating geometric concepts. For instance, they designed dynamic models that allowed students to manipulate angles and shapes in real-time. This hands-on experience not only facilitated a deeper understanding of geometry but also honed students' spatial reasoning skills. Secondly, some pre-service teachers chose to integrate mathematics videos for conceptual understanding. As part of the lesson plan, pre-service teachers integrated educational mathematics videos. For example, they curated videos that visually explained complex mathematical concepts, such as the addition of fractions with different denominators. The multimedia approach provided an additional layer of explanation, catering to diverse learning styles and fostering conceptual understanding among students. Lastly, a few pre-service teachers used interactive problem solving on smart board. These pre-service teachers leveraged smart board technology to conduct interactive problem-solving sessions. They projected mathematical problems onto the smart board, allowing students to come to the board and collaboratively solve equations, work through algorithms, and discuss problem-solving strategies as a class. This interactive approach not only enhanced students' problem-solving skills but also promoted a collaborative learning environment.

These examples highlight how the integration of technology, including GeoGebra, mathematics videos, and Smart Board interactions, enriched the learning process, making it more dynamic and engaging. Moreover, the incorporation of such technological tools contributed to an increased awareness of STEM disciplines by providing students with hands-on experiences that bridge theoretical concepts with real-world applications.

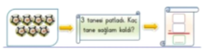
d. Experiencing the Active Principle

When experiencing the active principle, pre-service teachers provided opportunities for students to use tangible materials and models in their lesson plans. Enabling students to understand abstract mathematical concepts through concrete objects or visual representations, this experience helped students better comprehend abstract mathematical concepts and increased their levels of participation. Table 2 presents examples of used tangible materials, where pre-service teachers are referred to as teachers.

Table 2.
Sample Uses of Tangible Materials Developed by the Pre-service Teachers

Questions/ Examples	Related material
1. The teacher introduced a material to the class, such as a box with a tree drawn on it. Each pompom represented an apple, and a realistic story was narrated about the apples, including their rotting and falling to the ground. The teacher then wrote a subtraction problem, for instance, 19-8 = ? The student pushed three pompoms to make them fall into the box, and by counting the remaining apples, they found the result of the operation, 19-8.	

Table 2 continuing

2. The teacher brought pre-prepared materials to the class and demonstrated operations that required and did not require decimal breaking. For example, when subtracting 168 from 293, the student placed 2 hundreds, 9 tens, and 3 ones in the missing part, and 1 hundred, 6 tens, and 8 units in the output part. By performing the subtraction step by step, the student learns with hands-on experiences.	
3. Similarly, Nilgün expressed her difficulties in deciding whether the activities she prepared were appropriate for the grade levels and whether the students would be able to complete them. However, upon receiving feedback, an examination of Nilgün's revised lesson plan revealed that the activities she prepared were indeed suitable for the grade level she had chosen. Figure 1 provides an example of the activity she developed for teaching the objective, "Making mental subtraction with natural numbers."	
4. The teacher placed five paper clips on the desk and stated, "I need to use five of them for filing. How many paper clips do I have left for future use?"	
5. Balls from the gym were brought into the classroom. The teacher presented the situation: "We have seven balls. If three of these balls explode," and then hid three balls under the table, "how many balls are left?"	

In conclusion, the study's findings illuminate the transformative impact of the RETA model on pre-service teachers' attitudes towards STEM, showcasing a significant positive correlation between RETA-based lesson planning and STEM attitudes, evident changes in lesson plans, and the overall positive experiences of pre-service teachers.

Discussion, Suggestion and Conclusion

Discussion

The findings of this study underscore the effectiveness of the RETA model in positively influencing the STEM attitudes of senior-grade pre-service teachers. As seen in other topics, the integration of Realistic, Exploratory, Technology-enhanced, and Active principles in lesson planning in fractions and integers contributed to a perceptible shift in participants' perceptions and beliefs regarding STEM education (Renkl, 2011; Saralar-Aras & Tiflis, 2020). This study revealed that providing training that encourages pre-service teachers to use these resources in courses created with appropriate technology-enhanced mathematics resources positively impacted their attitudes towards the STEM approach.

Previous study findings (Clark-Wilson & Hoyles, 2019; Dick & Hollebrands, 2011) concluded that technology-based mathematics teaching courses were useful in developing pre-service teachers' skills in designing and teaching technology-based tasks. Similar to their approach with the addition of the RETA model, in this study, pre-service teachers were expected to design mathematics lessons with technology and various concrete materials in order to explore mathematics in daily life. The students, who were encouraged to use these features of the RETA model, provided an important transition to the STEM approach with the engineering and science knowledge they addressed in the realistic part of RETA. Therefore, supporting pre-service teachers with the specific teaching model we chose in their teaching courses enriched their course design knowledge, supporting earlier research findings (Bozkurt & Yiğit Koyunkaya, 2022; Dick & Hollebrands, 2011) and adding on to them with the specific model we used.

In this study, in particular, pre-service teachers who received high scores during the evaluations for the RETA approach showed a higher competence in developing comprehensive and interesting lesson plans.

Contributing to the literature regarding this need (Özdemir et al., 2018), the correlation between attitudes and the quality of lesson plans suggests that a favourable mindset towards innovative teaching models contributes to the effective implementation of such strategies in the classroom (Huang, & Zbiek, 2017). Post-course evaluations revealed an increased awareness among participants regarding the equity-promoting potential of the RETA model. Aligning with the literature (Bybee, 2013; English, 2017), interdisciplinary principles embedded in the model were perceived by pre-service teachers as agents for fostering inclusivity and addressing diverse learning needs.

Suggestions

Future research should explore the long-term impact of the RETA model on pre-service teachers as they transition to professional roles. Longitudinal studies can provide insights into the sustained influence of the model on teaching practices and attitudes over an extended period.

Comparative analyses with other innovative teaching models can shed light on the unique contributions and advantages of the RETA model. Understanding how different models impact STEM education can inform educators and policymakers in selecting the most effective approaches.

Investigating the impact of the RETA model on student learning outcomes is crucial. Future research should focus on assessing whether the positive attitudes and enhanced lesson planning translate into improved academic performance and increased interest in STEM subjects among students.

Implications for Practice

Educators and policymakers should consider incorporating the RETA model or similar innovative teaching approaches in pre-service teacher training programs to foster positive STEM attitudes and enhance lesson planning efficacy. The findings of this study contribute to the ongoing discourse on effective strategies for transforming STEM education and promoting equity in the classroom.

Conclusion

In conclusion, the integration of the RETA model in pre-service teacher education demonstrated promising outcomes in shaping STEM attitudes and lesson planning efficacy. The positive shift in attitudes post-course suggests the model's potential to contribute significantly to the ongoing evolution of STEM education methodologies. Recognizing the importance of fostering positive attitudes towards innovative teaching approaches, this study advocates for the continuing exploration and integration of similar models to enhance the quality of STEM education.

Acknowledgement

Ethics statement: Due to COVID-19, the distance education process was postponed and completed with face-to-face training. In the research, pre-service teachers were asked to prepare individual lesson plans during the process. The lesson plans were requested to be as original as possible, and they were warned to pay attention to the sharing of different ideas among themselves. In addition, before the semi-structured interviews were conducted, all participants were informed about the content of the study and it was stated that their answers would be used only for research purposes, that the data would be kept, and that they could leave the study if they wished. However, it was emphasized that their sincere answers to the research questions were important for the scientific validity and reliability of the research.

Author Contributions: Conceptualization, Türker-Biber, B., and Saralar-Aras, İ.; methodology, Türker-Biber, B., and Saralar-Aras, İ.; validation, Türker-Biber, B., and Saralar-Aras, İ.; analysis, Türker-Biber, B., and Saralar-Aras, İ.; writing, review and editing, Türker-Biber, B., and Saralar-Aras, İ.

Funding: This research received no funding.

Institutional Review Board Statement: The research started with the decision of the Aksaray University Human Research and Ethics Committee dated 25/10/2021 and numbered 2021/07-21.

Data Availability Statement: Data generated or analyzed during this study will be available from the authors upon request.

Conflict of Interest: We declare that there is no conflict of interest among authors.

References

Altan, E. B., & Ucuncuoglu, I. (2019). Examining the development of pre-service science teachers' STEM-focused lesson planning skills. *Eurasian Journal of Educational Research, 19*(83), 103-124.

Brown, C. A., Kouba, V. L., Carpenter, T. P., Lindquist, M. M., Silver, E. A., & Swafford, J. O. (1988). Secondary school results for the Fourth NAEP 270 Mathematics Assessment: Algebra, geometry, mathematical methods, and attitudes. *The Mathematics Teacher, 81*(5), 337–397.

Bybee, R. W. (2013). *The case for STEM education: Challenges and opportunities.* NSTA Press.

Bozkurt, G., & Yiğit Koyunkaya, M. (2022). Supporting prospective mathematics teachers' planning and teaching technology-based tasks in the context of a practicum course. *Teaching and Teacher Education, 119,* 103830. https://doi.org/https://doi.org/10.1016/j.tate.2022.103830

Cady, J., Meier, S. L., & Lubinski, C. A. (2006). Developing mathematics teachers: The transition from preservice to experienced teacher. *The Journal of Educational Research, 99*(5), 295-306. https://doi.org/10.3200/JOER.99.5.295-306

Campbell, L. O., & Damico, N. (2023). Investigating an Instructional Model for Integrated STEM in Teacher Education. *Journal of STEM Teacher Education, 58*(1), 70-86.

Chi, M. T. H. (2009). Active-constructive-interactive: A conceptual framework for differentiating learning activities. *Topics in Cognitive Science, 1*(1), 73–105.

Clark-Wilson, A., & Hoyles, C. (2019). From curriculum design to enactment in technology enhanced mathematics instruction—Mind the gap!. *International Journal of Educational Research, 94,* 66-76. https://doi.org/10.1016/j.ijer.2018.11.015

Creswell, J. W., & Clark, V. L. P. (2017). *Designing and conducting mixed methods research*. Sage publications.

Daugherty, M. K., & Carter, V. (2018). The nature of interdisciplinary STEM education. In M. J. de Vries (Ed.), *Handbook of technology education* (pp. 159–171). Berlin: Springer.

Daugherty, M. K., Kindall, H. D., Carter, V., Swagerty, L. M., Wissehr, C., & Robertson, S. (2017). Integrating informational text and STEM: An innovative and necessary curricular approach. *Journal of STEM Teacher Education, 52*(1), 4.

Dick, T. P., & Hollebrands, K. F. (2011). *Focus in high school mathematics: Technology to support reasoning and sense making* (pp. 11-17). National Council of Teachers of Mathematics.

Eker Uka, E., & Bedir, H. (2023). Exploring EFL teachers' perceptions on 21st century skills: A case study. *e-Kafkas Journal of Educational Research, 10(*2), 169-182. https://doi.org/10.30900/kafkasegt.1240904

English, L. D. (2017). Advancing Elementary and Middle School STEM Education. *International Journal of Science and Mathematics Education, 15*(1), 5-24. https://doi.org/10.1007/s10763-017-9802-x

English, L. D. (2018). Learning while designing in a fourth-grade integrated STEM problem. *International Journal of Technology and Design Education, 29,* 1011-1032. www.doi.org/10.1007/s10798-018-9482-z.

Esen, B., & Saralar-Aras, İ. (2022). The effects of RETA Model on student achievement and perception: Case of polygons. *Necmettin Erbakan University Ereğli Education Faculty Journal, 4*(2) , 96-121.

Evans, S., & Swan, M. (2014). Developing students' strategies for problem solving in mathematics: The role of pre-designed "Sample Student Work". *Educational Designer, 2*(7), 1-30.

Gravemeijer, K. (1994). Educational development and developmental research in mathematics education. *Journal for Research in Mathematics Education, 25*(5), 443–471.

Hamilton, E., Lesh, R., Lester, F., & Brilleslyper, M. (2008). Model-eliciting activities (MEAs) as a bridge between engineering education research and mathematics education research. *Advances in Engineering Education, 1*(2), 1-25.

Honey, M., Pearson, G. & Schweingruber (Eds.). (2014). *STEM integration in K-12 education: Status, prospects, and an agenda for research.* Washington, DC: National Academies Press.

Huang, R., & Zbiek, R. M. (2017). Prospective secondary mathematics teacher preparation and technology. In M. E. Strutchens, R. Huang, L. Losano, D. Potari, M. C. d. C. T. Cyrino, J. P. da Ponte, & R. M. Zbiek (Eds.), *The mathematics education of prospective secondary teachers* *around the world* (pp. 17-23). Springer International Publishing. https://doi.org/10.1007/978-3-319-38965-3_3

Kelly, K. (2021). Planning an intervention for learners with mathematics difficulties: models of mathematical development (M. H. Sarı & İ. Saralar-Aras, Trans). In *Identifying, assessing and supporting learners with dyscalculia* (pp. 166-182). Vizetek Publication. (Original work published 2020).

Kennedy, T. J., & Odell, M. R. (2014). Engaging students in STEM education. *Science Education International, 25*(3), 246-258.

Ministry of National Education. (2010). *Movement of Enhancing Opportunities and Improving Technology (FATIH).* http://fatihprojesi.meb.gov.tr/en/

Ministry of National Education. (2018a). *2018 LGS merkezi sinavla yerlesen ogrencilerin performansi [The performance of the students placed by LGS 2018 National Exam].* Ankara: MoNE.

Ministry of National Education. (2018b). *Primary and middle school mathematics program update (Grades 1-8).* Ankara: MoNE.

Ministry of National Education. (2019). *2019 LGS ortaogretim kurumlarına ilişkin merkezi sınav analiz ve değerlendirme raporu [Analysis and evaluation report of the LGS 2019 National Exam for entering secondary education institutions].* Ankara: MoNE.

Moch, P. L. (2001). Manipulatives work! *Educational Forum*, *66*(1), 81–87.

Mostofo, J. (2014). The impact of using lesson study with pre-service mathematics teachers. *Journal of Instructional Research, 3*(1), 55-63.

National Centre for Education Statistics [NCES]. (2018a). NAEP - Distribution of M-mathematics questions: 2017. https://nces.ed.gov/nationsreportcard/mathematics/distributequest.aspx

National Centre for Education Statistics [NCES]. (2018b). NAEP Mathematics: National student group scores and score gaps. https://www.nationsreportcard.gov/math_2017/nation/gaps?grade=8

Özdemir, A., Yaman, C., & Vural, R. A. (2018). STEM uygulamaları öğretmen öz-yeterlik ölçeğinin geliştirilmesi: Bir geçerlik ve güvenirlik çalışması. *Adnan Menderes Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 5*(2), 93-104.

Renkl, A. (2011). Instruction based on examples. In R. E. Mayer, & P. A. Alexander (Eds.), *Handbook of research on learning and instruction* (pp. 272–295). Routledge.

Ruys, I., Keer, H. V., & Aelterman, A. (2012). Examining pre-service teacher competence in lesson planning pertaining to collaborative learning. *Journal of Curriculum Studies, 44*(3), 349-379. https://doi.org/10.1080/00220272.2012.675355

Salomon, G., & Perkins, D. (2005). Do technologies make us smarter? Intellectual amplification with, of, and through technology. In R. J. Sternberg, & D. D. Preiss (Eds.), *Intelligence and technology: The impact of tools on the nature and development of human abilities* (pp. 71–86). Erlbaum.

Sanders, M. (2009). STEM, STEM education, STEMmania. *Technology Teacher*, *68*, 20–26.

Saralar-Aras, İ. (2022). RETA model for mathematics teaching: From the United Kingdom to Turkey. In O. Kartal, G. Popovic & S. Morrissey (Eds.), Global Perspectives and Practices for Reform-based Mathematics Teaching (pp. 42-78). IGI Global. https://doi.org/10.4018/978-1-7998-9422-3.ch003

Saralar-Aras, İ., & Tiflis, O. (2020, November). *A literature review on technology use of British and Chinese pre-service mathematics teachers*. Paper presented at the British Society for Research into Learning Mathematics Autumn Conference 2020. Online, UK: BSRLM.

Saralar, İ., Ainsworth, S., & Wake, G. (2019, March). A design study on improving spatial thinking of middle school children. *Proceedings of the British Society for Research into Learning Mathematics, 39*(1), 1-6.

Saralar, İ., Ainsworth, S., & Wake, G. (2018, November). *Helping students learn two-dimensional representations of polycubical shapes*. Paper presented at the British Society for Research into Learning Mathematics Conference 2018. King's College London, London, The UK: BSRLM.

Schank, R. C. (1994). Active learning through multimedia. *IEEE MultiMedia, 1*(1), 69–78. https://doi.org/10.1109/93.295270

Shaughnessy, M. (2013). By way of introduction: Mathematics in a STEM context. *Mathematics Teaching in the Middle School, 18*(6), 324.

Standards and Testing Agency (STA). (2019a). Key stage 2 tests: 2019 mathematics test materials. https://www.gov.uk/government/publications/key-stage-2-tests-2019-mathematics-test-materials

Standards and Testing Agency (STA). (2019b). Mathematics paper 2: Reasoning. In *2019 National Curriculum Tests: Key stage 2*.

Stohlmann, M. (2019). Three modes of STEM integration for middle school mathematics teachers. *School Science and Mathematics*, *119*(5), 287-296. https://doi.org/10.1111/ssm.12339

Sutaphan, S., & Yuenyong, C. (2019, October). STEM education teaching approach: Inquiry from the context based. *Journal of Physics: Conference Series*, *1340*(1), 12003. https://doi.org/10.1088/1742-6596/1340/1/012003

Tas, Y., Yerdelen, S., & Kahraman, N. (2016). Adaptation of Teacher Efficacy and Attitudes Toward STEM (T-STEM) Survey into Turkish. In *International Conference on Education in Mathematics, Science & Technology (ICEMST)*. Bodrum, Türkiye.

van de Walle, J. A., Karp, K. S., & Bay-Williams, J. M. (2010). Geometric thinking and geometric concepts. In *Elementary and middle school mathematics teaching developmentally* (7th ed., pp. 402–433). Pearson Education.

Wang, F., & Hannafin, M. J. (2005). Design-based research and technology-enhanced learning environments. *Educational Technology Research and Development, 53*(4), 5–23.

Yu-Wen, L. A., & Andrews, P. (2009). Linking geometry and algebra: English and Taiwanese upper secondary teachers' approaches to the use of GeoGebra. *Proceedings of the British Society for Research into Learning Mathematics, 29*(1), 61–65.

Appendix 1. Rubric for Assessing the Use of the Reta Model Lesson Plan

Lesson Design Rubric with RETA Model
PART 1 (To be filled in by the researchers)
Item 1. Incorporation of the principle of realistic learning into the lesson plan (0 points) The pre-service teacher did not include the principle of realistic learning in the lesson plan. (1 point) The pre-service teacher included a real-life example in the lesson plan but designed a teacher-taught environment. (2 points) The pre-service teacher included one real-life example in the lesson plan and provided a discussion environment for the students. (3 points) The pre-service teacher included more than one real-life example in the lesson plan and encouraged students to find different real-life examples.
Item 2. Incorporation of the investigative learning principle into the lesson plan (0 points) The pre-service teacher did not include the principle of investigative learning in the lesson plan. (1 points) The pre-service teacher included worked examples in the lesson plan but designed a teacher-taught environment. (2 points) The pre-service teacher included a worked example in the lesson plan and provided the students with a solution and discussion environment. (3 points) The pre-service teacher included more than one worked example in the lesson plan and encouraged students to reflect on the worked examples and reach a conclusion.
Item 3. Incorporation of the principle of technology-facilitated learning into the lesson plan (0 points) The pre-service teacher did not include the principle of technology-facilitated learning in the lesson plan. (1 point) The pre-service teacher included a technology (calculator, GeoGebra, etc.) in the lesson plan but designed a teacher-taught environment. (2 points) The pre-service teacher included one technology in the lesson plan and provided opportunities for students to use this technology. (3 points) The pre-service teacher included more than one technology in the lesson plan and used technology to enhance student learning at different stages of the lesson (e.g. showing a video in the introduction, using a calculator in the content, using assessment tools such as Kahoot, etc. in the assessment phase)
Item 4. Incorporation of the active learning principle into the lesson plan (0 points) The student teacher did not include the principle of active learning in the lesson plan. (1 point) The pre-service teacher included a concrete material/tool in the lesson plan but designed an environment where the teacher narrates. (2 points) The pre-service teacher included one concrete material/tool in the lesson plan and provided an environment for students to use the materials actively. (3 points) The pre-service teacher included more than one concrete material/tool in the lesson plan and encouraged students to find innovative examples and/or mathematical modelling with the help of these tools.

Appendix 1. Rubric for Assessing the Use of the Reta Model Lesson Plan (Continue)

PART 2 (to be filled in by the participant) **Self-assessment**
What did I know? …………………………………….
What did I want to learn? ……………………………
What did I learn? ……………………………………..

Appendix 2. Interview Form

Interview Questions
(Introduction) Thank you for volunteering for the interview, informing that the interview will be audio-recorded, introductory speech reiterating the aims of the study
1. What do you think is the STEM approach?
2. Can you describe the RETA model in a few sentences?
3. What would you say if you were asked to associate the STEM approach with RETA?
3.a. Which characteristics are similar/not similar? How did you realize this?
4. What are the challenges you faced while preparing lessons with the RETA model?
5. What are the advantages of preparing lessons with the RETA model?
6. Which of the principles: realistic, investigative, technology-facilitated, and active, do you think is the most/least effective among them? Why?
7. Is it important to integrate real-life examples into lesson plans? Why is this important? What are your experiences in this regard?
8. Is it important to integrate worked examples into lesson plans? Why is this important? What are your experiences in this regard?
9. Is it important to integrate technology into lesson plans? Why is this important? What are your experiences in this regard?
10. Is it important to integrate concrete materials and/or modelling into lesson plans? Why is this important? What are your experiences in this regard?
11. What do you think are the advantages/disadvantages of having active students and preparing student-centered lesson plans?
12. After 14 weeks of experiencing the lessons, when we check the scale, the change in your attitudes is as follows (*here the relevant result is reported*). What do you think could be the reason for this? How would you evaluate yourself in this field?
(Conclusion) Asking the participant for any extra topics he/she would like to add, thank you