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Research Article

AI-Generated STEM Activities: The Impact of the Activities on the Scientific Creativity of Gifted Students

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Abstract – This study aims to answer the questions: "Does the implementation of AI-generated STEM activities have an impact on students' levels of scientific creativity?" and "What are the students' views and experiences regarding AI- generated STEM activities?". The study group consists of 49 gifted 4th-grade students enrolled in a Science and Art Center in Bursa, Turkey during the 2023-2024 academic year. Utilizing a case study analysis, the research demonstrates that AI-generated STEM activities significantly enhance students' scientific creativity levels. Additionally, most students expressed positive views about the activities and stated that they developed their creativity, gained various skills and felt like engineers due to their involvement in design. The "Scientific Creativity Scale," adapted for use in Turkish context by Aktamış (2007), and a semi-structured interview form were employed in the research. This study highlights the potential of artificial intelligence in designing STEM activities and offers a new approach to develop students' scientific creative thinking skills.

Keywords: Artificial intelligence, STEM, gifted-students, scientific creativity.

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Introduction

STEM and Artificial Intelligence

Artificial intelligence (AI) is one of the most significant technologies in use today, and its impact is growing daily. The term "artificial intelligence" was first introduced in 1921 in a play by Czech writer K. Capec (Arslan, 2020), and since then, AI has continued to develop, being integrated into nearly every field, especially education. In their study, İşler and Kılıç (2021) discussed the various benefits of using AI in education and teaching. AI helps personalize learning by offering an educational experience tailored to each student's individual needs and learning styles. It also saves teachers time by providing tools that can perform certain tasks, such as preparing necessary materials and digitizing textbooks. Moreover, AI enables continuous assessment and feedback, allowing students to identify and fill gaps in their knowledge (Arnett, 2016). Through virtual reality and immersive environments, AI promotes active student engagement by offering interactive, three-dimensional worlds that enhance interaction with learning materials (Karsenti et al., 2019). Additionally, AI facilitates the easy collection and storage of student data, making it highly effective in the education of students with special needs and contributing to the accessibility of global classrooms for all learners (Woolf et al., 2013).

AI is increasingly being utilized in teaching, particularly in STEM (Science, Technology, Engineering, Mathematics) education (Linn et al., 2023; Xu & Ouyang., 2022). The primary goal of AI in STEM education is to enhance the quality of teaching and learning in STEM fields (Hwang et al., 2020). Integrating AI into STEM education offers various advantages, such as providing personalized and adaptive learning opportunities, helping teachers better understand students' learning behaviors, and automatically assessing STEM learning outcomes (Alabdulhadi & Faisal, 2021; Walker et al., 2014). AI is believed to enable more effective student-centered STEM education, potentially leading to better student achievement (Barkoczi et al., 2024; Triplett, 2023; Xu & Ouyang, 2022). Although this study uses AI-generated STEM content, both the focus of this study and research on the direct integration of artificial intelligence into STEM teaching practices remain limited. A review of the literature using both the keywords “artificial intelligence education” and “STEM” in the Web of Science and Google Scholar databases revealed 24 studies published between 2019 and 2024. Among them, Skowronek et al. (2022), Xu and Ouyang (2022), Kong et al. (2021), Hebebci (2023), Chang et al. (2023), and Triplett (2023) discussed the benefits of AI in learning STEM content, developing educational materials, evaluating student performance, and improving learning environments. Jang et al. (2022) developed a STEM-based AIED (Artificial Intelligence Education) program for primary school students aged K-6. Students have been tasked with researching topics such as ecosystem conservation and social integration of disadvantaged individuals, developing solutions to these issues using artificial intelligence, and programming AI models to propose solutions. Lin et al. (2021) discuss a STEM-based artificial intelligence learning approach for non-engineering undergraduate students. A three-week STEM-based artificial intelligence curriculum was implemented, and the results indicated a significant positive impact on students' perceptions of both artificial intelligence and teamwork. Körpeoğlu and Yıldız (2024) used “Adaptive Neural Network-Based Fuzzy Logic Model”, created with the help of AI, to measure students' attitudes towards STEM and compare these with actual attitude scores.

In the study of Uğraş et al. (2024), it was revealed that teachers generally agreed on the benefits of integrating ChatGPT into early childhood STEM education. Teachers emphasized ChatGPT’s significant role in providing instant feedback, offering personalized content suggestions, encouraging creativity, relating learning to real-life contexts, and increasing student motivation. According to the study by Zhai et al. (2023), AI enables time and labor savings in assessment processes in STEM education. It can analyze student learning in real-time, especially in complex tasks such as open-ended responses, modeling, and argumentation, and create a feedback loop. When used appropriately, AI technologies can provide a more equitable, effective, and personalized STEM education. In another study conducted by Sun et al. (2024), they provide concrete recommendations in their research for enhancing pre-service STEM teachers' willingness to integrate AI technologies into their teaching practices.

Previous studies have discussed the positive role of AI in STEM education, and they also highlight AI's potential in the process of designing educational activities. In other words, AI has the potential to assist teachers in lesson and activity planning (Çelik et al., 2022; Zawacki-Richter et al., 2019). For example, a study by Cooper (2023) examined the effectiveness of AI tools like ChatGPT in creating science education activities. The researchers suggest that the developed activities are consistent with effective pedagogical practices and can serve as supportive tools for teachers. Thus, artificial intelligence technologies have the potential to support teachers in lesson planning processes, making learning more effective and helping reduce teachers' workload. (Althuwaybi, 2020; Luckin et al., 2016). However, despite increasing interest in the integration of artificial intelligence into

STEM education, there remains a notable gap in the literature regarding its effectiveness, particularly in the context of designing activities tailored for gifted learners. The current body of research has largely focused on general applications, leaving implementation methods and student-specific impacts underexplored. Given the unique cognitive and emotional needs of gifted students, it is essential to investigate how AI-generated educational activities can address their learning potential more effectively. Therefore, this study aims to contribute to the field by examining the design, implementation, and outcomes of AI-driven STEM activities specifically developed for gifted learners, with the goal of informing future educational practices and policies.

STEM and Scientific Creativity

Creativity in science is defined by the term "scientific creativity." Scientific creativity refers to the ability to present or generate an original idea using existing knowledge. This ability often emerges when encountering a problem (Aktamış & Ergin, 2006). Additionally, scientific creativity is the ability to create original products with societal or personal value toward a specific goal using given information, or the potential capacity to produce such products. Furthermore, this process is based on scientific knowledge and skills (Hu & Adey, 2002).

In the literature, creativity is defined by its core features, such as problem-solving and product design (Kale, 2010), and encompasses scientific creativity. These features align with the goals of STEM education. STEM education is based on an interdisciplinary approach that integrates science, technology, engineering, and mathematics. Rather than merely transferring knowledge, STEM education aims to instill 21st-century skills such as creativity, problem-solving, product development, collaboration, and entrepreneurship (Voogt & Roblin, 2012). Through this, students are expected to develop alternative solutions to everyday problems by approaching them with a scientific perspective. Integrating creativity into STEM education is believed to not only enhance students' creative thinking abilities but also positively impact the success of STEM education (Kaplan Sayı, 2021).

Many studies on STEM and scientific creativity highlight the positive effects of STEM education on students at different levels. For instance, Kutru and Hasançebi (2024) reported that “Argumentation-Based Science Learning”, supported by STEM, enhanced creativity in 7th-grade students, while Asal Özkan and Sarıkaya (2023) found similar results in 4th-grade students through engineering design-based activities. Sarıçam (2019) examined creativity development in 6th-grade students through digital game-based applications, and Uğraş (2018) studied creativity development in 7th-grade students through STEM activities. Similarly, Rasul et al. (2018), Siew and Ambo (2018) and Zhang et al. (2024) emphasized that STEM activities supported creativity across various age groups. In their study, Eroğlu and Bektaş (2022) demonstrated the effectiveness of 5E-based STEM strategies in 9th-grade students.

In summary, the existing literature highlights the crucial role of STEM activities, conducted through various methods, in enhancing students' scientific creativity. Therefore, this study aims to examine the impact of AI-generated STEM activities on students' scientific creativity. It is hypothesized that, if the activity is a suitable STEM activity, it will increase students' scientific creativity.

Gifted Students and Scientific Creativity

Gifted students are defined as individuals who possess high-level abilities and skills in one or more areas (Philips, 2019). These students exhibit high potential in terms of creativity and problem-solving skills (Ercan Yalman & Çepni, 2021). Moreover, it is believed that above-average intelligence is required to demonstrate scientific creative performance (Hu & Adey, 2002). According to Hennessey (2004) gifted individuals possess the innate abilities to meet all the requirements of the scientific creativity process. Given these characteristics, it is reasonable to assume that gifted students possess a high level of scientific creativity. However, there is a need for more research on how to cultivate scientific creativity in these students, as it is crucial for both scientific advancement and their personal development. Due to their advanced cognitive abilities, such as creativity, gifted students require specialized educational approaches to meet their unique learning needs (Kaya & Mertol, 2022). These students benefit from educational environments and instructional methods that are specifically tailored to their developmental characteristics and intellectual potential (Baltacı, 2016). Moreover, gifted individuals, who can be described as advanced learners, are expected to play a significant role in the future scientific and technological progress of society (Keser & Kalender, 2016). These considerations underscore the necessity for further research focused on understanding and supporting the educational development of gifted students, particularly in ways that nurture their scientific creativity.

While some progress has been made, there is a clear need for further development and implementation of educational policies that cater to the unique needs of gifted students in Turkey (Cevher Kılıç, 2015). Research on scientific creativity and gifted students can contribute to the improvement of educational policies and practices. Such research can help us better understand the specific needs and potential of these students, enabling us to provide them with more suitable educational environments and programs. Bıçakçı and Baloğlu (2018) examined studies conducted in Turkey on the creativity skills of gifted students and they raised concerns about whether the programs and curricula designed for gifted students in Turkey are sufficient to cultivate creativity.

Camcı Erdoğan (2014) found that differentiated science and technology instruction based on scientific creativity increased the achievement, attitudes, and creativity of gifted students. Therefore, it is evident that enriched environments with diverse activities and approaches are essential for these students.

Ercan Yalman and Çepni (2021) concluded that gifted students lacked self-confidence in scientific creativity and scientific problem-solving. According to the researchers, creating motivating environments in the teaching process is crucial for students to develop self-confidence in creativity. Although these students are recognized for their superior creativity, it is predicted that educational environments supported by contemporary and innovative tools will enhance their scientific creativity. Cevher (2023) emphasized the need to support STEM-focused schools and faculties for gifted individuals and stated that innovative techniques and tools based on anomalies, challenging processes, and argumentation can be used to enhance scientific creativity.

In this study, gifted students were selected to participate in activities developed by artificial intelligence. There are several reasons for this. Primarily, these students are strong in problem-solving and creative thinking skills (Ercan Yalman & Çepni, 2021) and have high-level learning potential (Philips, 2019). For this reason, they may require more than standard programs and teaching methods (Renzulli, 2013). STEM activities developed by artificial intelligence can help further develop students' skills in these areas. Additionally, these activities can be personalized for each student and support their learning processes.

Purpose and Importance of the Research

The research aims to investigate the impact of STEM activities developed by artificial intelligence on the scientific creativity of gifted fourth-grade students, while also evaluating students' experiences and views throughout the process to gain a better understanding of AI's role in this context. To this end, the research question to be addressed is: "How successful is artificial intelligence in creating STEM activities for gifted students?" In this context, the following sub-problems will be examined:

1. Does the implementation of STEM activities generated by artificial intelligence have an effect on students' levels of scientific creativity?

2. What are students' opinions and experiences regarding STEM activities developed by artificial intelligence?

To the best of the author's knowledge, and in light of the researches discussed thus far, there appears to be a lack of studies, both domestically and internationally, on the role of artificial intelligence in designing activities and the impact of AI-generated STEM activities on scientific creativity. Additionally, although this is not the main focus of the study, no studies have been found in the domestic literature that encompass both artificial intelligence and scientific creativity; yet, one study exists in the international literature (Colton & Steel, 1999). This research discusses how artificial intelligence serves as a facilitator in generating new ideas, analyzing data, designing experiments, and conveying results in the context of scientific creativity.

This study is expected to contribute significantly to the literature by addressing critical gaps at the intersection of artificial intelligence, STEM education, and scientific creativity. More specifically, it aims to highlight how AI-generated STEM activities differ from traditional approaches in terms of personalization, adaptability, and cognitive challenge. These differences are particularly relevant for gifted learners, who require more complex, enriched, and stimulating educational experiences. By focusing on these distinctions, the study will provide valuable insights and practical guidance for researchers, educators, and policymakers interested in optimizing AI-based educational strategies to meet the advanced learning needs of gifted students.

Method

Research Design

This study employed an experimental design, specifically a one-group pretest-posttest design. In this design, a single group of participants is exposed to the intervention, and their performance is measured both before (pretest) and after (posttest) the implementation of the intervention (Frankell & Wallen, 2016).

Participants

The study group consists of 49 gifted 4th grade students attending a Science and Art Center (BİLSEM) in Bursa, Turkey during the 2023-2024 academic year. Convenience sampling was employed in this study. Convenience sampling is a practical and low-cost method that allows researchers to easily access participants (Yıldırım & Şimşek, 2008). 18 (36.7%) of the participants are girls and 31 (63.3%) are boys. Additionally, the majority (81%) attend public schools.

Data Collection Tools

Scientific Creativity Scale

The scale developed by Hu and Adey (2002) to measure students' scientific creativity skills and adapted into Turkish by Aktamış (2007) for 7th grade students. It consists of 6 open-ended questions. For example prompts and questions such as; "Please design an apple picking machine. Draw a picture, point out the name and function of each part." or 'If you invented a time machine, which time would you travel to and which scientific questions would you like to investigate?' are included in this scale. Asal (2020) applied this scale to the 4th grade level and calculated the Cronbach Alpha coefficient of internal consistency as 0.74. In this study, the alpha value was 0.70 for the pretest and 0.68 for the posttest. Although a reliability coefficient of .70 or higher is generally recommended, values slightly below .70 (e.g., .65–.69) can be considered acceptable, particularly when the number of items is limited (George & Mallery, 2003).

Interview

A semi-structured interview were conducted to obtain students' opinions about the activities. Students were asked about their feelings and thoughts during these activities, the difficulties they encountered and what they learned during the activity. The interviews lasted approximately between 5 and 11 minutes. During data analysis, inter-coder reliability was established. Two researchers independently coded a subset of the interview data, and discussed until a consensus was reached. The intercoder agreement rate was above 80%, which is considered (Miles & Huberman, 1994).

Implementation Process

After the Scientific Creativity Scale was applied to the students as a pre-test, the selected 3 activities were applied to the students for three weeks without any changes. Although scientific creativity is a multifaceted skill that typically develops over time, several studies have shown that short-term interventions can produce measurable gains. For example, a meta-analysis conducted Bi et al. (2020) demonstrated that even brief instructional interventions could significantly enhance students' scientific creativity.

In the following week, the same scale was applied as a post-test, followed by interviews in which students' opinions about the activities were obtained. The process is shown in Figure 1.

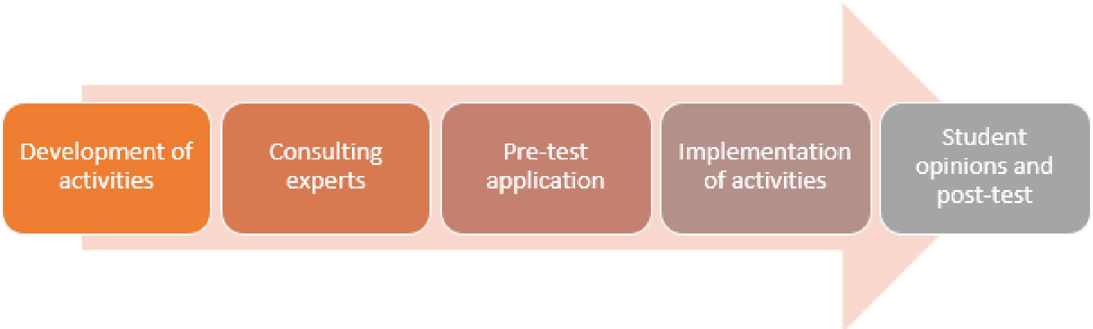

Figure 1 Implementation Process

Development of Activities

In line with the purpose of the study, the ChatGPT artificial intelligence robot was used to design the activities for the students. Firstly, some articles about scientific creativity, gifted individuals, Science and Arts and Centers and STEM subjects were entered into the artificial intelligence, and then, based on these texts and its own database, it was asked to design different STEM activities that could improve the scientific creativity of 4th grade gifted students (OpenAI, 2024). An example of the input prompt is presented in Figure 2.

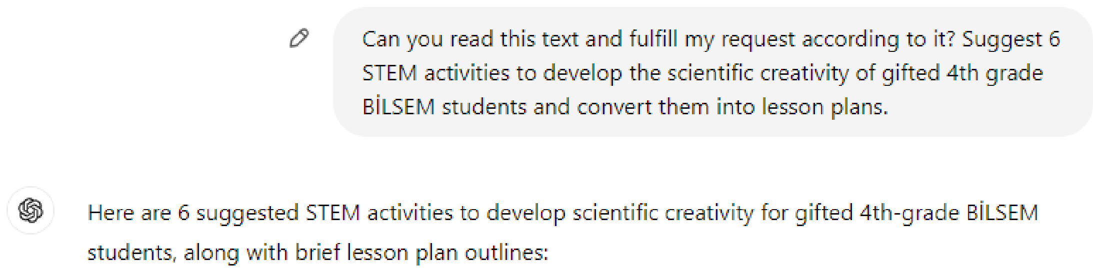

Figure 2 The Prompt Entered into ChatGPT

Three experts were consulted for these designed activities. The experts are individuals who work as science teachers in Science and Art Centers where gifted students are educated and who have doctoral level education in science education. In addition, the experts have various academic studies in the field of STEM. The experts were asked for their opinions about the appropriateness of the activities for gifted students, grade level and STEM, and they were mostly found to be appropriate for the students. However, since the purpose of this study is to examine the impact of AI-generated STEM activities as they are, no revisions or content changes were made based on expert feedback.

Implementation of Activities

Three activities were selected based on expert opinions and each activity was implemented for one week. The AI suggested version of the activities were presented in Appendix A. The description of the implemented activities and aims were presented in Table 1. In total, the implementation process lasted three weeks.

Table 1 The Description of the Implemented Activities

Activity name	Aim	Learning outcomes in the BİLSEM program	Number of hours
Engineering Inspired by Nature	To explore the concept of biomimicry and design innovative solutions inspired by nature.	1)Observes and analyzes structures and functions in nature. 2) Identifies problems and generates solutions. 3)Develops creativity and collaborative working skills."	40’+40’+40’ (three class hours)
Sustainable House Design	To help students understand the concept of sustainability and use scientific principles to design a sustainable house.	1)Recognizes the concept of sustainability and relates it to daily life. 2)Explains the importance of renewable energy sources and eco-friendly practices. 3)Develops problem-solving skills through the design thinking process.	40’+40’+40’ (three class hours)
Machine Design and Construction	To help students develop engineering skills and produce creative solutions to problems.	1)Explores the working principles of simple machines and relates them to daily life. 2)Develops problem-solving skills using the design thinking process. 3)Engages in productive collaboration by sharing different ideas. 4)Integrates engineering and creativity skills to solve a problem.	40’+40’ (two class hours- as suggested by ChatGPT)

Activity 1: Engineering Inspired by Nature

The aim of this activity is for students to explore the concept of biomimicry and design innovative solutions inspired by nature. Sample designs of students for the activity are shown below.

Figure 3 Example of Design Created by Students_1: Insect Hunter Inspired by Insect Trap

Figure 4 Example of Design Created by Students_2: Safe Climbing Shoes Inspired by the Lizard

Figure 5 Example of Design Created by Students_3: Hedgehog-inspired Home Security Tool

Figure 6 Example of Design Created by Students_4: Fishing Gear Inspired by Octopus and Angler Fish

Activity 2: Sustainable House Design

The aim of this activity is to help students understand the concept of sustainability and design a sustainable house using scientific principles. Student design examples of the activity are presented below.

Figure 7 Examples of Sustainable House Designs Created by Students

Activity 3: Machine Design Construction

The aim of this activity is to improve the engineering skills of the students and to enable them to produce creative solutions to problems. Student design examples of the activity are presented below.

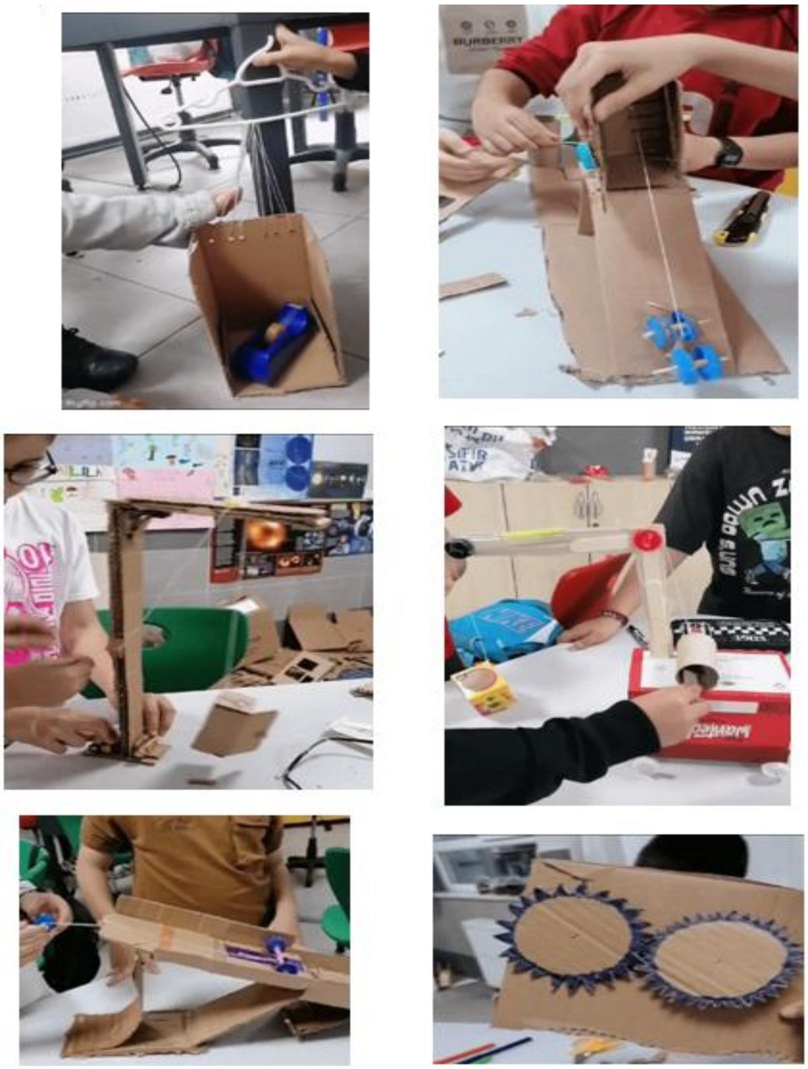

Figure 8 Examples of Machine Designs Created by Students

Data Analysis

For the first four questions of the Scientific Creativity Scale consisting of six open-ended questions, fluency, flexibility and originality scores were examined. For each answer produced 1 point (fluency score), for each different application suggested + 1 point (flexibility score), for each answer found in less than 5% of the participants 2 points, for each answer found in between 5% and 10% 1 point (originality score). In question 5, a maximum of 9 points for each method given (3 points for tools, 3 points for principle, 3 points for procedure), a total of 18 points if an answer suggests two perfect methods, plus 4 points for methods less than 5% of all answers, 2 points for 5% to 10%. In question 6, 3 points were awarded for each separate function of the machine, plus an originality score between 1 and 5 based on a comprehensive overall impression (Asal, 2020).

For example, 19 of the students responded with "test tube" to the question "Can you write what you can use an empty tin can for in the laboratory?" in part a of question 1.

Although each of the students received a "fluency score" of "1" point for giving a scientific answer, they did not receive an "originality score" for giving an answer that is common to most people. The student who wrote "sound transmission material" in the same question received "2" points for "originality" in addition to the fluency score because he gave an answer that is common in less than 5% of the students.

In the quantitative analysis of the data, normality analysis was performed to decide whether parametric or nonparametric tests should be applied. Skewness and kurtosis values, Q-Q Plot and histogram graphs were used for normal distribution. According to the normality analysis, the skewness and kurtosis values for the pre-test were .272 and -0.577, respectively, with standard errors of .340 and .668. For the post-test, the skewness was .206 and the kurtosis was .066, with the same standard errors (.340 and .668, respectively). Considering the distribution of the graphs and skewness and kurtosis values in the range of -2, +2 (George & Mallery, 2010), the distributions were accepted as normal. For this reason paired-sample T test, which is a parametric test, was used in the comparison of the mean scores of the students from the Scientific Creativity Scale in the pre-test and post-test.

The interviews were conducted one-on-one with the students after the activities were completed. Considering the age range of the students, it was observed that they generally preferred to give short answers. The answers given to the interview form were analyzed by MAXQDA 24 program for content analysis.

Findings

Findings Related to the First Research Question

The table obtained as a result of the statistical analysis of the research question "Is there a significant difference between the pre-test and post-test scores when the scientific creativity levels of the students are compared as a result of the implementation of STEM activities produced by artificial intelligence?" is as follows.

Table 2. Analysis Results Regarding the Pre-Test and Post-Test Scores of the Students' Scientific Creativity Levels

Scale	Test	N	M	SD	t	df	p
Scientific creativity	Pre-test	49	4.59	1.65	-6.928	48	<.001
	Post-test	49	6.19	1.97			

When the paired samples T-test results in Table 2 were examined, it was found that there was a significant difference in favor of the post-test scores in terms of students' scientific creativity scores after the activities ($t(48) = 6.928$, $p < .05$, Cohen's $d = .990 > 0.8$).

Findings Related to the Second Research Question

As a result of the content analysis of the answers received from the students as a result of the interviews within the scope of the research question "How are the opinions and experiences of the students about the STEM activities developed by artificial intelligence?", the opinions of the students about "what they learned from the STEM activities developed by artificial intelligence" were grouped under five main themes. A prominent theme was the enhancement of creative thinking. Most students reported that the activities were beneficial in enhancing their creativity. One student noted:

- " *These activities helped me improve my creativity and think in more diverse ways"*

Additionally, it was observed that students gave responses such as*:*

- *"I realized that I am very creative"*
- *"I was able to generate more creative ideas"*

Many students described how the activities helped them draw connections between natural phenomena and the process of creating new designs and inventions. For example, students provided responses such as the following:

- *"I found out that many innovations are based on ideas drawn from nature."*
- *"Each animal has different characteristics, and we can create various things by taking inspiration from animals."*
- *"It is very important to take inspiration from nature."*

Several students highlighted how the projects increased their understanding of sustainability. One participant explained:

- *"I now have a clearer understanding of what sustainability means."*

One of the students also expressed this idea by saying:

- *"I learned what a sustainable home includes and how to create related projects.'"*

Teamwork was another emergent theme. Some students appreciated the collaborative nature of the tasks, expressing that working in groups improved their communication and cooperation skills. For example, a student mentioned:

- *"I learned the meaning of the phrase 'strength comes from unity' through teamwork."*

Last but not least, some students emphasized that they discovered the enjoyable and engaging aspect of science, noting that the activities made science feel more accessible and exciting. For example, a participant underlined that:

- "*I learned that science is very fun and interesting*."

Another student stated the following*:*

- *"I liked science more."*

During the activity, most students stated that they felt like engineers, describing their experience through four key themes. One of the most prominent themes that emerged was the process of designing. Several students associated engineering with the act of creating designs. In other words, thinking and designing how to do it before the application reminded them of the tasks of an engineer.

This was followed by the process of creating something new. Students described the excitement of developing original solutions and making unique connections between ideas, as reflected in statements like:

- "*I realized that I can create new inventions from some objects or materials, and that I can design something unique even with just two materials."*

In addition, some students emphasized that working on a project made them feel like an engineer, and a few of them stated that making calculations contribute them feel like engineers.

Finally, when students were asked what the activities contributed to them, their responses revealed four main themes that reflected different dimensions of learning and development. The most prominent theme was skill development. Many students emphasized that the activities helped them improve their skills:

- *"Using hot glue and cutting cardboard improved my skills."*
- *"Working with different materials to design objects enhanced my hands-on skills."*

The second theme that emerged was social development. Several students pointed out that working collaboratively helped them strengthen their communication and teamwork skills:

- *"I learned to socialize a bit more with my friends."*

- *"I got to know my friends better, and they got to know me better too."*

Another theme was the acquisition of knowledge. Some students stated that they learned new concepts related to science, technology, or sustainability through the activity process. Lastly, some students also expressed that they had a great time during the activities:

- *"I learned a lot and had fun."*
- *"The activities weren't challenging for me—in fact, I really enjoyed them."*

Results, Discussion and Suggestions

This study aimed to examine the impact of AI-generated STEM activities on the scientific creativity of gifted fourth-grade students, as well as to explore students' experiences and opinions regarding these activities. For this purpose, firstly, operational definitions related to STEM and gifted students were given to the AI and then it was asked to design STEM activities suitable for the target group. Expert opinion was taken about the designed activities and they were deemed appropriate for the student level. In line with the objective, the findings revealed a statistically significant increase in students' scientific creativity levels after the intervention, as demonstrated by the results of the paired-samples t-test ($t(48) = -6.928$, $p < .001$). The effect size (Cohen's $d = 0.99$) indicates a large effect, which is considered highly impactful in educational research (Cohen, 1988).

From a methodological standpoint, the convergence of quantitative and qualitative findings strengthens the internal validity of the study. The increase in scientific creativity scores is not only statistically significant but also meaningfully perceived by the students themselves. This consistency between numerical data and student experiences provides a robust case for the effectiveness of AI-generated STEM activities.

This finding supports existing literature emphasizing the positive effects of STEM education on creativity (Asal Özkan & Sarıkaya, 2023; Ercan Yalman & Çepni, 2021; Eroğlu & Bektaş, 2022; Kutru & Hasançebi, 2024; Renzulli, 2013). Moreover, in a meta-analysis conducted by Bi et al. (2020), short-term interventions were also shown to significantly enhance scientific creativity, with moderate effect sizes averaging around 0.6. Therefore, the high effect size found in this study suggests that AI-generated activities may offer an even more powerful intervention tool in this context.

In addition to the quantitative findings, student interviews provided deeper insights into their learning experiences. Many students reported that the activities helped them think more creatively, make original designs, and draw inspiration from nature. For example, themes such as *"feeling like an engineer," "learning from nature,"* and *"discovering science is fun"* emerged prominently. This not only reflects the students' cognitive engagement but also their affective connection to the subject matter.

The theme of *"feeling like an engineer"* was particularly striking. Students expressed that processes such as planning, designing, and solving problems made them feel like real engineers. This is consistent with findings by Lin et al. (2021), who emphasized that STEM-based AI interventions promote professional identity and teamwork among students. Similarly, students' recognition of nature as a source of innovation highlights the value of biomimicry in STEM learning (Chang et al., 2023; Rasul et al., 2018). By linking animal characteristics with product design, students demonstrated authentic engagement with scientific creativity.

Furthermore, the activities increased students' awareness of sustainability. Several students indicated that they had learned what it means to design an eco-friendly house and how renewable energy relates to daily life. These findings align with the goal of STEM education to cultivate environmentally responsible citizens (Walker et al., 2014).

Interview responses also indicate that students had positive views towards the activities and discovered the fun aspect of science. The statement of one of the students, "*I learned that science is very fun and science is very interesting,*" shows that STEM activities are effective not only in terms of academic gains but also in developing positive attitudes towards science. This finding is in accordance with the literature that STEM activities can increase student motivation and encourage interest in science (Eroğlu & Bektaş, 2022; Sarıçam, 2019). Finally, although most of the students stated that they did not have any difficulties during the activities, some students stated that they had difficulties. These difficulties were experienced in issues such as using materials and finding design ideas. It was observed that there was no difficulty in understanding the activity or content. This can be considered an indicator of the suitability of the activities for the students.

Another important finding is that students identified teamwork, skill development, and enjoyment as major outcomes of their participation. These non-academic gains reinforce the holistic value of STEM activities, which aim not only to build academic knowledge but also to develop 21st-century skills such as collaboration, problem-solving, and creativity (Voogt & Roblin, 2012).

Moreover, the positive outcomes of AI-generated content highlight the potential of such systems to democratize high-quality instructional design, especially for specialized populations such as gifted students. These learners require enriched and differentiated experiences (Kaya & Mertol, 2022; Renzulli, 2013), and AI offers a scalable method to meet those needs.

In conclusion, it can be stated that STEM activities developed by artificial intelligence can be integrated into educational environments. This study also emphasizes the role of AI in supporting the lesson planning processes for science courses and increasing the potential of the learning environment. According to a study by Ateş and Sungur Gül (2023), STEM education faces a range of complex challenges, including first-order barriers (time, resources, and support), second-order barriers (teacher beliefs), and third-order barriers (curriculum redesign). The emergence of these barriers as a source of concern for teachers inevitably influences their ability to incorporate STEM education into their classrooms or learning environment. They also found that STEM self-efficacy and STEM concerns have a positive and significant relationship. It is thought that the use of artificial intelligence will be a facilitating factor for teachers who have low self-efficacy perceptions in integrating STEM activities into their lessons and finding activities. In addition, considering the importance of lesson plans for science education and the fact that teachers cannot devote enough time to the planning process due to their workload and can face limited access to resources, and difficulties in curriculum adaptation (Ateş & Sungur Gül, 2023; Mon et al., 2016). AI support can facilitate this process for teachers. In parallel to this, Zawacki-Richter et al. (2019) and Çelik et al. (2022) state that artificial intelligence can help teachers design lessons or activities. AI technologies, such as ChatGPT, may serve as effective tools for reducing teachers' workload and generating developmentally appropriate, personalized, and creative STEM content (Althuwaybi, 2020; Luckin et al., 2016; Zawacki-Richter et al., 2019).

The results of this study indicate that the inclusion of AI-generated STEM activities in teacher education programs is essential. In-service training should be organized to help teachers understand how to utilize artificial intelligence in STEM planning processes. Furthermore, policy recommendations can be developed to promote the widespread implementation and curriculum integration of such practices in special education institutions, such as science and art centers.

However, several limitations must be acknowledged. First, although the "Scientific Creativity Scale" was adapted for younger students by Asal (2020), its original development was intended for seventh-grade students (Aktamış, 2007; Hu & Adey, 2002). While reliability coefficients were acceptable, the conceptual suitability of the questions for fourth graders may require further investigation. Additionally, the study was conducted with a relatively small, convenience sample drawn from a single Science and Art Center (BİLSEM) in Bursa, limiting the generalizability of the results. Moreover, considering the limited weekly instruction hours in BİLSEM compared to regular schools, spreading the implementation of the activities over a longer period in future studies may further enhance the reliability of the findings.

Future research should explore the long-term impacts of AI-generated STEM activities across different age groups and educational settings. Additionally, it is recommended that teachers' attitudes, efficacy beliefs, and cognitive readin**ess** regarding AI-supported lesson planning be investigated. This can inform teacher training programs and policy-level decisions on AI integration in curricula.

It is also important to mention that as this study implemented a novel approach by using artificial intelligence to design STEM activities, reflections on the functionality and limitations of the method are critical. While the AI successfully generated activity drafts aligned with the operational definitions provided, expert evaluation was necessary to ensure educational appropriateness and coherence with pedagogical goals. Although the activities were found effective and engaging by students, it was observed that not all of the designed activities included learning outcomes and activity duration. This indicates that the prompts given to the AI play a crucial role, and that human intervention is necessary to improve the outputs. According to the authors The AI demonstrated potential in accelerating lesson planning; however, it could not fully replace teacher insight, especially in terms of emotional, cultural, and developmental appropriateness.

In summary, the study provides strong evidence that AI-generated STEM activities significantly enhance the scientific creativity of gifted fourth-grade students. The combination of quantitative and qualitative data underscores the cognitive, emotional, and social benefits of such interventions. While limitations regarding sample and tool suitability exist, the results point to promising applications of artificial intelligence in instructional design. As AI tools continue to evolve, their thoughtful integration into STEM education can offer enriched, personalized learning environments that foster creativity, innovation, and engagement particularly for gifted learners.

Compliance with Ethical Standards

Disclosure of potential conflicts of interest

The authors declare no conflict of interests with respect to the study.

Research involving Human Participants and/or Animals

This study was approved by the Uludağ University Research and Publication Ethics Committees and conducted in accordance with the ethical standards set by the relevant institutional and national regulations, including the approval of the Ministry of National Education.

Informed consent was obtained from all participants involved in the study.

Data availability

The data of this study are not publicly available due to confidentiality and privacy considerations. For further details regarding the dataset, please contact the corresponding author.

Yapay Zeka ile Geliştirilen STEM Etkinlikleri: Özel Yetenekli Öğrenciler için Önerilen Etkinliklerin Bilimsel Yaratıcılıkları Üzerine Etkisi

Özet:

Bu çalışma, "Yapay zeka tarafından oluşturulan STEM etkinliklerinin öğrencilerin bilimsel yaratıcılık düzeyleri üzerinde bir etkisi var mıdır?" ve "Öğrencilerin yapay zeka tarafından üretilen STEM etkinliklerine ilişkin görüşleri ve deneyimleri nelerdir?" sorularına yanıt aramaktadır. Araştırmanın çalışma grubunu, 2023-2024 eğitim-öğretim yılında Bursa'daki bir Bilim ve Sanat Merkezi'ne devam eden 49 özel yetenekli 4. sınıf öğrencisi oluşturmaktadır. Durum çalışması deseninin kullanıldığı bu araştırmada, yapay zeka tarafından geliştirilen STEM etkinliklerinin öğrencilerin bilimsel yaratıcılık düzeylerini anlamlı ölçüde artırdığı tespit edilmiştir. Ayrıca, öğrencilerin büyük bir çoğunluğu etkinliklere ilişkin olumlu görüşler bildirmiş, yaratıcılıklarının geliştiğini, çeşitli beceriler kazandıklarını ve tasarım sürecine dahil olmaları sebebiyle kendilerini mühendis gibi hissettiklerini ifade etmiştir. Araştırmada, Türkçeye Aktamış (2007) tarafından uyarlanan "Bilimsel Yaratıcılık Ölçeği" ile yarı yapılandırılmış görüşme formu kullanılmıştır. Bu çalışma, yapay zekânın STEM etkinliklerinin tasarımındaki potansiyelini ortaya koymakta ve öğrencilerin bilimsel yaratıcı düşünme becerilerinin geliştirilmesine yönelik yeni bir yaklaşım sunmaktadır.

Anahtar Kelimeler: Yapay zeka, STEM, özel yetenekli öğrenciler, bilimsel yaratıcılık.

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Appendix A

Activity-1

"Engineering Inspired by Nature"

Objective:

To explore the concept of biomimicry and design innovative solutions inspired by nature.

Materials:

- Books or videos about biomimicry and examples of nature-inspired designs
- Various building materials (paper, cardboard, craft sticks, etc.)
- Glue, scissors, markers

Activity Steps:

1. Start by introducing the concept of biomimicry and displaying examples of products or designs inspired by nature.
2. Discuss different natural phenomena such as animal adaptations or plant structures.
3. Invite students to identify a specific problem or need and design a solution inspired by nature.
4. Allow time for idea generation, prototype creation, and testing of the designs.
5. Have students present their designs, explain how nature inspired their ideas, and discuss the potential real-world applications.

Activity-2

Sustainable House Design

Objective:

To help students understand the concept of sustainability and use scientific principles to design a sustainable house.

Materials:

- Cardboard or construction materials (for model houses)
- Recycled materials (cardboard tubes, plastic bottles, etc.)
- Solar panels (optional)
- Rainwater collection systems (optional)
- Glue, tape, scissors
- Paint and brushes (optional)

Implementation:

1. Assign students the task of designing a sustainable house.
2. Students use the provided materials to design a house following sustainability principles. This design may include renewable energy sources such as solar power or rainwater harvesting systems.
3. Encourage students to consider aspects like energy efficiency, material usage, and waste management in their designs.
4. Once completed, students display their designs in the classroom or school and share them with other students.
5. During the exhibition, students discuss their designs and are evaluated based on their sustainability awareness and scientific thinking skills.

Activity-3

Machine Design and Construction

Objective:

To help students develop engineering skills and produce creative solutions to problems.

Materials:

- Used cardboard boxes
- Scissors
- Glue
- Colored markers
- Materials for simple machines such as gears, washers, and cranks (optional)

Lesson Plan:

Introduction (15 minutes):

Give a brief presentation about what machines are and provide examples of machines encountered in everyday life. Then, assign students the task of designing and building their own simple machines.

Design Phase (20 minutes):

Give students time to work with cardboard boxes and other materials to design their machines. Allow them to share different ideas and collaborate with one another.

Construction (30 minutes):

Give students time to bring their designs to life. Help when necessary, but encourage them to solve problems on their own as much as possible.

Presentation and Evaluation (15 minutes):

Have students present their designs in class and allow them to examine each other's work. Encourage them to discuss what worked, what didn't, and what they learned during the design process.