



# A mixed method quasi-experimental study on transforming preservice teachers' mathematics anxiety and teaching self-efficacy beliefs

Osman Cil<sup>1</sup> · Ahmet Oguz Akcay<sup>2</sup>

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## Abstract

The main purpose of this study was to explore the effects of two college-level mathematics courses on preservice elementary teachers' mathematics anxiety and mathematics teaching self-efficacy beliefs. For this purpose, a quasi-experimental study was implemented on two college-level mandatory mathematics teaching methods courses that were specifically designed based on Bandura's (1977) self-efficacy expectations theory. The findings of the study revealed a statistically significant difference between the beliefs of participants in the control and intervention groups for mathematics teaching self-efficacy after the intervention process, and a statistically significant change was found on the preservice elementary teachers' mathematics anxiety and mathematics teaching self-efficacy beliefs within the intervention group. Moreover, qualitative exploration revealed the important aspects of this change as being pedagogical and emotional transformation, in which the intervention process helped the preservice teachers to develop a positive attitude and a better understanding towards mathematics and its teaching. Creation of discussions around preservice teachers' previous mathematics related experiences and helping preservice teachers to succeed at challenging mathematical tasks could help teacher educators design more effective mathematics teaching courses on decreasing mathematics anxiety and increasing mathematics teaching self-efficacy.

**Keywords** Mathematics anxiety · Self-efficacy beliefs · Preservice elementary teachers · Emotional transformation · Pedagogical transformation

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✉ Osman Cil  
ocil@ahievran.edu.tr

Ahmet Oguz Akcay  
aoguzakcay@gmail.com

<sup>1</sup> School of Elementary Education, Kırşehir Ahi Evran University, Kırşehir, Türkiye

<sup>2</sup> School of Elementary Education, Eskisehir Osmangazi University, Eskisehir, Türkiye

## Introduction

A frequently utilized teaching habit of instructors is establishing the expectations of their students during the initial week of a teaching course. When preservice elementary teachers on a teaching mathematics methods course were asked about their expectations, they expressed struggling with or disliking mathematics-related concepts, anxiety about teaching mathematics to others, and a wish to somehow achieve a pass in the mathematics methods course. Although many of these negative responses may not be very reassuring, the anxiety that many of the preservice teachers were feeling has also been clearly defined and highlighted in the literature (Bekdemir, 2010). When one considers how the anxiety that preservice teachers may feel regarding the teaching of mathematics could be carried until they start working as inservice teachers, and how teachers' anxiety and negative emotions towards mathematics could be passed to their students in the classroom, it is becomes imperative to break the anxiety cycle that preservice teachers may experience when completing their teacher education programs (Gresham, 2010). Gresham (2018) emphasized the importance of utilizing mathematics methods courses as a tool to decrease teachers' and thereby their students' mathematics anxiety, and highlighted teachers' requests for well-designed mathematics methods courses that prepares them for their subsequent inservice teaching careers. With these notions in mind, the researchers of the current study redesigned two teaching mathematics methods courses in an attempt to decrease preservice elementary teachers' mathematics anxiety and increase their mathematics teaching self-efficacy by providing opportunities to better understand mathematics-related concepts, and in educating them on how to then go on to teach these concepts to their own elementary school classes.

## Mathematics anxiety

Academic interest with regards to preservice and inservice teachers' mathematics anxiety has been expanding, since mathematics anxiety affects teachers' attitudes and actions whilst interacting with their students, and these attitudes and actions therefore can influence their students' perspective of mathematics (Vinson, 2001). When we consider the negative emotions that mathematics anxiety causes both teachers and teacher candidates, it becomes imperative to gain a better understanding on the reasoning behind this phenomenon (Gresham, 2018). Mathematics anxiety can be defined as individuals' negative emotional reactions that manifest as fear, panic, anxiety, tension, discomfort, uncertainty, and helplessness, towards mathematics-related performance (Beilock et al., 2010; Bursal & Paznokas, 2006). Studies on mathematics anxiety have focused on the correlation between self-efficacy and mathematics anxiety (Başpınar & Peker, 2016; Gonzalez-DeHass et al., 2017), the association between motivation and mathematics anxiety (Kuzu & Caliskan, 2018), and on preservice teachers' performances (Boyd et al., 2014; Gresham, 2018; Rodrigues et al., 2017), the factors that affect mathematics anxiety (Bekdemir, 2010), and ways to decrease individuals' mathematics anxiety (Núñez-Peña et al., 2015). Many research studies on this topic have emphasized the level of mathematics anxiety that preservice teachers feel during their teacher education programs (Perry, 2004), whilst others have identified preservice elementary teachers' mathematics anxiety as most common forms of teacher anxiety (Bekdemir, 2010; Novak & Tassell, 2017; Swars et al., 2007). Preservice teachers' mathematics anxiety can be caused by their past experiences of failing with

mathematics-related concepts (Bekdemir, 2010), learning mathematics via poorly implemented teaching practices (Gresham, 2007), negative attitudes linked to their past instructors of mathematics, and exam/test-related stress (Bandalos et al., 1995). There have been numerous studies that have established a negative correlation between high levels of mathematics anxiety and mathematics achievement (Zakaria & Nordin, 2008).

## Self-efficacy

Self-efficacy is an important motivational paradigm that influences human behavior and performance, especially their perception of mathematics. The ability to understand and the confidence to learn mathematics-related concepts are considered vital qualities that teachers should possess (Wilson, 2009). As Bandura (1993) suggested, individuals' self-efficacy determines how much effort they would put into the desired goal by controlling their emotions, motivations, thought processes, and actions. Teachers' self-efficacy proved to be a substantial predictor of their instructional practices in student-centered classrooms (Schiefele & Schaffner, 2015). Teachers' high self-efficacy is important to determine students' mistakes easily and help them when they need it, and apply new instructional practices (Swackhamer et al., 2009). Students' confidence in their ability to solve mathematical tasks, known as mathematics self-efficacy, is widely considered a significant learning outcome. It plays a crucial role in the learning process and is a key predictor of students' choices in their educational careers. Self-efficacy generally refers to an individual's belief in their ability to perform various tasks, whereas "self-efficacy beliefs" refer to focused assessments of confidence in particular domains or contexts. This term is often used when discussing context-related aspects of an individual's perceived competence. Self-efficacy beliefs in mathematics teaching can be defined as teachers' confidence in their abilities to plan and carry out the necessary actions to achieve desired outcomes (Takunyaci & Takunyaci, 2014). This belief reflects teachers' assessments of their competence in guiding student learning (Pajares, 1996).

In addition, teachers' self-efficacy is related to their student's learning behaviors. If primary school teachers' self-efficacy towards teaching mathematics is positive, it is expected that the students will be more successful and self-confident in mathematics (Gresham, 2018). For this reason, it is of great importance to examine the self-efficacy of prospective primary school teachers in teaching mathematics.

There have been a significant number of studies that have suggested a negative correlation between teaching mathematics self-efficacy and teachers' mathematics anxiety (e.g., Başpınar & Peker, 2016; Cil, 2017); thus, increasing preservice teachers' mathematics teaching self-efficacy could provide significant benefit in terms of decreasing preservice teachers' levels of mathematics anxiety. As Bekdemir (2010) cautioned, preservice teachers' previous mathematics-related negative experiences could cause mathematics anxiety, and that teacher educators could take these negative experiences into consideration while creating discussions on teacher candidates' anxiety. Similarly, teachers' self-efficacy expectations can affect their professional performance (Bandura, 1993); in other words, teachers' self-efficacy beliefs on their ability to teach mathematics-related concepts regulates their performance on teaching mathematics. As Gresham (2018) noted, preservice teachers' mathematics anxiety could be carried over to their inservice careers if the issue of their mathematics anxiety is not addressed within their teacher education program. Additionally, teachers might inadvertently pass on their negative emotions and anxiety towards mathematics to their own students (Johnson & vanderSandt, 2011). As Cil (2017) suggested,

tailoring specific mathematics teaching methods courses to decrease preservice teachers' mathematics anxiety, and thereby increasing their mathematics teaching self-efficacy, could help teacher educators to better support preservice teachers in decreasing the levels of mathematics anxiety experienced by their students over the years.

Bandura's work (1977) on self-efficacy expectations could provide a theoretical framework for developing a mathematics teaching course to increase students' self-efficacy beliefs, since they can be easily associated with individuals' academic performances. Bandura (1977) defined efficacy expectations as an individual's faith in their own ability to successfully complete a desired goal, categorizing them as performance accomplishments, vicarious experience, verbal persuasion, and psychological (emotional) states. Whilst performance accomplishments concern how individuals' mastery of desired topic negatively or positively affects their self-efficacy beliefs, vicarious experience regulates their self-efficacy as the individual reflects upon other people's achievements or perseverance in life (Bandura, 1977). Verbal persuasion signifies the negative or positive effects of feedback that individuals acquire on their self-efficacy (Bandura, 1977), while psychological states are concerned with negative emotions such as stress and anxiety that emerge from performing a desired task (Van Dinther, et al., 2011).

In this study, each of the four categories is explained in a way that connects with how to raise self-efficacy. Lectures about Bloom's Revised Taxonomy, mathematical modeling, and a problem-based teaching methodology are provided to improve individuals' self-efficacy positively. In addition, students implement mathematical modeling and make connections between mathematical modeling and mathematical concepts in their lesson plans and micro-teachings. To improve vicarious experience, whole class discussion, interdisciplinary work, and designed lesson plans created and implemented by small groups were provided. For verbal (social) persuasion, preservice teachers worked collaboratively with an instructor in planning micro-teaching sessions and making conversations about micro-teaching. For psychological states, group discussions were organized to create awareness about mathematics anxiety to decrease mathematics anxiety for preservice teachers.

## Teaching of mathematics

Traditionally, the teaching of mathematics generally starts with the introduction of mathematical information and algorithms, and their use in resolving abstract mathematical problems (Barnes, 2004). However, some individuals are unable to internalize mathematical concepts and algorithms prior to experiencing some of the steps that mathematicians need to take in order to reach those mathematical concepts and algorithms (Delice & Kertil, 2015; Sfard, 1995). Passive teaching methods such as knowledge transfer on how to utilize specific algorithms does not provide adequate opportunities for preservice teachers to understand the reasoning behind the use of such algorithms. Therefore, whilst redesigning a specific course for decreasing mathematics anxiety in preservice teachers, suggestions were made on increasing fundamental mathematical understanding and reasoning by providing opportunities for learners to experience, analyze, and discuss mathematical concepts through solving daily life problems (Gresham, 2018). The effectiveness of teaching mathematical concepts via mathematical modeling of real-life situations have been repeatedly noted in the literature (Lesh & Doerr, 2003) and utilization of these realistic problem based and student-centered activities support the preservice elementary teachers on analytically using their cognitive skills to better understand and resolve mathematics related problems.

Another important aspect of learning how to teach mathematics is gaining a deeper understanding on the cognitive classification of mathematical goals, learning activities, and questions. Since most mathematical learning goals include cognitive skills; Bloom's Revised Taxonomy could be utilized as a teaching tool in order for preservice elementary school teachers to describe, apply, and analyze learning goals, educational activities and exam questions for gaining a better understanding of mathematical concepts. It is also important to create an awareness of preservice teachers' potential mathematics anxiety through holding discussions (Bekdemir, 2010; Boyd et al., 2014); therefore, preservice teachers who take such courses could have the opportunity to explore their own perspective with regards to dealing with mathematic-related concepts and the teaching of mathematics.

## Mathematical modeling

Mathematical modeling could be used as a tool for helping individuals to build a connection between mathematics and daily life. Mathematical modeling is an external representation of structures in the mind that allows interpretation and analysis of a real-life situation, converted into a mathematical form (Lesh & Doerr, 2003). Also, mathematical modeling competency is important for primary school teachers, since it is a person's capacity to build and use mathematical models to solve real-world problems, as well as analyze and compare given mathematical models. (Kaiser & Brand, 2015). Modeling could simply be defined as the creation of mathematical frameworks (Drakes, 2012) and discussions (Frejd & Bergsten, 2016) for the purpose of explaining a life related issues, while the term mathematical modeling is associated with complex mathematical processes such as interpretation, mathematization of real-life problems to reach generalizations and solutions (Lesh & Doerr, 2003). Mathematical modeling can be defined as a cycle that explores and defines real-life mathematical problems, creates new mathematical models, and refines some of these mathematical models to discover and apply an effective mathematical model to solve problems (Lehrer & Schauble, 2003). Researchers connect mathematical modeling to mathematical competency by defining it as the individual's ability to use, construct, compare, or analyze mathematical models (Blum et al., 2007). Moreover, the National Council of Teachers of Mathematics (NCTM) highlights the importance of using mathematical modeling whilst teaching mathematics (NCTM, 2000). Global exams like the Program for International Student Assessment (PISA) also design mathematical questions that require individuals to utilize their mathematical modeling skills. Cho (2015) displayed how the use of mathematical modeling could help individuals to develop their mathematical competencies and transfer them to real-life situations with mathematical modeling examples that portray a clearer picture by building connections between mathematical concepts and the daily life that we live. Mathematical modeling also offers opportunities for instructors to create positive mathematics experiences for their students. Nyman and Berry (2002) noted how the use of mathematical modeling can help students to gain transferable mathematical skills, while Sevinç and Lesh's (2018) study presented a modeling-based course that helped preservice teachers to create an effective course lesson by utilizing their critical thinking and creativity skills. Mathematical modeling also encourages students to work collaboratively on given real-life problems and to support them in developing their social and communication skills (Lesh & Doerr, 2003). Moreover, Daher and Shahbari (2015) mentioned how mathematical modeling increases student motivation to learn mathematics by providing wide-ranging, real-life situations. Preservice teachers find mathematical modeling more effective than traditional mathematics education (Özdemir & Üzel, 2011), since it

can help to increase their understanding of mathematics (Zbiek & Conner, 2006). Although the use of mathematical modeling as teaching methods are highly valued, the avoidance of mathematical modeling is also evident (Sriraman & Lesh, 2006), since the application of mathematical modeling in the classroom is demanding (Ikeda, 2007), and it therefore complicates teaching and assessment processes (Cho, 2015). The utilization of a conceptual framework to better understand, learn, and teach mathematical questions, activities, and learning goals is a common process (Radmehr & Drake, 2018). Since mathematics mostly concerns cognitive learning goals, the utilization of Bloom's Revised Taxonomy could be seen to provide excellent opportunities to effectively internalize the topics by categorizing mathematical activities, questions and educational goals. Benjamin Bloom and his colleagues created the taxonomy of educational activities for the purpose of creating a common language that could be used between educators, establishing a basis for generating educational goals for courses via the consideration of national standards, determining the compatibility between educational goals, objectives and course curricula, and presenting opportunities to address the limitations of established courses or curricula (Krathwohl, 2002). A few decades later saw Krathwohl (2002) revise the original Bloom's taxonomy by structuring individual's cognitive actions into the cognitive process and knowledge dimensions. The cognitive process dimension consists of the following six categories in order to classify cognitive actions: remembering, understanding, applying, analyzing, evaluating, and creating, while the knowledge dimension was constructed around factual, conceptual, procedural, and metacognitive categories (Krathwohl, 2002). Bloom's Revised Taxonomy uses these two dimensions in order to pinpoint a cognitive process. While the cognitive process dimension is strictly concerned with verb-based phraseology to define a cognitive action, the knowledge dimension is concerned with noun-based phraseology to define the context in which the cognitive action takes place (Krathwohl, 2002). This dual structure of Bloom's Revised Taxonomy could therefore be used in order to help preservice teachers better understand how their students learn (Anderson, et al., 2001) and support them planning, evaluating and teaching mathematics-related concepts. Moreover, almost all of the mathematics curricula defined around cognitive educational learning goals (MEB, 2018); thus, utilization of Bloom's Revised Taxonomy as a teaching tool helps pre-service teachers to classify both the context and the required actions for effective instruction in which they could understand how to employ their mathematical knowledge for teaching a mathematical learning goal.

Overall, mathematical modeling allows individuals to associate mathematics with real-life situations, leading them to develop positive attitudes towards mathematics and increase their mathematics teaching self-efficacy. Teachers and educators need to adopt strategies that promote a positive learning environment, enhance self-efficacy, and demonstrate the practical applications of mathematics through modeling. This approach can contribute to more effective mathematics education and help alleviate anxiety associated with the subject.

## Methodology

Gresham (2018) emphasized the importance of creating longitudinal studies on the mathematics anxiety of preservice teachers when constructing mathematics methods courses, whilst Bursal and Paznokas (2006) talked of studies that attempt to transform the way pre-service teachers experience mathematics through instructional applications. With these

perspectives in mind, a mixed method quasi-experimental study on transforming preservice teachers' mathematics anxiety and teaching self-efficacy beliefs was created. The researchers of this study aimed to redesign and implement two third-year mathematics teaching methods courses to increase the preservice elementary teachers' mathematics teaching self-efficacy and to decrease their mathematics-related anxiety. For the purpose of investigating effectiveness of these courses the following research questions were designed:

1. Was a significant difference found in the mathematics teaching self-efficacy and the mathematics anxiety beliefs of the intervention and control groups prior to and following the intervention?
2. Did the participants' metaphors, drawings and descriptions of these drawings towards mathematics and mathematics teaching change prior to and following the intervention?
3. How did the participants' metaphors, drawings and descriptions of these drawings change after the intervention?

### **Participants and setting**

The participants of the study were chosen from students enrolled in two mathematics teaching methods courses, namely Mathematics Teaching-I and Mathematics Teaching-II. Although participation in the two courses was mandatory for all junior level preservice elementary teachers, participation in this study was voluntary, and they were informed that their choice whether they participate in the study or not would not affect their grades. For the purpose of this research, purposive sampling method was utilized to ensure that all of the participants were junior preservice elementary school teachers and took pre-requisite courses before taking Mathematics Teaching-I course. Of the 158 preservice elementary teachers who took these two mathematics method courses, 100 agreed to voluntarily take part in this study. While 28 female and 22 male participants aged between 21 and 23 were placed in modified version of the courses, 32 female and 18 male participants aged between 21 and 23 were selected and received their education based on the traditional version of the courses. Since the purposive sampling methodology is utilized while choosing participants in both experiment and control groups, participants' characteristics, such as gender and age and knowledge on mathematics and its teaching were similar.

### **Traditional and modified versions of mathematics teaching courses**

The Mathematics Teaching-I and Mathematics Teaching-II courses are both mandatory content courses that are required for preservice elementary teachers in Türkiye during the 5th and 6th semesters of their university studies. These courses were designed in order to help preservice elementary teachers develop an understanding of mathematics, mathematics principles and strategies, and of mathematics teaching pedagogy. The courses were taught in physically similar classrooms by two separate instructors from the Department of Elementary Education to negate any instructional bias towards the traditional version of the course. There are disadvantages of giving lectures by different instructors. These are the potential for inconsistent pacing, teaching methods, and communication styles of each lecturer. However, based on the research purpose, lecturing by different lecturers is not a great advantage for students because two-method courses have specific goals, preferences, and educational contexts. While both of the courses aimed to provide information on how to teach mathematics to elementary school students, the modified version of the courses

were designed with activities that to increase pre-service teachers' mathematical understanding and abilities to boost their mathematics teaching self-efficacy beliefs and reduce their mathematics anxiety. Table 1 showcases brief descriptions of activities implemented in the modified and traditional versions of the Mathematics Teaching I and II courses.

Since the definitions of Mathematics Teaching-I and Mathematics Teaching-II courses and the necessary topics should be covered were determined by Turkish Higher Education Committee both modified and traditional version of the courses constructed around same topics. The difference between the two versions of these courses triggered by the implementation of the teaching methodologies shown in Table 1. For instance, both modified and traditional versions of the courses covered the definitions of the mathematics, mathematics teaching and mathematics anxiety. In the traditional version of the course information regarding these concepts were provided via lectures. While in the modified version the instructor asked participants to recollect and wrote down a positive or negative memory regarding mathematics and generated discussions around these memories to support students on thinking their attitude towards mathematics teaching and mathematics as subject. Another words the discussions around positive and negative emotions and anxiety help to participants to explore their psychological states around mathematics and its teaching.

It can be seen at Table 1 that both modified and traditional versions of the courses implemented micro teaching activities; however, the way this teaching methodology was implemented was different. In the traditional version of the course the instructor lectured on how to teach certain topics and students planned and implemented these courses in front of the whole class then their peers and the instructor of the course provided feedback. In the modified version students directly created their first version of lesson plan and met with instructor at least three times to discuss the implementation of the theoretical lectures around mathematical subjects and activities to ensure all of the students that prepared that lesson plan understood the topic. Thus, the implementation of the lesson plan is likely to be successful and provide a challenging and positive experience for students. After the implementation of the topic students received feedback from their peers and instructor. Implementation of the well-planned and implemented micro teaching activities supported participants on showcasing their mastery of teaching a mathematical topic and helped them to reach performance accomplishment expectation, while all other participants were observing their peers' successful performances that led them to reach vicarious experience expectation.

## Data gathering process

For the purpose of investigating the effectiveness of the intervention process on preservice teachers' levels of mathematics anxiety and mathematics teaching efficacy, a quasi-experimental research was planned and both pre- and post-tests were implemented. First, all of the preservice elementary teachers, both the control and intervention groups, were asked to complete the Mathematics Teaching Efficacy Belief Instrument (Hacıömeroğlu & Şahin-Taşkın, 2010) and the Turkish Version of the Bidimensional Mathematics Anxiety Scale (Akçakin et al., 2015), whilst drawing on what it means for them to teach mathematics. Moreover, the participants were requested to answer metaphorical questions and to draw and describe what it meant to them to teach mathematics. Then, while the intervention group received the Mathematics Teaching-I and Mathematics Teaching-II courses that had been specially redesigned for this study in order to decrease preservice elementary teachers' mathematics anxiety and introduce them to certain ways to teach mathematics to

**Table 1** Modified and Traditional Versions of Mathematics Teaching I and II

Efficacy expectation	Instructional activity	Educational activities implemented in modified version of the courses	Educational activities implemented in traditional version of the courses
Performance (mastery) accomplishments	Use of lectures	<p>Lecture on definition Bloom's Revised Taxonomy provided</p> <p>Lecture on definition of modeling and mathematical modeling provided</p> <p>Lecture on a problem-based Teaching Methodology (RME) provided</p>	<p>Lecture on the principles of teaching in mathematics education</p> <p>Lecture on how to teach mathematics in primary schools</p> <p>Lectures on how to teach mathematics in primary schools (e.g., the four mathematical operations and fractions)</p>
	Use of mathematical modeling	<p>Students implement mathematical modeling process using life-related problems</p> <p>Connection between mathematical modeling and mathematical operations analysed and discussed</p> <p>Problem-based Teaching Methodology (RME) implemented to showcase and discuss connections between mathematics and real-life</p>	
	Use of B.R.T	<p>Practice opportunities provided to preservice teachers on classifying learning goals, activities, and questions</p> <p>Practice opportunities provided for preservice teachers on creating learning goals, activities and questions for specific cognitive levels</p>	

**Table 1** (continued)

Efficacy expectation	Instructional activity	Educational activities implemented in modified version of the courses	Educational activities implemented in traditional version of the courses
	Use of micro teaching activities	<p>Instructors met at least three times to discuss draft theoretical lectures around mathematical subjects and micro teaching activities</p> <p>Preservice teachers experienced micro activities on various subjects (e.g., the four mathematical operations and fractions)</p> <p>After micro teaching, whole class discussion created about the micro teaching</p> <p>Elements of an effective lesson plan discussed and small group activities created for practice</p> <p>Peer assessment process implemented to provide experience on creating and evaluating lesson plans</p> <p>Interdisciplinary work included in lesson plans</p> <p>Well-designed lesson plan created and implemented by small groups</p> <p>All learning activities implemented at desired cognitive level</p>	<p>Instructors met once with the preservice teachers to discuss draft lectures and micro teaching activities</p> <p>Preservice teachers experienced micro activities on various subjects (e.g., the four mathematical operations and fractions)</p> <p>After micro teaching, whole class discussion created about the micro teaching</p>
Vicarious experience	Use of mathematical modeling	<p>Problem-based Teaching Methodology (RME) implemented to showcase and discuss connections between mathematics and real-life</p>	
	Use of B.R.T	<p>Practice opportunities provided for preservice teachers on creating learning goals, activities and questions for specific cognitive levels</p> <p>All learning activities implemented at desired cognitive level</p>	

**Table 1** (continued)

Efficacy expectation	Instructional activity	Educational activities implemented in modified version of the courses	Educational activities implemented in traditional version of the courses
	Use of Micro Teaching Activities	<p>Peer assessment process implemented to provide experience on creating and evaluating lesson plans</p> <p>Practice opportunities provided to preservice teachers on classifying learning goals, activities, and questions</p> <p>Preservice teachers experienced micro activities on various subjects (e.g., the four mathematical operations and fractions)</p> <p>After micro teaching, whole class discussion created about the micro teaching</p> <p>Interdisciplinary work included in lesson plans</p> <p>Well-designed lesson plan created and implemented by small groups</p>	<p>Preservice teachers experienced micro activities on various subjects (e.g., the four mathematical operations and fractions)</p> <p>After micro teaching, whole class discussion created about the micro teaching</p>
	Verbal (social) persuasion	<p>Use of discussions</p> <p>Use of micro teaching activities</p>	Discussions of preservice teachers' performance immediately following micro teaching activities

**Table 1** (continued)

Efficacy expectation	Instructional activity	Educational activities implemented in modified version of the courses	Educational activities implemented in traditional version of the courses
Psychological states	Use of discussions	<p>Implementation of the pre-intervention data collection process provided opportunities for preservice teachers to think about their mathematics anxiety and teaching mathematics</p> <p>Each student defined what teaching mathematics is for them</p> <p>Group discussions held to create awareness about mathematics anxiety, and its effects on preservice teachers and their prospective students</p> <p>Group discussions held to explore ways to decrease mathematics anxiety for preservice teachers</p> <p>Implementation of post-intervention data collection process provided opportunities for preservice teacher to think about their mathematics anxiety and to discuss their mathematics teaching self-efficacy</p>	

**Table 2** The implementation of the quasi-experimental research design

Before the implementation	First week	28 Weeks of instruction	Last week
Selection of the experiment group	Implementation of pre-tests	Modified version of Mathematics Teaching I and II courses	Implementation of post-tests
Selection of the control group	Implementation of pre-tests	Traditional version of Mathematics Teaching I and II courses	Implementation of post-tests

elementary school students, the participants of the control group received regular teaching for the same two courses. Following implementation of both the traditional and modified versions of the two courses, post-tests were applied to complete the data gathering process. There was not any missing data on pre- and post-tests of participants. The information on the implementation of the quasi-experimental research design can be seen at Table 2.

Since both modified and traditional versions of the Mathematics Teaching I and II courses designed with the consideration of the mandatory requirements of the Elementary School Bachelor Curriculum (YÖK, 2018) and comprised with same primary information on mathematics teaching, modified versions of the courses were not offered to the control group after the intervention process. However, the participants of both control and experiment group were invited to attend next year's Mathematics Teaching I and II courses that were redesigned with the findings of this study if they chose to do so.

### Validity and reliability of the study

Miles and Huberman (1994) highlighted the importance of creating a well-established and thoroughly explained research methodology to increase the reliability of a study. In order to increase the reliability of the study, the content of the traditional and modified courses was described in detail, the data collection tools and questions used were presented to the reader, and data found to contain bias and misunderstanding were removed from the data set before analysis.

Moreover, both traditional and modified versions of the Mathematics Teaching I and II courses were implemented in coordination with Akhi Competency-Based Training Project (ACBTP) (Özüdoğru & Şimşek, 2021) to ensure the intervention process implemented properly. ACBTP is a learning management system that aiming to monitor learning process via predetermined standards. For that purpose, instructors have to define learning goals of the courses, topics and exams questions even before semester starts. The ACBTP learning management system also requires instructors to connect teaching topics with learning goals and exam questions so that student performances in the exams could provide direct feedback on effectiveness of the learning activities in regard to teaching topics and learning goals of the course. Moreover, the information that put in ACBTP learning management system by instructor is also checked by independent experts to ensure content validity before the semester starts. Overall, the ACBTP system helped the instructors to plan educational activities related to course topics and connect them with the learning outcomes of course and exam questions to ensure all of the planned educational activities in both traditional and the intervention programs were implemented properly; thus, validity and reliability of the study was increased.

Lincoln and Guba (1985) noted the significance of establishing deep data collection processes to increase validity and reliability of the research. For the purpose of describing change in the participants' perspective of mathematics anxiety and mathematics teaching efficacy, the preservice elementary teachers' metaphors, drawings and their descriptions were analyzed via directed content analysis (Hsieh & Shannon, 2005). Metaphors provide a great medium for exploration of the change, since they aim to consider a concept or phenomenon from different perspectives and to express it through analogy (Lakoff & Johnson, 2010). Metaphors and drawings are tools to establish a connection between information while providing opportunities for making complex ideas easier to understand and they could enable individuals to easily identify the meanings they attribute to concepts. Overall, exploration of the participants' metaphors and drawings not only presented opportunities to analyze multiple types of data forms but also helped to acquire a deeper understanding about their perspectives; thus, increased validity and reliability of the research.

### Data gathering tools

The revised version of the Mathematics Teaching Efficacy Belief Instrument (Hacıömeroğlu & Şahin-Taşkın, 2010) consists with 17 items and an internal consistency value of 0.71, while the Turkish Version of the Bidimensional Mathematics Anxiety Scale (Akçakın et al., 2015) consists of 14 items and an internal consistency value of 0.91. For the current study, the internal consistency values for the revised version of Mathematics Teaching Efficacy Belief Instrument and the Turkish Version of the Bidimensional Mathematics Anxiety Scale were calculated as being 0.72 and 0.92, respectively. Moreover, two questions were asked to collect qualitative data. In order to investigate the participants' thoughts about the mathematics course, the question of "Mathematics is like ..... Because....." was asked. In the intention of investigating the participants' views on mathematics teaching through drawings, the question of "Try to explain what the process of teaching mathematics means to you by drawing a picture and describing your picture with a few sentences?" was asked.

### Data analysis process

In order to compare the participant preservice elementary teachers' perspectives on mathematics anxiety and mathematics teaching efficacy beliefs prior to and following the intervention process, IBM's SPSS 23 statistical program was utilized in the analysis of the data. Since the data was not normally distributed, Mann-Whitney U-test was applied in order to compare results of the pre- and post-tests between the control and intervention groups, while the Wilcoxon signed-rank test was used to compare the pre- and post-tests results within the control and intervention groups. More specifically, Wilcoxon signed-rank test first used to ensure participants in control and experiment groups did not have any statistically significant difference before the implementation of the Mathematics Teaching-I and Mathematics Teaching-II courses and then it is used after the experiment process to explore whether modified versions of the courses generated a statistically significant change on preservice teachers' mathematics teaching self-efficacy and the mathematics anxiety beliefs.

For the purpose of implementing directed content analysis, the researchers first analyzed 20% of the preservice teachers' metaphor examples and descriptions of their drawings with general theme of change to create a codebook. Before and after intervention all

**Table 3** Comparison of Mathematics Anxiety and Teaching Self-Efficacy Between Intervention and Control Groups

	Group	<i>n</i>	Mean Rank	Sum of Ranks	<i>U</i>	<i>p</i>	
Mathematics anxiety	Pre-test	Intervention group	50	48.77	2,438.50	1,163.50	.551
		Control group	50	52.23	2,611.50		
		Total	100				
	Post-test	Intervention group	50	46.41	2,320.50	1,045.50	.159
		Control group	50	54.59	2,729.50		
		Total	100				
Mathematics teaching self-efficacy	Pre-test	Intervention group	50	46.17	2,308.50	1,033.50	.135
		Control group	50	54.83	2,741.50		
		Total	100				
	Post-test	Intervention group	50	57.19	2,859.50	915.50	.021
		Control group	50	43.81	2,190.50		
		Total	100				

of the emerging codes such as joy, feeling of accomplishment, gamification, and student-centered educational activities were analyzed with the perspective of change. For instance, when metaphors created by participant 67 were analyzed, emotions such as anxiety and unhappiness coded before the intervention process, while joy was the emerging emotion from the metaphor participant created after the intervention process and this data coded as Cha/EmoP/Anxiety-Joy. When participant 85' s data was explored before the intervention process boredom was the main code arised from his drawings and after the intervention process activity-based learning environment was the emerging code and this data was coded as Cha/PedagoP/Boredom-ActivityBEnv. Additionally, codes related with continual negative feelings like fear and anxiety grouped under resistance to transformation sub-theme. For example, fright was the emotion that emerged from participants 60' s drawings, while helplessness was the main emotion arise after the intervention process and coded as ResCha/Emo/Fright-Helplessness. Thus, the main themes of the directed content analysis revolved around the emotional transformation, pedagogical transformation, and resistance to transformation of the participants. After creation of the codebook all of the students' responses to metaphorical questions and descriptions of their drawings were analyzed. Finally, researchers investigated the drawings with consideration of the preservice teachers' descriptions and codebook and completed the directed content analysis process.

## Results

The main goal of this study was to explore the potential effects of the intervention program on preservice elementary teachers' mathematics anxiety and mathematics teaching self-efficacy beliefs. For this purpose, Mann–Whitney U Test was implemented in order to compare the beliefs of the participants in both the intervention and control groups, while the Wilcoxon signed-rank test was used to compare the pre- and post-tests results of the participants within the intervention and control groups.

As can be seen in Table 3, the Mann–Whitney U test revealed no statistically significant difference between intervention (Median = 26.21) and control (Median = 28.07)

groups for mathematics anxiety ( $U=1045$ ,  $p=0.159$ ). While there was a statistically significant difference for mathematics teaching self-efficacy ( $U=915$ ,  $p=0.021$ ) between intervention (Median=68.76) and control (Median=64.23) groups. Although the mean rank score for mathematics anxiety decreased while the mean rank score for teaching mathematics self-efficacy increased for the intervention group, the mean rank score for mathematics anxiety increased and the mean rank score for teaching mathematics self-efficacy decreased for the participants in the control group.

As shown in the results in Table 4, a statistically significant difference was found within the pre- and post-tests of the intervention group, whilst no statistically meaningful difference was found within the pre- and post-tests of the control group. The Wilcoxon test results indicated statistically significant change in the participants' beliefs regarding their mathematics anxiety ( $z=-2.477$ ,  $p<0.05$ ,  $r=0.24$ ) and mathematics teaching self-efficacy ( $z=-3.640$ ,  $p<0.01$ ,  $r=0.36$ ) following the intervention process. However, the participants' scores in the control group did not reveal any statistically significant change for mathematics anxiety ( $z=-1.492$ ,  $p>0.05$ ) or mathematics teaching self-efficacy ( $z=-.757$ ,  $p>0.05$ ) following the courses taken.

### Changes of preservice teachers' perspectives towards mathematics

The quantitative findings of this research revealed a statistically significant change in the preservice teachers' mathematics anxiety and mathematics teaching self-efficacy beliefs for the intervention group participants. Providing a qualitative description to this statistically significant transformation might provide a better understanding of how the preservice teachers' perspectives changed through this intervention process. The qualitative data analyses revealed emotional and pedagogical transformations under two main themes, although it was clear that only a limited number of the preservice teachers that participated in the intervention process held on to their negative perspectives with regards to performing and teaching mathematics.

#### Emotional transformation

Prior to the intervention process application, many of the preservice teachers acknowledged the importance of mathematics in the daily life of individuals, and the importance of the role that mathematics plays in relation to other science subjects. However, after they had the opportunity to encounter problems and resolve them via their mathematical knowledge, they repeatedly expressed the pleasure and joy felt after being able to overcome these mathematical problems. Preservice teachers initially described feeling negative emotions such as anxiety or fear towards mathematics; however, the implementation of the intervention process triggered a change, since many of the preservice teachers displayed a positive emotional change following the intervention process.

The preservice teachers defined the mathematics course in a very broad sense by noting its importance to the life of the individual. However, following the intervention process, they acknowledged the joy felt when able to successfully cope with the mathematics topics. For instance, Participant 091 exemplified this change with the following metaphors:

**Table 4** Comparison of mathematics anxiety and teaching self-efficacy within intervention and control groups

Control group	Post-test-Pre-test	<i>n</i>	Mean rank	Sum of ranks	<i>z</i>	<i>p</i>
Mathematics anxiety	Negative Ranks	28	24.18	677.00	- 1.492	.136
	Positive Ranks	18	22.44	404.00		
	Ties	4				
Mathematics teaching self-efficacy	Negative Ranks	29	21.91	635.50	- .757	.449
	Positive Ranks	18	27.36	492.50		
	Ties	3				
Mathematics anxiety	Negative Ranks	31	26.76	829.50	- 2.477	.013
	Positive Ranks	17	20.38	346.50		
	Ties	2				
Mathematics teaching self-efficacy	Negative Ranks	16	16.28	260.50	- 3.640	.000
	Positive Ranks	34	29.84	1,014.50		
	Ties	0				

Before intervention	After intervention
<p><b>Water and soil</b> Without both, no living thing can grow. Without mathematics, other beings and courses would not be possible</p>	<p><b>Amusement Park</b> We had some trouble solving problems from time to time because each job has a certain level of difficulty. But when I figured out the solution, I felt the happiness of playing in an amusement park</p>

When asked about her opinions on teaching mathematics, Participant 064 echoed 091's notion by showcasing how she altered her opinion on mathematics from a vital course that affects individuals' academic success to a complex but engaging subject with the following metaphors:

Before intervention	After intervention
<p><b>To a plant</b> If you provide the necessary conditions that a plant needs, it will grow more effectively. Just like individuals who are active in other classes, thanks to their success in mathematics</p>	<p><b>Tasmanian Devil</b> Although mathematics is fast, effective, complex and difficult to understand, it also has a catchy, interesting and lovable side</p>

In another example, when Participant 056 was asked about her opinions on teaching mathematics, she responded with the following metaphors that revealed a positive emotional change on teaching mathematics:

Before intervention	After intervention
<p><b>To the blue cloud in the black sky</b> The main task of mathematics is shedding light on the future and humanity, to provide the ability to think, and to create a baseline to enable social and rational thinking</p>	<p><b>Running downhill</b> Running downhill requires courage, concentration and attention to detail. However, the feel of the wind in one's hair is like freedom. Mathematics had opened up a different world for me, but it was hard to open, but I can best express this pleasure like this</p>

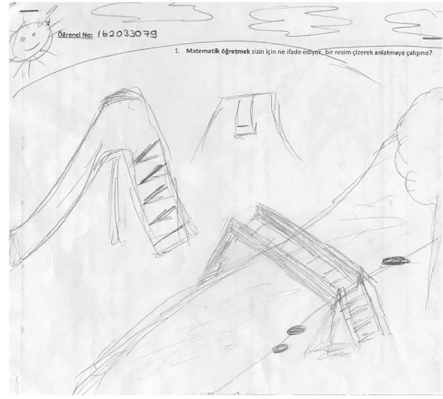
It was clear that not all of the participant preservice teachers see mathematics as an important subject, since many clearly expressed concerns regarding the implementing and teaching of mathematics. For instance, prior to the intervention process, Participant 074 associated mathematics courses with gambling since he believed that "*he always loses when he plays.*" However, after intervention he related mathematics with a last-minute goal that brought championship since he noted "*when he coped with mathematics and successfully solves a problem, he becomes very happy*". In another example, 067 displayed an emotional change from anxiety to joy with following metaphors while defining mathematics as a subject:

Before intervention	After intervention
<p><b>Darkness</b> I was never happy and relaxed in that class. I'm as worried about math as I get worried in the dark. I need a light in the dark, and I need a break in math class</p>	<p><b>İstanbul</b> İstanbul [a cosmopolitan city in Türkiye] ... hard to learn, but after you adjust it is fun to live in</p>

An even more significant emotional change can be observed in Participant 079's drawings, since in his first drawing he expressed his fears through the relationship between a killer and a victim, while after the intervention he correlated the teaching of mathematics with calming nature:

Before intervention

After intervention



Teaching mathematics is my nightmare. It's like the victim's fear of seeing his killer. Like death

The painting I've drawn is about nature. It describes the peace that spring air, streams and running water gives to human beings. It is picture of human activities that take place in the fresh air

### Pedagogical Transformation

During the intervention process, many of the preservice teachers' perspective of mathematics transformed and they started to actively think about how to teach mathematics since having the opportunity to experience activities themselves that solely focused on the teaching of mathematics. They started to express preferences on how to teach mathematics and highlighted a few important issues such as the implementation of game-based learning activities or the importance of connecting mathematics teaching with real-life experiences. Participant 023 expressed his desire to implement game-based teaching activities with following metaphors:

Before intervention

After intervention

#### The Matryoshka Dolls

Even though they [mathematical topics] seem to be large and one thing from the outside, there are beautiful unknown wonders inside of it

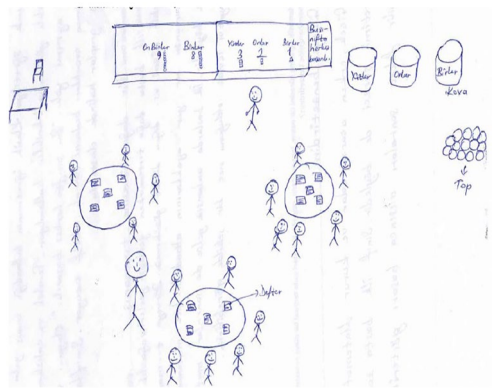
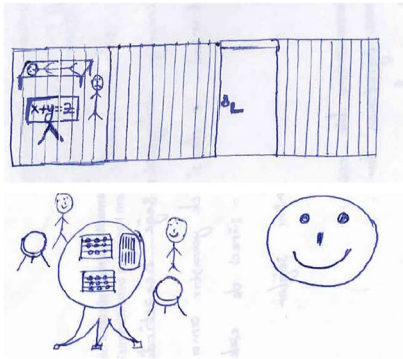
#### Survivor

Entertainment, competition and training are taking place. Math should be given to students in an entertaining way. Games attract the interest of children at that age. Teaching with games is always catchier

The following example demonstrates the change on Participant 42' perspective from highlighting teachers' importance on creation of educational atmosphere in the classroom to elaborate description of his/her teaching philosophy and prospective classroom:

Before intervention

After intervention



\* Turkish phrases in these drawings are translated as follows:

**On the board:** Ten thousands, thousands, hundreds, tens, ones

**Right side of the board:** Everyone in this class is successful

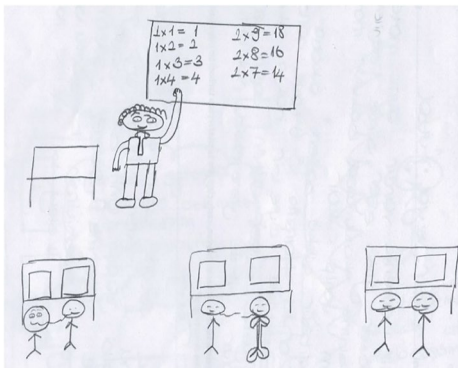
It is in the hands of the teacher to transform the area where mathematics is taught into a prison or a playground

This is a classroom where teachers and students are active. The teacher emphasizes the slogan "Everybody is successful in this class" and uses various teaching methods and techniques instead of teaching with traditional presentation methods. The teacher is not at his desk and teaches students in a fun way using gamification

In another example, it can be seen how Participant 85' notions regarding boring mathematics lessons transformed and how he inspired to design an activity-based learning environment to boost creative thinking for his prospective students:

Before intervention

After intervention



\* Turkish phrases in these drawings are translated as follows:

**Upper image:** Math for creative thinking

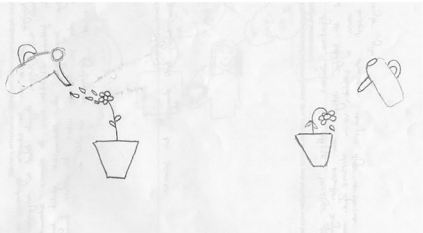

**Lower image:** The area where I will teach the activities, I have learned

Before intervention	After intervention
The lesson is so boring that the students are tired of the math lesson and they start talking among themselves	Instead of using the rows in the traditional order we studied in, I will order them as the "U" shape. Thus, I will be able to implement most of the activities I learned in my course [Mathematics Teaching I and II]

Similarly, Participant 004 highlighted the structured nature of mathematics education with the following metaphor:

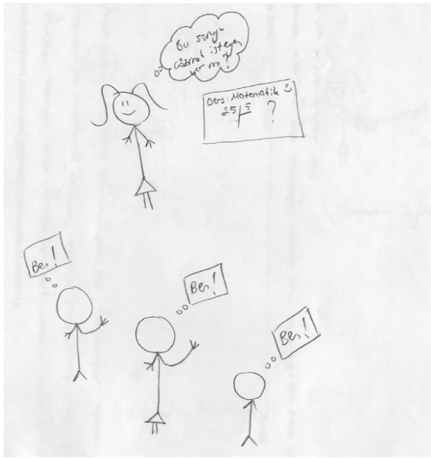
Before intervention	After intervention
<b>Lion</b> I think it is very powerful. Just as a lion suppresses other animals with his strength, mathematics suppresses many other lessons with the right teaching process	<b>Is a shopping cart</b> Accumulates objects by adding them one by one. In the mathematics course, the subjects are placed on top of each other to form the whole

The following drawings demonstrate how Participant 064's notion on teaching mathematics evolved from connecting mathematics achievement with teacher-centric ideas to showcasing important attributes that need to be in her mathematics class:

Before intervention	After intervention
 <p>I am a growing and flourishing flower, and my teacher is a fundamental need for the survival of living things. Therefore, I am a flower and my teacher is the water</p>	 <p><b>Clock...</b> symbolizes using my time efficiently to help children learn at their best  <b>Boys and girls...</b> symbolize smiling faces, happy kids, math-loving children  <b>Cup...</b> symbolizes success  <b>Present...</b> the crowning of success with awards within proper time periods</p>

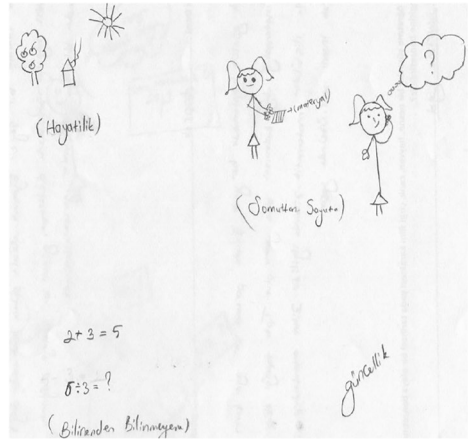
Even the preservice teachers that did not significantly change their anxiety over teaching mathematics displayed a pedagogical change following the intervention process. For instance, prior to the intervention process, Participant 066 expressed her desire to create a classroom environment that encouraged students to be active in mathematics classes. Following the intervention process, she was able to clearly express which important characteristics her mathematics classes should have:

Before intervention



I want my students to be active when they come to class. I want to prevent students from saying, 'I can't solve this problem, I can't sum this up.' Because I can understand how much I taught them and that I did not reflect any of my concerns even if I had them

After intervention



Teaching a child something in every field. It's not just mathematics, using mathematics but giving examples from everyday life, to address a current topic, learning through experience, from known to unknown, performing learning activities

Preservice teachers' perspectives on teaching evolved towards the implementation of game-based mathematical activities. The following example presents the positive transformation seen in Participant 005, from an individual that defined mathematics as an inevitable subject that people get irritated about to a person that correlates mathematics with life and games:

Before intervention

#### It is like water cut off in the shower

Every individual can learn math more or less, but at some point, a person cannot go any further. Math is frustrating and cannot be got rid of

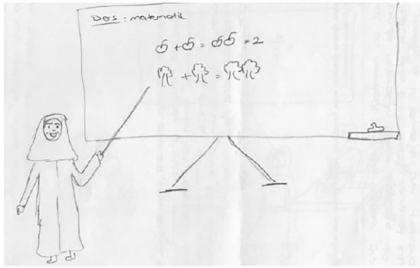
After intervention

#### Game for kids

Both are associated with daily life and fed from it

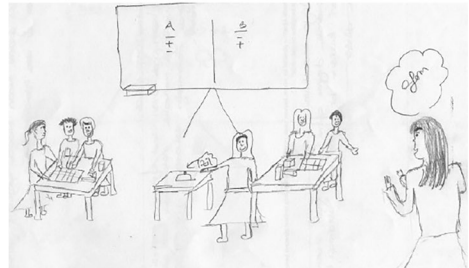
The following drawings demonstrate the change seen with Participant 090's preferences on how to teach mathematics. While the drawings made prior to the intervention represent teacher-centric and less risky teaching methodology, the drawings made following the intervention show a complicated and student-centered activity:

Before intervention



In the lesson, I drew pictures of tangible objects and made them [my students] sum those objects

After intervention



I thought that using a cooperative learning model; a course could be taught with the students in a contest format

### Resistance to transformation

Although the implementation of the intervention process triggered a statistically significant change to the preservice elementary teachers' mathematics anxiety and mathematics teaching self-efficacy beliefs, four preservice teachers retained their negative perceptions. In the following example, Participant 086 expresses frustration with the learning and teaching of mathematics with the following metaphors:

Before intervention

#### Road

There are so many topics and formulas that it does not seem to have end

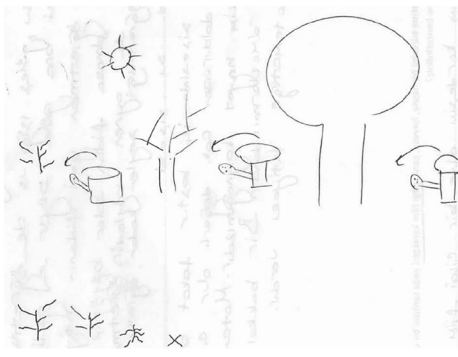
After intervention

#### Sea

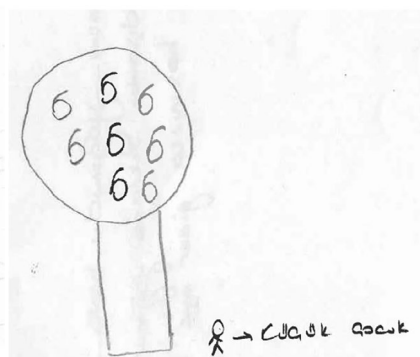
Its' subjects never stop. Every day a new formula and a new topic is added

In the following example, Participant 63' perspective about importance of teachers' abilities on students' success and his/her frustration of not being able to effectively teach mathematics can be observed:

Before intervention



After intervention



\*Turkish phrases in these drawings are translated as follows:

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 Before intervention

If the student was a sapling, the water and sunlight needed by the sapling would be the teacher. Students would develop according to teachers' performance. But if the teacher can't provide the needs of the sapling, the sapling cannot grow and eventually fade

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After intervention

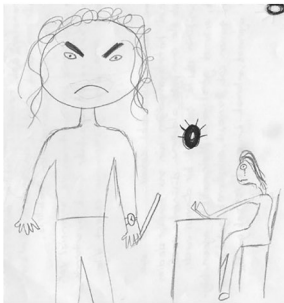
**Lower image:** A small child

The little boy craves apples but can't reach them. Because he can't climb the tree. I also love mathematical and solving problems, but I get stuck while teaching mathematics to students

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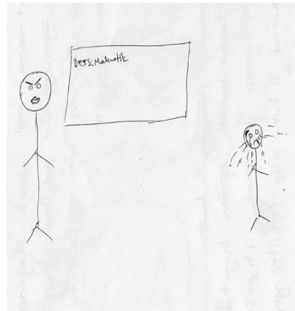
These five preservice teachers' negative experiences in early life were so significant that the intervention process did not change their emotional insecurity towards the teaching or implementing of mathematics. In the following drawing, it can be seen how Participant 060's negative experiences in the past clearly showed through her drawings and subsequently hindered her progress in the mathematics courses:

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 Before intervention


We have a teacher and a student in the picture. The teacher is angry and has a stick in his hand. The child may learn in this environment, but he does not even dare to show it

After intervention



Depending on the teacher, mathematics attitude is shaped for students. When they don't even have an idea of whether or not they can do it, the teacher will be the most important factor

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Their negative notions regarding mathematics created hesitation towards their teaching of mathematics. In the following example, Participant 094 explained his desperation regarding teaching mathematics with the following cartoon-inspired metaphors:

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 Before intervention

**Tom & Jerry**

Consider Jerry as math, and Tom as me. I miss him when I started to fully understand, and again and again I missed catching him in my hand with every try. This is the most annoying situation with math

After intervention

**Road Runner**

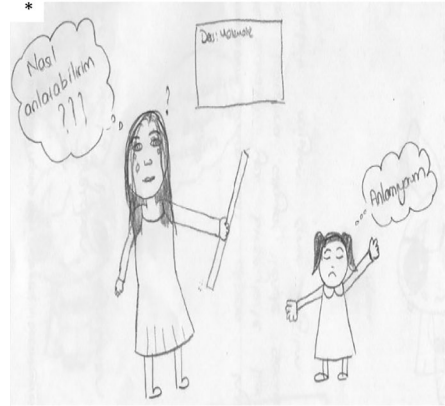
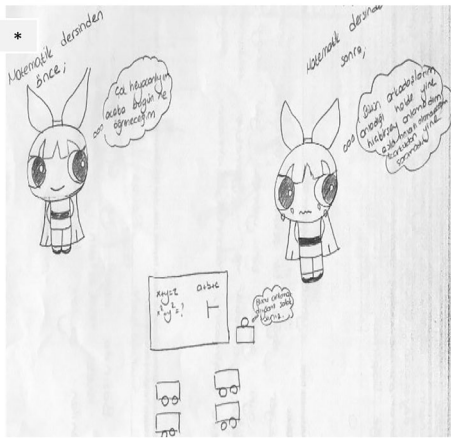
You say you caught him like the fox in the cartoon, but you can't catch the question and the problem. You say that I got it this time, but there is always a new problem and things are irreversible

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The following drawings express Participant 089's frustration and despair towards mathematics. How the preservice teacher's frustration with performing mathematics are carried forwards to the teaching of mathematics can clearly be observed in the following drawings:

Before intervention

After intervention



\* Turkish phrases in these drawings are translated as follows:

**Upper left corner:** Before math lesson:

“I am so excited, what we will learn today?”

**Upper right corner:** After math lesson:

“I did not understand anything, and even none of my friends understood it. I will never succeed, I turned to yellow because of fear again.”

**Teacher in lower image:** “You are stupid if you don’t get this.”

Although the student is willing to participate in the math lesson, the teacher explains things in ways the student cannot understand. The student is frightened and turns yellow because he does not want to feel offended

**Teacher:** “How can I teach it?”

**Student:** “I don’t get it?”

Unhappy student  
Unhappy teacher  
Confused teacher  
The teacher is alone in the classroom

## Discussion and conclusion

This quasi-experimental study was created in order to explore the effectiveness of an intervention process applied to preservice elementary teachers to address their mathematics anxiety and mathematics teaching self-efficacy. The findings of the study revealed a statistically significant change in the preservice elementary teachers’ mathematics anxiety and mathematics teaching self-efficacy within the intervention group and a statistically significant difference found for mathematics teaching self-efficacy between the control and intervention groups. Moreover, the qualitative findings highlighted pedagogical and emotional transformations of the preservice elementary teachers throughout the intervention program, while revealing that only a few of the preservice elementary teachers resisted this positive transformation. The following paragraphs discuss these findings.

Mathematics anxiety is a widely explored topic in the literature, and over the years many studies have pointed to the ineffectiveness of simply providing more mathematics courses in order to decrease students’ mathematics anxiety (Palmer, 2006). Even decades ago, many research studies indicated no statistically significant association between the number

of previous college-level courses received and preservice teachers' attitudes towards those subjects (Stevens & Wenner, 1996). The findings of the current research also echo earlier findings presented in the literature, since the preservice elementary teachers in the control group took two mathematics teaching methods courses, yet there was no statistically significant change seen in their levels of mathematics anxiety or mathematics teaching self-efficacy beliefs. However, when the preservice elementary teachers took mathematics courses that were specifically designed under the intervention process, the results showed a statistically significant change in their mathematics anxiety and mathematics teaching self-efficacy. The findings of the current study indicate that the intervention program that the preservice elementary teachers received decreased their levels of mathematics anxiety, while it increased their mathematics teaching self-efficacy. It is therefore significant to highlight the ineffectiveness of simply providing yet more mathematics courses in an attempt to decrease students' mathematics anxiety.

Mathematics educators could specifically design their mathematics courses to address the issue of mathematics anxiety potential and mathematics teaching self-efficacy if they wish to create a positive change in preservice teachers' perspectives of mathematics in terms of mathematics anxiety and mathematics teaching self-efficacy. Suggestions of using constructivist methods to support conceptual understanding on mathematical methods courses (Gresham & Burleigh, 2019) and utilization of individuals' past schooling experiences to understand how these experiences effects their performances (Jong & Hodges, 2013) resonated with the findings of this study since discussions about participants past experience on mathematics and the issue of mathematics anxiety supported them thinking on how their prospective students would feel in their classroom. Moreover, successful implementation of the educational activities and group practices on solving various mathematical modeling questions both presented a challenge and provided positive experience about mathematics teaching and supported them on developing conceptual understanding. Thus, generating discussion on positive or negative past schooling experiences and supporting students to succeed on well planned challenging mathematical exercises could help teacher educators to create more effective mathematics methods courses.

When the potential negative effects of high levels of mathematics anxiety on preservice teachers' beliefs (Kesici & Erdoğan, 2009) and performance (Ma & Xu, 2004) are considered, it becomes clear that teacher educators and teacher education programs could take the initiative to ensure that they support preservice teachers in decreasing their levels of mathematical anxiety and correspondingly increasing their mathematics teaching self-efficacy. With these perspectives in mind, the intervention program in the current research study was designed around Bandura's (1977) self-efficacy expectations, and throughout the intervention program, exercises about mathematical modeling processes, meticulously planned and successfully implemented micro-teaching activities that overseen by instructors, and the use of Bloom's Revised Taxonomy helped the preservice teachers to better understand mathematical concepts and to successfully implement teaching activities within a controlled environment so as to acquire the expected levels of performance as candidate teaching professionals.

As Swars et al. (2007) highlighted, preservice teachers' pre-existing mathematical beliefs can be influenced by teacher education programs. The frequency of implementation of the mathematical exercises and micro-teaching activities in the current study's intervention also provided vicarious experiences for the preservice teachers to observe their peers' accomplishments, which provided opportunities for them to increase their own self-efficacy beliefs regarding the teaching of mathematics. The constant constructive feedback received from the course instructor during the discussions and micro-teaching

activities also presented guidelines for the preservice teachers to regulate their self-efficacy beliefs. Finally, discussions held regarding the topics of mathematics anxiety and mathematics teaching self-efficacy also promoted inquisitive thinking and prompted the preservice teachers to question and describe their own psychological state regarding mathematics anxiety and mathematics teaching self-efficacy beliefs. Although we cannot claim that designing the Mathematics Teaching I and II courses around Bandura's (1977) self-efficacy expectations is the sole reason for the change of the preservice teachers' beliefs, they could be effectively utilized to support preservice teachers in decreasing their anxiety levels and correspondingly increasing their teaching self-efficacy.

A recent study by Saadati et. al.'s (2023) noted that participation in effective problem solving activities supported teachers strengthening their procedural and conceptual knowledge. Sevinc and Lesh (2022) also suggested that implementation of activities that challenge pre-service teachers' mathematical content and pedagogical knowledge were effective to deepen mathematical understanding of pre-service teachers. Similarly, significant implications for preservice teacher education arise from findings of this study. Student-centered activities and carefully adjusted challenges were purposefully used to plan activities in Mathematics Teaching I and II courses and effects of these activities and challenges were evident at preservice teachers' positive transformation. For instance, student-centered activities in these courses supported preservice teachers to transfer these experiences to their future teaching plans. For instance, traces of the change from teacher centric perspective to learner centered teaching approaches can be observed at participants 42, 85, and 90's drawings. Well-adjusted challenges were also implemented in these college level courses. While mathematical modeling process and various life-related mathematics questions were used to challenge preservice teachers on their mathematical abilities and content knowledge, Bloom's Revised Taxonomy used as a tool for preservice teachers to cognitively analyze various learning goals, questions and mathematics activities to challenge their pedagogical knowledge. Moreover, as it can be seen in metaphors of participants 64, 96, and 56 overcoming these challenges generated positive emotions that could support preservice teachers in increasing their mathematics teaching self-efficacy. Overall teacher educators could use student centered learning approaches such as project based learning or realistic mathematics education and carefully adjusted challenges that focus on mathematical skill such as problem solving and mathematical modeling to create effective undergraduate level mathematics courses that help preservice teachers cope with their mathematics anxiety and increase mathematics teaching self-efficacy beliefs.

This study has two notable limitations. First, all the data gathered for this study is acquired from students of two teaching institutions in Türkiye and although many of the findings in this study could have been generalized to international teaching settings, some of the cultural mathematics teaching in Türkiye might have affected pre-service teachers' prior experiences, since some of them displayed negative perspectives towards mathematics and mathematics teaching even before they chose to participate study. Second, although this study directly explored how preservice teachers' perspective changed, it did not attempt to explore preservice teachers' opinions regarding utilized teaching methodologies in Mathematics Teaching I and II courses. Since preservice teachers are both students and actively acquiring extensive information about teaching, they have a unique perspective that could be used to explore effectiveness of the applied teaching methodologies. Thus, future studies can investigate the effects of college level courses prepared with various educational methodologies on development of preservice teachers' mathematical skills such as mathematical modeling and literacy via exploration of pre-service teachers' experiences. Moreover, studies can be conducted to investigate the effects of college level instructional

courses using various mathematical skills as the theoretical framework on international students' beliefs about mathematics and mathematics teaching.

Although the intervention process of the current study was shown to be effective in decreasing the participants' mathematics anxiety levels, it was clear that a few of the pre-service teachers' perspectives remained largely unaffected. Particularly, two of the preservice teachers displayed strong negative emotional reactions both prior to and following the intervention process. As Brady and Bowd (2005) suggested, preservice teachers' anxiety towards mathematics might well be triggered by previous negative experiences in the classroom, which was evidenced by traumatic experiences portrayed in two of the participants' drawings. These strong negative emotions likely created a resistance towards developing a positive perspective concerning mathematics-related activities. For example, it could clearly be seen in Participant 089's drawing that her fear of implementing mathematical skills transformed to a fear of teaching mathematical concepts. In Participant 060's case, even following the intervention process she defined the teacher as the most important factor in mathematics teaching since she might be believing that teachers have the power to set the emotional ambience of the classroom. The expressions of these two preservice teachers clearly showed that for some students, simply providing additional mathematics courses might not be enough to overcome high levels of anxiety or fear towards mathematics. When we consider how teachers' anxiety or fear towards mathematics could later be transformed to their own students (Furner & Berman, 2005), it becomes imperative for mathematics educators to take into account the psychological state of preservice teachers, and to encourage them to seek the necessary psychological support from the appropriate professionals.

## Declarations

**Conflict of interest** On behalf of all authors, the corresponding author states that there is no conflict of interest.

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