

Research paper

The Impact of STEM Technology on the Development of Primary School Students' Creative Thinking Skills: An Experimental Study in Kazakhstan

Aidana Yeraliyeva , Assel Yesnazar *, Lyazzat Akynova , Gulbanu Urystenbekova ,
Nazerke Berikbayeva 

Zhanibekov University, KAZAKHSTAN

*Corresponding Author: asel.esnazar@mail.ru

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ABSTRACT

This study is aimed at developing the scientific, technological, engineering, and mathematical (STEM) skills of primary school pupils, as well as their creative and higher-order thinking abilities, through STEM-based teaching. The main aim of the study is to determine the effectiveness of developing primary school pupils' creative thinking abilities within the context of STEM education. The research was conducted in three phases: diagnostic, formative, and summative. Within the experimental design, pre and post-tests were administered to the experimental and control groups. The experimental group was taught a specially developed, STEM-based programme over one academic term, while the control group received instruction through traditional teaching methods. The measurement instruments used in the study included Chambers' "Draw-A-Scientist Test" tasks and Torrance's "Finish-a-Picture" creative thinking tasks. The collected data were processed using the SPSS statistical programme and analyzed with the appropriate statistical methods. The research findings revealed statistically significant differences between the experimental and control groups. The effectiveness of the STEM programme implemented during the experiment was confirmed by comparing the pre and post-test results. In conclusion, the results clearly demonstrate the high effectiveness of the STEM-oriented teaching approach in enhancing the creative thinking abilities of primary school pupils.

Keywords: STEM, creative thinking skills, primary school, quasi-experimental design, DAST, TTCT

The incorporation of STEM technology into basic education has emerged as a strategic focus in modern educational advancement. STEM (Science, Technology, Engineering, and Mathematics) is a progressive educational approach that emphasizes interdisciplinary instruction by integrating these subject areas. This approach seeks to provide learners with comprehensive knowledge by linking scientific concepts across disciplines. STEM technologies enable students to gain theoretical knowledge and cultivate practical application skills through project-based activities and research endeavors.

According to Yesnazar et al. (2025), STEM technology is an educational approach grounded in interdisciplinary integration and implemented through project-based and inquiry-driven learning. Similarly, Henseruk et al. (2022) describe STEM as a contemporary approach that fosters students' creativity and research skills through scientific methods, mathematical modeling, and engineering design. STEM education equips students with the competencies needed to address real-world problems and develop critical thinking in an

effective and meaningful way (Bybee, 2013; Gee & Wong, 2012; Rosicka, 2016). This approach shifts the focus from isolated subject learning to problem-oriented, inquiry-based, and practice-driven learning experiences.

Under current economic conditions, one of the key challenges facing education systems is enhancing learners' functional literacy and developing competencies in demand in the future labor market. From this perspective, implementing STEM technologies at the primary school level enables students, from an early age, to develop an understanding of natural phenomena, foster technical and creative thinking, and cultivate an interest in scientific inquiry and exploration.

The process of fostering a research culture in Kazakhstani schools is closely linked to the renewal of educational content, the development of STEM technologies, and the large-scale integration of digital technologies into the educational process (Methodological Guidelines for the Implementation of the Updated State Compulsory Education Standard and Model Curriculum, 2024). At present, students' participation in project-based and research activities has become systematic, enabling them to demonstrate their scientific potential through international Olympiads and academic competitions.

Through engagement with STEM technologies, learners adapt to the demands of the contemporary digital environment and acquire the knowledge, skills, and competencies necessary to become competitive professionals in the future labor market. Collectively, these trends underscore the strategic importance of developing research skills within the general education system.

The effectiveness of STEM integration lies in its ability to eliminate rigid disciplinary boundaries and to conceptualize learning as a unified educational space. This educational methodology enhances students' subject-specific knowledge while fostering practical skills, collaboration, creative thinking, and complex problem-solving abilities. The integration of STEM technology into primary education is essential for developing learners who fulfill the requirements of the twenty-first century.

Moreover, primary school children's emerging understanding of the concept of science directly influences the effectiveness of STEM technologies. Children's perceptions of who a scientist is and what scientists do shape their interest in science and their level of cognitive engagement. Interest in science typically develops before age 14 (Archer et al., 2013). If children's curiosity toward science is not supported at an early age, the likelihood that they will develop a new and sustained interest in science after Grade 10 is extremely low or may not occur at all (Aschbacher et al., 2010). When a child demonstrates an interest in science, they are more likely to pursue further study and professional activity in this field, indicating that such interest usually originates in early childhood (Adam & Tai, 2010). Therefore, fostering STEM-oriented career aspirations from an early age is critical.

If children perceive scientists solely as inaccessible professionals working exclusively in laboratory settings, their motivation to engage with science may decline. In contrast, through STEM technologies, learners come to understand the connection between science and everyday life, recognize that anyone can engage in research, and realize that scientific thinking skills can be developed regardless of age.

Nevertheless, there remains a need for further research focused on primary school students' perceptions of science and scientists, as well as on the development of early interest in STEM fields. In particular, there are few studies examining how young learners conceptualize scientific ideas, how stereotypical images of scientists are formed, and how these factors influence future choices of STEM-related pathways. Most existing studies in this area have been conducted in developed countries (e.g., the United States, China, Singapore, South Korea, Japan). Consequently, there is a growing need for large-scale, longitudinal research to identify effective approaches to integrating STEM education at the primary school level.

The role of STEM technologies in unlocking the creative potential of primary school students warrants particular attention. To examine this issue in depth, the present study is guided by the following research question: (Q1) In what ways do STEM technologies impact the cultivation of creative thinking skills in primary school students?

LITERATURE REVIEW

STEM technology in Kazakhstan

The development of STEM technology in Kazakhstan has been progressing gradually, with a growing number of schools implementing elements of this approach to foster students' research skills through interdisciplinary learning (Methodological Guidelines for Enhancing Students' Research Skills in Natural Science and Mathematics Subjects, 2024). In recent years, domestic scholars have increasingly examined STEM technology from multiple perspectives, producing research that elucidates its theoretical, methodological, and practical dimensions.

In particular, Akhatay et al. (2024) investigated the methodological foundations of integrating STEM technologies into mathematics education, analyzing ways to strengthen interdisciplinary connections in order to foster students' logical and research-oriented thinking. Kazbekova and Ismagulova (2022) explored the practical

aspects of implementing the STEM approach, including integrating academic disciplines and applying project- and research-based methods in schools and higher education institutions in Kazakhstan. Their findings highlight the positive impact of STEM projects on students' research and creative skills.

Ualikhan et al. (2025) examined methods for integrating STEM approaches into university curricula in Kazakhstan. The authors demonstrated that the core principles of STEM—interdisciplinarity, inquiry-based learning, and project-based methods—contribute to deeper subject understanding and the development of skills necessary for solving real-life problems.

In addition, Mankesh et al. (2024) analyzed the application of STEM elements in preschool education, proposing theoretical and methodological frameworks for introducing technical skills to young children. The authors emphasized that STEM should not be introduced in isolation but implemented systematically through alignment with teacher preparation, methodological support, the development of children's skills, and the enhancement of material and technical resources.

Baimakhanbetova et al. (2023) focused on developing students' research skills and analytical abilities through practice-oriented STEM instruction. Employing both quantitative and qualitative research methods, the authors identified a key distinction between STEM-based and traditional education: rather than teaching subjects in isolation, STEM emphasizes integrative, active, problem-based learning through practice, projects, and research activities. At the same time, the study revealed several challenges associated with implementing STEM technologies at the primary school level, including insufficient materials and technical infrastructure, limitations in the quality of science education, and low motivation to learn among primary and lower secondary school students.

In a subsequent study, Bekbauova and Turebaeva (2022) examined ways to enhance students' motivation, subject interest, and thinking skills through the application of STEM technologies in mathematics education. By designing instructional plans for challenging mathematical topics based on STEM principles and implementing them in classroom practice, the authors found a significant increase in students' interest in mathematics, as well as improvements in their research abilities and creative thinking.

Ramankulov et al. (2023) investigated STEM technology from a physics education perspective. The authors focused on the effective teaching of the concept of energy by integrating STEM approaches, aiming to deepen students' scientific understanding. Their study involved analyzing scientific literature, school textbooks, and curricula, as well as incorporating digital learning resources into the instructional process. The findings emphasize the need to cultivate learners who possess engineering skills, research and experimental competencies, digital literacy, and the ability to think critically and systematically. STEM education is proposed as an instructional approach that effectively supports the development of these competencies.

Overall, these studies indicate that STEM technology in Kazakhstan is developing dynamically and is increasingly implemented across various levels of education, from preschool institutions to primary and secondary schools to higher education establishments. STEM approaches have proven particularly effective in subjects such as physics, computer science, mathematics, and general science education, where they contribute to the development of students' research, creative, and engineering thinking skills.

Nevertheless, practical execution exposes numerous enduring problems. This encompasses a restricted quantity of instructional materials, inadequate preparedness of both educators and learners to proficiently utilize STEM technology, and constrained access to practical resources and digital tools, all of which hinder the full-scale integration of STEM methodologies. Therefore, there is a clear and ongoing need for further research to advance the development and effective implementation of STEM technologies within Kazakhstan's educational system.

Integrated STEM education

The integrated education approach seeks to impart knowledge in science, technology, engineering, and mathematics within an interrelated and multidisciplinary framework. This approach has proven highly effective in fostering students' creative thinking, research engagement, and engineering-oriented thinking. Over the past decade, integrated STEM education has become a central focus of educational reforms in developed countries. Empirical research from countries such as the United States, Singapore, Finland, South Korea, Japan, China, and Germany provides substantial evidence of the effectiveness of systematically integrating STEM technologies into national education systems.

In the context of Kazakhstan, Nurgazinova and Mukhamedieva (2025) investigated an integrated STEM technology and described a concrete STEM project. The authors emphasized the need to modernize the education system by applying STEM project-based and integrative approaches to develop engineering thinking among learners.

Mesutoglu and Akgündüz (2025) examined the integrated STEM approach by exploring how teachers conceptualize the notion of "integrated STEM." Their findings indicate that STEM should not be perceived

merely as a collection of separate disciplines but rather as a holistic and coherent educational approach. Similarly, Portillo-Blanco et al. (2025) provided a strong scientific and theoretical foundation for STEM integration by proposing a unified conceptual model intended for teachers, researchers, and curriculum developers. According to the authors, when teachers lack a clear understanding of how to integrate STEM, classroom instruction often fails to achieve genuine interdisciplinary integration.

Halawa et al. (2024) addressed issues of instructional design in K–12 STEM education, focusing on how disciplines can be meaningfully integrated, how students' skills can be systematically developed, and how STEM learning can be translated into concrete instructional activities. The study highlights that effective STEM instruction depends on clearly defined objectives, appropriately selected instructional designs, and faithful implementation.

Zhan and Niu (2023) conducted a systematic review of STEM education research at both the K–12 and higher education levels, analyzing subject integration and the evolution of research themes. They identified future research trends emphasizing the development of students' thinking competencies, professional development, and the impact of STEM learning outcomes. The authors also noted that while STEM education initially gained prominence in higher education, it has now become widely implemented at the K–12 level.

Chen et al. (2024) investigated students' STEM career aspirations and their likelihood of pursuing future employment in STEM fields. When planning STEM-related lessons and activities, the authors emphasized the importance of introducing STEM professionals as highly skilled yet accessible role models, rather than as distant or unattainable figures. They highlighted that even when children hold positive perceptions of STEM, this does not necessarily translate into pursuing a STEM career, as self-efficacy may serve as a critical mediating factor.

Chiu et al. (2025) analyzed research activity over the past decade (2014–2023) in the *International Journal of STEM Education*, aiming to identify research trends, integration practices, and emerging directions in STEM education. Their review considered STEM education broadly, framing it as a comprehensive, interdisciplinary, and inclusive educational model.

Dillon and Wong (2025) revisited the 2010 report by the Center for Advancement of Informal Science Education (CAISE), *Making Science Matter: Collaborations Between Informal Science Education Organizations and Schools*, using historical insights to discuss the contemporary development of STEM integration across both formal (schools, colleges) and informal (museums, science centers, leisure-oriented learning) educational contexts. The authors framed STEM education as a tool for addressing wicked problems (complex, ill-structured social, ecological, and economic challenges that lack clear definitions and single solutions), complex, multifaceted social, ecological, and economic challenges, and emphasized the need for interdisciplinary learning that bridges formal and informal education.

Tarlochan et al. (2025) highlighted the importance of cultivating sustainability-oriented competencies in STEM education, such as systems thinking, forecasting, and normative reflection. The authors argue that STEM professionals should be oriented toward creating sustainable impacts and note a significant increase in sustainability-focused STEM research since 2010.

Overall, recent years have seen a rapid expansion in research on integrated STEM education, with careful consideration of its theoretical foundations, practical implementation, and professional development dimensions. The scientific community has provided strong evidence that interdisciplinary STEM instruction significantly enhances learners' creativity, research skills, engineering thinking, and capacity for solving complex problems. The ongoing evolution of STEM research indicates that refining the theoretical and conceptual models of integration will remain a primary focus in the field.

Draw-a-scientist test (DAST)

Children's early perceptions of scientists are considered a key factor in shaping their interest in science and their potential pursuit of STEM-related careers. These perceptions are shaped by social environments, mass media, and school experiences. One of the most widely used methods for studying this phenomenon is the Draw-A-Scientist Test (DAST). Originally proposed by Chambers (1983), DAST has been recognized as an effective tool for identifying children's stereotypical views of scientists.

Using the DAST method, Fotakopoulou et al. (2025) investigated how children visualize scientists, including characteristics such as gender, clothing, and professional activity, and how these perceptions may influence their interest in science and their future scientific aspirations. Their study confirmed that children often hold stereotypical views of scientists; however, it also indicated that many children retain curiosity about science and hope for future engagement in the field.

Christidou et al. (2021) expanded the DAST methodology to include the emotional aspects of children's depictions of scientists, a method referred to as Emo-DAST. They argued that analyzing emotions in scientists' drawings is important not only through observable features but also by considering the child's perspective on "what the scientist feels?", thereby capturing a deeper understanding of children's conceptualizations.

Lee (2025) conducted a pilot study using generative artificial intelligence tools (Midjourney, GPT) to create images of scientists and evaluated them using the DAST framework. The study revealed that AI is capable of producing scientific images, but these representations often reinforce stereotypical features, such as white lab coats, male gender, and laboratory settings. This finding suggests a potential link to STEM education, highlighting that societal and familial stereotypes about science continue to shape children's perceptions.

Early conceptions of scientists play a critical role in shaping children's interest in science and influencing future career choices. Within the context of STEM education, addressing these stereotypes at an early age and providing hands-on, practical experiences can foster students' creativity, research skills, and scientific thinking.

Creative thinking skills

Creative thinking is the ability to perceive the surrounding world from new perspectives and to generate novel ideas and unique solutions. It is not a skill exclusive to the arts; rather, it is a versatile competency that enables individuals to solve problems in daily life, academic learning, and professional activities in flexible and effective ways. Torrance (1998), a leading scholar in the psychology of creativity, describes creativity as an innate human trait that requires deliberate support and development. According to Torrance, creative thinking is a skill that can be taught, and a well-structured environment can enhance imagination, cognitive flexibility, and alternative problem-solving abilities. To assess creativity, Torrance developed the Torrance Tests of Creative Thinking (TTCT), which has since been translated into over 35 languages and adopted as an international standard.

Chacón-López and López-Martínez (2025) highlighted the theoretical viewpoint that creativity should be seen as a multidimensional phenomenon rather than a single quantitative quality by illustrating the intricate relationships between creativity and psychological and emotional components. Massy et al. (2025) conceptualize creativity not merely as an outcome but as a process encompassing thinking, experimentation, and imagination. They emphasize that standard evaluation systems often focus only on tangible or visual products, while their research underscores the significance of the creative process, including idea generation, risk-taking, experimentation, and imaginative thinking.

Natalia et al. (2025) offer an interesting insight, showing that the relationship between *creatividad* (creativity) and academic performance is not straightforward, challenging the conventional "high grades = effective learning" paradigm in education. Sevimli-Celik and Güvelioglu (2025) argue that creativity is not restricted to the arts but represents a crucial skill and mindset for the professional and personal development of future teachers.

Cieslik et al. (2025) provide important guidance on tools and limitations for assessing creativity in early childhood. They distinguish between performance-based measures, which capture a child's actual creative behavior, and parent- or teacher-report measures, which rely on observation and subjective evaluation. Their findings reinforce the pedagogical and psychological view that creativity is a complex, multidimensional phenomenon. Behnamnia et al. (2025) further emphasize that creative skills can be fostered from early childhood through the integration of STEM elements, demonstrating that STEM-oriented education can go beyond academic knowledge to include creativity as a core educational goal.

Winarto et al. (2025) found that game-based STEM-EfSD learning significantly improved the creative thinking abilities of Grade 7 students, demonstrating the potential of STEM-oriented learning environments to support the development of higher-order thinking skills.

Overall, these studies collectively underscore the importance of considering creative thinking as a critical skill within the education system. Creative thinking is not a narrowly defined or subject-specific ability; rather, it is a multidimensional developmental phenomenon encompassing cognitive, emotional, and motivational dimensions of learning and personal growth.

RESEARCH METHODS AND MATERIALS

Framework

This study is grounded in constructivist and socio-constructivist theories, which emphasize the active construction of knowledge through hands-on and collaborative learning. These theoretical perspectives originate from the work of Piaget and Cook (1952), who developed the theory of constructivism. Vygotsky (1978), who advanced socio-constructivist theory, and Dewey (1938), who introduced the concept of learning by doing and highlighted the importance of experience and practical activity in the learning process.

In addition, the study draws on the theory of creative thinking proposed by Torrance (1966), which identifies fluency, flexibility, originality, and elaboration as the core dimensions of creativity. It also incorporates the systems model of creativity developed by Csikszentmihalyi (1997), according to which creativity emerges through the interaction of the individual, the domain of knowledge, and the social field in which ideas are evaluated and recognized by others.

Within this theoretical framework, the STEM intervention was designed to engage students in authentic problem solving, thereby fostering the development of creative thinking, including fluency, flexibility, originality, and elaboration as its key components.

To systematically organize students' learning activities, the following stages are proposed within STEM technologies. For example:

- Problem identification
- Research
- Idea generation
- Design and modeling
- Construction and experimentation
- Testing
- Improvement and presentation

At the problem identification stage, students define real-life, context-based problems and formulate relevant questions. During the research stage, they collect necessary information, review scientific data, and conduct analysis. In the next stage, idea generation takes place, where possible solutions to the problem are considered and various hypotheses are proposed. Subsequently, in the design and modeling stage, a project or model is developed based on the selected solution, and the implementation process begins. During the construction and experimentation stage, the project is carried out in practice and proceeds to the testing phase, where the effectiveness of the results is evaluated. In the improvement and presentations stage, students refine their project based on the obtained results, draw conclusions, and present their findings.

Through this structure, students actively engage in the learning process and develop skills in independent inquiry, analysis, and practical decision-making. The STEM framework enables the systematic acquisition of knowledge and its effective application in real-life contexts.

Research design

The aim of this study was to evaluate the impact of STEM technologies on the development of creative thinking skills among primary school students. Diagnostic methods were employed to assess the extent to which students develop creative thinking through integrated STEM instruction. Specifically, the TTCT – Figural Form A test (Torrance, 1966), adapted through the Finish-a-Picture Test, was used to examine students' ability to demonstrate creative thinking via STEM tasks. The adapted test was preliminarily piloted and administered twice to samples of fourth-grade students, each comprising 50 respondents. The study employed a test-retest design, with a one-week interval between the initial administration and the subsequent measurement. The results of the correlation analysis indicated that the Pearson correlation coefficient between Test 1 and Test 2 was high and statistically significant (see [Table 1](#)).

Table 1

Reliability scale of the adapted "finish-a-picture test" from the TTCT – Figural Form A.

Correlations			
		test1	test2
test1	Pearson	1	,804**
	Correlation		
	Two-tailed sig.		,000
	N	50	50
test2	Pearson	,804**	1
	Correlation		
	Two-tailed sig.	,000	
	N	50	50

**. The correlation is sig. at the 0,01 level (two-tailed)

According to the test-retest results, a high and statistically significant correlation was observed between the measures ($r = 0.804$, $p < 0.001$) indicating a high level of reliability of the adapted test.

The internal consistency of the adapted "Finish-a-Picture" test from the TTCT was evaluated using the Cronbach's alpha, as presented in [Table 2](#).

Table 2*Internal consistency of the “Finish-a-Picture” test*

Reliability statistics	
Cronbach’s alpha	N elements
0.900	4

The internal consistency of the adapted TTCT “Finish-a-Picture” task was assessed using Cronbach’s alpha ($\alpha \geq 0.70$). The results indicated $\alpha = 0.900$, demonstrating a high level of consistency of the test across four criteria. In assessing children’s creative abilities, the following criteria were applied: fluency (number of ideas), flexibility (variety of ideas), originality, and elaboration (degree of detail). These results indicate a high level of internal consistency of the adapted instrument across the four creativity dimensions assessed in this study.

In the study, the Draw-A-Scientist Test (DAST) Chambers (1983) was applied to evaluate students’ levels of stereotypical thinking about science. To determine primary school students’ interest in STEM technologies, an author-designed questionnaire was also administered. The research design is presented in [Table 3](#).

Table 3*Research design*

School	Number of Students	Class Code	Method	Diagnostic Tool	SPSS Test Type
Control Class					
School-Lyceum №23	28	CC1	Traditional Instruction	DAST; TTCT – Figural Form A (Finish-a-Picture Test interpretation)	Shapiro–Wilk Test, Kruskal–Wallis H Test
IT School-Lyceum №7	29	CC2			
Experimental Class					
School-Lyceum №23	27	EC1	Think, Research, Create!	DAST; TTCT – Figural Form A (Finish-a-Picture Test interpretation)	Shapiro–Wilk Test, Kruskal–Wallis H Test
IT School-Lyceum №7	28	EC2	(Integrated STEM Instruction)		

The purpose of employing these diagnostic methods was to determine the effectiveness of the instructional process in developing creative thinking skills through STEM technologies and to monitor students’ interest and engagement in STEM. The collected data provided insights into how primary school students enhance their creative thinking abilities by completing STEM-based tasks. The study was conducted with primary school students in Shymkent, Kazakhstan.

Research sample

The study was conducted among fourth-grade students at School-Lyceum No. 7 IT, named after K. Syptayev, and School-Lyceum No. 23, named after Kosmodemyanskaya, in Shymkent, Kazakhstan. The schools were selected based on convenience sampling, and two classes from each school were included. All students within these classes participated in the study, forming a full-class census. Initially, 121 students completed the pre-test administration of the Draw-A-Scientist Test. Nine responses were excluded because they consisted of blank sheets or drawings that did not correspond to the task instructions. As a result, the final sample comprised 112 fourth-grade students. All subsequent assessments were administered to these 112 students, and all analyses reported in this study were based on data from this final sample.

A total of 57 students were selected from School No. 7, comprising 31 boys and 26 girls, while 55 students were selected from School No. 23, including 34 boys and 21 girls. For the study, one experimental group and one control group were designated in each school. Participation in the study was fully voluntary. Students were not randomly assigned to the experimental and control groups. Instead, four intact fourth-grade classes were designated as the experimental group and the control group. Because existing classroom groups were used without random assignment, the study employed a quasi-experimental design. Both schools are state-run institutions offering primary and lower secondary education, with curricula closely aligned, allowing the results of this study to be generalized to other similar schools in the country. The study was conducted with the consent of parents and school administration.

Fourth-grade students were selected because children aged 9–10 demonstrate an active interest in lessons organized around STEM technologies and begin to develop creative thinking skills more intensively. Research indicates that at this age, children's interest in science becomes more stable and tends to increase over time (DeWitt et al., 2014).

The experimental groups participated in STEM-oriented lessons, while the control groups continued with traditional instruction. All students completed diagnostic assessments to evaluate their creative thinking skills and attitudes toward science. The aim of the STEM-oriented lessons was to develop students' multifaceted thinking abilities while acquiring scientific, technological, engineering, and mathematical knowledge through practical tasks and to enhance creative thinking. Instructional sessions were conducted once a week for 12 sessions. All lessons were organized with the school administration's permission and structured to avoid interfering with the students' core academic curriculum.

Research instrument

Draw-a-scientist test (DAST)

In this study, 121 students participated in the Draw-A-Scientist Test (DAST), with 112 completed responses included in the final analysis. Each student worked individually in a quiet, distraction-free space designated within the school. The procedure was allotted 40 minutes. Students received a single instruction: "Draw a scientist." No additional guiding questions or examples were provided, allowing students to naturally express their internal image of a scientist, whether stereotypical or non-stereotypical. This approach is particularly useful for examining how children perceive professionals in STEM (science, technology, engineering, and mathematics) fields, as the image of a scientist is closely linked to their overall understanding of science. A child's mental representation of a scientist directly influences their understanding of scientific processes, technological innovations, and mathematical thinking. Therefore, the scientist drawings serve as a key indicator of how students conceptualize STEM disciplines.

Evaluation Criteria

Each drawing was evaluated according to seven primary stereotypical features proposed by Chambers (1983):

1. The existence of a lab coat
2. The wearing of eyeglasses
3. Facial hair, such as lengthy sideburns, a mustache, or a beard
4. Research symbols, such as flasks, microscopes, chemical apparatus, and scientific equipment.
5. Knowledge symbols, such as documents, cabinets, and books
6. Technological products, such as tools, instruments, robots, machines, and mechanisms
7. Scientific labels (e.g., terminology written on the drawing), formulas, or science-related phrases such as "Eureka!"

Every characteristic was assigned a code of either 0 (absent) or 1 (present). The cumulative score showed how well a student's idea of a scientist matched stereotypes.

Score Interpretation

* High Score (6–7 points): Students' drawings show extremely stereotyped depictions of scientists, who are usually seen sitting alone, working with chemical equipment, and donning a lab coat and spectacles.

* Medium Score (3–5 points): Some stereotyped aspects are included in the drawings, but not all requirements are satisfied.

* Low Score (0–2 points): Students portray scientists who lack conventional or stereotyped characteristics, demonstrating a more varied, flexible, and unconventional understanding of what a scientist is.

This scoring system made it possible to evaluate children's internalized prejudices about scientists in a nuanced way and revealed how they saw STEM careers.

TTCT – figural form a (finish-a-picture test)

The study involved 112 students. Data were collected individually in a quiet, designated room at the school. Each student was given 20 minutes to complete the task, which required them to "Finish the Picture" by transforming a simple abstract figure into a meaningful, complete image.

Instructions were brief and age-appropriate to ensure clarity. This task was used to assess creativity, particularly the visual thinking, divergent thinking, and creative association skills essential in STEM disciplines. Students were not provided with the full TTCT protocol or complex instructions, as these would require more time and a separate, extended study. Since the primary focus was to observe creative thinking in the context of STEM education, the test was adapted and simplified.

The adaptation of the TTCT – Figural Form A (Finish-a-Picture) was limited to the administration procedure rather than the content of the original task. The instructions were simplified to ensure age-appropriate

comprehension for fourth-grade students, and the administration time was standardized to 20 minutes. The original open-ended drawing task and the creativity constructs assessed (fluency, flexibility, originality, and elaboration) were preserved. The psychometric properties of the adapted instrument were evaluated prior to its use in the main study, as described in the Research Design section.

Each student received a sheet of paper with a pre-drawn abstract shape or figure, along with a pencil and an eraser. The main task was to complete the given abstract figure and transform it into a meaningful, coherent drawing. This adapted version retained the core principles of Torrance's (1966) Finish-a-Picture method while focusing on practical application within the study context.

During the task, students' imaginative engagement, ability to create new meaning, and skills in transforming a simple shape into a novel object or narrative image were assessed. The evaluation considered four key creativity criteria:

- * Fluency – number of ideas generated
- * Flexibility – variety and adaptability of ideas
- * Originality – uniqueness and novelty of ideas
- * Elaboration – depth of development and detail

The drawings were scored using a three-level scale:

* High Level (6–7 points): The student demonstrated high creativity, transforming the figure into a complex, unique, and unexpected image, showing strong imaginative freedom, fantasy, and compositional coherence.

* Medium Level (3–5 points): The drawing was understandable and logical, but relied on conventional solutions and showed limited complexity.

* Low Level (0–2 points): Minimal completion of the figure; few or no changes made; limited evidence of creativity.

Because the complete TTCT materials are protected by copyright and are not publicly available, the study employed an adapted Finish-a-Picture task based on the original conceptual framework. The adaptation preserved the essential characteristics of the original task while ensuring compliance with copyright requirements and the objectives of the present study.

Author-designed questionnaire for assessing interest in STEM technology

This questionnaire was designed to determine primary school students' interest in STEM technologies and their motivation for learning. Comprising seven questions, the study assessed students' motivation to engage with the domains of science, technology, engineering, and mathematics (STEM), their interest in applying this knowledge in practice, and their willingness to pursue learning in this area. The questionnaire items were designed to be clear, concise, and appropriate for the respondents' age characteristics.

The content validity of the questionnaire was confirmed through evaluation by one STEM specialist and three independent experts in primary education. The experts assessed the relevance of the items to the research objectives, their appropriateness for the target age group and their coverage of STEM components. All recommendations were incorporated, and the final version was approved. In addition, the internal consistency of the questionnaire items was assessed using Cronbach's α (1951).

A total of 112 respondents participated in the survey, which was administered over a duration of 20 minutes. The questionnaire included the following items:

1. I enjoy exploring scientific discoveries made by scientists.
2. I like conducting experiments in science classes.
3. I would like to learn more about the fields of science, technology, engineering and mathematics.
4. I am interested in studying new topics in science more deeply.
5. I enjoy completing various tasks in science classes.
6. I would like to learn how to invent and create new things.
7. I would like science classes to include content related to mathematics, technology, and engineering.

Data analysis

Statistical analysis

To objectively and accurately assess the impact of STEM technologies on the development of creative thinking skills among primary school students, the collected data were subjected to statistical analysis, with significance determined at $p < 0.05$. Given that the measured indicators may be unevenly distributed due to developmental and motivational characteristics of young children, the Shapiro–Wilk test (Shapiro & Wilk, 1965) was used to assess data normality. This test is widely recognized as the most robust criterion for small-to-medium-sized samples and allowed the researchers to determine whether classical parametric methods were appropriate.

During the diagnostic phase, the results of the author-designed questionnaire indicated that primary school students demonstrated interest in learning based on STEM technologies. However, the results of the DAST indicated a predominance of stereotypical thinking patterns among students, while the Finish-a-Picture test revealed below-average levels of creativity. Because the test results indicated non-normal data distribution, the nonparametric Kruskal–Wallis test (Kruskal & Wallis, 1952) was used to evaluate differences among multiple independent groups. This test is suitable for comparing ranked or interval-scale data across two or more independent groups. All analyses were performed using SPSS 26.0.

Formative phase

The formative phase constituted the core experimental stage, focusing on practically testing the effectiveness of STEM-based instruction in fostering creative thinking. During this phase, the experimental classes were taught using a specially developed methodology entitled “Think, Explore, Create!” The content was designed to be age-appropriate, engaging, and visually appealing for primary school students, incorporating game elements and tasks connected to real-life situations. Examples of activities included “Adventures in the World of Experiments”, “Little Designer’s Workshop”, and “Constructing the 3D World!” Methodology for One Semester is presented in Table 4.

Table 4

“Think, explore, create!” methodology for one semester

No.	Lesson Title	Learning objective / Standards	Hours	Learning Outcomes
	Introductory Lesson	Introduce the course objectives and content	1	
SECTION 1: Introduction to STEM Technologies and Foundations of Creative Thinking				
General Theme: My Vast Kazakhstan				
1.1	Adventures in the World of Experiments	Science: identify a relevant research topic based on own reasoning; justify the choice of research method (observation or experiment) based on its advantages and limitations; Technology & Work: provide examples of material properties (softness, density, strength, color, shape, volume)	1	Compares the advantages and disadvantages of observation and experiment, selects an appropriate method for own research; describes common materials and develops observation skills.
1.2	Magical Plant World: Counting, Exploring, Comparing	Mathematics: read, write, and compare multi-digit numbers; round numbers to a given place value; Science: determine the role of plants in food chains; describe the life cycle of a plant	1	Reads, writes, and compares multi-digit numbers, rounds numbers; identifies the role of plants in food chains; describes the plant life cycle based on observations.
1.3	Nature Engineer: The Journey of Seeds	Science: describe seed formation and dispersal as a result of pollination; Technology & Work: summarize knowledge about material applications and provide examples	1	Explains seed formation and dispersal; uses different materials to model seed dispersal and provides examples; applies observation and experimentation skills and interprets results.
1.4	Plant World	Science: differentiate between lower and higher plants; Technology & Work: master effective methods of creative work using provided materials	1	Differentiates lower and higher plants, describes their characteristics; selects plants for own investigation and observes them; creates creative projects using provided materials (models, applications, dioramas).
1.5	Little Designer’s Workshop	Science: suggest ways to protect plants; Mathematics: measure using volume (mm ³ , cm ³ , dm ³ , m ³) and area (ha, a) units	1	Proposes methods to protect plants (e.g., following ecological rules, maintaining parks, applying laws); measures real-life objects using volume and area units, calculates and compares results, draws conclusions.
1.6	World of Insects: Explore and Create	Science: classify local animals; describe the life cycle of insects; Technology & Work: master creative work methods using provided materials	1	Classifies local animals based on characteristics (type, habitat, insect or not); describes insect life cycles; models insect life cycles using paper, clay, or natural materials.
1.7	Animal Life and Movement	Science: differentiate herbivores and carnivores; provide examples of symbiotic relationships; Mathematics: apply relationships between speed and distance in problem solving	1	Differentiates herbivores and carnivores with examples; provides concrete examples of symbiosis (e.g., bees and flowers, algae and microbes, seals and fish); uses speed-distance relationships to solve problems and analyze movement scenarios in nature.
1.8	Constructing the 3D World!	Science: explain the structure of a food chain; construct a model of a food chain in a specific habitat; explain the purpose of national parks and reserves and provide examples of endangered species	1	Describes the interconnections of plants, herbivores, and carnivores; provides examples of endangered species; constructs models of food chains and relates them to protected areas, can build a 3D representation of a food chain.
Total			8 hours	

Throughout the lessons, students were encouraged to conduct investigations, make predictions, carry out experiments, and model and defend their ideas. These activities aimed to enhance cognitive flexibility, creative imagination, problem-solving abilities, and scientific inquiry skills.

Assessment Phase

During the assessment phase, post-tests were administered to both the experimental and control groups. This allowed a comparative evaluation of changes in students' creative thinking skills and attitudes toward science.

The study was conducted during the first semester of 2024–2025. Lessons and assessments were organized weekly, with ES1 in the experimental group attending on Wednesdays and ES2 on Fridays.

RESULTS

Draw-a-scientist test (DAST)

The study collected 121 student drawings using the Draw-A-Scientist Test (DAST). During the initial screening, nine drawings — including blank sheets and abstract images unrelated to a scientist — were excluded from analysis. Consequently, the results of 112 students ($n = 112$) were analyzed.

Each drawing was evaluated according to seven stereotypical indicators proposed by Chambers (1983). Each indicator was coded as 0 (absent) or 1 (present), and a total stereotypical score was calculated for each student. Based on these scores, students' stereotypical perceptions of scientists were classified into low, medium, and high levels. To enhance reliability, the drawings were analyzed by two independent experts. Any disagreements during scoring were resolved through consensus discussion. Examples of students' drawings for pre-tests and post-tests are presented in [Figures 1](#) and [2](#).

Figure 1

DAST pre-test results

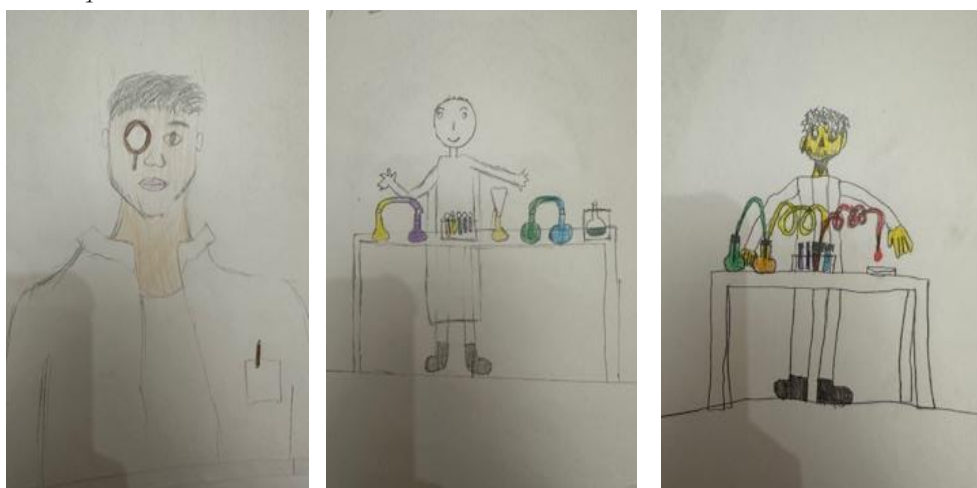


Figure 2

DAST post-test results



Table 5*Tests of normality*

Variable	Kolmogorov-Smirnova			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Lab coat	0.377	112	0.000	0.629	112	0.000
Eyeglasses	0.373	112	0.000	0.631	112	0.000
Facial hair	0.488	112	0.000	0.495	112	0.000
Research symbols (scientific instruments, chemical equipment, flasks, microscopes, etc.)	0.500	112	0.000	0.465	112	0.000
Knowledge symbols	0.359	112	0.000	0.635	112	0.000
Technological products (equipment, machines, robots, tools)	0.480	112	0.000	0.514	112	0.000
Relevant annotations (formulas, scientific terms, writings such as "Eureka")	0.423	112	0.000	0.598	112	0.000
Post-test lab coat	0.354	112	0.000	0.635	112	0.000
Post-test Eyeglasses	0.454	112	0.000	0.559	112	0.000
Post-test Facial hair	0.377	112	0.000	0.629	112	0.000
Post-test Research symbols	0.414	112	0.000	0.606	112	0.000
post-test Knowledge symbols	0.427	112	0.000	0.593	112	0.000
pre-test Technological products	0.377	112	0.000	0.629	112	0.000
post-test Relevant annotations (formulas, scientific terms, writings such as "Eureka")	0.500	112	0.000	0.465	112	0.000

Note. Lilliefors significance correction applied.

The Shapiro–Wilk test indicated that all measured variables were not normally distributed ($p < 0.001$). Consequently, subsequent analyses were conducted using non-parametric methods appropriate for non-normal data. Frequencies and percentages of variables were calculated by dividing the number of participants exhibiting a particular characteristic by the total number of participants and multiplying by 100 (Table 6). To evaluate differences between groups, the Kruskal–Wallis test was applied (Table 7).

Table 6*Frequencies of variables (percentage)*

Indicator	Pre-test % (Yes)	Post-test % (Yes)
Lab coat	57,1%	47,3%
Eyeglasses	43,8%	27,7%
Facial hair	79,5%	42,9%
Research symbols (instruments, flasks, microscopes, etc.)	82,1%	64,3%
Knowledge symbols (books, documents, cabinets)	53,6%	33,0%
Technological products (equipment, machines, robots, tools)	77,7%	42,9%
Relevant annotations (formulas, scientific terms, "Eureka")	33,9%	17,9%

The pre-test results indicate that students' perceptions of scientists were dominated by traditional stereotypical features: facial hair (79.5%), research symbols (82.1%), and technological products (77.7%). In contrast, eyeglasses (43.8%) and relevant annotations, such as formulas or scientific terms (33.9%), were relatively rare. These findings suggest that at the initial stage, students primarily relied on external and formal attributes when conceptualizing a scientist.

During the post-test phase, a general decrease in stereotypical indicators was observed across all variables: facial hair declined from 79.5% to 42.9%, research symbols from 82.1% to 64.3%, and technological products from 77.7% to 42.9%. Similarly, the prevalence of lab coats decreased from 57.1% to 47.3%, and that of eyeglasses decreased from 43.8% to 27.7%. This reduction indicates a shift away from conventional scientist stereotypes following the STEM-focused intervention.

The results of the Kruskal–Wallis test during the pre-test phase indicate that the groups did not differ statistically on most indicators of the scientist image, confirming the initial equivalence of the groups. A statistically significant difference was observed only for the Technological Products variable ($H = 9.276$; $df = 3$; $p = 0.026$).

The post-test Kruskal–Wallis analysis revealed statistically significant differences between the groups following the STEM-based instructional intervention (Table 8).

The post-test Kruskal–Wallis results confirmed statistically significant differences between groups for several key indicators: facial hair ($H = 73.970$; $p < 0.001$), research symbols ($H = 32.090$; $p < 0.001$), technological products ($H = 49.398$; $p < 0.001$), and relevant annotations ($H = 24.863$; $p < 0.001$).

Post-test results show a decrease in the number of students exhibiting highly stereotypical representations of scientists in the experimental group, whereas the proportion of drawings classified as low and medium stereotype levels increased.

Table 7*Statistical criteria a,b (Pre-test)*

Indicator	Lab coat	Eyeglasses	Facial hair	Research symbols (scientific instruments, chemical equipment, flasks, microscopes, etc.)	Knowledge symbols (books, cabinets, documents)	Technological products (equipment, machines, robots, tools)	Relevant annotations (formulas, scientific terms, writings such as “Eureka!”)
Kruskal–Wallis H	0.974	0.161	0.699	4.224	3.082	9.276	0.619
df	3	3	3	3	3	3	3
p	0.808	0.984	0.874	0.238	0.379	0.026	0.892
Note: a. Kruskal–Wallis test							
b. Grouping variable: group							

Table 8*Statistical criteria a,b (Post-test)*

Indicator	Post-test lab coat	Post-test Eyeglasses	Post-test Facial hair	Post-test Research symbols (scientific instruments, chemical equipment, flasks, microscopes, etc.)	Post-test Knowledge symbols (books, cabinets, document)	Pre-test Technological products (equipment, machines, robots, tools)	Post-test Relevant annotations (formulas, scientific terms, writings such as “Eureka!”)
Kruskal–Wallis H	4.074	9.709	73.970	32.090	7.009	49.398	24.863
df	3	3	3	3	3	3	3
p	0.254	0.021	0.000	0.000	0.072	0.000	0.000
Note: a. Kruskal–Wallis test							
b. Grouping variable: group							

TTCT — figural form a (finish-a-picture test)

The TTCT — Figural Form A (Finish-a-Picture Test), as originally proposed by Torrance (1966), was adapted to assess the creative thinking and visual creativity of 112 students. The adapted test was age-appropriate and sufficiently robust for diagnostic purposes, providing a practical measure of creativity. Each student’s work was evaluated using a three-level scale (low, medium, high), taking into account their ability to transform an abstract figure into a meaningful image, the freedom of imagination, and the novelty of ideas. In addition, the evaluation considered the fluency (number of ideas), flexibility (adaptability of ideas), originality, and elaboration (extent of detail) criteria.

Analysis of the results revealed considerable variability in students’ levels of creative thinking. The majority of participants transformed the abstract figures into conventional, everyday objects (e.g., the sun, a ball, decorative motifs, or geometric shapes). While these creations were logically coherent, their ideational novelty and complexity were limited; therefore, they were classified as medium-level creativity (3–5 points).

A smaller proportion of students demonstrated high-level creativity. These students transformed abstract figures into unexpected, symbolic, or narrative images, often combining multiple semantic elements into cohesive compositions. Their drawings reflected freedom of imagination, non-standard thinking, spatial organization, and clear visual logic, and were rated as high-level creativity (6–7 points).

Conversely, some students displayed minimal engagement with the task. Their drawings involved only minor alterations to the given figure, or no meaningful image was produced. These works lacked compositional

integrity and ideational development and were classified as low-level creativity (0–2 points). This finding indicates that some students may feel insecure when completing creative tasks or may have underdeveloped skills in applying visual imagination. The results of the adapted TTCT — Figural Form A (Finish-a-Picture Test) are illustrated in **Figures 3** and **4**.

Figure 3

TTCT — *figural form a (finish-a-picture test) pre-test results*



Figure 4

TTCT — *figural form a (finish-a-picture test) post-test results*



Since the Shapiro–Wilk test indicated that the data were not normally distributed (**Table 9**), initial analyses focused on calculating variable frequencies (**Table 10**). To assess differences between groups, the non-parametric Kruskal–Wallis test was applied (**Table 11**).

Table 9

Normality tests

Indicator	Kolmogorov–Smirnova			Shapiro–Wilka		
	Statistic	df	Sig.	Statistic	df	Sig.
pre-test	0.168	112	0.000	0.937	112	0.000
post-test	0.239	112	0.000	0.824	112	0.000

Note: a. Lilliefors significance correction

The results of the Shapiro–Wilk tests indicated that the data were not normally distributed for either the pre-test or post-test phases ($p < 0.05$).

Table 10*Frequency analysis*

Level	Pre-test (Frequency)	Pre-test (%)	Post-test (Frequency)	Post-test (%)
Low	8	7.1 %	9	8.0 %
Average	74	66.1 %	45	40.2 %
High	30	26.8 %	58	51.8 %
Bcero	112	100 %	112	100 %

The pre-test results showed that the majority of participants (66.1%) were clustered at the average level, with the lowest proportion (7.1%) at the low creativity level.

Following the post-test, there was a substantial increase in the proportion of high-level students (26.8% → 51.8%) and a corresponding decrease in the proportion of average-level participants (66.1% → 40.2%). The proportion of low-level participants in the control group increased slightly (7.1% → 8.0%).

Table 11*Kruskal–Wallis test results*

Indicator	Pre-test	Post-test
Kruskal–Wallis H	1.426	69.472
df	3	3
p	0.699	0.000
Note: a. Kruskal–Wallis test		
b. Grouping variable: group		

During the pre-test phase, the Kruskal–Wallis test ($H = 1.426$; $p = 0.699$) indicated no statistically significant differences among the groups in creative thinking levels.

Following the intervention, the Kruskal–Wallis test revealed statistically significant differences among the groups ($H = 69.472$; $p < 0.001$). In this analysis, the group variable was treated as a categorical factor, enabling comparisons of students' creativity levels (low, medium, high) across the experimental and control groups.

Author-designed questionnaire

Since the questionnaire data were collected in a binary yes/no format, it was not necessary to test for classical normality, as the distribution of binary data is non-continuous and does not satisfy the assumptions of the t-test. **Table 12** presents the reliability of the questionnaire items.

Table 12*Reliability statistics*

Reliability Statistics		
Cronbach's alpha	Cronbach's alpha if item is deleted	N elements
0.767	7	

To assess the internal consistency of the data, Cronbach's Alpha (1951) was calculated, yielding a coefficient of $\alpha = 0.767$, which indicates the homogeneity and reliability of the questionnaire items. The data were analyzed using the Binomial test, as presented in **Table 13**.

Table 13*Binomial test results*

			Binomial Test			
Category			N	Observed Proportion	Test Proportion	Exact Sig. (2-tailed)
Q1	Group 1	yes	103	0.92	0.50	0.000
	Group 2	no	9	0.08		
	Total		112	1.00		
Q2	Group 1	yes	95	0.85	0.50	0.000
	Group 2	no	17	0.15		
	Total		112	1.00		
Q3	Group 1	yes	95	0.85	0.50	0.000
	Group 2	no	17	0.15		
	Total		112	1.00		
			Binomial Test			

Category	N	Observed Proportion	Test Proportion	Exact Sig. (2-tailed)
Q4	Group 1	yes	95	0.85
	Group 2	no	17	0.15
	Total		112	1.00
Q5	Group 1	yes	107	0.96
	Group 2	no	5	0.04
	Total		112	1.00
Q6	Group 1	yes	86	0.77
	Group 2	no	26	0.23
	Total		112	1.00
Q7	Group 1	yes	86	0.77
	Group 2	no	26	0.23
	Total		112	1.00

For all seven items, the proportion of children responding “yes” was statistically significantly greater than 50% ($p < 0.001$).

DISCUSSION

DAST results

This study adopted the Draw-A-Scientist Test (DAST) to examine the structure and dynamics of students' stereotypical perceptions of scientists. By comparing pre-test and post-test results, the study evaluated the effectiveness of STEM-based instruction in shaping these perceptions. This change may be explained by the interdisciplinary and inquiry-based nature of STEM activities, which provide students with opportunities to engage in authentic problem-solving, collaboration, and creative exploration beyond traditional representations of science.

Overall, the analysis revealed that a significant proportion of students held stereotypical views of scientists. Many drawings included lab coats, eyeglasses, and scientific instruments (microscopes, flasks, etc.), indicating that students often perceived scientists as laboratory-bound, isolated, and primarily technical professionals. Some drawings also included technological devices and robots, suggesting that students are beginning to associate science with modern technology. However, these elements were still largely framed within traditional scientific stereotypes.

These results are consistent with prior research conducted in other countries (Bozzato et al., 2021; Toma et al., 2022; Meyer et al., 2019). International studies employing the DAST methodology have consistently shown that children often depict scientists as male, working alone in enclosed spaces, wearing lab coats, and using typical scientific instruments. Such stereotypical images have been observed among school children in the United States, Europe, Australia, and various Asian countries from an early age. Research suggests that these one-dimensional portrayals of scientists can negatively affect children's interest in science, particularly influencing girls' identification with STEM fields. Consequently, scientist-related stereotypes appear to emerge similarly across different cultural contexts.

The present study revealed some positive changes in students' perceptions; however, certain stereotypical elements were not entirely eliminated. For instance, the “lab coat” remained a frequently depicted feature. As highlighted by Hayes et al. (2020), achieving substantial shifts in children's images of science and scientists requires not only school-based interventions but also carefully designed external activities and extracurricular programs. While the methodology applied in this study proved effective in reducing some stereotypical elements, complete transformation may necessitate additional factors, such as systematic external lessons and broader cultural shifts in attitudes toward science. This shift suggests that students began to perceive scientists more broadly, multidimensionally, and realistically, rather than relying solely on traditional, one-dimensional stereotypes.

Another line of research has examined the potential of mass media to shape children's stereotypical thinking. Children's perceptions of science are highly sensitive to the images conveyed through media (Steinke et al., 2007). Through media, stereotypical representations of teachers and scientists are often reinforced—scientists are frequently depicted as men wearing glasses, conducting experiments with flasks, and working in isolated laboratory settings. Today, the media plays a central role in shaping children's understanding of science and STEM-related careers, answering questions such as who can become a scientist and what professions are associated with science. If the media portrays scientists solely as individuals engaged in complex, demanding laboratory work, children's interest in science may decline, or feelings of apprehension may arise. Therefore, promoting interest in STEM fields requires presenting diverse, accessible, and positive role models in the media.

Lamminpää et al. (2023) explored an alternative to the traditional DAST method by having children express their ideas through comics. These comics captured not only the characters' actions but also their emotions and interpersonal relationships—illustrating feelings such as curiosity, wonder, and frustration in various situations. This approach provided insights not only into children's perceptions of scientists but also into their broader attitudes toward science. However, stereotypical elements persisted, as many children still depicted scientists in lab coats working in laboratories, reflecting traditional scientific imagery.

The findings of these studies indicate that children's stereotypical images of scientists are widespread across cultural contexts and cannot be entirely altered through school-based instruction or supplementary programs alone. Therefore, a comprehensive approach is required to reduce stereotypes and foster interest in STEM fields, integrating media representations, extracurricular activities, and diverse role models.

TTCT — figural form a (finish-a-picture test) results

In this study, an adapted version of the Torrance (1966) TTCT — Figural Form A (Finish-a-Picture) test was employed to assess students' creative thinking and visual creativity during pre-test and post-test phases. The results indicated that students' initial creative thinking abilities were heterogeneous and improved substantially following the targeted STEM-based instructional intervention.

Pre-test results revealed that the majority of participants (66.1%) demonstrated an average level of creativity, typically transforming the provided abstract figures into standard, everyday objects. These findings are consistent with other studies using the Torrance test (Krumm et al., 2016; Eshun & Amoako-Agyeman, 2016), which note that students initially tend to engage in reproductive, stereotypical thinking. This observation aligns with the findings of Mouchiroud & Lubart (2001), who reported a strong correlation between originality and fluency: students who generated more ideas generally achieved higher originality scores. In the present study, the predominance of standard, everyday-object interpretations suggests that most participants had a moderate level of idea generation, and consequently, a moderate level of originality.

Additionally, the relatively small proportion of students at the low creativity level (7.2%) indicates that participants generally possessed baseline visual and spatial skills necessary to complete the task. Conversely, the high-creativity group (26.8%) demonstrated creative potential, underscoring the need for structured interventions to fully develop these abilities.

These findings reinforce the view that creativity is not a fixed, immutable trait but is substantially shaped by the educational environment and the organization of the learning process (Yoon, 2017). Comparative analysis of pre-test and post-test data demonstrated that a deliberately designed pedagogical intervention could substantially enhance students' creative thinking abilities. Specifically, STEM-based activities that emphasized research, inquiry, open-ended tasks, and the development of visual-spatial thinking led to a marked increase in students' creativity.

The results indicate that appropriately structured learning environments can effectively foster creativity, underscoring that it should not be viewed solely as an innate ability. Furthermore, the findings suggest that interdisciplinary STEM-based learning environments can effectively foster creative thinking by promoting idea generation, cognitive flexibility, and visual creativity. Consistent with the findings of Khalil et al. (2023), the present study demonstrates that creativity can be enhanced through carefully designed educational interventions rather than being viewed solely as an innate trait. Taken together, these findings directly address the research question, demonstrating that STEM technologies can effectively cultivate creative thinking skills and visual creativity among primary school students.

Author-designed questionnaire results

Several studies have explored primary school students' enthusiasm for learning and their interest in STEM technologies. For instance, Ahmad and Siew (2021) investigated the key indicators of STEM-related interest among fifth-grade students through a questionnaire, focusing on Learners' curiosity, engagement in research, and willingness to acquire new concepts.

Post and Walma van der Molen (2019) developed a questionnaire for primary school students and demonstrated that fostering children's eagerness to learn is closely associated with their expressed interests and influence of gnoseological curiosity.

Jeffers (2019) examined both primary school students and their parents regarding the need for STEM education and collected survey data. The study revealed that many children exhibited a natural curiosity aligned with effective STEM learning objectives and demonstrated strong motivation for experiential and interactive learning. Notably, the survey indicated that children often associate STEM activities with enjoyable challenges that stimulate their creativity and problem-solving skills.

Consistent with these studies, the findings of the present study showed that fourth-grade students demonstrated a high level of interest in STEM learning and expressed a strong willingness to participate in experimental activities, acquire new knowledge, and complete practical tasks. These findings suggest that primary school students are receptive to STEM-based learning experiences when they are actively engaged in hands-on and inquiry-based activities. Based on these results, the author-designed STEM curriculum “Think, Explore, Create!” was implemented to further strengthen students’ interest, motivation, and creative engagement through experiential learning.

CONCLUSION

The present study offered a comprehensive evaluation of the impact of STEM- based technologies on the development of creative thinking skills in primary school students. Statistical analyses were performed to ensure objective and accurate processing of the collected data. The Shapiro–Wilk test indicated that the data were not normally distributed; consequently, nonparametric methods, specifically the Kruskal–Wallis test, were employed for comparative analyses. This approach confirmed the appropriateness of the chosen methodology for the study’s objectives.

Results from the diagnostic phase revealed that students predominantly held stereotypical perceptions of scientists and demonstrated average levels of creative thinking. These findings underscore the need for carefully structured pedagogical interventions to nurture and enhance young learners' creative potential.

During the formative phase, the application of the specially designed STEM-based instructional program, “Think, Explore, Create!”, effectively increased students’ research engagement, promoted cognitive flexibility, and supported the development of imaginative thinking, idea modeling, and argumentation skills. The incorporation of hands-on, project-based, and play-oriented activities fostered students’ intrinsic motivation for learning and heightened their engagement in the educational process.

Post-test results demonstrated significant improvements in students’ creative thinking and more positive perceptions of science and scientists. Although some stereotypical perceptions persisted, the findings suggest that STEM-based instruction can effectively support both creativity development and broader understanding of science in primary education.

Furthermore, the results support the view that creativity is not solely an innate trait but can be developed through a well-organized educational environment. Consequently, when designing pedagogical interventions, particular attention should be given to STEM-based approaches that emphasize inquiry, exploration, open-ended tasks, and the development of visual-spatial thinking, as these elements have been shown to significantly enhance students’ creative capacities.

This study contributes to the growing body of STEM education research by providing empirical evidence from the primary school context in Kazakhstan. It also demonstrates the potential of the author-designed “Think, Explore, Create!” instructional program as an effective approach for fostering creative thinking and promoting more positive perceptions of science among young learners.

The findings have practical implications for primary school teachers, curriculum developers, and educational policymakers by supporting the integration of inquiry-based and interdisciplinary STEM activities into primary education. Such approaches can contribute to the systematic development of creative thinking and strengthen students’ interest and engagement in STEM learning.

Limitations

This study was conducted in two school lyceums in Shymkent, Kazakhstan, with the aim of evaluating the impact of STEM technology integration on students’ perceptions of science and the development of creative thinking skills. However, several limitations should be considered when interpreting the findings:

- First, the adapted versions of the Draw-A-Scientist Test (DAST) and the Torrance Tests of Creative Thinking (TTCT) — the Figural Form A (Finish-a-Picture) used in this study- are indirect assessments employed to evaluate students’ perceptions of scientists and their creative thinking abilities. As such, the data may not fully capture the complexity of students’ cognitive and attitudinal processes.
- Second, convenience sampling and the use of intact classroom groups may have limited the representativeness of the sample. As the study was conducted in only two school-lyceums in Shymkent, Kazakhstan, the findings should be interpreted within the context of the participating schools and may not be generalizable to all primary school students in Kazakhstan or other educational settings.

For future research, it is recommended to expand the methodological toolkit to deepen the understanding of the effects of STEM technology integration on students’ STEM-related competencies and innovative thinking skills. Specifically, combining drawing-based assessments with qualitative methods such as interviews,

observations, or written reflections could provide a more comprehensive understanding of students' scientific understanding and creative processes.

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Ethical statement

The study was reviewed and approved in accordance with the ethical requirements of South Kazakhstan Pedagogical University named after O. Zhanibekov. Ethical approval was granted by the University Ethics Committee on September 10, 2025. The study was conducted in accordance with the ethical principles applicable to research involving human participants. Informed consent was obtained from the parents or legal guardians of the participating students, and participation was voluntary.

Competing interests

The authors declare that they have no relevant financial or non-financial interests to disclose.

Author contributions

All the authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by all the authors. All the authors read and approved the final manuscript.

Data availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request. All data were anonymized to protect the privacy of the participating students.

AI disclosure

No artificial intelligence tools were used in the conduct of the research, analysis of the data, or preparation of the original manuscript. AI-assisted tools were used only for language editing and improving the clarity of the manuscript.

Biographical sketch

Aidana Yeraliyeva is a doctoral student in the Department of Primary Education Methodology at O. Zhanibekov South Kazakhstan Pedagogical University, Kazakhstan. Her research focuses on STEM education, primary education, creative thinking, and innovative teaching technologies. Her current research interests include STEM-based learning, the development of students' creative thinking skills, educational technologies, and innovative pedagogical approaches in primary education.

Assel Yesnazar is the Head of the Department of Primary Education Methodology at O. Zhanibekov South Kazakhstan Pedagogical University, Kazakhstan. She holds a PhD in Primary Education. Her professional and academic work focuses on improving the quality of primary education and developing effective teaching methodologies. Her current research interests include STEM education, innovative learning environments, digital technologies in education, interdisciplinary approaches to teaching, and the development of students' creative and critical thinking skills.

Lyazzat Akyanova is a Senior Lecturer in the Department of Primary Education Methodology at O. Zhanibekov South Kazakhstan Pedagogical University, Kazakhstan. She holds a Candidate of Biological Sciences degree. Her academic and professional interests focus on primary education, teaching methodology, and the development of effective educational practices. Her research interests include innovative teaching methods, STEM education, interdisciplinary learning, and the development of students' cognitive and creative abilities.

Gulbanu Urystenbekova is a Senior Lecturer in the Department of Primary Education Methodology at O. Zhanibekov South Kazakhstan Pedagogical University, Kazakhstan. She holds a Candidate of Pedagogical Sciences degree. She has extensive teaching experience in Kazakh language and literature, as well as in teacher education. Her academic interests include primary education, teaching methodology, Kazakh language education, children's literature, and innovative approaches to language teaching.

Nazërke Berikbayeva is a master's student in the Department of Primary Education Methodology at O. Zhanibekov South Kazakhstan Pedagogical University, Kazakhstan. Her academic interests focus on primary education, STEM education, innovative teaching methods, and the development of students' creative thinking skills. Her current research interests include STEM-based learning, educational technologies, interdisciplinary approaches to teaching, and innovative pedagogical practices in primary education.

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