The Effect of TRIZ-Based Science Course Activities on Students' Creative Thinking and Problem-Solving Skills

Fatma Ferhan Bahçuvanoğlu[1] Bünyamin Bavlı[2]

ABSTRACT

This study investigates the impact of TRIZ-based instructional activities implemented in fourth-grade science lessons on students' creative thinking and problem-solving skills. The research employed a quasi-experimental design involving experimental and control groups. The study was conducted with 30 fourth-grade students selected through criterion-based purposive sampling. Sixteen students participated in the experimental group, while fourteen students formed the control group. The Torrance Tests of Creative Thinking and the Problem-Solving Skills Test were used as data collection instruments and were administered as both pre-tests and post-tests. During the intervention process, the experimental group participated in science lessons enriched with TRIZ-based learning activities, whereas the control group continued their instruction according to the existing curriculum. The collected data were analyzed using non-parametric statistical techniques. The Wilcoxon Signed-Rank Test was applied for within-group comparisons, while the Mann–Whitney U Test was used to examine differences between the groups. The findings showed that the experimental and control groups displayed similar levels of creative thinking and problem-solving skills prior to the intervention. However, after the implementation, students in the experimental group demonstrated significantly higher scores in several sub-dimensions of creative thinking as well as in both the sub-dimensions and overall scores of problem-solving skills. No statistically significant improvement was observed in the control group. These results indicate that integrating TRIZ-based activities into science instruction can effectively support the development of students' creative thinking and problem-solving abilities by encouraging the generation of original ideas, flexible thinking, and systematic approaches to solving problems.

©*TUARA Journal*. All rights reserved

Keywords:
TRIZ, creative thinking skill, problem-solving skill, higher-order thinking, primary school

INTRODUCTION

In recent years, the challenges encountered in the field of education have become increasingly complex and multidimensional compared to previous decades, largely due to the rapid pace of technological advancements and the multilayered nature of global transformation. The pervasive integration of digital technologies, robotic systems, artificial intelligence, and nanotechnology into nearly every sphere of life has fundamentally transformed individuals' modes of learning, patterns of social interaction, and the expectations of the labor market. The intensifying competition at the international level requires employees to possess interdisciplinary knowledge as well as higher-order thinking skills such as creative thinking, problem-solving, and innovation. This growing demand places significant pressure on education systems to both adapt to a rapidly evolving world and equip learners with the competencies necessary to navigate the complex professional and social roles of the twenty-first century (Kolokouri, 2025; Thornhill-Miller et al., 2023). These transformative dynamics have revealed the necessity of restructuring education systems in ways that prioritize higher-order thinking and problem-solving skills demanded by contemporary conditions. In this context, educational reforms have sought to align curricula and learning environments with evolving societal and technological needs. These reforms influence not only the aims and content of education but also the nature of learning environments and the characteristics of learners themselves. In today's world, individuals are expected to develop a range of competencies commonly referred to as "21st-century skills" (Güçlü, 2022).

According to *The Future of Jobs Report* published by the World Economic Forum (WEF, 2020), the core competencies expected of individuals include complex problem-solving, analytical and critical thinking, innovation, management and coordination skills, emotional intelligence, judgment and decision-making, service orientation, negotiation, and cognitive flexibility. Similarly, Gray (2016) argues that creative thinking is becoming increasingly central among higher-order cognitive skills and will rank among the top three competencies required in the workforce. Gray emphasizes that in an era characterized by the rapid

[1]fbahcuvanoglu@gmail.com, orcid.org/ 0000-0003-3959-9922
[2]Yildiz Technical University, bbavli@yildiz.edu.tr, orcid.org/ 0000-0002-7274-0935
Bu çalışma, Yıldız Teknik Üniversitesi Sosyal Bilimler Enstitüsü, Eğitim Bilimleri Anabilim Dalı bünyesinde yürütülmekte olan doktora tez çalışmasından üretilmiştir.

diversification of new products, technologies, and modes of work, individuals must enhance their creative capacities in order to effectively respond to and benefit from these ongoing transformations.

Given that many situations individuals encounter in their daily lives in the 21st century require problem-solving, fostering students' problem-solving skills from an early age is considered essential (McMullen et al., 2026). Problem-solving skill is defined as an individual's capacity to generate solutions to a problem situation by effectively employing appropriate cognitive processes, and it plays a decisive role in students' future success (Ngang et al., 2014; Jatmiko et al., 2016; Pandiangan et al., 2017). In the face of the complex and rapidly evolving challenges of the 21st century, teaching children to think creatively and innovatively has become a fundamental objective for educators. Cultivating individuals with strong problem-solving skills is critical not only for students' personal and academic development but also for the advancement of a contemporary and sustainable society. Students' success in this new era is directly associated with the level of 21st-century skills they possess (Rotherham & Willingham, 2009). In this respect, educational processes aim to cultivate individuals who are capable of identifying, analyzing, and developing effective solutions to the problems they may encounter throughout their lives. However, due to the inherently complex and non-linear nature of creativity and innovation, significant challenges arise in fostering these skills in a systematic manner (Suradin, Rasul, & Omar, 2025). At this point, TRIZ (Teoriya Resheniya Izobretatelskikh Zadach—Theory of Inventive Problem Solving) offers a structured framework for equipping children with problem-solving and innovative thinking skills.

TRIZ as Creative Thinking and Problem-Solving Skill

The Theory of Inventive Problem Solving (TRIZ) is a systematic problem-solving framework developed in the 1940s by Genrich Altshuller, grounded in the analysis of evolutionary patterns in technological systems. TRIZ posits that innovation is not a random or purely intuitive process; rather, it can be structured and guided through identifiable principles and patterns. At the core of the theory lie the concepts of ideality, contradictions, and the systems approach. While the pursuit of an ideal final result guides the problem-solving process, contradictions are regarded as the primary driving force of innovation. In this respect, TRIZ offers a comprehensive framework that includes the systematic analysis of underlying contradictions, the utilization of a structured knowledge base composed of solution principles proven effective in prior cases, and strategies designed to help individuals transcend habitual patterns of thinking (Terninko, Zusman, & Zlotin, 1998; Altshuller, 2005). From this perspective, TRIZ asserts that creative problem solving is not merely an innate talent but a process that can be explicitly taught and systematically developed.

By emphasizing the analysis of complex problems, the identification of contradictions, and the generation of inventive solutions, TRIZ enables students to produce innovative ideas through systematic processes rather than relying solely on chance or innate talent. For this reason, educators can employ TRIZ as a means of fostering both problem-solving and creative thinking skills in children from an early age (Schweizer, 2002).

The TRIZ approach comprises a range of systematic tools and techniques designed to support the generation of creative and innovative solutions. Among its core instruments are the 40 inventive principles developed for the systematic resolution of contradictions; the trends of evolution, which enable the analysis of the historical development patterns of technical systems; standard solution models applied to complex problems; and a knowledge base of scientific and engineering effects derived from various disciplines. In addition, TRIZ encompasses functional analysis and substance–field analysis, which enable the structural examination of problems, as well as the nine-window technique, which allows the problem context to be considered across temporal and systemic scales. The approach also includes creativity tools designed to overcome psychological inertia in thinking processes, along with ARIZ (Algorithm for Inventive Problem Solving), a structured procedure developed for addressing complex inventive problems. The systematic application of these tools and techniques frequently facilitates the development of innovative and original solutions (Savransky, 2000).

Although the theoretical foundations and problem-solving tools of TRIZ were initially developed within engineering and technical domains, over time the question of how this approach could be adapted to educational settings gained increasing attention. In this context, the systematic integration of TRIZ thinking tools into instructional processes gave rise to what is known as TRIZ pedagogy. Developed in alignment with the theoretical framework of the Theory of Inventive Problem Solving, TRIZ pedagogy has been implemented in educational contexts since the late 1980s. This approach seeks to foster robust thinking skills, structure

creative thought processes, and enable individuals to generate solutions to complex problems encountered across various domains of life. Grounded in problem-based learning and developmental education principles, TRIZ pedagogy not only presents students with problem situations but also simultaneously equips them with systematic tools and methods for resolving these problems. Such a structure allows the problem-solving process to be conducted in a more conscious, effective, and sustainable manner (Reymov et al., 2021).

TRIZ is fundamentally conceived as an approach aimed at solving inventive problems; however, TRIZ pedagogy maintains that the processes underlying such problem solving are both teachable and learnable. In this respect, it is emphasized that TRIZ can be acquired by individuals of all ages, including children, and that creativity and problem-solving skills can be systematically cultivated through structured thinking tools (Cameron, 2010). This approach facilitates the creation of creative learning environments for both teachers and students, while also supporting the development of innovative practices and technology-enhanced instructional designs in educational settings (Gredynarova, 2017). TRIZ pedagogy draws upon TRIZ-specific tools such as methods for overcoming stereotypical thinking, contradiction-based solution strategies, and inventive problem-solving algorithms. At the same time, it incorporates non-TRIZ methods—including brainstorming, project-based learning (Kiong et al., 2025), and morphological analysis—into the instructional process for pedagogical purposes (Guina & Guina, 2017; Reymov et al., 2021). It has been suggested that TRIZ makes the connection between science and everyday life more visible by enabling students to systematically generate solutions grounded in the application of scientific knowledge, thereby serving as an effective tool for enhancing interest in science education (Schweizer, 2002). In this context, the present study adapted the TRIZ approach to science instruction in order to foster students' problem-solving and creative thinking skills.

Recent studies on the adaptation of the TRIZ methodology to educational contexts have indicated that this approach holds the potential not only to enhance students' problem-solving skills but also to transform the structure of instructional processes. In this regard, Hatting (2025) argues that integrating TRIZ into teaching, learning, and educational management practices can foster systematic creativity and provide a functional framework for generating innovative solutions to educational problems. Similarly, the integration of TRIZ into the STEM curriculum in Malaysia aimed to enhance students' complex problem-solving and design skills, and the implementation was reported to be positively received by both teachers and students (Abdul Rahim & Iqbal, 2021). It is obvious that TRIZ is not merely a method for fostering individual competencies but also an approach capable of contributing to pedagogical transformation at the systemic level. Furthermore, a study conducted with pre-service teachers indicated that systematic creative problem-solving activities led to a statistically significant improvement in creative problem-solving skills (Yolcub & Karamustafaoğlu, 2024). When considered collectively, the studies suggest that TRIZ can yield effective outcomes across different educational levels and diverse learner groups. As a structured and systematic problem-solving approach, it appears to support development at both the student and teacher levels.

An examination of postgraduate theses and scholarly articles conducted in Türkiye in the field of education reveals two master's-level studies focusing on TRIZ: one investigating the integration of the TRIZ method into English language teaching and learning (Abdülkerımelcerbaa, 2023), and the other one exploring the use of TRIZ to enhance students' reading and writing skills in English language education (Alkasem, 2022).

A review of the literature indicates that although TRIZ has been widely implemented in engineering and industrial contexts, studies examining its application in education—particularly at the primary and lower secondary levels—remain limited (Hatting, 2025; Schweizer, 2002). The majority of the existing research has focused on the use of TRIZ in higher education and STEM courses, while systematic investigations into its impact on developing problem-solving and creative thinking skills among students at the basic education level appear to be scarce (Abdul Rahim & Iqbal, 2021; Yolcub & Karamustafaoğlu, 2024). Moreover, the existing literature provides limited comprehensive implementation models and long-term empirical studies that offer guidance on how TRIZ can be effectively integrated into different subject areas, such as science or technology design courses. These gaps highlight the need for further research exploring the potential of TRIZ to enhance primary school students' problem-solving and creativity skills.

In the present study, the activities designed in accordance with TRIZ principles were implemented in a fourth-grade primary school science course, and the effects of this TRIZ-based intervention on students' problem-solving and creative thinking skills were examined. In line with the overarching aim of the study, the following research questions were addressed.

Regarding the Sub-Dimensions of the Torrance Tests of Creative Thinking (TTCT):

1. Is there a statistically significant difference between the pre-test and post-test scores of the experimental group students on the sub-dimensions of the Torrance Tests of Creative Thinking (TTCT)?
2. Is there a statistically significant difference between the pre-test and post-test scores of the control group students on the sub-dimensions of the Torrance Tests of Creative Thinking (TTCT)?
3. Is there a statistically significant difference between the post-test scores of the experimental and control group students on the sub-dimensions of the Torrance Tests of Creative Thinking (TTCT)?

Regarding Problem-Solving Skills:

1. Is there a statistically significant difference between the experimental group students' pre-test and post-test scores on problem-solving skills?
2. Is there a statistically significant difference between the control group students' pre-test and post-test scores on problem-solving skills?
3. Is there a statistically significant difference between the experimental and control group students' post-test scores on problem-solving skills?

METHODS

Research Design

The purpose of this study is to examine the effects of TRIZ-based activities implemented in fourth-grade science instruction on students' problem-solving and creative thinking skills. Given that the random assignment of participants is often not feasible in educational settings, a quasi-experimental design with a pre-test–post-test control group was employed as the quantitative research model. Quasi-experimental designs provide a viable and reliable framework for conducting comparisons in situations where full experimental control cannot be achieved (Büyüköztürk, 2007).

At the outset of the research process, pre-tests were administered to both the experimental and control groups in order to determine their baseline levels prior to the intervention. Subsequently, the TRIZ-based instructional process was implemented only in the experimental group, whereas instruction in the control group was conducted in accordance with the existing curriculum prescribed by the Ministry of National Education. Upon completion of the intervention, post-tests were administered to both groups, and the collected data were compared to evaluate the impact of the TRIZ-based activities. This design enables the objective assessment of changes attributable to the intervention implemented with the students (Creswell, 2012; Fraenkel et al., 2012).

Participants

The study group consisted of fourth-grade students enrolled in a private school. The experimental and control groups were selected from among these students. As the study was designed to be conducted with primary school fourth graders, probability-based sampling methods could not be employed to select units representing the broader population. Instead, the sample was formed based on the researcher's access and the practical conditions of implementation. A purposive sampling method was adopted since it was intended that the sample group possess specific characteristics relevant to the research purpose (Merriam & Tisdell, 2015). Criterion sampling, one of the purposive sampling strategies, was employed to determine the study group. In criterion sampling, participants, events, or situations are selected based on predetermined characteristics directly related to the research problem (Merriam, 2015).

Accordingly, the following criteria were considered in selecting the study group: (a) being enrolled in the fourth grade during the 2024–2025 academic year; (b) regularly attending science classes without attendance-related issues; (c) obtaining parental consent for participation in the study; and (d) voluntarily agreeing to take part in the TRIZ-based instructional activities. Students who met these criteria were included in the study group.The demographic characteristics of the participating students are presented in Table 1.

Table 1. Demographic Information of Participating Students

Group	**N**	**%**
Experimental	16	53.3
Control	14	46.7
Total	30	100.0
Experimental	**N**	**%**
Male	8	50
Female	8	50
Total	16	100.0
Control	**N**	**%**
Male	5	35.7
Female	9	64.3
Total	14	100.0

Table 1 displays the demographic distribution of the students participating in the study across the experimental and control groups. In total, 30 students were included in the research, with 16 (53.3%) assigned to the experimental group and 14 (46.7%) to the control group. Regarding gender distribution, the experimental group consisted of 8 male and 8 female students. The control group included 5 male and 9 female students. As indicated in Table 1, the proportional distribution of genders across both groups appears to be relatively balanced.

Data Collection Procedures

In this study, data were collected within the framework of a pre-test and post-test control group experimental design. In order to conduct the research, official permission was obtained from the Ministry of National Education. Additionally, approval was secured from the relevant institute of the university and its ethics committee. Written consent form was obtained from the parents of the students in both the experimental and control groups prior to participation. Necessary permissions were taken and training procedures were also completed to ensure the proper administration of the measurement instruments used in the study. For the administration of the Torrance Tests of Creative Thinking, the researcher completed the required practitioner training provided by the authorized specialist responsible for the adaptation and implementation of the instrument in Türkiye and obtained official permission for its use. Similarly, necessary permissions were secured from the copyright holders of the Problem-Solving Test, and the relevant training for its administration was completed. The data collection process was conducted in accordance with ethical principles and on a voluntary basis.

The data for the study were obtained using standardized measurement instruments. The experimental and control groups were determined from two existing fourth-grade classes within the school where the research was conducted. Rather than reorganizing students, the intact classrooms were utilized, with one class assigned as the experimental group and the other designated as the control group. Prior to the implementation process, students in both the experimental and control groups were administered the Problem-Solving Skills Test and the Torrance Tests of Creative Thinking (TTCT) as pre-tests. While the TRIZ-based instructional activities specified in Table 2 were implemented in the experimental group, the control group continued with instruction based on the existing curriculum. Following the completion of the intervention, the same measurement instruments were administered to both groups as post-tests. The Torrance Tests of Creative Thinking were selected because they assess key dimensions of creative thinking, such as fluency, originality, and flexibility. The Problem-Solving Skills Test was employed to evaluate students' competencies related to their problem-solving processes.

The data collection process was planned in alignment with the objectives of the study, and all measurement instruments were distributed to both groups under equivalent conditions. The collected data were subsequently organized and prepared for statistical analysis

Table 2. Implementation Schedule of TRIZ Activities

Week 1	Administration of the Pre-test to the Experimental and Control Groups	
Week 2	Introduction to the 40 Inventive Principles of TRIZ	
	Activity No	Activity Title
	Activity 1	Good–Bad Game
	Activity 2	I Take You with Me
Week 3	Activity 3	Yes–No Game
	Activity 4	Volume Detectives and Find the Balance
Week4	Activity 5	TRIZ Connections Game
	Activity 6	Passport Activity
Week 5	Activity 7	Catch the Mistake
	Activity 8	False Alternative
Week 6	Activity 9	Delayed Guess
	Activity 10	Fantastic Guess
Week 7	Activity 11	Ice Experiment
	Activity 12	Find the Correct One, Stay on Track
	Activity 13	System Elevator
	Activity 14	TRIZ Riddles
Week 8	Activity 15	Good–Bad Game
	Activity 16	Yes–No Game
	Activity 17	System Analysis
	Activity 18	Problem Solving with the Contradiction Matrix
Week 9	Activity 19	Performance Task
Week 10	Administration of the Post-test to the Experimental and Control Groups	

As presented in Table 2, during the first week of the research process, pre-tests based on the measurement instruments used in the study were provided to students in both the experimental and control groups. In the second week, the 40 inventive principles of TRIZ were introduced through a variety of learning activities structured in accordance with the students' developmental levels, with the aim of establishing a foundational conceptual understanding of the TRIZ approach. In the subsequent weeks, activities aligned with the TRIZ framework (Ergashev, 2024; Gredynarova, 2017; Savransky, 2000), together with problem-solving tasks grounded in TRIZ thinking tools and the 40 inventive principles, were systematically implemented.

The implemented activities were structured based on the topics and learning outcomes included in the "Properties of Matter" unit of the fourth-grade science curriculum. Accordingly, the activities were aligned with the fundamental concepts of the unit, aiming not only to support students in achieving the intended science learning outcomes but also to enhance their creative thinking and problem-solving skills. TRIZ-based problem situations were designed to be directly connected to the relevant curricular objectives and were holistically integrated into the instructional process. In the 10th week, a TRIZ-based performance task encompassing the overall science learning outcomes was conducted. During the same week, the designated measurement instruments were administered as post-tests, thereby completing the data collection process.

An example of a TRIZ-based activity implemented during the intervention process is presented below.

In the second week of the implementation, a "Yes–No" questioning activity was conducted within the topic of "Properties of Matter" in the 4th-grade science course. In this activity, the teacher selected a specific material or a property of matter without revealing it to the students. The students were asked to identify the

selected item by posing questions that could only be answered with "yes," "no," or "both yes and no." Through this process, students generated systematic and purposeful questions (e.g., whether the material sinks in water, is attracted by a magnet, or absorbs liquids) and progressively narrowed down the problem space based on the teacher's responses. This activity encouraged students to eliminate irrelevant information, focus on key characteristics, and refine their questioning strategies. From a TRIZ pedagogy perspective, the activity is associated with the "Yes–No Trials" technique, which aims to structure the thinking process by narrowing the problem space through controlled questioning. Rather than relying on trial-and-error, students were guided to approach the problem systematically through functional questioning. The evaluation process was primarily process-oriented, focusing on students' abilities to recognize the problem, formulate meaningful questions, make inferences based on given responses, and classify materials according to their properties.

Data Collection Tool

In this study, the Torrance Tests of Creative Thinking and the Problem-Solving Skills Scale were employed to assess students' creative thinking and problem-solving abilities. The Torrance Tests of Creative Thinking (TTCT) were originally developed by E. P. Torrance in 1966. The Problem-Solving Skills Scale was developed by (Aydoğan et al., 2012).

Prior to the commencement of the study, pre-tests were implemented to students in both the experimental and control groups to determine their baseline levels. Instructional designs based on TRIZ methodology were then implemented with the students over an eight-week period. Following the intervention, post-tests were administered to both groups to examine whether a statistically significant difference existed between them.

Data Analysis

The quantitative data obtained from the study were analyzed using the SPSS statistical software package. Descriptive statistics were employed to summarize the data. To determine whether the assumption of normality was met, the Shapiro–Wilk test was conducted, and the results indicated that the data did not follow a normal distribution ($p < .05$). Since the assumptions required for parametric tests were not satisfied, the Wilcoxon Signed-Rank Test was used for comparisons between related (dependent) groups, and the Mann–Whitney U test was employed for comparisons between independent groups. Furthermore, given that the assumptions underlying parametric tests are often not met in studies with small sample sizes, and that non-parametric tests are considered more appropriate in such cases (Can, 2013), non-parametric statistical methods were preferred in the analysis.

Torrance Tests of Creative Thinking (TTCT)

In this study, the Verbal Forms A and B and the Figural Forms A and B of the Torrance Tests of Creative Thinking (TTCT) were used for data collection. Developed by Torrance, the TTCT is one of the most widely utilized instruments for identifying and assessing creativity, particularly in the United States and in many European countries (Sungur, 1997). First published in 1966, the test is applicable to a broad age range, from preschool to university level, and occupies a significant place in the literature due to its direct assessment of creativity. The TTCT consists of two primary components: a verbal section and a figural section. The verbal section comprises seven tasks, including asking questions, identifying causes, predicting consequences, product improvement, unusual uses, unusual questions, and "just suppose" activities.

The figural section consists of three tasks: picture construction, picture completion, and lines activities. The Verbal section consists of seven tasks: Asking Questions, Guessing Causes, Guessing Consequences, Product Improvement, Unusual Uses, Unusual Questions, and Just Suppose**.** The Figural section comprises three tasks: Picture Construction, Picture Completion, and Lines (Form A) / Circles (Form B)**.** The Torrance Tests of Creative Thinking (TTCT) assess several dimensions of creativity that are evaluated across both the Verbal and Figural sections. These dimensions include Fluency (the ability to generate a large number of ideas within a limited time), Flexibility (the ability to produce ideas across different categories), Originality (the capacity to provide unusual and unique responses), Elaboration (the ability to enrich ideas with detailed additions), Abstractness of Titles (the ability to provide higher-level and symbolic titles for drawings), and Resistance to Premature Closure (the tendency to avoid giving quick and superficial closure to incomplete stimuli).

In addition to these norm-referenced criteria, the test includes 13 criterion-referenced sub-dimensions under the Creative Strengths checklist, which evaluate prominent characteristics in individuals' creative thinking processes. These sub-dimensions are classified as Emotional Expressiveness, Storytelling Articulateness, Movement or Action, Expressiveness of Titles, Synthesis of Incomplete Figures, Synthesis of Lines, Unusual Visualization, Internal Visualization, Extending or Breaking Boundaries, Humor, Richness of Imagery, Colorfulness of Imagery, and Fantasy.

By encompassing these multiple sub-dimensions, the TTCT enables the assessment of various aspects of students' creative thinking processes and provides a framework for examining the multidimensional nature of creativity (Aslan, 2001).

Problem-Solving Skills Scale (PSSS)

In this study, the Problem-Solving Skills Scale (PSSS) – Form for Ages 8–11, developed by (Aydoğan et al., 2012) was executed to assess students' problem-solving skills. The scale is a performance-based assessment instrument designed to evaluate children's competencies in the cognitive processes they employ when addressing real-life problem situations. The 8–11 age form of the Problem-Solving Skills Scale (PSSS) consists of a total of 50 items and 10 sub-dimensions. Each sub-dimension represents a specific stage of the problem-solving process and includes five items.

The scale encompasses various components of problem solving, including recognizing the problem, defining the problem, asking questions, predicting possible causes, evaluating the adequacy of available information, identifying problem elements, using objects for different purposes, predicting the consequences of actions, selecting the most appropriate solution, and generating unusual solutions. Different types of response formats are used in the items, including yes–no, yes–no–I don't know, selecting one of three pictures, and choosing among three sentence options. The scoring procedure is based on assigning 1 point for correct responses and 0 points for incorrect responses. The total score obtainable from the scale ranges from 0 to 50, while scores for each sub-dimension range from 0 to 5. During the scale development process, both a pilot study and a nationwide norm study in Türkiye were conducted. The norm study for the 8–11 age group was carried out with 1,879 children from 12 provinces representing different socio-economic regions, based on the NUTS (Nomenclature of Territorial Units for Statistics) 2005 classification used by TÜİK (Turkish Statistical Institute).

The reliability of the PSSS was examined using KR-20 internal consistency and test–retest reliability methods. The results indicated that the internal consistency coefficients for the 8–11 age group were at an acceptable level. In this study, the 8–11 age form of the scale was administered in a group setting, and the original answer keys of the instrument were used for scoring. The scores obtained from the scale were analyzed to evaluate the students' levels of problem-solving skills and to determine the effectiveness of the TRIZ-based instructional process.

Validity and Reliability

In this study, measures appropriate to quantitative research methods were taken to ensure validity and reliability. The research was conducted using a pre-test–post-test control group quasi-experimental design, and the same measurement instruments were administered to both the experimental and control groups before and after the intervention to support internal validity. During the implementation process, TRIZ-based learning activities were carried out in the experimental group, while instruction in the control group continued in accordance with the existing curriculum, and similar implementation conditions were maintained for both groups. To enhance the external validity of the study, the research was conducted within a natural classroom setting. The instructional activities were carried out in various learning environments, including the classroom, the school laboratory, and the school garden.

The activities implemented during the intervention were planned in alignment with the learning outcomes of the science curriculum. During the design process of these activities, the opinions of three curriculum development experts and one science education specialist were consulted.In line with the expert feedback, revisions were made to the conceptual expressions, and the activities were adapted to be appropriate for the students' developmental level.The Torrance Tests of Creative Thinking, operated as a data collection instrument in the study, are standardized measurement tools developed to assess different dimensions of creative thinking, with their validity and reliability demonstrated in numerous previous studies. During the scoring process, students' responses were jointly reviewed with a second researcher who had received the same training in scoring the Torrance tests, and careful attention was given to ensuring scoring consistency.

In cases where discrepancies arose, consensus was reached through discussion to finalize the scores. The reliability of the other measurement instruments used in the study was examined prior to the analysis, and the obtained reliability coefficients were found to be at an acceptable level. The administration of the measurement instruments as both pre-tests and post-tests supported the consistency of the measurements. To determine the reliability of the Torrance Tests of Creative Thinking (TTCT) used in the study, the Cronbach's Alpha coefficient, an indicator of internal consistency, was calculated. Reliability analyses were conducted separately for both the pre-test and post-test data.

The analysis of the pre-test data yielded a Cronbach's Alpha coefficient of $\alpha = .869$, indicating that the scale demonstrated a high level of reliability. The reliability analysis conducted on the post-test data produced a Cronbach's Alpha coefficient of $\alpha = .952$. This finding suggests that the post-test measurements possessed a very high level of internal consistency and that the reliability of the measurement instrument increased further following the implementation process.

Since the obtained Cronbach's Alpha values exceeded .70, the TTCT can be considered a reliable measurement instrument within the scope of this study (Büyüköztürk, 2007). In particular, the high reliability coefficient obtained in the post-test indicates that the instructional process implemented during the study enhanced the consistency of students' responses and strengthened the stability of the measurements.

Ethical Issues

Prior to the commencement of the research process, the necessary approval was obtained from the relevant ethics committee of the university. Following the ethics approval, official research permission was secured from the Ministry of National Education, and authorization was also obtained from the administration of the school where the study was conducted. During the research process, a Parental Consent Form regarding the implementation was provided to the parents of the students in the experimental group, while an Informed Voluntary Consent Form containing information about the study was distributed to the parents of students in the control group, and the necessary written consents were obtained. The parents were clearly informed about the purpose and scope of the study, the implementation process, the voluntary nature of participation, and their right to withdraw from the study at any stage if they wished. Written parental consent was obtained for the participation of students in both groups. Due to a lack of parental consent, one student from the control group was excluded from both the pre-test and post-test assessments.Throughout the research process, the anonymity and privacy of the participants were strictly protected. Students' data were analyzed using coded identifiers, and personal information such as names and surnames was not used at any stage of the study. The collected data were evaluated solely for scientific purposes, were not shared with third parties, and confidentiality was carefully maintained.

During the study, the principles of voluntary participation, non-maleficence, and adherence to ethical standards were upheld. Participants were informed that they could withdraw from the research at any stage without providing any justification.

FINDINGS

To determine whether there was a significant difference between the pre-test and post-test scores of the experimental group students on the sub-dimensions of the Torrance Tests of Creative Thinking, the Wilcoxon Signed-Rank Test was applied, and the findings are presented in Table 3.

Table 3. Results of the Pre-test–Post-test Scores of the Experimental Group Students on the Sub-dimensions of the Torrance Tests of Creative Thinking (TTCT)

Sub-dimensions	Post- test-Pre-test	N	Mean Rank	Sum of Ranks	Z	P
Verbal Fluency	Negative Ranks	0	.00	0	-3.517	<.001
	Positive Ranks	16	8.50	136		
	Ties	0	-	-		
Verbal Flexibility	Negative Ranks	0	.00	0	-3.521	<.001
	Positive Ranks	16	8.50	136		
	Ties	0	-	-		
Verbal Originality	Negative Ranks	2	1.5	3	-3.238	.001
	Positive Ranks	13	9	117		
	Ties	1	-	-		
Figural Fluency	Negative Ranks	13	8.73	113.5	-3.042	.002
	Positive Ranks	2	3.25	6.5		
	Ties	1				
Figural Originality	Negative Ranks	1	2.5	2,5	-1.064	.288
	Positive Ranks	15	8.9	133.5		
	Ties	0				
Abstractness of Titles	Negative Ranks	1	5.5	5.5	-3.235	.001
	Positive Ranks	15	8.7	130.5		
	Ties	0				
Elaboration	Negative Ranks	3	7.33	22	-2.145	.032
	Positive Ranks	11	7.55	83		
	Ties	2				
Resistance to Premature Closure	Negative Ranks	2	7.5	15	-2.194	.028
	Positive Ranks	12	7.5	90		
	Ties	2				
Emotional Expressiveness	Negative Ranks	0	0	0	-3.307	<.001
	Positive Ranks	14	7.5	105		
	Ties	2				
Storytelling Articulateness	Negative Ranks	5	5.8	29	-1.769	.077
	Positive Ranks	10	9,1	91		
	Ties	1				
Movement or Action	Negative Ranks	2	2.5	5	-2.682	.007
	Positive Ranks	10	7.3	73		
	Ties	4				
Expressiveness of Titles	Negative Ranks	3	11	33	-1.543	.123
	Positive Ranks	12	7.25	87		
	Ties	1				
Synthesis of Incomplete Figures	Negative Ranks	0	0	0	-1.414	.157
	Positive Ranks	2	1.5	3		
	Ties	14				
Synthesis of Lines	Negative Ranks	0	0	0	-3.530	<.001
	Positive Ranks	16	8.5	136		
	Ties	0				
Unusual Visualization	Negative Ranks	2	4.5	9	-2.954	.003
	Positive Ranks	13	8.54	111		
	Ties	1				
Internal Visualization	Negative Ranks	8	7.06	56.5	-.255	.799
	Positive Ranks	6	8.08	48.5		
	Ties	2				
Extending or Breaking Boundaries	Negative Ranks	11	9.18	101	-2.332	.020
	Positive Ranks	4	4.75	19		
	Ties	1				
Humor	Negative Ranks	0	0	0	-2.333	.020
	Positive Ranks	6	3.5	21		
	Ties	10				
Richness of Imagery	Negative Ranks	0	0	0	-2.449	.014
	Positive Ranks	6	3.5	21		
	Ties	10				
Colorfulness of Imagery	Negative Ranks	2	3.5	7	-2.556	.011
	Positive Ranks	10	7.1	71		
	Ties	4				
Fantasy	Negative Ranks	3	4.5	13.5	-.707	.480
	Positive Ranks	5	4.5	22.5		
	Ties	8				

The results of the analysis indicate that there were statistically significant differences ($p < .05$) between the pre-test and post-test scores of the students participating in the study in the sub-dimensions of verbal fluency, verbal flexibility, verbal originality, figural fluency, abstractness of titles, elaboration, resistance to premature closure, emotional expressiveness, movement or action, synthesis of lines, unusual visualization, extending or breaking boundaries, humor, richness of imagery, and colorfulness of imagery. When the mean ranks and the sums of ranks of the difference scores are considered, it is evident that the observed differences are in favor of the positive ranks, that is, in favor of the post-test scores.

When the mean ranks and sums of ranks of the difference scores are examined, it is evident that this significant difference favors the positive ranks; in other words, students' post-test scores increased significantly compared to their pre-test scores. These results suggest that the TRIZ-integrated instructional framework significantly enhanced students' creative thinking proficiencies throughout the experimental intervention. In particular, the increase observed in favor of the post-test suggests that the intervention supported students' creative thinking processes and positively influenced their creative performance.

The results of the analysis conducted to determine the differences between the pre-test and post-test scores of the control group students on the sub-dimensions of the Torrance Tests of Creative Thinking are presented in Table 4.

Table 4. Results of the Pre-test–Post-test Scores of the Control Group Students on the Sub-dimensions of the Torrance Tests of Creative Thinking (TTCT)

Sub-dimensions	Post- test-Pre-test	N	Mean Rank	Sum of Ranks	Z	P
Verbal Fluency	Negative Ranks	7	8.5	59.5	-1.609	.108
	Positive Ranks	5	3.7	18.5		
	Ties	2				
Verbal Flexibility	Negative Ranks	9	7.78	70	-1.101	.271
	Positive Ranks	5	7	35		
	Ties	0				
Verbal Originality	Negative Ranks	11	7.77	85.5	-2.801	.005
	Positive Ranks	2	2.75	5.5		
	Ties	1				
Figural Fluency	Negative Ranks	9	9.72	87.5	-2.199	.028
	Positive Ranks	5	3.5	17.5		
	Ties	0				
Figural Originality	Negative Ranks	8	7.94	63.5	-1.927	.054
	Positive Ranks	4	3.63	14.5		
	Ties	2				
Abstractness of Titles	Negative Ranks	5	8.4	42	-.246	.805
	Positive Ranks	8	6.13	49		
	Ties	1				
Elaboration	Negative Ranks	8	6.75	54	-1.891	.059
	Positive Ranks	3	4	12		
	Ties	3				
Resistance to Premature Closure	Negative Ranks	6	5.5	33	-.564	.573
	Positive Ranks	4	5.5	22		
	Ties	4				
Emotional Expressiveness	Negative Ranks	7	7.57	53	-.529	.597
	Positive Ranks	6	6.33	38		
	Ties	1				
Storytelling Articulateness	Negative Ranks	5	6.6	33	.000	1.000
	Positive Ranks	6	5.5	33		
	Ties	3				
Movement or Action	Negative Ranks	8	6.38	51	-.053	.341
	Positive Ranks	4	6.75	27		
	Ties	2				
Expressiveness of Titles	Negative Ranks	14			-1.198	.231
	Positive Ranks	8	6.75	54		
	Ties	4	6	24		
Synthesis of Incomplete Figures	Negative Ranks	2			.000	1.000
	Positive Ranks	0	0	0		
	Ties	0	0	0		
Synthesis of Lines	Negative Ranks	14			-2.871	.004
	Positive Ranks	0	0	0		
	Ties	10	5.5	55		
Unusual Visualization	Negative Ranks	4			-1.642	.101
	Positive Ranks	7	6.14	43		
	Ties	3	4	12		
Internal Visualization	Negative Ranks	4			-2.923	.003
	Positive Ranks	11	7.91	87		
	Ties	2	2	4		
Extending or Breaking Boundaries	Negative Ranks	1			-2.766	.006
	Positive Ranks	11	7.73	85		
	Ties	2	3	6		
Humor	Negative Ranks	1			1.000	.317
	Positive Ranks	1	1	1		
	Ties	0	0	0		
Richness of Imagery	Negative Ranks	13			.000	1.000
	Positive Ranks	0	0	0		
	Ties	0	0	0		
Colorfulness of Imagery	Negative Ranks	14			-.265	.791
	Positive Ranks	5	6	30		
	Ties	5	5	25		
Fantasy	Negative Ranks	4			-1.414	.157
	Positive Ranks	2	1.5	3		
	Ties	0	0	0		

The results of the Wilcoxon Signed-Rank Test examining whether there was a difference between the mean pre-test and post-test scores of the control group students are presented in Table 4. The results indicate that there were statistically significant differences ($p < .05$) between the pre-test and post-test scores in several TTCT sub-dimensions, including verbal originality, figural fluency, synthesis of lines, internal visualization, and extending or breaking boundaries. When the mean ranks and sums of ranks of the difference scores are considered, the observed differences appear to favor the negative ranks, that is, the pre-test scores.

The statistical analysis results comparing the pre-test and post-test scores of the students in the experimental and control groups on the sub-dimensions of the Torrance Tests of Creative Thinking are presented in Table 5.

Table 5. Statistical Results of the Pre-test and Post-test Scores of the Experimental and Control Group Students on the Sub-dimensions of the TTCT

Sub-dimensions	Test	Group	N	Mean Rank	Sum of Ranks	U	p
Verbal Fluency	Pre-test	Experimental	16	17.59	281.5	78.500	.163
		Control	14	13.11	183.5		
	Post-test	Experimental	16	21.94	351	9.000	<.001
		Control	14	8.14	114		
Verbal Flexibility	Pre-test	Experimental	16	17.81	285	75.000	.123
		Control	14	12.86	180		
	Post-test	Experimental	16	22.44	359	1.000	<.001
		Control	14	7.57	106		
Verbal Originality	Pre-test	Experimental	16	17.19	275	85.000	.261
		Control	14	13.57	190		
	Post-test	Experimental	16	22.31	357	3.000	<.001
		Control	14	7.71	108		
Figural Fluency	Pre-test	Experimental	16	16.09	257.5	102.500	.692
		Control	14	14.82	207.5		
	Post-test	Experimental	16	16.31	261	99.000	.587
		Control	14	14,57	204		
Figural Originality	Pre-test	Experimental	16	14,78	237.00	100.500	.630
		Control	14	16,32	228.00		
	Post-test	Experimental	16	18,69	299	61.000	.033
		Control	14	11,86	166		
Abstractness of Titles	Pre-test	Experimental	16	15.34	245.50	109.500	.917
		Control	14	15.68	219.50		
	Post-test	Experimental	16	21.66	346.5	13.500	<.001
		Control	14	8.46	118.5		
Elaboration	Pre-test	Experimental	16	15.44	247	111.000	.966
		Control	14	15.57	218		
	Post-test	Experimental	16	19.34	309.5	50.500	.010
		Control	14	11.11	155.5		
Resistance to Premature Closure	Pre-test	Experimental	16	15.63	250	110.000	.932
		Control	14	15.36	215		
	Post-test	Experimental	16	19.31	309	51.000	.011
		Control	14	11.14	156		
Emotional Expressiveness	Pre-test	Experimental	16	16.88	270	90.000	.357
		Control	14	13.93	195		
	Post-test	Experimental	16	21.38	342	18.000	<.001
		Control	14	8.79	123		
Storytelling Articulateness	Pre-test	Experimental	16	16.44	263	97.500	.524
		Control	14	14.43	202		
	Post-test	Experimental	16	20.09	321.5	38.500	.002
		Control	14	10.25	143.5		
Movement or Action	Pre-test	Experimental	16	17.22	275.5	84.500	.237
		Control	14	13.54	189.5		
	Post-test	Experimental	16	20.5	328	32.000	<.001
		Control	14	9.79	137		

Expressiveness of Titles	Pre-test	Experimental	16	14.16	226.5	90.500	.344
		Control	14	17.04	238.5		
	Post-test	Experimental	16	18.31	293	67.000	.053
		Control	14	12.29	172		
Synthesis of Incomplete Figures	Pre-test	Experimental	16	15.5	248	112.000	1.000
		Control	14	15.5	217		
	Post-test	Experimental	16	16.38	262	98.000	.178
		Control	14	14.5	203		
Synthesis of Lines	Pre-test	Experimental	16	15.5	248	112.000	1.000
		Control	14	15.5	217		
	Post-test	Experimental	16	20.13	322	38.000	.002
		Control	14	10.21	143		
Unusual Visualization	Pre-test	Experimental	16	12.31	197	61.000	.029
		Control	14	19.14	268		
	Post-test	Experimental	16	18.66	298.5	61.500	.029
		Control	14	11.89	166.5		
Internal Visualization	Pre-test	Experimental	16	13.13	210	74.000	.108
		Control	14	18.21	255		
	Post-test	Experimental	16	18.56	297	63.000	.036
		Control	14	12	168		
Extending or Breaking Boundaries	Pre-test	Experimental	16	16.28	260.5	99.500	.601
		Control	14	14.61	204.5		
	Post-test	Experimental	16	17.81	285	75.000	.122
		Control	14	12.86	180		
Humor	Pre-test	Experimental	16	15	240	104.000	.285
		Control	14	16.07	225		
	Post-test	Experimental	16	18.13	290	70.000	.012
		Control	14	12.5	175		
Richness of Imagery	Pre-test	Experimental	16	16.38	262	98.000	.178
		Control	14	14.5	203		
	Post-test	Experimental	16	19	304	56.000	.002
		Control	14	11.5	161		
Colorfulness of Imagery	Pre-test	Experimental	16	14.22	227.5	91.500	.374
		Control	14	16.96	237.5		
	Post-test	Experimental	16	18.56	297	63.000	.033
		Control	14	12	168		
Fantasy	Pre-test	Experimental	16	16.75	268	92.000	.259
		Control	14	14.07	197		
	Post-test	Experimental	16	18.56	297	63.000	.006
		Control	14	12	168		

According to Table 5, no statistically significant differences were found between the pre-test scores of the experimental and control groups in terms of the sub-dimensions of creative thinking ($p > .05$). This indicates that the groups were comparable with respect to the relevant variables prior to the intervention. However, when the post-test results were examined, statistically significant differences were observed in favor of the experimental group in the sub-dimensions of, verbal flexibility, verbal fluency ,verbal originality, figural originality, abstractness of titles,emotional expressiveness, elaboration, resistance to premature closure, storytelling articulateness, movement or action, synthesis of lines, internal visualization, humor, richness of imagery, colorfulness of imagery, and fantasy ($p < .05$). In contrast, no statistically significant differences were detected in the post-test scores for the sub-dimensions of figural fluency, expressiveness of titles, synthesis of incomplete figures, and extending or breaking boundaries ($p > .05$).

The results of the Wilcoxon Signed-Rank Test conducted to determine the differences between the pre-test and post-test scores of the experimental group students on the sub-dimensions of the Problem-Solving Skills Test are presented in Table 6.

Table 6. Wilcoxon Signed-Rank Test Results for the Pre-test–Post-test Scores of the Experimental Group Students on the Sub-dimensions of the Problem-Solving Skills Test

Sub-dimensions	Post-test-Pre-test	N	Mean Rank	Sum of Ranks	Z	P
Recognizing the Problem	Negative Ranks	0	0	0	-3.580	.000
	Positive Ranks	16	8.5	136		
	Ties	0				
Defining the Problem	Negative Ranks	0	0	0	-2.232	.026
	Positive Ranks	6	3.5	21		
	Ties	10				
Asking Questions about the Problem	Negative Ranks	0	0	0	-1.633	.102
	Positive Ranks	3	2	6		
	Ties	13				
Predicting the Causes of the Problem	Negative Ranks	0	0	0	-2.970	.003
	Positive Ranks	10	5.5	55		
	Ties	6				
Evaluating the Adequacy of Information for the Solution	Negative Ranks	0	0	0	-3.359	.001
	Positive Ranks	13	7	91		
	Ties	3				
Identifying the Elements of the Problem	Negative Ranks	0	0	0	-3.286	.001
	Positive Ranks	13	7	91		
	Ties	3				
Using Objects in Unconventional Ways	Negative Ranks	0	0	0	-3.134	.002
	Positive Ranks	12	6.5	78		
	Ties	4				
Predicting the Consequences of Actions	Negative Ranks	1	3.5	3.5	-2.126	.033
	Positive Ranks	7	4.64	32.5		
	Ties	8				
Identifying the Most Appropriate Solution	Negative Ranks	1	3	3	-2.373	0.018
	Positive Ranks	8	5.25	42		
	Ties	7				
Selecting the Most Unusual Solution among Possible Alternatives	Negative Ranks	0	0	0	-3.547	0
	Positive Ranks	16	8.5	136		
	Ties	0				
Total Score	Negative Ranks	0	0	0	-3.524	0
	Positive Ranks	16	8.5	136		
	Ties	0				

In Table 6, the differences between the pre-test and post-test scores of the experimental group students on the sub-dimensions of problem-solving skills were examined using the Wilcoxon Signed-Rank Test. The

findings indicate that there was a significant increase in favor of the post-test scores in overall problem-solving skills and in the majority of its sub-dimensions. In the sub-dimension of recognizing the problem, all students' post-test scores were higher than their pre-test scores, with no negative ranks or tied values observed (Z = -3.580). This finding suggests that the implementation process substantially improved students' ability to recognize problems. Similarly, in the sub-dimension of defining the problem, positive ranks exceeded negative ranks, indicating improvement among a considerable number of students (Z = -2.232). In the sub-dimension of asking questions about the problem, an increase in favor of the post-test was also observed; although the number of tied scores was relatively high, the presence of positive ranks indicates that students demonstrated progress in this skill (Z = -1.633). Regarding the sub-dimension of predicting problem causes, the data is characterized by a total absence of negative ranks and a clear preponderance of positive ranks (Z = -2.970). Significant increases in post-test scores were also observed in the sub-dimensions of evaluating the adequacy of information required for the solution and identifying the elements of the problem (Z = -3.359; Z = -3.286). These results display that students improved their abilities to evaluate relevant information and identify the components of a problem during the problem-solving process. In the sub-dimension of using objects in ways different from their conventional purposes, a significant difference was found in favor of the post-test (Z = -3.134), suggesting that students' creative and flexible thinking abilities were supported. Although a small number of negative ranks were observed in the sub-dimensions of predicting the consequences of actions and identifying the most appropriate solution, the predominance of positive ranks indicates improvement in favor of the post-test scores (Z = -2.126; Z = -2.373). Data analysis for the sub-dimension of alternative solution selection revealed no negative ranks, as all participants demonstrated higher performance in the post-test phase compared to the pre-test (Z = -3.547). This result demonstrates that the intervention had a strong impact on students' ability to generate original and creative solutions. Finally, when the total scores of problem-solving skills were examined, all students' post-test scores were higher than their pre-test scores, and this difference was statistically significant (Z = -3.524). The present finding indicates that the TRIZ-based activities implemented in the experimental group significantly improved students' overall problem-solving skills.

The results of the Wilcoxon Signed-Rank Test conducted to determine the differences between the pre-test and post-test scores of the control group students on the sub-dimensions of the Problem-Solving Skills Test are presented in Table 7.

Table 7. Wilcoxon Signed-Rank Test Results for the Pre-test and Post-test Scores of the Problem-Solving Test Sub-dimensions of the Control Group

Sub-dimensions	Post test-Pre-test	N	Mean Rank	Sum of Ranks	Z	P
Recognizing the Problem	Negative Ranks	4	7	28	-.464	.642
	Positive Ranks	7	5.43	38		
	Ties	3				
Defining the Problem	Negative Ranks	0	0	0	-1.732	.083
	Positive Ranks	3	2	6		
	Ties	11				
Asking Questions about the Problem	Negative Ranks	4	4.38	17.5	-.632	.527
	Positive Ranks	3	3.5	10.5		
	Ties	7				
Predicting the Causes of the Problem	Negative Ranks	2	3	6	-1.000	.317
	Positive Ranks	4	3.75	15		
	Ties	8				

Evaluating the Adequacy of Information for the Solution	Negative Ranks	4	4	16	-.812	.417
	Positive Ranks	5	5.8	29		
	Ties	5				
Identifying the Elements of the Problem	Negative Ranks	5	4.9	24.5	-.933	.351
	Positive Ranks	3	3.83	11.5		
	Ties	6				
Using Objects in Unconventional Ways	Negative Ranks	2	5.25	10.5	-1.461	.144
	Positive Ranks	7	4.93	34.5		
	Ties	5				
Predicting the Consequences of Actions	Negative Ranks	0	0	0	-1.414	.157
	Positive Ranks	2	1.5	3		
	Ties	12				
Identifying the Most Appropriate Solution	Negative Ranks	3	4	12	-.378	.705
	Positive Ranks	4	4	16		
	Ties	7				
Selecting the Most Unusual Solution among Possible Alternatives	Negative Ranks	3	10.67	32	-.562	.574
	Positive Ranks	9	5.11	46		
	Ties	2				
Total Score	Negative Ranks	4	7.13	28.5	-1.199	.230

In Table 7, the differences between the pre-test and post-test scores of the control group students on the sub-dimensions of problem-solving skills were examined using the Wilcoxon Signed-Rank Test. The findings indicate that there were no statistically significant differences between the pre-test and post-test scores in the control group in terms of the sub-dimensions or the total score of problem-solving skills ($p > .05$). Analysis of the problem recognition sub-dimension revealed a balanced distribution of positive and negative ranks; consequently, the test result was not statistically significant ($Z = -.464$, $p = .642$). Similarly, although a limited increase in favor of the post-test was observed in the sub-dimension of defining the problem, this difference did not reach statistical significance ($Z = -1.732$, $p = .083$). In the sub-dimension of asking questions about the problem, the positive and negative ranks were balanced, indicating that there was no significant change between the pre-test and post-test scores ($Z = -.632$, $p = .527$). While a higher frequency of positive ranks was observed within the sub-dimension of predicting the causes of the problem, this distribution was statistically non-significant ($Z = -1.000$, $p = .317$). In the sub-dimensions of evaluating the adequacy of information for the solution and identifying the elements of the problem, slight increases in favor of the post-test were observed; however, these increases were not statistically significant ($Z = -.812$, $p = .417$; $Z = -.933$, $p = .351$). In the sub-dimension of using objects in ways different from their conventional purposes, although positive ranks were more frequent, the test result was not statistically significant ($Z = -1.461$, $p = .144$). Regarding the sub-dimension of predicting consequences, most participants demonstrated no shift in performance between testing phases. Although two students showed progress in the post-test, the overall discrepancy failed to reach statistical significance ($Z = -1.414$, $p = .157$). In a similar vein, no statistically significant differences were found between the pre-test and post-test scores in the sub-dimensions of identifying the most appropriate solution and selecting the most unusual solution among multiple possible

alternatives (Z = -.378, p = .705; Z = -.562, p = .574). When the total scores of problem-solving skills were examined, no statistically significant difference was found between the pre-test and post-test scores in the control group (Z = -1.199, p = .230). This result indicates that no significant improvement occurred in the sub-dimensions or overall level of problem-solving skills in the control group during the implementation process.

The results of the Mann–Whitney U Test conducted to determine the differences between the post-test scores of the experimental and control groups on the Problem-Solving Skills Scale are presented in Table 8.

Table 8. Mann-Whitney U Test Results for Final Test Scores on the Problem-Solving Scale for the Experimental and Control Groups

Sub-dimensions	Group	N	X	ss	Mean Rank	Sum of Ranks	U	p
Recognizing the Problem	Experimental	16	4.88	0.34	19.81	317	43.000	.001
	Control	14	4.00	.88	10.57	148		
Defining the Problem	Experimental	16	5	0	15.5	248	112.000	1.000
	Control	14	5.00	.00	15.5	217		
Asking Questions about the Problem	Experimental	16	4.88	.34	16.75	268	92.000	.233
	Control	14	4.57	.76	14.07	197		
Predicting the Causes of the Problem	Experimental	16	4.88	.34	17.81	285	75.000	.047
	Control	14	4.36	.84	12.86	180		
Evaluating the Adequacy of Information for the Solution	Experimental	16	4.81	.40	19.78	316.5	43.500	.002
	Control	14	3.93	.83	10.61	148.5		
Identifying the Elements of the Problem	Experimental	16	4.94	.25	21.19	339	21.000	.000
	Control	14	3.79	.80	9	126		
Using Objects in Unconventional Ways	Experimental	16	4.44	.73	19.56	313	47	.005
	Control	14	3.43	.94	10.86	152		
Predicting the Consequences of Actions	Experimental	16	4.94	.25	17.63	282	78.000	.043
	Control	14	4.50	.76	13.07	183		
Identifying the Most Appropriate Solution	Experimental	16	4.63	.50	20.13	322	38.000	.001
	Control	14	3.71	.73	10.21	143		
Selecting the Most Unusual Solution among Possible Alternatives	Experimental	16	4.63	.72	19.38	310	50.000	.005
	Control	14	3.14	1.66	11.07	155		
Total Score	Experimental	16	48	2.13	22.25	356	4.000	.000
	Control	14	40.43	3.57	7.79	109		

In Table 8, the post-test scores of the experimental and control groups on the problem-solving scale were compared using the Mann–Whitney U test. The findings indicate statistically significant differences in favor of the experimental group in the total problem-solving score and in most of its sub-dimensions. In the sub-dimension of recognizing the problem, the mean rank of the experimental group was significantly higher than that of the control group (U = 43.000, p = .001). This result suggests that students in the experimental group demonstrated more advanced skills in identifying and recognizing problems compared to those in the control group. In contrast, in the sub-dimension of defining the problem, the mean ranks of the experimental and control groups were equal, and no statistically significant difference was found between the groups (U = 112.000, p = 1.000).

Although the experimental group had higher mean scores in the sub-dimension of asking questions about the problem, the difference between the groups was not statistically significant (U = 92.000, p = .233). However, a significant difference in favor of the experimental group was found in the sub-dimension of

predicting the causes of the problem (U = 75.000, p = .047). This finding shows that students in the experimental group developed stronger abilities to analyze problem situations and establish cause–effect relationships. In the sub-dimension of evaluating the adequacy of information required for the solution, the mean rank of the experimental group was significantly higher than that of the control group (U = 43.500, p = .002). Likewise, a strong statistically significant difference was found in favor of the experimental group in the sub-dimension of identifying the elements of the problem (U = 21.000, p < .001). These results reveal that the instructional process implemented in the experimental group supported students' abilities to structure the problem-solving process and analyze problems by identifying their components.

A significant difference in favor of the experimental group was also found in the sub-dimension of using objects in ways different from their conventional purposes (U = 47.000, p = .005). This finding demonstrates that the students in the experimental group developed higher levels of creative and flexible thinking compared to those in the control group. A significant difference was also identified in favor of the experimental group in the sub-dimension of predicting the consequences of actions (U = 78.000, p = .043). Analysis of the sub-dimension for selecting the most appropriate solution revealed that the experimental group significantly outperformed the control group (U = 38.000, p = .001). By the same token, a significant difference was found in favor of the experimental group in the sub-dimension of selecting the most unusual solution among multiple possible alternatives (U = 50.000, p = .005). The findings indicate that participants in the experimental group not only refined their ability to identify optimal solutions but also cultivated a propensity for selecting original and creative alternatives.

Total scores of problem-solving skills display that the experimental group had statistically significantly higher scores than the control group (U = 4.000, p < .001). This finding demonstrates that the TRIZ-based activities implemented in the experimental group significantly improved students' overall problem-solving skills.

DISCUSSION, CONCLUSION and SUGGESTIONS

In this study, the effects of TRIZ-based instructional activities on primary school students' creative thinking skills were examined. The findings indicated that the intervention led to significant improvements in several sub-dimensions of creative thinking within the experimental group. In particular, statistically significant increases were observed in favor of the experimental group in the dimensions of verbal fluency, flexibility, originality, abstractness of titles, elaboration, resistance to premature closure, and imagination. However, no statistically significant improvement was observed in some sub-dimensions of creative thinking. When the findings are examined, it is evident that creativity is not a unidimensional construct but rather a multidimensional one. As emphasized by Torrance, relying on a single total score in assessing creativity may be misleading, and each sub-dimension carries its own distinct meaning. In this regard, it is expected that different dimensions of creativity may be influenced by instructional processes at varying levels and may develop differently from one another.

Furthermore, the multidimensional structure of the test allows for the identification of individuals' specific strengths and weaknesses in creativity. This also indicates that individuals may differ not only in their overall level of creativity but also in their creative styles. Supporting this view, findings in the literature suggest that multidimensional measurement models provide a better fit to the data compared to unidimensional models and support the validity of creativity as a multidimensional construct (Hu & Bentler, 1999).

In contrast, no systematic or comprehensive improvement in creative thinking skills was observed in the control group. Comparisons between the groups also revealed statistically significant differences in favor of the experimental group following the intervention.

Overall, the findings indicate that TRIZ-based activities are effective in enhancing primary school students' creative thinking skills. This result suggests that structured and systematic problem-solving approaches can support the development of creative thinking processes from an early age. The findings related to problem-solving skills revealed that the experimental group demonstrated significant improvement both in the sub-dimensions and in the total problem-solving score. Comparisons of the experimental group's pre-test and post-test results showed statistically significant increases in favor of the post-test in the abilities of recognizing the problem, defining the problem, asking questions about the problem, predicting the causes of the problem, evaluating the adequacy of information needed for the solution, identifying the elements of the problem, using objects in ways different from their conventional uses, predicting the consequences of actions,

selecting the most appropriate solution, and choosing the most unusual solution among multiple possible alternatives. The experimental group exhibited a statistically significant improvement in overall problem-solving performance. Conversely, the control group demonstrated no statistically significant variance between pre-test and post-test assessments, either within individual sub-dimensions or in the total composite score. This finding indicates that the instructional process implemented in the control group had a limited effect on the development of problem-solving skills. When the post-test scores of the experimental and control groups were compared, statistically significant differences were found in favor of the experimental group in the dimensions of recognizing the problem, predicting the causes of the problem, evaluating the adequacy of information for the solution, identifying the elements of the problem, using objects in unconventional ways, predicting the consequences of actions, identifying the most appropriate solution, selecting unusual solutions, and the total problem-solving score. Yet, no significant differences were observed between the groups in the sub-dimensions of defining the problem and asking questions about the problem. Taken together, the overall results of the study demonstrate that TRIZ-based instructional practices significantly and multidimensionally enhance students' creative thinking and problem-solving skills. These findings suggest that TRIZ constitutes an effective pedagogical approach that actively engages students, promotes systematic thinking, and addresses creative problem-solving processes in a comprehensive manner.

The related literature generally indicates a positive trend regarding the effects of TRIZ-based instructional practices on students' creative thinking and problem-solving skills. In particular, studies conducted with primary school and gifted students reported that structured TRIZ programs significantly improve creativity and problem-solving performance (Lee & Kim, 2023; Ayasrah, 2015). In these studies, no significant differences were detected between the experimental and control groups prior to the intervention; however, the differences that emerged in favor of the experimental group after the implementation suggest that the systematic structure of TRIZ in organizing thinking processes is effective. In a similar vein, TRIZ applications integrated with STEM at the secondary school level were reported to support problem-solving, creative thinking, and 21st-century skills (Orhan, 2025). Nevertheless, some studies indicated that the effects on cognitive skills may remain limited, while positive developments were observed in students' attitudes and perceptions toward the related disciplines (Çavdar et al., 2024). This suggests that the effectiveness of TRIZ-based applications may vary depending on factors such as the duration of the intervention, the type of targeted skills (cognitive or affective), sample characteristics, and the level of structure in the instructional design. In addition, findings indicating that problem-based learning supported by structured tools enhances creative and analytical thinking skills more effectively (Simanjuntak et al., 2021) also provide theoretical support for the pedagogical value of TRIZ. Furthermore, recent studies showing that TRIZ can foster creative thinking not only in science or STEM fields but also in verbal disciplines (Zhapisheva et al., 2025) demonstrate the interdisciplinary applicability of the method. In this context, the findings of the present study are consistent with the existing literature by demonstrating the positive effects of TRIZ-based activities on creative thinking sub-dimensions and problem-solving skills, particularly at the primary school level, and they highlight the importance of implementing structured creative problem-solving models at early ages.

Suggestions

Based on the findings of this study, the following recommendations are presented:

- TRIZ-based instruction appears to support the development of primary school students' creative thinking and problem-solving skills.
- In order to ensure the systematic and sustainable implementation of this approach, it is recommended that structured in-service training programs be developed for teachers.
- Integrating TRIZ into primary school curricula through pedagogical adaptations—extending beyond science education to include interdisciplinary applications in subjects such as mathematics, Turkish language, and social studies—also aligns with the Türkiye Century Education Model, which emphasizes higher-order thinking and productivity skills.
- The findings indicate that, when appropriately adapted, the teaching of TRIZ principles at early ages is both feasible and effective.
- The results also suggest that designing activities tailored to learners with different initial ability levels may be beneficial.

- Furthermore, to enhance the generalizability of the findings, future research should be conducted with larger samples and across diverse socioeconomic contexts.
- In addition, longitudinal studies should be designed to examine the sustainability and long-term effects of TRIZ-based instructional practices.

Limitations of the Study

This study has several limitations. First, the research was conducted with a limited number of fourth-grade students from a single primary school; therefore, the findings cannot be generalized to all primary school students or to different grade levels. Second, the study was limited to creative thinking and problem-solving skills, while other cognitive, affective, and academic variables that could be examined at the primary school level were excluded from the scope of the research. In addition, the implementation period was limited to a specific time frame, and considering the continuity of developmental processes during the primary school years, longer-term implementations may yield different results. Finally, the findings are limited by the scope of the measurement instruments used in the study.

Conflict of Interest

No potential conflicts of interest were disclosed by the author(s) with respect to the research, authorship, or publication of this article.

Ethics Approval

The formal ethics approval was granted by the Social and Human Sciences Research and Publication Ethics Committee of Yildiz Technical University. We conducted the study in accordance with the Helsinki Declaration in 1975.

Funding

No specific grant was given to this research by funding organizations in the public, commercial, or not-for-profit sectors.

Research and Publication Ethics Statement

The study was approved by the research team's university ethics committee of the Yildiz Technical University (Approval Number/ID: 05/01/2025/2025-01. Hereby, we as the authors consciously assure that for the manuscript the following is fulfilled:

- This material is the authors' own original work, which has not been previously published elsewhere.
- The paper reflects the authors' own research and analysis in a truthful and complete manner.
- The results are appropriately placed in the context of prior and existing research.
- All sources used are properly disclosed.

Acknowledgement

This article was derived from the doctoral dissertation conducted at the Institute of Social Sciences of Yıldız Technical University under the supervision of Assoc. Prof. Dr. Bünyamin Bavlı. The dissertation examined the effects of TRIZ-based instructional practices on primary school students' creative thinking and problem-solving skills.

Contribution Rates of Authors to the Article

1st author contributed 50%, 2nd author 50%.

REFERENCES

Abdul Rahim, Z., & Iqbal, M. S. (2021). The adoption of the theory of inventive problem solving (TRIZ) in the Malaysia education policy and curriculum for STEM subject. *ASEAN Journal of Engineering Education, 4*(2). https://doi.org/10.11113/ajee2020.4n2.11

Abdülkerimelcerbaa, R. (2023). *The integration of TRIZ method in English language teaching and learning* [Master's thesis, Gaziantep University].

Alkaseem, B. (2022). *TRIZ as an innovative method in English language teaching to support learners' reading and writing skills* [Master's thesis, Gaziantep University].

Altshuller, G. (2005). *And suddenly the inventor appeared: TRIZ, the theory of inventive problem solving.* Technical Innovation Center.

Aslan, E. (2001). The Turkish version of the Torrance Test of Creative Thinking [Torrance Yaratıcı Düşünce

Testi'nin Türkçe versiyonu]. *M.Ü. Atatürk Eğitim Fakültesi Eğitim Bilimleri Dergisi, 14*, 19–40. https://izlik.org/JA67XC88NG

Ayasrah, S. M. M. (2015). The effect of a developed program based on the theory of inventive problem solving (TRIZ) on the development of creativity and innovation among gifted and talented students in Jordan. *International Journal for Talent Development, 6*(2).

Aydoğan, Y., Ömeroğlu, E., Büyüköztürk, Ş., & Özyürek, A. (2012). *Problem solving skills scale (ages 8–11)* [Problem çözme becerileri ölçeği (8–11 yaş)]. Koza Yayın Dağıtım.

Aydoğan, Y., Ömeroğlu, E., Büyüköztürk, Ş., & Özyürek, A. (2012). *Problem solving skills scale guidebook* [Problem çözme becerileri ölçeği rehber kitap]. Koza Yayın Dağıtım.

Büyüköztürk, Ş. (2007). *Data analysis handbook for social sciences* (8th ed.) [Sosyal bilimler için veri analizi el kitabı (8. baskı)]. Pegem Akademi.

Cameron, G. (2010). *Trizics: Teach yourself TRIZ, how to invent, innovate and solve "impossible" technical problems*. Trizics.

Can, A. (2013). *Quantitative data analysis in the scientific research process with SPSS* [SPSS ile bilimsel araştırma sürecinde nicel veri analizi]. Pegem Akademi.

Creswell, J. W. (2012). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research.* Pearson.

Çavdar, O., Yıldırım, B., Kaya, E., & Akkuş, A. (2024). Exploring the nanoworld: Middle school students use TRIZ–STEM in nanotechnology education. *Journal of Chemical Education, 101*(3), 1049–1061. https://doi.org/10.1021/acs.jchemed.3c01031

Ergashev, J. M. (2024). Using TRIZ technology techniques in primary school. *Science and Innovation, 3*(1). https://doi.org/10.5281/zenodo.10562730

Fraenkel, J., Wallen, N., & Hyun, H. H. (2012). *How to design and evaluate research in education.* McGraw Hill.

Gray, A. (2016). *The 10 skills you need to thrive in the Fourth Industrial Revolution.* World Economic Forum.

Gredynarova, O. (2017). TRIZ pedagogy as the basis of the educational process. *In Proceedings of the TRIZfest 2017 International Conference* (pp. 587–596).

Guina, E., & Guina, A. (2017, September 14–16). *Smart education: TRIZ-pedagogy* [Keynote address]. TRIZfest 2017, Krakow, Poland.

Güçlü, M. (2022). Partnership for learning for 21st century skills [21. yüzyıl becerileri için öğrenme ortaklığı]. In S. B. Filiz (Ed.), *21. yüzyıl becerilerinin eğitime yansımaları* (pp. 43–60). Pegem Akademi.

Hatting, S. (2025). Adapting the TRIZ methodology to innovative problem-solving in education. *Journal of Strategic Innovation and Sustainability, 20*(2).

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling, 6*(1), 1–55. https://doi.org/10.1080/10705519909540118

Jatmiko, B., Widodo, W., Budiyanto, M., Wicaksono, I., & Pandiangan, P. (2016). Effectiveness of INQF-based learning on general physics for improving students' learning outcomes. *Journal of Baltic Science Education, 15*(4), 441–451. https://doi.org/10.33225/jbse/16.15.441

Karasar, N. (2002). *Bilimsel araştırma yöntemi* [Scientific research methods]. Nobel Yayın Dağıtım.

Kiong, T. T., Rusly, N. S. M., Azid, N., Singh, C. K. S., Nabawi, R. A., Ichwanto, M. A., & Putra, A. B. N. (2025). Inventive problem-solving skills effectiveness in RBT project-based learning (PBL). *Journal of Curriculum and Teaching, 14*(3), 119–130. https://doi.org/10.5430/jct.v14n3p119

Kolokouri, E. (2025). 21st century skills in higher education: A differentiated learning approach. *International Journal of Research in Education and Humanities and Commerce*. https://doi.org/10.37602/IJREHC.2025.6311

Lee, J., & Kim, J. (2023). The effects of practical TRIZ-based classes on the improvement of creativity and problem-solving ability of invention gifted elementary students. *Korean Science Education, 15*(2), 279–290.

McMullen, E., Perlman, M., Burns, S., Falenchuk, O., White, L., & Dhuey, E. (2026). Teaching interpersonal problem-solving skills to young children in early childhood education and care (ECEC) settings. *Review of Educational Research.* https://doi.org/10.3102/00346543251399668

Merriam, S. B. (2015). *Qualitative research: A guide to design and implementation* (S. Turan, Ed.) [Nitel

araştırma: Desen ve uygulama için bir rehber]. Nobel Akademi.
Merriam, S. B., & Tisdell, E. J. (2015). *Qualitative research: A guide to design and implementation.* John Wiley & Sons.
Ngang, T. K., Nair, S., & Prachak, B. (2014). Developing instruments to measure thinking skills and problem-solving skills among Malaysian primary school pupils. *Procedia - Social and Behavioral Sciences,* 116, 3760–3764. https://doi.org/10.1016/j.sbspro.2014.01.837
Orhan, S. (2025). Implementation of STEM education with TRIZ in middle schools: An experimental study [Ortaokullarda STEM eğitiminin TRIZ ile uygulanması: Deneysel bir çalışma] [Master's thesis, Muş Alparslan Üniversitesi].
Pandiangan, P., Sanjaya, I. G. M., & Jatmiko, B. (2017). The validity and effectiveness of a physics independent learning model to improve students' problem-solving and self-directed learning skills in open and distance education systems. *Journal of Baltic Science Education, 16*(5), 651–665.
Reymov, M. K., Zueva, A. V., & Zueva, V. V. (2021). Using TRIZ to activate students' creativity. *Eurasian Journal of Learning and Academic Teaching, 1*(1), 11–13. https://geniusjournals.org/index.php/ejlat
Rotherham, A. J., & Willingham, D. (2009). 21st century skills: The challenges ahead. *Educational Leadership, 67*(1), 16–21.
Savransky, S. D. (2000). *Engineering of creativity: Introduction to TRIZ methodology of inventive problem solving.* CRC Press.
Schweizer, T. P. (2002). Integrating TRIZ into the curriculum: An educational imperative. *The TRIZ Journal*. http://thetrizjournal.com/integrating-triz-curriculum-educational-imperative/
Simanjuntak, M. P., Hutahaean, J., Marpaung, N., & Ramadhani, D. (2021). Effectiveness of problem-based learning combined with computer simulation on students' problem-solving and creative thinking skills. *International Journal of Instruction, 14*(3), 519–534. https://doi.org/10.29333/iji.2021.14330a
Sungur, N. (1997). *Yaratıcı düşünce* [Creative thinking]. Evrim Yayınevi.
Suradin, S., Rasul, M. S., & Omar, M. (2025). Identifying challenges of cultivating creativity in product design. *International Journal of Evaluation and Research in Education.* https://doi.org/10.11591/ijere.v14i2.29568
Terninko, J., Zusman, A., & Zlotin, B. (1998). *Systematic innovation: An introduction to TRIZ.* CRC Press.
Thornhill-Miller, B., Camarda, A., Mercier, M., et al. (2023). Creativity, critical thinking, communication, and collaboration. *Journal of Intelligence, 11*(3), 54. https://doi.org/10.3390/jintelligence11030054
World Economic Forum. (2020). *The future of jobs report 2020.* https://www.weforum.org/publications/the-future-of-jobs-report-2020/
Yolcu, H., & Karamustafaoğlu, O. (2024). Sistematik yaratıcı problem çözme aktivitelerinin etkisi. *Boğaziçi Üniversitesi Eğitim Dergisi, 41*(3–2). https://doi.org/10.52597/buje.1419683
Zhapisheva, G. K., Adiyeva, P. M., & Zhorabekova, A. N. (2025). Developing students' creative thinking skills. *PEDS, 78*(3), 467–484. https://doi.org/10.48371/PEDS.2025.78.3.029