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An Application Based on the 5E Learning Cycle Model Supported by Concept Cartoons with Primary Pre-Service Teachers*

Filiz Tuba Dikkartın Övez[1]
Balıkesir University

Güliz Şahin[2]
Balıkesir University

Abstract

The study aims to examine the effect of concept cartoon supported lesson plan development practices based on the 5E learning cycle model on the non-routine problem solving skills and attitudes towards mathematics teaching of primary pre-service teachers, to determine the level of problem construction, to evaluate the texts in the problems constructed with concept cartoons developed by primary pre-service teachers in terms of text writing success level and to reveal their opinions about the practices. The study utilized a nested design, which is a mixed-method research approach, and employed a convenient sampling method for participant selection. Data collection was carried out using the attitude towards mathematics teaching scale, problem solving scale, interview form, and lesson plans developed by primary pre-service teachers. The data were evaluated by content analysis, t-test for related samples, descriptive analysis, progressive scoring scale, problem posing skills scoring key, grading scale. Significant enhancements in attitudes toward mathematics teaching were observed in favor of the post-test, with opinions categorized into six distinct groups, highlighting challenges encountered during the evaluation phase and the process of problem posing. It was ascertained that the overall level of achievement in text creation was generally deemed satisfactory.

Key Words

Analysis of language mistakes • Concept cartoons • 5E • Pre-service classroom teachers • Problem solving

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[1] **Correspondance to:** Filiz Tuba Dikkartın Övez, Balikesir University, Necatibey Faculty of Education, Department of Mathematics and Science Teaching, Balıkesir, Türkiye. E-mail: f.tubadikkartin@gmail.com **ORCID:** 0000-0003-2646-5327

[2] Balıkesir University, Necatibey Faculty of Faculty, Department of Primary Education, Balıkesir, Türkiye. E-mail: guliz@balikesir.edu.tr **ORCID:** 0000-0003-4487-5258

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Introduction

The ability to solve problems remains a crucial and vital talent in fields other than mathematics despite being one of the goals of the primary school mathematics curriculum (MoNE, 2018). It is important to develop these abilities during school hours, especially in primary school, if someone wants to work in the business sector and can think interdisciplinaryly, solve problems, and use 21st-century talents. The primary school mathematics curriculum aims to cultivate students' ability to express their ideas and arguments with clarity in the context of problem-solving, as well as to equip them with the competence to discern deficiencies or omissions in the mathematical reasoning of others. Consequently, prospective instructors of the subject must exhibit an awareness of this imperative, as underscored by the Ministry of National Education (MoNE, 2018).

Math operations by themselves are insufficient to develop this skill. In this situation, it is important to practice addressing non-routine and verbal problems as well as routine ones during the learning process. It is also important to give the necessary studies so that students can develop their problem-solving techniques by following the problem-solving procedures. All educational levels consider problem-solving as a learning activity (Jonassen, Howland, Moore, & Marra, 2003; Lazakidou & Retalis, 2010). Even though it is a crucial task, research indicates that most students struggle to use their mathematical understanding to solve issues, particularly those that involve reading comprehension. Some research has examined the mistakes or challenges that students run into when answering word problems, highlighting the preponderance of linguistic-based problems (Fatmanissa & Kusnandi, 2017). For example, "identifying keywords, using vocabulary, analyzing long sentences, and understanding the written context" are linguistic elements that can make it difficult to understand word problems (Gafoor & Sarabi, 2015; Seifi, Haghverdi, & Azizmohamadi, 2012). As posited by multiple authors (Lamb, 2010; Phonapichat, Wongwanich, & Sujiva, 2014; West, 1977), the most formidable impediment hindering students' proficiency in mathematical problem-solving resides in their challenge to grasp the intended meaning embedded within the textual representations. This prevents them from even beginning the process of problem-solving. Reading comprehension is considered a factor directly related to the structure of the problem, which is a critical factor for beginning the problem-solving process and improving problem-solving skills. According to a study on factors influencing mathematics studies, reading is the most important element (Jiban & Deno, 2007; Lamb, 2010). According to Durkin (1993), reading comprehension is the process of developing a mental image of a text. According to Schnotz and Bannert (2003), mathematics problems are typically texts with discrete features like tables, diagrams, or formulas. Consequently, the conceptualization of reading comprehension can also be regarded as a subsidiary competency essential for formulating a coherent model, as a proficient comprehension of written material is imperative for the organization and elucidation of presented content, as noted by Krawitz, Chang, Yang, and Schukajlow (2022). Schleppegrell (2007) accentuated the significance of engaging with language in the construction of knowledge, a process intrinsic to mathematical endeavors such as teaching and problem-solving. This entails the utilization of diverse linguistic modalities encompassing mathematical symbols, oral discourse, written communication, as well as various semiotic systems such as graphical representations and diagrams. Language provides the reader with contextual information about the mathematical situation to be addressed. This connection is formulated in oral language in the classroom. Thus, written language, mathematical, symbolic expressions, visual representation, oral language, grammatical patterns, technical vocabulary, dense noun phrases, verbs to be and to have, conjunctions with technical meanings, etc., work together to construct the meaning with which the teacher and students interact when discussing the problem. Schleppegrell (2007) points out that students should be able to use technical vocabulary in meaningful language patterns in mathematics and argues that it is not enough to know only mathematical words such as "more, less, as much"; students should also learn the language patterns associated with these words and how they form concepts in mathematics. Among the linguistic challenges, particular emphasis is placed on the multiple semiotic constructions of mathematics, the dense noun phrases involved in relational processes, and the literal meaning of conjunctions and implicit logical relations that connect elements in mathematical discourse. It also states that research on pedagogical practices supports the development of mathematical knowledge by paying attention to how language is used and suggests strategies for moving students from informal and casual ways of talking about mathematics to more technical and precise processes of meaning-making. Thus, learning mathematics is not only a matter of manipulating symbols but also of understanding how different systems interact to construct meaning. Both linguistic and numerical complexity contribute to the difficulty in solving verbal problems. Researchers working in this area have observed that even in the related fields of linguistics and mathematics, some aspects of the process have been studied comprehensively while others have been neglected. For example, they observed that semantics and discourse structures are often studied in the context of the complexity of verbal problems, but systematic syntactic manipulations are rare (Daroczy, Wolska, Meurers, & Nuerk, 2015). Given that word problems do not present students with a straightforward mathematical expression, their resolution necessitates the undertaking of intricate procedural steps. These steps include reading, comprehending, transforming into a mathematical expression, processing the mathematics, interpreting the result according to the given context, and evaluating the result (Fatmanissa & Kusnandi, 2017; Reys, Lindquist, Lambdin, & Smith, 2008; Verschaffel, Van Dooren, Greer, & Mukhopadhyay, 2010). Verbal problems are problems that take place in real-life contexts (Verschaffel et al., 2010). They require students to read, comprehend, and make mathematical connections to solve the problem. Despite their real-life context, word problems are coded based on the language and symbols of mathematics (Reed, 1998). Consequently, students' interpretation and comprehension of linguistic components within word problems are subject to the influence of the mathematically situated context. Language serves as a cognitive instrument, and an array of studies has underscored the substantial contribution of the interplay between procedural expertise and linguistic aptitude in mathematics to the process of conceptual advancement, as exemplified by the work of Aiken (1972). Thought is not only expressed in words; its existence is revealed through words (Vygotsky, 1978). Therefore, a student working on a problem alone solves the problem based on prior learning and existing mathematical knowledge. However, a student who solves a problem with the help of friends or a teacher can interactively construct mathematical meanings. This interaction, characterized as the zone of proximal development in the context of learning, represents a phenomenon that occurs as students collaborate in the pursuit of a shared task, in accordance with Vygotsky's seminal work in 1978. Language, communication, problem-solving, and mathematical thinking cannot be separated from each other in any mathematics course. In problem-solving, language is important in terms of verbal representations and plays a role as a tool for mathematical thinking (Khalid & Tengah, 2007). The most important reason for students' poor performance in solving verbal problems is their inability to understand the problems. Although some teachers resort to teaching using keywords, this is known to have harmful consequences

(Clements, 1999). The language system and its function is to organize the choices of mathematical symbols and visual representations. If there are problems in understanding the system, this will lead to a lack of understanding of the problems due to linguistic features. Hence, in order to surmount linguistic challenges encountered in the resolution of such problems, it is imperative not to disregard the linguistic attributes inherent in these problems, as emphasized by Fatmanissa and Kusnandi in their study (2017). The instructor's role within the context of solving verbal problems is multifaceted. This is because they try to guide their students towards a familiar solution either based on their own experiences or by utilizing the contexts of the problems they have solved before. At the same time, teachers have the task of carefully selecting from a variety of problem types, as well as gradually modifying problems according to their level of difficulty. To find out what students know and understand, they allow them to talk or write about how they solved the problems. This is not only important for the development of students' problem-solving skills but also valuable for encouraging them to construct their problems (Roche, 2013). In the problem-solving process, teachers need to provide sufficient context for students to see the problem (Monroe & Panchyshyn, 2005). In this process, reading comprehension and linguistic features in the problems presented play an important role in conveying the message. It is important that teachers, who are in charge of providing these skills to students and planning and executing the process, are competent in terms of both problem-solving and language skills. For this reason, for students to make sense of mathematics and for the problem-solving process to be carried out healthily, it is necessary to ensure that students talk and interact with each other in the mathematics classroom, take an active role, and carry out activities and studies that will enable them to develop skills in language and reading comprehension. This is attributed to the fact that language functions as an intermediary link connecting the genesis of a problem and the subsequent processes involved in its resolution. Language is divided into two: receptive language, which is the ability to understand what is said, and expressive language, which is the ability to communicate with the knowledge and use of the spoken language (Deniz & Gönen, 2021, p. 1378). At the same time, from a linguistic point of view, a text is a series of sentences that follow each other and form sequential and meaningful wholes (Günay, 2003). Therefore, it is necessary to know that a mathematical expression is also a text, and the expressive language skill must be used competently to be perceived correctly and clearly by the student, to make the thinking process effective, to develop the solution strategy appropriate to the problem statement to be explained and to reach the result.

In the most basic sense, the process of producing written texts takes place in three stages. These are planning, writing, and revision. Bayat (2019, p.4), while describing the planning stage, says that the person writing the text should have a certain amount of knowledge about the subject and should reformat this knowledge by using his/her thinking ability. If the planning stage is completed correctly, the second stage, the writing stage, begins, in which thoughts are transformed into written text. The author of the text is expected to proficiently utilize their preexisting linguistic foundation in a functional manner, effectively transposing their cognitive ideas into a coherent and intelligible format, replete with grammatical structure and an appropriate array of lexical elements. Finally, in the revision stage, it is observed and checked whether the written text is fully comprehensible, linguistically, and lexically adequate, and in harmony with the plan, and if there are errors, the problem is corrected by going back to the stage where the problem originated. When all stages are completed, a text is produced.

It is expected that the concept cartoons and problem statements created by primary pre-service teachers within the scope of this research will be designed by taking into account the specified elements. These texts, which were produced after the correct completion of this process, were evaluated analytically. In analytical evaluation, there are some features that the literary text produced should have, and the text is analyzed in specified sections, and each section is evaluated separately through grading. The Analytical Grading Scale, originally formulated by Weigle in 2002 and subsequently adapted to the Turkish context by Ülper in 2019, served as the instrument employed for the examination of the texts generated in this research endeavor. The overarching objective encompassed the assessment of the concept cartoons and problem statements crafted by pre-service teachers within a comprehensive framework. The five subcategories determined within the scope of this evaluation are content (the level of knowledge about the subject, being understandable, being well developed, including details about the subject), organization (fluency in expression, clearly determined and organized thought transfer, coherence with logical sequence), vocabulary (the level of vocabulary possessed, The following are defined: language use (level of originality and sophistication in sentence construction and expression disorder), mechanics (proficiency in spelling, punctuation, and paragraphing, and spelling).

Teachers' duties and responsibilities are becoming more complex over time due to the technically, economically, socially, and politically changing world. Due to changing needs, teachers have to face new methods of technology, motivation, teamwork, differentiation, classroom management, and assessment links with parents (OECD, 2009, p. 62). Therefore, teachers should raise individuals with problem-solving skills as decision-makers in the learning-teaching process (from planning to evaluation). Within this context, a fundamental imperative of teacher education lies in the cultivation of educators' problem-solving proficiencies. In educational settings that prioritize student-centered methodologies, the pedagogical paradigm revolves around experiential and hands-on learning, fostering independent problem-solving. Such a pedagogical approach not only engenders lasting comprehension but also empowers students as active participants in the learning milieu. The constructivist learning approach has been one of the most effective theories in mathematics teaching as in other teaching processes. Constructivism, which is a theory about how knowledge is formed and how people obtain knowledge, is related to the nature of knowledge and the way it is obtained. In this context, it is known that many student-centered approaches and strategies are used. Concept cartoons are one of the strategies based on constructivism. Concept cartoons are used as a strategy that activates students' ideas and enables them to make connections with their previous learning. Students' understanding of knowledge can be improved in learning environments supported by concept cartoons (Naylor & Keogh, 2013). Because the ideas conveyed through cartoons are easily understood with the movement of the cartoon character (Subhan & Lilia, 2010). Several studies have indicated that pedagogical utilization of concept cartoons yields several advantageous outcomes, including enhancements in students' discourse proficiency (Naylor & Keogh, 2013), augmentation of the enjoyment factor in the learning process (Narayan, 2016), a favorable impact on students' attitudes and enthusiasm (Kaptan & İzgi, 2014), and a marked increase in student academic achievement (Jamal, Ibrahim, & Surif, 2019). With a concept cartoon, many complex thoughts that occur throughout life can be explained with a picture or drawing. Concept cartoons are drawings that visually represent an idea or symbols and should often be supported by the use of strong language. In this context, cartoons can be effective in overcoming the difficulty of explaining a complex or abstract statement simply and effectively. Naylor and Keogh (2013) list the contributions of concept cartoons to students in the teaching process: a. It prevents students who lack confidence from experiencing anxiety and fear in the scientific process because it is based on everyday life situations that do not appear to have scientific content, b. It offers alternative perspectives on the topic being discussed, including scientifically acceptable perspectives, c. Although most concept cartoons contain scientific ideas about the problem situation in everyday life, they can affect how the problem is interpreted and create the opportunity to present more than one scientifically acceptable alternative, d. To encourage the students to explore the alternative ideas they have, the students were given a clue that there may be more than one idea to solve the problem in question through empty speech bubbles that have not yet been dialogued, and since all alternative points of view have equal status in the process of creating concept cartoons, students with low self-confidence level were allowed to voice what they think. Consequently, in instances where misconceptions arise, the conveyance of such erroneous notions through the caricatured character, rather than originating directly from the student, fosters an environment that mitigates potential hesitancy or embarrassment associated with the articulation of their perspectives, regardless of their accuracy. Concept cartoons are additionally harnessed as a potent means to interrogate and address students' misconceptions.

In many studies, concept cartoons have been used to teach difficult or complex concepts encountered in the learning process to students more easily and understandably (Topkaya, 2016), to provide an effective classroom discussion environment (Bing & Tam, 2003), and to provide a student-centered teaching process unlike the traditional teaching model (Altun, 2009). Simultaneously, within the constructivist paradigm that prioritizes student engagement, the focal point of pedagogy centers on the learner. The attainment of meaningful learning transpires when students adeptly cultivate efficacious strategies for navigating and resolving problem-laden scenarios. Such situations increase student motivation and offer students the opportunity to experience pleasure and satisfaction in problem-solving (Karagiorgi & Symeou, 2005). Concept cartoons are of great benefit to students at this point. Problem-solving is an important component of mathematics education. Problem-solving provides an environment for students to reflect on their ideas about the nature of mathematics and to develop a relational mathematical understanding (Lester, 1994). As students solve mathematical problems, they discover ways of mathematical thinking outside the mathematics classroom and gain problem-solving habits and confidence. In mathematics education, problem-solving is seen as a skill that should be taught, a goal for mental development, and a teaching method (Brown, 2003; NCTM, 2000). Since the importance given to problem-solving has become widespread, it has become a necessity for both pre-service and in-service teachers to have a common understanding of the importance of problem-solving in mathematics education. Nonetheless, the efficacy of initiatives to reform curricular content is contingent upon the degree of receptivity exhibited by educators towards the newly adopted curricula. Should teachers, who function as the executors of these curricula, not fully internalize the significance of problem-solving, such reform endeavors may ultimately prove unsuccessful. De Mesquita and Drake (1994) showed that there is a direct relationship between teachers' perceptions of innovation and the success of innovation. Therefore, teachers and pre-service teachers, who are expected to have some responsibilities in the reform process, should be examined in terms of their knowledge, skills, and beliefs about the necessity of innovation. In this direction, the scope of this study is to reveal the knowledge and skills of pre-service teachers about non-routine problems and solution strategies, to design teaching materials using concept cartoons, one of the innovative teaching approaches for the development of these skills, and to examine the effect of these materials.

Constructivism, which is based on the assumption that learning is a product of the structuring of the mind, requires individuals to take more responsibility by actively participating in the learning process (Kılıç, Karadeniz, & Karataş, 2003). Students who actively participate in the learning process develop strategies by trying different solutions to the problem situation presented to them and increase the permanence and meaningfulness of learning. The establishment of learning environments grounded in the constructivist pedagogical framework, coupled with the incorporation of multisensory modalities within the learning process under consideration, augments the effectiveness of information structuring within students' cognitive faculties.

Concept cartoons, which we encounter in this process, were created for the first time in 1991 by Naylor and Keogh (2013), based on the constructivist approach, in 1992 "to develop an innovative teaching and learning strategy that takes into account the views of learning in constructivist science" (Keogh & Naylor, 1999; Stephenson & Warwick, 2002) and the cartoons, which were designed primarily for students aged 9-13, were included in the learning environment in primary and secondary education with the expansion of the studies (Stephenson & Warwick, 2002). Most mathematical concepts are abstract concepts that require high-level cognitive activity. Studies conducted in this direction have revealed that the constructivist approach is effective in helping students construct these concepts in their minds and adapt to abstract mathematical concepts easily. Concept cartoons have been developed as an innovative learning and teaching strategy based on the constructivist learning approach. It is known that concept cartoons have positive effects on mathematics teaching, developing mathematical thinking, creating brainstorming and discussion environments, and writing mathematical problems. It is thought that concept cartoons will be effective in improving the skills of primary pre-service teachers who are known to have problems with non-routine problem-solving skills. In this study, as researchers working in the field of Turkish and mathematics, research was conducted to provide a different perspective on the grammatical and numerical aspects related to the problem statement and solving process of primary pre-service teachers as well as their interaction in educational situations based on the 5E learning cycle enriched with concept cartoons and adopting the constructivist learning approach. In this direction, the aim is to examine the effect of lesson plan development practices based on the 5E learning cycle model supported by concept cartoons on the non-routine problem-solving skills and attitudes towards mathematics teaching of primary pre-service teachers to determine their problem statement levels, to evaluate the texts in the problems established with concept cartoons developed by primary pre-service teachers in terms of content, organization, vocabulary, language use and mechanics, and to reveal their opinions about the teaching practices. In this context, the research problems were determined as follows:

1. How are the problem-solving skills of primary pre-service teachers after the lesson plan development practices based on the 5E learning cycle model supported by concept cartoons for teaching problem-solving steps and strategies?

2. What is the level of problem statement skills of the problems posed by primary pre-service teachers in the concept cartoons developed by considering problem-solving steps?

3. What is the level of success of the texts in the concept cartoons prepared by the primary pre-service teachers and the texts in the problems they set up?

4. Do the practices of developing lesson plans based on the 5E learning cycle model supported by concept cartoons for teaching problem-solving steps and strategies affect the attitudes of primary pre-service teachers towards mathematics teaching?

5. What are the opinions of primary pre-service teachers about the implementation?

Method

Research Model

One of the mixed method studies, the nested design, was used in the study as its model. Nested design is a strategy that combines quantitative and qualitative designs. A qualitative phase can be introduced to the experimental studies within the quantitative research in studies employing the nested design, and vice versa for the case study within the qualitative studies (Creswell, Shope, Plano-Clark, & Green, 2006). The principal objectives of this study encompassed the assessment of the problem-posing proficiency exhibited by primary pre-service teachers, an evaluation of the content, organizational structure, vocabulary, and language utilization within the texts comprising concept cartoons and problems crafted by these pre-service teachers, and an exploration of the impact of pedagogical practices related to lesson plan development predicated on the 5E learning cycle model, reinforced by the integration of concept cartoons, on the attitudes of these educators toward the instruction of mathematics. The quantitative portion of the study utilized a pretest-posttest one-group quasi-experimental design in this situation. The case study is employed in the qualitative portion of the study when there are several data sources and supporting evidence, and the underlying causes of some events are real-world factors (Yıldırım & Şimşek, 2018). The pre-service teachers' thoughts on the application were solicited through a semi-structured interview form.

Study Group

The study's objectives involved 38 primary pre-service teachers (20 female, 18 male) who were enrolled in the faculty of education at a medium-sized state university in the west of Turkey. One of the purposive sampling techniques, the criterion sampling approach, served as the foundation. In the criterion sampling approach, the researchers may opt for a predetermined set of criteria or alternatively, they may select and scrutinize instances aligning with criteria formulated by the researchers themselves (Yıldırım & Şimşek, 2018). In the context of the present research, the criteria for the chosen study group were delineated as follows: individuals classified as senior-level students majoring in primary education, those who have successfully completed the Mathematics Teaching I course, and individuals who have undertaken the Turkish Teaching course.

Data Collection Tools

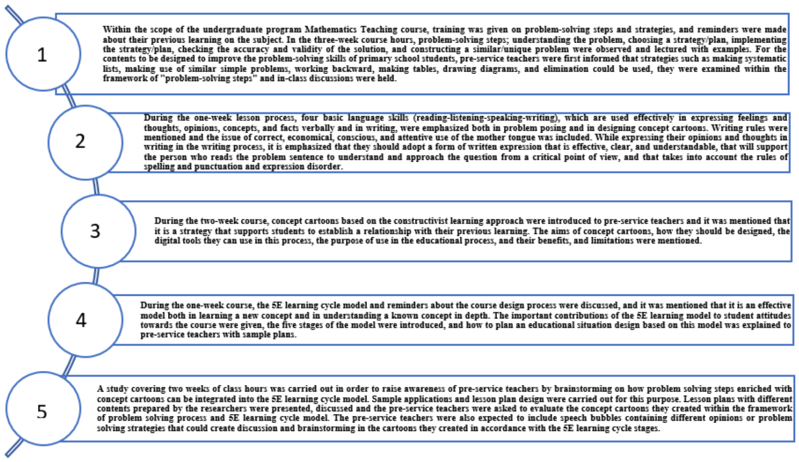
The problem-solving scale created by the researchers, the interview form, the lesson plans created by the primary pre-service teachers, and the attitude scale toward mathematics teaching created by Göloğlu-Demir and Çetin (2012) were used as data collection tools within the context of the research problems. For the evaluation of problem-solving proficiencies among primary pre-service teachers, an open-ended "problem-solving scale" was meticulously constructed. Prior to its formulation, an extensive review of pertinent literature was undertaken to inform the development of this scale, comprising 11 tasks designed to appraise the application of nine distinct problem-solving techniques. Following the problem-solving phases (understanding the problem, selecting a strategy, using the selected strategy, and evaluating the outcome), pre-service teachers were asked to respond to the scale's questions. 23 challenges were found in the first stage that attempted to employ the identified tactics, including generating a systematic list, using related small problems, working backward, creating a table, creating a diagram, and eliminating possibilities. Following the presentation of these challenges to two subject-matter experts, 12 problems that shared a common method were eliminated, 11 problems were chosen, and the scale was created. Outside of the study group, the scale was administered to three potential classroom teachers. It was found that there were no comprehensibility issues, so the scale was then finished. After the application, primary pre-service teachers were given the 11 questions from the scale. The pre-service teachers also chose one of the problems on the problem-solving scale, and they were tasked with creating concept cartoon-supported 5E lesson plans for introducing the technique to be applied to the chosen problem. The success rates of text construction for similar problems created within the parameters of the acquired concept cartoons and lesson plans were assessed. To ascertain the attitudes of potential primary pre-service teachers toward teaching mathematics, the "Attitude Scale towards Mathematics Teaching" created by Göloğlu-Demir and Çetin (2012) was utilized. A Likert-type scale with 25 items makes up the scale. As a result of the factor analysis performed to determine the construct validity, it was seen that the factor loads of the scale items ranged between 0.46 and 0.77, the Kaiser-Meyer Olkin (KMO) value was .90, and the internal consistency coefficient (Cronbach alpha) value calculated for the reliability study was $\alpha = .92$. To get perspectives on the practices, a semi-structured interview form was created. An item pool was developed for this purpose after a literature assessment. A panel of two field education experts were subjected to a series of 20 open-ended inquiries. Subsequent to obtaining expert input with regard to the items' efficacy in gauging the targeted construct, as well as their lucidity and overall comprehensibility, a portion of the items were deemed unsuitable and, as such, excluded. The resulting pre-test form, encompassing a total of 13 elements, was then finalized. To ascertain the applicability, duration, and understandability of the scale, the pre-test form was administered to four pre-service teachers who were not a part of the study group. The scale was completed once it was determined to be understandable.

Data Collection Process

Based on the primary school mathematics curriculum, problem-solving strategies were identified within the research's purview, and a teaching procedure was designed for the development of these strategies. Pre-service instructors were given a variety of issues to solve using these tactics, and concept cartoons that were modified to fit the 5E learning cycle were used to teach problem-solving phases and strategies. A five-stage method that spanned eight weekly class hours was used to achieve the research's goal. Figure 1 displays the research-related procedure steps.

Figure 1.

Research Process Steps

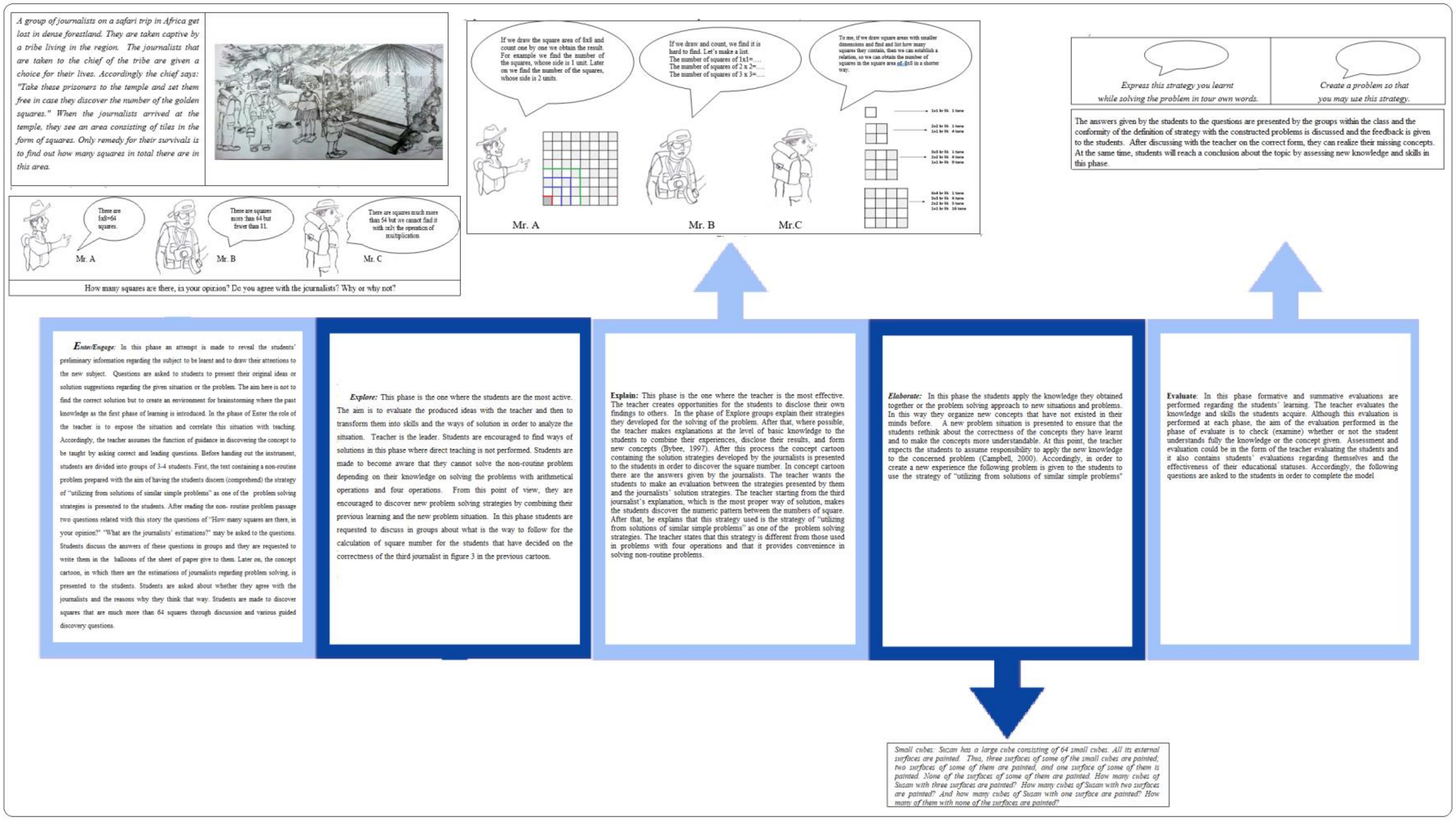


Example of a Plan Integrating the 5E Learning Cycle

The research team created the following sample plan stages and explanations based on the concept of a cartoon-assisted 5E learning cycle model for teaching problem-solving processes and methods.

Figure 2.

Example of a concept cartoon supported 5E lesson plan



Data Analysis

The problem-solving skills of primary pre-service teachers were evaluated within the scope of the problem-solving scale applied after the lesson plan development practices based on the 5E learning cycle model supported by concept cartoons for teaching problem-solving steps and strategies. Subsequent to the implementation, the pre-service teachers responded to the items within the scale by adhering to a structured sequence of problem-solving stages, which encompassed the phases of problem comprehension, strategy selection, strategy implementation, and solution evaluation. To evaluate the problem-solving skills of pre-service teachers, the answers given to the problem-solving scale were examined and evaluated with the progressive scoring scale used in the problem-solving process created by Baki (2008). The progressive scoring scale consists of five categories (understanding the problem, preparing a plan, implementing the plan, evaluating, and posing a problem) and defines the highest and lowest performance of each criterion as 0, 1, 2, and 3 points. A maximum score of 3 and a minimum score of 0 is obtained from each step of problem-solving. The data obtained were presented and interpreted with frequency and percentage values using descriptive analysis techniques.

In addition, pre-service teachers were asked to select one of the problems they solved and develop a concept cartoon-supported 5E lesson plan by considering the problem-solving steps in which the strategies they used in the solution were aimed to be taught. The pre-service teachers were tasked with the formulation and explication of their pedagogical lesson plans, whereby they were required to buttress their instructional solutions, which inherently comprised four distinct stages. These stages included the presentation of a concept cartoon corresponding to the phase of comprehending the problem, a concept cartoon associated with the strategy selection phase, a concept cartoon featuring annotations signifying the application of the chosen strategy, and a concept cartoon dedicated to the critical evaluation of the obtained solution. The problems constructed by the pre-service teachers in the evaluation step were analyzed in terms of their problem-posing skills. The rubric for evaluating problem statement skills developed by Özgen, Aydın, Geçici and Bayram (2017) was used to analyze the problems. The criteria for evaluating problem-posing skills in the rubric include the criteria of using mathematical language (symbol, notation), grammar and expression appropriateness, the appropriateness of the problem to the learning outcomes, the amount and quality of data in the problem, the solvability of the problem, the originality of the problem, and the solvability of the problem by the student. The minimum score for each criterion is 0, and the maximum score is 3. The level range is scored as Level 1 for values between 0.00 and 0.75, Level 2 for values between 0.76 and 1.50, Level 3 for values between 1.51 and 2.25, and Level 4 for values between 2.26 and 3.00 (Güner, 2021). Level contents are defined as the level at which the problem provides mathematical problem properties. Two field education experts examined the problems. Inter-coder reliability was found to be approximately 80%.

The texts in the problems constructed with concept cartoons prepared by primary pre-service teachers were scored using the "Analytical Grading Scale" developed by Weigle (2002) and adapted into Turkish by Ülper (2019). The rubric has five sub-dimensions: "content, organization, vocabulary, language use, and mechanics." These sub-dimensions were scored at four levels (very good, good, fair, poor): 30-22 (very good), 26-22 (good), 21-17 (fair), 16-13 (poor) for the first sub-dimension "content"; 20-18 (very good), 17-14 (good), 13-10 (fair), 9-7 (poor) for the second sub-dimension "organization"; 20-18 (very good), 17-14 (good), 13-11 (medium), 9-7 (bad) for the third sub-dimension "word use"; 25-22 (very good), 21-18 (good), 17-11 (medium), 10-5 (bad) for the fourth sub-dimension "language use"; and 5 (very good), 4 (good), 3 (medium), 2 (bad) for the fifth sub-dimension "mechanics". The evaluations were made by two Turkish education experts and one mathematics education expert, and the agreement between the raters was 85%.

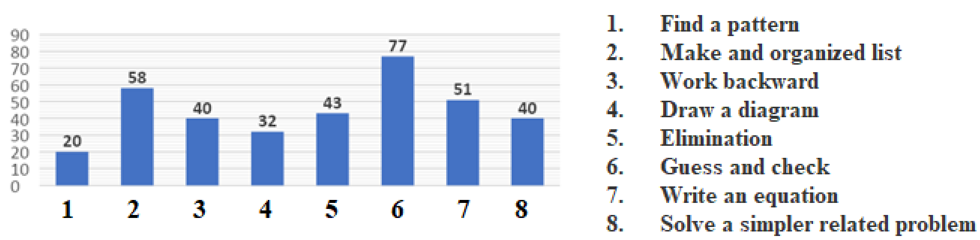
The attitude toward mathematics teaching scale data obtained before and after the applications in the study was evaluated using t-tests for unrelated samples. The opinions of the pre-service teachers regarding the application were obtained through a semi-structured interview form, and the content analysis method was used for data analysis. The primary objective of content analysis resides in the systematic organization and interpretation of data sharing analogous characteristics, encapsulated within the context of overarching concepts and thematic constructs, as expounded by Yıldırım and Şimşek (2018). To analyze the data obtained from the interview form, the interviews with the pre-service teachers were recorded, and then the opinions were coded. After coding and organizing the themes, the opinions of two field experts were taken. The code agreement between the two experts was determined as 89%, and a consensus was reached on the issues where there were differences.

Findings

Within the framework of the first problem of the study, the responses of the pre-service teachers to the problem-solving scale were evaluated with the progressive scoring scale (Baki, 2008) used in the problem-solving process. The distribution of the strategies used by the pre-service teachers in solving the problems is presented in Graph 1.

Graph 1.

Distribution of The Strategies Used by Pre-Service Teachers



For the problems in the problem-solving scale, some students presented solutions using more than one strategy. When Graph 1 was analyzed, it was seen that 6% of the strategies used by the pre-service teachers were image finding, 16% were systematic list making, 11% were working backward and using similar and simple problems, 9% were drawing shapes and diagrams, 12% were elimination, 21% were prediction control, and 14% were equation construction strategies. Certain strategies employed by the primary pre-service teachers were omitted from consideration due to their lack of accuracy and alignment with the intended criteria. It was seen that the most commonly used strategies were the prediction control strategy and equation construction strategy. Some of the pre-service teachers did not make solutions to the strategy they specified. For example, although they stated that they chose the estimation control strategy, they solved the problem by setting up an equation. The problem-solving skills of the pre-service teachers were evaluated by examining their problem solutions for the problem-solving steps. Mean scores were calculated for the data obtained from the rubric used. The answers of the pre-service teachers to the questions in the problem-solving scale were evaluated according to the rubric. The results obtained are presented in Table 1.

Table 1.

Problem-Solving Scale Progressive Scoring Key Results

	Components				
	Understanding the Problem ($\bar{X}$)	**Making the Plan ($\bar{X}$)**	**Implementing the Plan ($\bar{X}$)**	**Evaluation ($\bar{X}$)**	**Problem Statement ($\bar{X}$)**
Question 1	2.89	2.81	2.52	2.42	1.76
Question 2	2.89	2.79	2.52	2.36	1.60
Question 3	2.89	2.81	2.52	2.42	1.76
Question 4	2.89	2.81	2.53	2.42	1.77
Question 5	2.81	2.73	2.47	2.42	1.92
Question 6	2.86	2.73	2.42	2.42	1.97
Question 7	2.84	2.73	2.44	2.42	1.92
Question 8	2.84	2.76	2.43	2.34	1.97
Question 9	2.78	2.71	2.42	2.36	1.76
Question 10	2.89	2.78	2.44	2.36	1.94
Question 11	2.89	2.81	2.52	2.42	1.30
Total	2.86	2.77	2.47	2.39	1.78

When Table 1 is examined, among the 11 questions in the "understanding the problem" and "understanding a part of the problem" categories in the "understanding the problem" step, pre-service teachers scored an average of 2.86 points, among the questions in the "preparing a plan" step in the categories of "choosing a strategy that will lead to an appropriate solution", "choosing only a part of the strategy that will help the solution" and "choosing an inappropriate strategy", pre-service teachers scored an average of 2. 77 points, an average of 2.47 points was obtained from the categories of "reaching an appropriate and correct solution", "making a partially correct solution", "making an appropriate and incorrect solution" in the "implementing the plan" step, and an average of 2.42 points was obtained from the categories of "solving the problem and the new problem created according to this problem", "logical verification of the results", "partial verification of the results", "not knowing how the results will be correct" in the "evaluation" step. When analyzed in terms of problem posing, it was determined that the average score of the primary pre-service teachers was 1.78. In general, when the problem-solving skills of the primary pre-service teachers who participated in the application were examined, it was seen that they were successful in the steps of understanding the problem, preparing a plan, and implementing the plan, but some students had difficulty in using the strategies they determined as appropriate strategies, especially in the step of making a plan and preparing the plan. For example, in "making a table" or "estimation control" strategies, it was determined that they solved the problems based on the strategy of forming and solving equations different from the strategies specified by the students or that they characterized a solution with an estimation control strategy as a systematic list and misnamed it. In addition, it was observed that the average scores of the pre-service teachers were low mostly in setting up a simple similar problem and evaluating the accuracy and validity of the solution.

Secondly, the primary pre-service teachers were instructed to choose one of the problem scenarios addressed in the problem-solving scale and construct a 5E lesson plan supplemented by a concept cartoon, intended to facilitate the instruction of the problem-solving strategies they had employed during the solution process, while taking into account the sequential problem-solving phases. The problems framed by the primary pre-service teachers within the concept cartoons, which were created through a consideration of the problem-solving steps, underwent a comprehensive analysis focusing on the proficiency of the problem statement skills. A rubric (Özgen et al., 2017) was used to evaluate problem posing skills. When the results obtained were analyzed, it was seen that the pre-service teachers constructed 32 problems, and 6 pre-service teachers did not construct any problems. When the constructed problems were examined, it was seen that the average score for the criterion of using mathematical language (symbol, notation) was 1.12, i.e., level 2; the average score for the criterion of grammar and expression appropriateness was 1.75, i.e., level 3; the average score for the criterion of the appropriateness of the constructed problem to the gains / selected strategy was 1.87, i.e., level 3; the average score for the amount of data and expressions in the problem and logical, procedural appropriateness for solving the problem was 2. 06, i.e., level 3; the average score for the criteria of the solvability of the problem, i.e., the solvability of the problem, was 2, i.e., level 2; the average score for the criteria of the originality of the problem in terms of the textual organization and the steps to reach the solution was 1.62, i.e. level 2; and the average score for the criteria of the solvability of the problem by the student was 0.25, i.e. level 1. The problem suggested by PT21 to be solved with the prediction control strategy is as follows.

Uncle Yusuf wants to plant trees on his newly bought land. Every year, Uncle Yusuf reforests his farm 3 times more than the first year he planted trees. After 5 years, Uncle Yusuf has 2430 trees. How many trees did Uncle Yusuf plant in the first year?

When the problem presented is examined, it is seen that the expressions given to solve the problem are incorrect and unsolvable. He used mathematical language incorrectly. Similarly, the problem text that T11 suggested to be solved with the guessing control strategy is as follows.

There are 21 questions in an exam with over 100 points. Some of these questions are worth 4 points, and some are worth 6 points. How many 6-point questions did a student who answered all the questions and got 60 on this exam do?

The data provided within the problem context reveals an incongruity between the information proffered for the problem's solution and the assertion that a solution is unattainable. The problem in question, which was recommended for resolution through the implementation of the diagramming strategy by PT8, is articulated as follows. *Mr. Arif will plant vegetables again after leaving his 100-meter by 100-meter field fallow for a year. But he could not decide how many kinds of vegetables to plant. For this reason, he decides to divide his field with different colored fences that he likes and plant one kind of vegetable in each section. How many kinds of vegetables can Mr. Arif plant in his field by dividing it with blue, pink, and yellow colored hedges of 30 m by 20 m in length?*

The mathematical language used in the problem is incorrect, as in the expression "100 meters by 100 meters field". Geometric features are left incomplete. There are inappropriate data and incomplete expressions in the problem text. In this case, it is not solvable due to the uncertainty of the shape of the field and the lengths given. According to the results obtained, it was seen that the pre-service teachers were not sufficient in terms of problem-posing criteria, and only eight pre-service teachers solved the problems they posed. It was observed that many pre-service teachers constructed new problems by unconsciously changing the numerical value of the questions in the problem selected in the problem-solving test, thus producing unsolvable problems. In addition, it was seen that there were various expression disorders or spelling mistakes in the problem texts, which should be paid attention to the use of mathematical language and the conformity of the question text to the grammar rules. Within the scope of the third sub-problem of the study, the texts and problem statements in the concept cartoons prepared by the pre-service teachers were scored with the "Analytical Grading Scale," which is a scoring key developed by Weigle (2002), the text formation levels of the pre-service teachers were determined, and the results were analyzed with percentages and frequencies. The results obtained are presented in Table 2 and Table 3.

Table 2.

Findings Related to the Analytic Grading Scale of Concept Cartoons

	Very good		**Good**		**Moderate**		**Bad**	
	f	**%**	**f**	**%**	**f**	**%**	**f**	**%**
Content	-	-	31	81.57	7	18.42	-	-
Regulation	25	65.78	13	46.42	-	-	-	-
Word	20	52.63	16	42.19	2	5.27	-	-
Language Use	17	44.73	10	26.31	11	28.94	-	-
Mechanical	4	10.52	6	15.78	17	44.73	11	28.94

When Table 2 is examined, there were no texts characterized as very good or bad in terms of content in the concept cartoon texts prepared by primary pre-service teachers. 81.57% of the texts were found to be good, and 18.47% were found to be at a moderate level. This implies that the extent of knowledge possessed by primary pre-service teachers concerning the subject matter or the strategy employed within the written expression process is characterized by a moderate level of proficiency. Moreover, the information conveyed to the reader pertaining to the subject matter is noted to be somewhat lacking in comprehensibility, often resulting in an incomplete dissemination of the requisite information, thereby precluding a satisfactory degree of developmental depth. In terms of organization, it was found that none of the concept cartoons were included in the moderate or bad subcategory; 65.78% were described as very good, and 46.42% were described as good. This means that the narration in the concept cartoons prepared by the pre-service teachers progressed at a fluent and logical level, the sentences were well organized, and the principle of coherence was met. Simultaneously, the utilization of concept cartoons is noted for its ability to convey intended ideas with a commendable degree of clarity and organization, albeit occasionally characterized by a degree of disconnection between ideas and, on certain occasions, limitations in the scope of the desired thoughts. When evaluated in terms of word usage, 52.63% of the texts in concept cartoons are at a very good level; that is, it is seen that primary pre-service teachers prefer rich, original, and effective words or phrases in text construction and there is no problem in this usage. It was seen that 42.19% of them created texts at a good level, the vocabulary used was at a sufficient level, although not very rich, and sometimes there were mistakes in the use of selected words or phrases. In the remaining 5.27% of the texts, the level of the texts was limited to moderate, and there were frequent errors in the selection and use of words or phrases. No text was found to be at a poor level. When the concept cartoons prepared by pre-service teachers were analyzed in terms of language use, it was seen that 44.73% of them were at a very good level. In the texts prepared at this level, there are very few expression disorders, and original and advanced sentence construction is observed. Among the texts, 26.31% of the texts with simple but partially original sentence structure and rare expression disorders were found to be at a good level with 26.31%. The remaining 28.94% of the texts were at a moderate level, where significant problems were observed even in simple sentence constructions, and expression disorders were observed in written expressions. No text was found to be at a poor level. When the prepared concept cartoons are analyzed mechanically, it is seen that 44.73% of the texts are at a moderate level. This situation shows that pre-service teachers frequently make mistakes in spelling, punctuation, and paragraphing while creating written texts. Their writing is bad, and there is uncertainty in inferring meaning. While 15.78% of the texts were found to be at a good level, 10.52% were found to be at a very good level. Two examples of the linguistic problems encountered in concept cartoons designed by pre-service teachers is presented in Figure 3 and Figure 4.

Figure 3.

Example of a concept cartoon prepared by PT11

As it can be understood from the example given in Figure 3, the sentences formed by the pre-service teacher do not conform to Turkish syntax, and it is seen that there are mistakes in the use of spelling and punctuation marks and the use of conjunctions - mistakes in the spelling of the conjunction de and the suffix -de. Therefore, it can be said that the criteria of expression disorder and clarity are also violated. As it is known, spelling rules aim to facilitate communication between the reader and the writer and to ensure integrity in writing. However, it is seen that this example expression makes comprehensibility difficult. Another example belongs to PT13, presented in Figure 4.

Figure 4.

Example of a concept cartoon prepared by PT13

When the concept cartoon in Figure 4 is examined, it is seen that in addition to word order, spelling, and punctuation errors, there are also errors in terms of word and phrase selection. The "backward strategy", which is used as a mathematical term, was identified as an error in the use of a missing word group.

Table 3.

Scores of Similar Constructed Problems on the Analytic Grading Scale

	Very good		Good		Moderate		Bad	
	f	**%**	**f**	**%**	**f**	**%**	**f**	**%**
Content	7	21.87	10	31.25	9	28.12	6	18.75
Regulation	32	100	-	-	-	-	-	-
Word	30	93.75	2	6.25	-	-	-	-
Language Use	30	93.75	2	6.25	-	-	-	-
Mechanical	29	90.62	3	9.37	-	-	-	-

When Table 3 is examined, it is seen that 31.25% of the similar problem texts created by the primary pre-service teachers are at a good level in terms of content. This indicates that a sufficient level of comprehensibility is provided in the texts; information about the subject is included, but the details provided are incomplete. Following these texts, it is seen that there are texts at moderate level (28.12%), very good level (21.87%), and bad level (18.75%). Upon analysis conducted with regard to organizational attributes, it is evident that the entirety of the texts, constituting 100% of the sample, consistently exhibit a high degree of organizational proficiency. In such instances, the predominant feature entails an unwavering fluency in expression, the articulation of thoughts in a methodical and logical manner, and the preservation of the fundamental principle of coherence. In terms of word usage, 93.75% of the texts are at a very good level, while 6.25% are at a good level. This situation shows that the words and word groups used in the texts were chosen correctly, an original usage was adopted, and there were no problems in word usage. In terms of language use, it was observed that most of the texts (93.75%) were at a very good level, there were not many expression disorders, and originality and sophistication were dominant in sentence construction. It is seen that 6.25% of the texts are at a moderate level. This situation shows that pre-service teachers created texts that contain expression disorders. In terms of mechanics, 90.62% of the texts were at a very good level, showing that there were almost no errors in spelling, punctuation, and paragraphing. The remaining 9.32% of the texts were found to be at a good level.

Regarding the fourth sub-problem of the study, the data obtained to examine the effect of the teaching practices on the attitudes of primary pre-service teachers towards mathematics teaching were examined in terms of normality. Table 4 presents the normality test results.

Table 4.

Shapiro-Wilk Test Normality Results of Pre-Post Attitude Scores

	Shapiro-Wilk Value	**Skewness**	**Kurtosis**
Pre-attitude	.20	.094	.83
Post-attitude	.10	-26.	-.88

According to George and Mallery (2010), if the kurtosis and skewness values are between -2.0 and +2.0, it is assumed that the data are normally distributed. Consequently, upon meticulous scrutiny of the data in Table 4, it becomes evident that the data acquired from the attitude scales, both prior to and following the intervention, adhered to a normal distribution pattern ($p > .05$). In light of this observed normal distribution, the disparities between the pre- and post-attitude scores were subjected to comparison through the utilization of a t-test for related samples, with the resultant findings duly presented in Table 5.

Table 5.

t-test Results Regarding The Pre-Post Attitude Towards Mathematics Teaching Scores of Primary Pre-Service Teachers

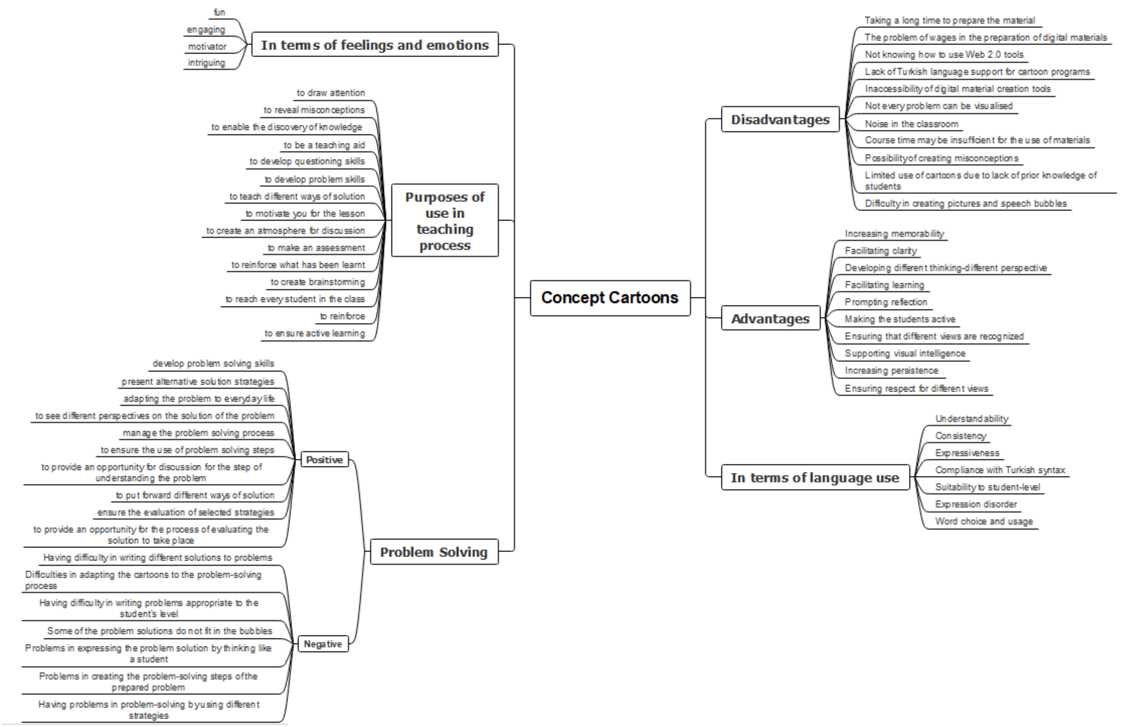
	N	$\bar{X}$	**Ss**	**t**	**sd**	**p**
Pre-attitude	38	3.70	.30	-3.94	37	.00*
Post-attitude	38	4.01	.34			

When Table 5 was examined, it was determined that the mean pre-test attitude score of pre-service teachers towards mathematics teaching was 3.70, and the mean post-test attitude score was 4.01. When the difference between pre-test and post-test mean scores was analyzed by applying a t-test for related samples, a statistically significant difference was found ($p>.05$). This result was interpreted as the teaching practices made a significant difference in favor of the post-test in increasing students' attitudes towards mathematics teaching.

When the opinions of pre-service classroom teachers regarding the fifth sub-problem of the research were examined, it was seen that the opinions on the use of concept cartoons in the education process were gathered in six categories. These were discussed in terms of advantages, disadvantages, purposes of use in the teaching process, problem-solving, emotions and feelings, and language use. The six categories and codes related to the sub-problem in question are shown in Figure 5.

Figure 5.

Categories and Codes for Concept Cartoons and Their Use In Teaching



In Figure 5, according to the evaluations of pre-service teachers, in the category of "advantages," opinions were obtained under the codes of "increasing retention, facilitating comprehension, developing different thinking or different perspectives, facilitating learning, encouraging students to think, making students active, enabling different opinions to be noticed, supporting visual intelligence, increasing retention, ensuring respect for different opinions" and sample opinions are presented below.

PT5: Concept cartoons increase the retention of the subject and make it easier to understand. It helps to develop different ways of thinking.

PT8: Concept cartoons develop different perspectives on an event or problem.

PT9: It makes the lesson fun. ... being visual and interesting makes learning easier. It supports visual intelligence.

In the second category, "disadvantages", "the preparation of the material takes a long time, there is a fee problem in the preparation of digital materials, not knowing how to use Web 2. 0 tools, lack of Turkish adaptation (language support) of cartoon programs, inaccessibility of digital material creation tools, inaccessibility of digital material creation tools, inability to visualize every subject, noise environment in the classroom, insufficient class time for the use of materials, the possibility of creating misconceptions, limited use of concept cartoons in students' lack of prior knowledge, difficulty in creating pictures and speech bubbles", and sample opinions are given below.

PT4: It causes confusion and noise in the classroom. ... It can be tiring for teachers in terms of preparation.

PT12: The only disadvantage is that the preparation process is laborious and time-consuming.

PT14: It is a time-consuming preparation process, and the use of Web 2.0 tools should be well known.

In the third category, "purposes of use in the teaching process", opinions were reached under the codes of "attracting attention, revealing misconceptions, eliminating misconceptions, enabling the discovery of knowledge, using it as an auxiliary tool for teaching, developing questioning skills, developing problem-solving skills, teaching different ways of solution, motivating towards the lesson, creating a discussion environment, making an evaluation, reinforcing what is learned, creating brainstorming, reaching every student in the class, reinforcing, providing active learning" and sample opinions are presented below.

PT24: I can make my lesson more interesting and attention-grabbing with cartoons instead of lecturing with lectures.

PT12: I use them to reinforce the lesson better and to make learning more effective and fun. I use it to make students' mind levels and thought structures more different. It saves me time. It allows me to easily identify where students have learned and where they have not learned. This facilitates me in terms of feedback and elimination of deficiencies. I use it because I support a student-centered education.

PT8: Since students are active with concept cartoons, meaningful learning is more, and permanent learning is provided.

PT20: For the teacher, the information before starting a new subject can be tested. The teacher can use it for evaluation at the end of the subject. The teacher can involve children in the discussion and let them brainstorm. For the student, reinforcement of a newly learned subject is ensured. Children reach the information themselves as a result of learning by thinking.

In the fourth category, "feelings and emotions" category, opinions were reached under the codes "fun, interesting, motivating, intriguing", and examples of the opinions are presented below.

PT20: Since cartoons are given visually, cartoons make learning easy and fun.

PT32: Students have fun in the process, and their motivation to learn increases.

The fifth category, "problem-solving", was analyzed in two subcategories under the titles of "positive" and "negative". Accordingly, in the "positive" subcategory; "developing problem solving skills, presenting alternative solution strategies, adapting the problem to daily life, seeing different perspectives on the solution of the problem, managing the problem solving process, ensuring the use of problem solving steps, providing discussion opportunities for the step of understanding the problem, revealing different solution ways, providing the evaluation of the selected strategy, providing an opportunity for the development of the process of evaluating the solution"; In the "negative" subcategory, opinions were found under the codes "having difficulty in writing different solutions to problems, having difficulty in adapting cartoons to the problem solving process, having difficulty in writing problems appropriate to the student level, some of the problem solutions not fitting into the bubbles, having problems in expressing the problem solution by thinking like a student, having problems in creating the problem solving steps of the prepared problem, having problems in solving problems using different strategies". Examples of the opinions are presented below.

PT11: Cartoons show children both the right way and the wrong solution in the problem-solving process. It shows that the problem can be solved in another way.

PT12: Before starting to use concepts cartoons, a good scenario about the problem should be created. Cartoons should be designed in a way to evoke the problem in the other party.

PT15: We need to integrate the steps of problem-solving into the cartoons. Thus, the child tries to solve the problem in the cartoon, recognizes different ideas, and learns different strategies and problem-solving steps while solving the problem.

PT32: While preparing the concept cartoon, I had the question, "What would the students answer to this?". Because I had a problem expressing the problem solution by thinking like a student, I had difficulty in predicting where and how they would have misconceptions and what ways they would think. Other than that, I did not have any other problems.

Under the sixth category, "in terms of language use," the codes of "comprehensibility, consistency, expressiveness, syntactic appropriateness, level appropriateness, expression disorder, word choice, and usage" were found. Examples of opinions are presented below.

PT11: The language should be simple and understandable. Problems should be at a level of comprehensibility that students can discuss.

PT28: Written texts and visuals should be consistent with the subject.

PT22: Texts should be written according to the literacy level of each student.

PT2: Sentences should be proper and understandable. Attention should also be paid to the words used.

PT3: Attention should be paid to the use of abstract and concrete concepts.

According to the findings obtained, it was determined that prospective classroom teachers had positive opinions about the use of concept cartoons in the problem solving process. They think that the use of cartoons will be effective in the realization of problem solving steps. However, it is seen that they have difficulty in writing thinking bubbles in the process of pedagogical organization of cartoons. In this process, pre-service teachers are expected to give examples of faulty reasoning and solutions that can create discussion. It is thought that the reason why pre-service teachers have difficulty in this process is that they have little interaction with students in the real learning environment. It is thought that pre-service teachers who interact with students only during teaching practice will increase their knowledge of understanding students more during their real teaching experiences. Thus, it may be easier to create possible answers that students can give in cartoons. The pre-service teachers articulated that concept cartoons may be effectively integrated into the pedagogical process to achieve a spectrum of objectives, including capturing students' attention, fostering an environment conducive to discussion, motivating learners, consolidating knowledge, and conducting assessments. Furthermore, they underscored the significance of certain elements such as comprehensibility, cohesiveness, clarity of expression, and lexical precision in the creation of concept cartoons, particularly with respect to linguistic utilization. Additionally, during the process of devising these visual aids, they discerned potential drawbacks associated with the utilization and accessibility of digital tools. In addition, they considered classroom management problems and new misconceptions that may arise during the implementation of concept cartoons as disadvantages.

Discussion, Conclusion and Recommendations

When the texts in the concept cartoons and issues created by primary pre-service teachers were assessed for text generation success levels, it was discovered that they were often at very good and good levels. In terms of percentages, it is clear that there are issues with text production's usage of language and substance. One may say that there are some knowledge gaps, particularly in terms of mathematics topic understanding, problem-solving skills, and problem presentation. Additionally, there are issues with advanced sentence formation and expressive disorder. Word sequences should be achieved by taking into consideration specific rules to transmit the thoughts to be expressed accurately, not only in written expression studies connected to daily life but also in writing studies related to the process of developing a mathematical problem. Syntactic analysis can be used to check for and correct errors in this area. According to research, mathematics lessons should include knowledge that is relevant to writing skill studies (McCarthy, 2008). People consider ideas carefully. The ability to communicate one's thoughts through language is crucial, and the easier and clearer one's ability to do so will depend on the depth of one's vocabulary.

According to the parameters of this study, it was discovered that the aspiring primary pre-service teachers were unable to very effectively and appropriately use the language in the written texts they produced during the concept cartoon and related problem-posing processes. Therefore, it is believed that studies on the creation of language-related content should be incorporated not only in research for the Turkish teaching course but also in research on teaching in other subjects. This can be reinforced, for instance, through the use of problems in the teaching of mathematics, oral history studies in the teaching of social studies, experimental setup in the teaching of science, or poster studies that can be created in the lives of scientists. Although few studies address problem statement studies with an interdisciplinary approach in terms of mathematics and linguistics (Arıkan & Ünal, 2013; Karakuş, Turhan-Türkkan, & Karakoç-Öztürk, 2020; Silver & Cai, 1996; Şengül-Akdemir & Türnüklü, 2017; Turhan & Türkkan, 2017), this is an indication that the sensitivity and importance given to the effective use of verbal language skills are not ignored. It is a complex and challenging procedure that necessitates high-level thinking to create a form of expression and a language result through written expression in mathematics (Karakuş et al., 2020). As a result, both students and pre-service teachers have trouble using their communication abilities when posing problems. To address the topic from many viewpoints, field specialists who are working on this issue can be provided because research suggests that reading and problem-solving abilities are closely related to the skills and success improvements that students need to ensure the effectiveness of the educational process (Balow, 1964; Call & Wiggins, 1966; Hollander, 1978; Muraski, 1979; Muth, 1988).

Making the constructivist method effective is crucial because the mathematics curriculum was developed within its parameters. Concept cartoons are one means of ensuring this efficacy. Concept cartoons are believed to enhance the constructivist learning process by making mathematics enjoyable, captivating, and engaging despite its abstract nature. According to research on concept cartoons, they aid pupils in developing affective behaviors and boost their motivation (Keogh & Naylor, 1999). Concept cartoons are viewed as a technique to cultivate good attitudes toward mathematics, according to the social constructivist theory that relates the cause of low mathematics self-efficacy to the attitude toward mathematics (Hackett & Betz, 1989). Dabell (2008) mentions that after students are shown a cartoon focusing on a conceptual obstacle, they are allowed to think independently about this problem situation/challenge, and small group discussion is encouraged. This is in reference to the use of concept cartoons that positively affect learning when used in many different disciplines in addition to the aforementioned positive effects. He stresses the value of providing chances for the entire class to provide input on competing theories, working toward a consensus, and giving students a chance to explore a variety of potential points of view to gain more knowledge. In this way, he argues that it is crucial to communicate the findings of the studies, giving students the chance to consolidate and apply what they have learned while also thinking about how their ideas may evolve. It is advised that concept cartoons be widely employed in basic and secondary educational institutions as well as higher education to make mathematics instruction understandable and remarkable because the usage of concept cartoons in the educational process is so effective. A one-group experimental design was implemented in the construction of this study. It is recommended that future research endeavors explore the utilization of pre-test-post-test control group experimental designs to enhance the depth of investigation or employ a combination of qualitative and quantitative research methods for a more comprehensive evaluation of the observed impacts. Mathematical problem solving skills and effective communication through language are two inseparable elements. Considering the relationship between problem solving skills and reading and reading comprehension skills, it is recommended that studies that support pre-service teachers' language and expression skills for writing skills as well as problem solving skills should be carried out. In this context, interdisciplinary instructional designs can be developed between the concepts of Turkish and Mathematics teaching and their impacts can be analyzed.

From the perspective of future classroom teachers, the concept cartoons diagnostic method has a very important role in professional preparation. Because it can shed light on the potential reasoning of prospective teachers that may emerge in the classroom during teaching practices. The concept cartoon method can link teachers' professional vision with knowledge-based, reasoning and noticing skills and reveal these skills in the process of observing teaching practices and supporting them with discussions. The use of educational concept cartoons as an assessment tool in a mathematics content course for future teachers will provide them with a broad knowledge of various aspects of knowledge that are more or less related to the mathematical content they will teach in their teaching practice. The use of concept cartoons in the educational process provides a detailed reflection of how pre-service teachers reason about the topic, how they understand the basic concepts, what mathematical language they use, what kind of arguments they can present, and how they react to alternative ideas. Assessing content knowledge using concept cartoons also provides information about the mathematical language and argumentation of future teachers. What is important here is to use the mother tongue and mathematical language in harmony. Because while creating a concept cartoon, it is necessary to choose the focus of the mathematical task in the background, determine the accuracy of each speech bubble, and check the formal features, language structure, expression disorders, and language features that provide correct transfer of the texts in the speech bubbles (Fernández-Verdú et al., 2022; Samková, 2019a; Samková, 2019b; Samková, 2020). Henceforth, this research is anticipated to make a valuable contribution to the corpus of pedagogical content knowledge studies by shedding light on the non-routine problem-solving acumen of aspiring primary pre-service teachers, their aptitude for problem posing, as well as the multifaceted dimensions encompassing the content, structural organization, lexicon, language application, and mechanical attributes characterizing the texts embedded within the problem statements.

Ethics

Scientific, ethical, and citation rules were followed during the writing process of the study. No tampering was made on the collected data, and they were not sent to any other academic publication environment for evaluation. Ethical permission was obtained from the Ethics Committee of Balıkesir University of Science and Engineering Sciences (52899066/302.08.01/27445).

Author Contributions

All authors contributed equally to the study.

Conflict of Interest

There is no conflict of interest.

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