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Investigation of Special Education Teacher Candidates' Problem-Solving Skills and Their Views on Mathematical Creativity

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Abstract

Mathematical creative thinking and problem-solving skills are essential for success in the 21st century. The present study investigated 43 special education teacher candidates' creative processes by examining their mathematical problem-solving skills and, later, by interviewing them. This qualitative case study revealed the creative process stages of the respondents while they worked on mathematical problems and examined how they achieved original ideas and strategies. The results showed that pre-service teachers did not produce enough original solutions to an arithmetic mathematical problem. Teacher candidates and teachers play a vital role in developing students' creative thinking skills in the teaching process. For this reason, the results show that it is essential to create, develop, and use learning activities that support the creativity of teacher candidates.

Keywords: Creative thinking, mathematical problem-solving, special education teachers, mathematical creativity.

Introduction

Problem solving, creative thinking, and mathematical creativity are all essential aspects of pure and applied mathematics education. These skills are needed by individuals who will one day research, criticize, question, and use creative thinking skills in school or future work. Creativity is a skill that every individual possesses and can take place in every aspect of daily life; it is involved in all mental and emotional processes and is fundamental to all aspects of development in many areas of life. In this process, new relationships are created by combining unrelated ideas. For this reason, creativity is a skill that is required for all kinds of occupations. Creativity is a solution individuals can use to be sensitive to inadequacies, problems, and incompatibilities—and to overcome difficulties.

Experts in the fields of psychology, design, education, and art are at the forefront of the researchers studying creativity in terms of personality. Some researchers working on this issue include Torrance, Lowenfeld, Ausubel, Guilford, Maslow, Adarno, Getzels, and Landua. Lowenfeld, in "Creative and Mental Growth," described creativity as a basic instinct that all humans have from birth and as something that makes us human (Lowenfeld, 1947). Torrance (1972) emphasized that creativity comprises divergent thoughts consisting of subcomponents such as fluency, flexibility, and originality. According to the author, fluency is the number of ideas produced or solutions that can be generated to deal with a problem in a given period. Flexibility is the ability to switch between approaches quickly. Originality involves distancing oneself from mediocrity or certain thoughts. Therefore, original ideas are based on unique, unexpected, unconventional, new, creative, original, and remarkable contexts or situations. Because of this, creativity, the personal, potential power that is more or less likely to emerge in a given situation—depending on the circumstances—differs from person to person.

Since creativity is related to the day-to-day and involves solving daily life problems, it is also related to mathematics. Since there is no universally accepted definition of creativity, there is also no agreed-upon definition of creativity in mathematics (Haavold, 2013). For this reason, various researchers define creativity in mathematics in different ways. According to Sriraman (2004), creativity in mathematics is the process of providing unusual (unconventional), precise, and deep solutions to a given problem regardless of complexity. Chamberlin and Moon (2005) and Shriki (2010) stated that when mathematical creativity is developed, a non-standard solution is created for a problem that can be solved using an algorithm. When these definitions are examined, it is understood that creativity in school mathematics deals with problem solving and problem posing; regarding creativity in mathematics, there is a growing consensus that problem-posing and problem-solving processes are central to creativity (Silver, 1997).

Today, practitioners are continuously improving several education methods in mathematical creativity and problem-solving studies in mathematics. Problem-solving and inquiry-based creative problem-solving processes enable students to produce and use new ideas. Therefore, problem-solving and mathematical creativity have been identified as central themes in mathematics education, and the importance of problem-solving and constructing activities that develop creative thinking skills in mathematics education is gradually increasing (Silver and Cai, 1996; NCTM, 2000). Creativity is not a momentary situation; instead, it is a skill that sometimes requires a controversial, critical, effortful thought process and develops with age (Sawyer, 2011). Due to its dynamic nature, to develop creativity in mathematics teaching, students should be given problems with multiple solutions that increase the flow of mathematical ideas, flexible thinking, and originality in their answers.

Creativity in mathematics includes analyzing given problems from different angles and solving problems in original, creative, and appropriate ways. This process develops by noticing the similarities and differences between seemingly independent fields, understanding known results more profoundly, discovering new mathematical concepts and realizing what is important in mathematics (Chamberlin and Moon, 2005; Chamberlin and Payne, 2022; Haylock, 1987; Laycock, 1970).

The development of creativity and problem-solving skills in mathematics in teaching the subject necessitates examining teachers' perspectives on the issue because the views and abilities of active and pre-service teachers are essential for further progress. In this study, the opinions of pre-service special education teachers on creativity in general and, more specifically, mathematical creativity, were collected and observed. Pre-service teachers were given a mathematical problem requiring creative thinking skills, and their problem-solving processes were subsequently examined. The investigation continued by taking the pre-service teachers' opinions on the subject. When the literature is reviewed, it can be seen that mathematical creativity studies mainly aim to examine students' creativity at different levels (Contreras, 2013; Tabach and Friedlander, 2013). Taking into account the critical role of teachers in the development of creativity, many studies examining teachers' views on creativity, their skill levels, and the development of creativity-related skills have also been conducted. Lev-Zamir and Leikin's study (2011), in which teachers' understanding of creativity was examined and put forward in a model, can be an example of the recent research on mathematical creativity in schools. The authors asked pre-service teachers to express their thoughts about components of creativity such as fluency, flexibility, and originality. Therefore, attempts have been made to reveal the characteristics of the creative individual, the student, and the creative mathematics teacher in mathematics.

Although various studies have been carried out on creativity in mathematics, studies about teacher candidates are limited. Undoubtedly, any new research on creativity in mathematics instruction will contribute to the literature. However, studies conducted with special education teachers are also quite limited. Examining the opinions of teachers who will work in this field on creativity in mathematics is very important in determining and addressing the mathematical needs of students in need of special education. Therefore, in this study, the views of special education teacher candidates on creativity were examined. The methods used by the pre-service teachers in the creative mathematics problems they solved contributed to a more detailed examination of teachers' views on creativity. Considering the above, the main research questions are: "What are the opinions of special education preservice teachers on mathematical creativity, and what are their creative problem-solving skills?"

Method

The case study method, one of the ways to conduct qualitative research, was used to examine pre-service teachers' creativity in solving mathematical problems and their views on creativity in mathematics. This method provides an opportunity to deeply explore one or more cases, phenomena, or events using a limited number of samples (Yıldırım and Şimşek, 2005).

Participants

The study group consisted of 43 pre-service teachers studying in their 3rd (22 candidates) or 4th (21 candidates) year in the Special Education Teaching Program at a state university in Türkiye. The literature indicates that students below a certain level of proficiency with insufficient mathematical knowledge and skills may

not be able to demonstrate their mathematical creativity because they do not have the adequate knowledge and experience to show their creative thinking skills (Haavold, 2013; Mann, 2004). For this reason, we ensured that the academic achievement levels of the pre-service teachers were at a minimum moderate and that respondents voluntarily participated in the study. To determine the participants' achievement levels, the opinion of their Mathematics Teaching in Special Education course instructor was consulted, and the relevant lecture notes were taken into account regarding their academic achievement. In addition, we ensured that the grade-point averages of the participants were all above 2.5, according to the 4-point scale. Therefore, the purposive sampling method was used in selecting the participants who were coded as T1, T2, T3, and so forth.

Data collection

The data were obtained by giving two forms to the teacher candidates, each of which consisted of interview-type questions. In the first form, six open-ended questions were asked of respondents to elicit their views on general creativity and mathematical creativity. The questions are as follows:

1. What do you think about creativity?
2. What are the characteristics of creative people?
3. How would you explain mathematical creativity?
4. Do you think people who know mathematics well also have mathematical creativity?
5. Are experience and talent important in mathematical creativity?
6. Can mathematical creativity be developed? How?

In the second interview phase, pre-service teachers were asked to answer the following math question:

Question: How many times does the number "1" occur in the sequence of natural numbers from 1 to 500? (Hershkovitz et al., 2009)

The participants were given 20 minutes to answer the question. Many of the pre-service teachers were still working on a method to solve the problem after the time was up. Afterward, the following questions were posed, and the respondents were asked to detail the process they had used in solving this problem.

1. Do you understand the problem?
2. How did you decide on a way to solve the problem?
3. Do you think your solution(s) are original?
4. Did you have difficulty solving the problem?

All the questions used in the interviews were finalized by submitting them to two math education experts and one special education consultant for review. In this way, we ensured that the semi-structured interview forms were carefully examined in terms of suitability for purpose, language, expression, and intelligibility criteria. Using the experts' opinions, the forms were prepared to ensure further clarity and comprehensibility and made ready for dissemination.

Data analysis

The systematic analysis method proposed by Wolcott (1994) was used to analyze the data obtained from the semi-structured interviews. Systematic analysis is a qualitative data analysis method in which data are presented with direct quotes

from the participants' answers. In addition, the data obtained using the content analysis method in systematic analysis can be shown using themes, categories, and codes. The data obtained in this study were examined with the help of codes and categories.

The data obtained from the interview form, through which the pre-service teachers' opinions on creativity and mathematical creativity were gathered, along with the data obtained from the semi-structured interview form used in the second step of the research, were analyzed using the descriptive analysis method. Thus, we ensured that the data obtained were described as thoroughly and carefully as possible.

The analysis was made in terms of the number of answers to the math question, the methods used in its solution, and the originality of the solutions. The findings were interpreted in line with the model developed by Leikin (2009) to evaluate creativity through multiple production activities. For this purpose, to examine the math problems given to the pre-service teachers more efficiently in terms of creativity indicators, first of all, the problems submitted to each respondent were coded, codes with similar structures were brought together, and themes were subsequently created. Later, for each code, we determined how many students developed a solution for each code category. Each student could see the problems in different categories (flexibility) and interpret original or unusual problems (originality).

In the second form of the study, the answers of the pre-service teachers to the mathematics question used in the examination of their mathematical creativity were analyzed by two researchers. Afterward, the codes obtained were examined by these researchers, and the items on which a consensus was reached and disagreements were determined. The percentage of consensus between encoders was calculated using the following formula: Reliability = Consensus/(Consensus + Disagreement) × 100, suggested by Miles and Huberman (1994). A rate of 91% was accepted as reliable for this study.

Results and Comments

1. Pre-service teachers' views on creativity and mathematical creativity

This section presents the results obtained from the prospective teachers' views on creativity and mathematical creativity. Later, findings regarding the analysis of the mathematical problem they solved regarding creativity in mathematics are described under the sub-headings.

Pre-service teachers' opinions on creativity

The pre-service teachers' views on creativity were subjected to descriptive analysis and examined under five themes and seven codes. The themes and codes obtained are shown in Table 1.

Table 1. Pre-service teachers' views on creativity

Theme	Code	Number of pre-service teachers
Meaning	Making sense of situations in life	2
	Giving direction to events by making sense of those events	5
Innovation	Presenting new situations	12
Productivity	Revealing or creating a product	15
Originality	Developing original ideas or concepts	15
	Thinking of something new before others	13

Problem solving	Developing effective solutions to problems encountered in daily life	7

When Table 1 is examined, the pre-service teachers define "creativity" as "meaning, innovation, productivity, originality, originality, problem solving." Some prospective teachers' views on or definitions of creativity are presented below.

Creativity is the creation of a product to make one's life easier (T9).

It is the ability to think differently from everyone else in any subject or event and to apply it (T32).

Creativity is finding fast and effective solutions to daily life problems. People with this skill produce original solutions to problems (T4).

Thinking differently from everyone else and developing different products can explain creativity (T18).

It is the design and creation of new products that did not exist before. But it also includes the development of previous products and the creation of different designs. Creative people think in a convergent to divergent way (T22).

Pre-service teachers' opinions on the characteristics of creative people

When the pre-service teachers' views on the characteristics of creative people were examined, they exhibited a wide variety of opinions. In the descriptive analysis made in line with the answers given by the respondents, three themes and 18 codes emerged, as seen in Table 2.

Table 2. Pre-service teachers' opinions on the characteristics of creative people

Theme	Code	Number of pre-service teachers
Social characteristics	Being advanced in communication	4
	Living an authentic life	2
	Being useful to society	4
	Being open to innovation	12
	Being curious	13
Innovative breakthroughs	Exhibiting leadership	3
	Being calm	3
	Having their own new ideas	15
	Being a researcher	6
	Advanced fantasy world	7
	Critical thinking	18
	Being practical minded	5
	Enhanced mental ability	17
Intellectual skills	Originality	7
	Developed abstract thinking skills	4
	Having metacognitive thinking skills	6
	Developed analytical thinking skills	6
	Excellence	4

In the analysis of the pre-service teachers' views on the characteristics of creative people, it can be observed that they consider the characteristics that these individuals should have to be in the social characteristics, innovative breakthroughs, and intellectual skills-related categories. Some of the specific respondent views on the characteristics of creative people are presented below.

They have average or above intelligence and produce new ideas outside of general acceptance (T13).

Due to their critical thinking skills, their questioning structure has developed. They analyze events very well and interpret events differently from everyone else (T25).

They produce new solutions to problems by analyzing today's needs. In addition, abstract thinking skills are developed. Their curious nature allows them to be open to new ideas (T1).

They can develop a dream, an idea, or a thought by putting it forward. Their opinions differ from everyone else's. These people can look at things through windows that no one else looks through (T6).

They are individuals who have developed abstract, analytical, and critical thinking skills—and they have no mental limits (T19).

Pre-service teachers' opinions on mathematic creativity

When their views about being creative in mathematics were examined, it was determined that they saw this concept as mathematical ability and thought it should be used in problem-solving skills.

Table 3. Pre-service teachers' opinions on mathematical creativity

Theme	Code	Number of pre-service teachers
Educational transmission	Ability to make sense	3
	Transferable to anyone	8
Originality	Developing new theories in mathematics	14
	Solving new problems	9
	Associating daily life in the context of originality	10
Connecting with different fields	Linking different fields with math	11
Ability	Possessing mathematical ability	18

The data analysis revealed that the pre-service teachers used four themes and seven codes when explaining mathematical creativity. It is interesting to note that some respondents consider mathematical creativity as the ability to "teach mathematics to others" and "transfer mathematical knowledge" (educational transmission theme). Some of their views on mathematic creativity are presented below.

It is the diversification of mathematics in all areas of life to facilitate human life, integrating it into other fields and revealing original products (T1).

It is the development and solution of different mathematical equations with the help of previously developed mathematical equations (T36).

Mathematical creativity is finding your own way in the problem. It requires originality (T3).

In fact, life always consists of 1s and 0s. These and mathematical creativity are necessary for technology that has not yet been developed (T17).

Pre-service teachers' opinions on mathematical creativity with those who are good at mathematics

The pre-service teachers' views on the association between good mathematical knowledge and mathematical creativity were examined. While most found this situation unrelated, a few participants believed it was related. Some of the views regarding this opinion are presented below.

I think knowing math is not a special skill, but mathematical creativity definitely is a skill (T26).

People who are good at math have studied hard. But creativity is innate (T5).

The two are interconnected. People with mathematical creativity are also good at math; therefore, the reverse is also true (T20).

Mathematics is an objective science. Creativity is subjective. I think these two are separate situations and do not affect each other (T38).

People who know and understand mathematics have creative thinking skills. They can develop new theories (T41).

Pre-service teachers' opinions on whether mathematical creativity is an experience or a skill

The respondents answered this question using the codes found in Table 4. The general view is that both constitute mathematical creativity.

Table 4. Pre-service teachers' opinions on whether mathematical creativity is an experience or a skill

Code	Number of pre-service teachers
Both	18
Skill	14
Experience	4
Experience comes first, then skill	2
Skill comes first, then experience	5

Just as the fields of music and painting are talents, so it is in mathematics (T36).

Mathematical creativity is an experience born of skill (T16).

Mathematical creativity is an innate chance (T7).

The ability for mathematical creativity is gained by trying. For this reason, activities that will reveal and develop creativity should be used in education (T43).

Pre-service teachers' opinions on the development of mathematical creativity

The participants stated that mathematical creativity is a phenomenon that can be developed and that it can be employed using different methods. In this respect, they observed that descriptive and formative methods could be used (16 respondents). "*Each skill can be enhanced if handled with a developmental framework; therefore, it should be supported by different applications and adaptations*" (T6*)*. They also emphasized that it should be worked on to develop mathematical creativity (27 respondents). "*Mathematical creativity can be developed through hard work and experience*" (T19*)*. According to some pre-service teachers, mathematical creativity cannot only be developed by developing methods or studying. Several also mentioned that individuals should be given appropriate motivation (7 respondents). "*It can be developed. However, it should be supported by the appropriate environment, appropriate motivation, and adequate arousal*" (T39*)*. In addition to these responses, two pre-service teachers stated that mathematical creativity could not be developed. "*It cannot be developed because it is an innate skill. For this reason, if a person does not have an innate mathematical ability, he cannot do mathematics no matter how hard he studies*" (T18).

2. Findings related to pre-service teachers' mathematical problem-solving skills

After collecting their opinions about creativity and mathematical creativity, the participants were asked the following mathematical problem:

Question: How many times does the number "1" occur in the sequence of natural numbers from 1 to 500? (Hershkovitz et al., 2009).

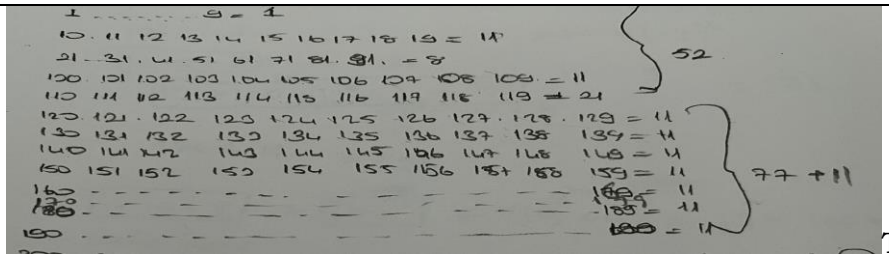
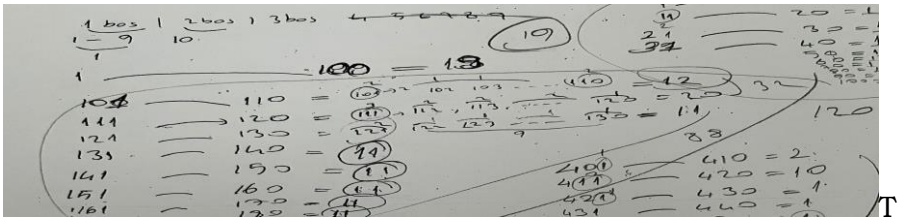
This question aimed to examine their ability to transfer their views on mathematical creativity to the mathematical problem they had solved. Their solutions were evaluated according to the methods used and their originality; the results are presented in Table 5.

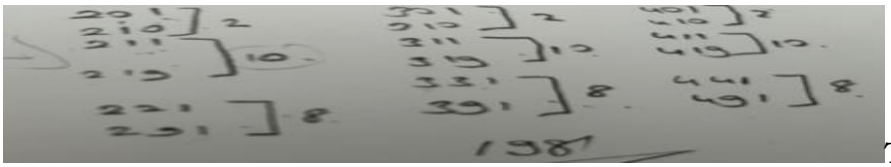
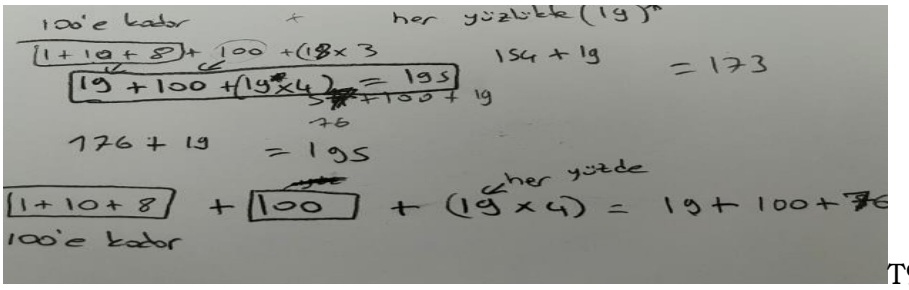
Table 5. Pre-service teachers' solution methods and ranking in terms of originality

Method	Total number	Originality ranking for the method used
Counting from 1 to 500	3	1
Grouping the numbers: 1–100, 101–200, …	7	-
Grouping the numbers: 1–10, 11–20, …	21	9
Irrelevant answers	2	-
Split by digits	3	1
Counting by forming various patterns	7	1

When Table 5 is examined, it can be seen that the respondents used five different methods to solve the mathematics question. They mostly grouped numbers from 1 to 500 by dividing them into small groups. This method also appears in the most original responses. In these novel methods, the correct solutions were accepted as original. Three of the pre-service teachers did their counting by writing all of the numbers from 1 to 500. Using this method, one participant gave an original answer. Some separated the numbers according to their place values and tried to count them one by one. Out of this group, one respondent provided an original answer. Others noticed patterns in the numbers and completed the counting process that way; it was determined that the solution made by one of the respondents using this method was original. Table 6 presents the original solutions of several of the pre-service teachers.

Table 6. Examples of pre-service teachers' original solutions

Method	Original solution
Counting from 1 to 500	 T25
Grouping the numbers: 1–10, 11–20, …	 T17

Split by digits	 T33
Counting by forming various patterns	 T9

When some of the original solutions in Table 6 are closely examined, it can be seen that the teacher candidates demonstrate various thinking skills. These skills differed according to the mathematical thinking levels of the respondents. This case is most evident in the "split by digits" and "counting by forming various patterns" categories.

After the participants had solved the math problem, their opinions were elicited once more with the following question: "Do you understand the problem?"All of the teacher candidates answered this question positively. When asked how they determined a way to solve the problem, they answered the question in the following ways: "by making patterns" (15 respondents) or "counting" (28 respondents). When asked whether their solutions were original, the majority (33 respondents) did not evaluate them as original. On the other hand, although the solution was considered original in the study, T33 stated that her solution was not original. "*If I have made counting errors, the result will not be correct. It was a little difficult to think of the numbers that could be in each digit. I also noticed that a certain pattern emerged. This made my job easier. Maybe this case can make my solution original. But I still think my solution is not original*" (T33*)*. Finally, the respondents were asked whether they had difficulty solving the problem. Twenty-seven participants stated that they had trouble solving it. "*I had a hard time because there were so many numbers. Maybe it would have been easier if I had been given a smaller set of numbers*" (T8). Sixteen respondents related that they had not felt pressure while solving the problem. "*No, I didn't have trouble; I thought about a lot of things while solving it; it was good*" (T42).

Conclusion and Discussion

This study examined preservice special education teachers' views on mathematical creativity and problem-solving skills. Our analyses of the data on "creativity" show that the participants summarize creativity under five themes (Table 1). Most of the opinions fall under the themes of production and originality. This indicates that respondents identify creativity with competencies such as putting forth new ideas or methods, producing original solutions to problems, and producing/thinking about different ways of doing things. These findings are parallel with explanations regarding creativity in the literature. Gunawan et al. (2017) define creativity as being able to think outside of the existing patterns, think critically, and present unconventional ideas to solve problems. Eckhoff (2011) states that most pre-service teachers have views that emphasize creativity as the ability to think in original and creative ways. Jahnke et al. (2017) showed that pre-service teachers from different disciplines view creativity as creating a new and original product and developing a new and different perspective on problems. As such, the opinions given by the teachers in the current study largely overlap with the literature.

When the prospective teachers were asked about the characteristics of creative people, three different categorical themes emerged: social characteristics, innovative breakthroughs, and intellectual skills. The respondents mainly stated that creative people develop critical thinking skills, have their own ideas, and possess developmental skills. These findings support the research results in the literature (Chamberlin and Chamberlin, 2010; Feldhusen, 1997; Karp, 2010; Shayshon et al., 2014; Whitlock and DuCette, 1989; Zain, Sailin and Mahmor, 2022). In this context, Merrotsy (2013) found that the creative personality possesses characteristics such as autonomy, flexibility, preference for complexity, openness to experience, sensitivity, playfulness, tolerance for ambiguity, risk taking or risk tolerance, intrinsic motivation, psychological androgyny, self-efficacy, broad interests, and curiosity. Montgomery et al. (1993) obtained similar results in their study; the authors found that creative people exhibit important characteristics such as imagination, openness to experience, curiosity, intuition, finding ideas, tolerance for uncertainty, independence, innovation, and insight.

Within the scope of the research, the special education teacher candidates' opinions on mathematical creativity were also collected. According to them, those who can use logic, develop new theories in mathematics, and solve new problems easily—and relate them to daily life—display mathematical creativity. In this respect, the findings align with the skills related to logical inferencing and problem solving by revealing mathematical relations that Ervynck (2002) observed in a study on mathematical creativity. They view mathematical creativity as the ability to associate mathematics with different disciplines. Their opinions also indicated that mathematical creativity is equal to mathematical ability. In the literature, several studies include opinions similar to the ones found in our research on mathematical creativity. Those studies concluded that mathematical creativity lies in problem-solving (Bicer, 2021; Sinniah et al., 2022) and problem-posing skills (Sadak et al., 2022; Hidayat and Evendi, 2022). Therefore, the results obtained in the current study are supported by the literature. However, pre-service teachers in other studies mostly specified that mathematical creativity results from skill and experience (Karsenty, 2014; Shayshon et al., 2014).

In this study, the candidate teachers believed that mathematical creativity is a phenomenon that can be developed. In their view, this can be accomplished using different descriptive and formative methods. They also mentioned that every skill could be developed. This belief was also expressed in various studies in the literature (Abraham and Collins, 2011; Sousa and Rocha, 2019).

In the current study, a mathematics question was posed to the teacher candidates. All of the participants answered the question using their own methods. Our analysis revealed that the teacher candidates frequently used five different solution techniques. Among the techniques used, they mainly preferred to arrive at solutions by dividing numbers into small groups. Twelve solutions were accepted as original solutions (Table 6). In the post-problem-solving interviews, all the participants stated that they had tried to solve the question by using patterns or counting when explaining the process they had gone through to solve the problem. The fact that only 12 of the participants reached the correct solution, developing solutions according to principles related to finding patterns or counting, suggests that the participants' creative thinking skills used to solve an arithmetic problem are not at the desired level. Several outcomes from various studies also support this finding. In those studies, pre-service teachers and teachers from different disciplines also experienced pronounced difficulties when they faced mathematical problems that necessitated using their creativity (Hoth et al., 2017; Nadjafikhah et al., 2012).

It is crucial that teacher candidates, as individuals who play an important role in educating generations with higher creative thinking skills, are able to effectively develop student creativity (Diakidoy and Kanari, 1999; Chamberlin and Chamberlin, 2010). A plethora of evidence suggests that creativity can be enhanced with adequate teacher training. Teacher education is an important issue in education research, and developing creativity is an important goal in teacher education. Activities that improve creative and critical thinking skills should be increased in teacher education and integrated into active learning (Gunawan et al., 2019; Leikin, 2011) since this type of activities foster both pre-service teachers' and students' growth in these skill domains.

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