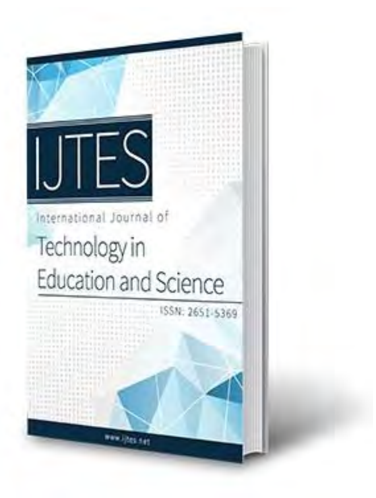

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Uğur Sarıçam
Marmara University, Turkey

Mehtap Yıldırım
Marmara University, Turkey

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The Effects of Digital Game-based STEM Activities on Students' Interests in STEM Fields and Scientific Creativity: Minecraft Case

Uğur Sarıçam, Mehtap Yıldırım

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Abstract

This research is determined to investigate the effects of STEM activities practiced by using digital games in 6th-grade science classes on students' level of interest in STEM fields and their scientific creativity. As a digital game, Minecraft Education Edition was applied. As a data collecting tool for this survey, the STEM Career Interest Survey and Scientific Creativity Scale were used in the quantitative part and semi-structured interview forms were used in the qualitative part of the study. As a result of the research, it was seen that there is a statistically significant difference between the scientific creativity and STEM interest levels of students in favor of the posttest. In order to investigate the results obtained from the quantitative data more deeply, the students' remarks on STEM education were scrutinized. Students have stated that they were constantly in communication with each other as they had been working as teams throughout the application process inside the Minecraft world, shared decision making processes and that this situation enabled them to learn to respect different ideas; they were fully active during the application of the lessons and thus the information was more consistent; and that the education process was both instructing and informative.

Introduction

Playing games is almost as old as human history. According to Huizinga (1949), games are older than cultures. He described human as Homo Ludens ―person playing a game" in his book in which he explains the importance of the game for society and social life. With the rapid advancement and development of technology, games have started to be played digitally and take up more and more in our lives each day (Sarıçam & Dostoglu, 2017). Today's students represent the very first generations growing up with the new technology, and those who are born after the year 2000 are called Generation Z (Mengi, 2009). Their lives are all surrounded by digital tablets, computer games, digital music players, video cameras, mobile phones and all other toys and tools of the digital age, and they are actively using these technological tools. Research conducted exhibits that a young person with a solid game culture in a country spends almost more than 10.000 hours playing video games (Prensky, 2001; McGonigal, 2010). Considering that this research was conducted about ten years ago, it can be asserted that this rate is higher in the present day.

Minecraft is one of the most popular video games today. Minecraft enables its players to build simulated virtual worlds. Thus, it develops creativity, control and imagination of players, enables collaborative learning, and activates critical thinking and problem solving skills. Therefore, it is beneficial to use Minecraft to improve students' learning in STEM / STEAM fields (Ellison, Evans, & Pike, 2016).

Digital Games in Science Education

Digital games are also applied to enhance interest and motivation of students, to present information and principles, to raise students with the necessary equipment in cases where they need to express their arguments or pre-information, and also with the purpose of educating students for the skills that they will require in the future (Greenblat, 1973). It is also stated that digital games promote solving complex problems, increase an individual's self-confidence and improve visual and focusing skills (Green & Bavelier 2003, Griffiths, 2002). When taking into account that youngsters spend most of their time dealing and playing these kinds of games bring forward the idea of using digital games for education. Even though it is not very widespread yet, it would not be wrong to say that digital games bear the potential of giving science and mathematics knowledge to millions of people in the future. On the contrary of other mass media tools in education, digital games are utterly interactive tools including many fundamental qualifications that have multifaceted pedagogical approaches (Mayo, 2009). Moreover, the usage of digital games in education proves to be affecting the academic success of students positively (Green & Bavelier 2003, Prot et al., 2014).

Although applying digital games to education is confronted with prejudice, there are many researches that demonstrate the positive effects of educative digital games on many variables as learning performance and learning persistence (Mayo, 2009). Minecraft, being a digital game that is developed by Mojang company, is a multi-player video game based on a virtual world, modeled in the real world. With Microsoft‘s purchase of all copyright from Mojang Company in 2014 to design Minecraft Education Edition (MinecraftEdu), it is used actively in classrooms as an education tool in more than 11 countries (Keskin, 2020). Within Minecraft, students can present solutions to real-life problems. For example; students can design a dam and design their solution thoughts to a city‘s water problem inside the game or they can design tools that can use renewable energy to reduce air pollution in their own regions. Through this game, students can use their knowledge and skills arising from various disciplines such as science and mathematics (Sarıçam & Dostoglu, 2017). In this context, transforming digital games that are often played amongst children and youngsters these days into a tool for education and using this tool as an interdisciplinary education tool by combining it with other disciplines became essential. Hence, digital games students play to spend their spare time can turn into an education tool.

In a report published by PricewaterhouseCoopers (PwC), it is emphasized that digital transformation effects the competition in business world considering today‘s conditions with the ease of access to information, and also that Turkey needs qualified workforce prevailing technology and innovation in order to keep up and even retain with the digital transformation (PwC, 2017). Along with the differentiation of the workforce that sectors need, intended behaviors and skills to be gained in education show alteration (Accenture, 2016). The outcome of the digital transformation that affects the business world influenced both the gaming and education world. In consequence, educators are on the quest of new objective acquisitions, and new methods and strategies for the diversifying student profile. As an interdisciplinary model that recently became prominent through these quests, STEM education aims at blending research and technologic design processes through project-based learning that focuses on developing students‘ questioning, researching, critical thinking, problem-solving, logical reasoning, technic, communication, cooperation, self-governance, and creativity skills (MoNE, 2018). Rather than teaching the four disciplines - science, technology, engineering, and mathematics - as separate subjects, STEM is based on a cohesive learning paradigm based on real-world applications in an interdisciplinary. Thus, STEM provides children the opportunity to survey and learn an idea at various extents (Allsop, 2017).

Minecraft Education Edition is an educational based game since its creation. Therefore it has an effective use potential in the formal education process (Eroğlu, 2019). It is an open-world game that supports creativity, collaboration and problem-solving by blending it with an environment where the only limit is the imagination (Sarıçam & Dostoğlu, 2017). Inside Minecraft, gamers can use and prepare daily objects through using blocks. Minecraft is considered to create quite substantial opportunities for educators. The reason behind this is the fact that Minecraft‘s cubic geometry helps to teach a variety of academic topics. Minecraft Education Edition also embodies an ecology that can be applied for developing scientific literacy within a game and that processes math, biology, chemistry, and physics qualifications intertwined in the game. Minecraft is a splendid opportunity for science and mathematics teaching as it supports teamwork and manufacturing a product (Short, 2012). For this reason, performing STEM activities with Minecraft‘s Education Edition is considered to present tremendous benefits in terms of developing 21st-century knowledge and skills for students. Already, many of the skills students will need later in their lives can be developed in the STEM education programs they are currently taking (Seage & Türegün, 2020).

Recently, the number of researches on digital game-based learning has been increasing with the development of technology. However, any research on the application of Minecraft specifically in science teaching or STEM education is not available in Turkey. Outside the country; on the other hand, Minecraft is applied in teaching geometry (Foerster, 2017), language and literacy subject (Bebbington, 2014; Garcia Martinez, 2014; Hanghøj et al., 2014), digital storytelling (Garcia Martinez, 2014), social skills (Petrov, 2014), computer-enhanced art application (Garcia Martinez, 2014), and project management (Saito, Takebayashi &Yamaura, 2014). Hence, this study conducted by combining the Minecraft game with STEM education is considered to make a significant contribution to science teaching.

Starting from these causes stated above, the question of ―What are the effects of digital game-based STEM activities on 6th-grade students‘ level of interest in STEM fields and scientific creativity?" is determined as the problem statement in this study. The following sub-problems were determined based on the research problem:

- Do digital game-based STEM activities have an effect on 6th grade students‘ interest in STEM fields?
- Do digital game-based STEM activities have an effect on 6th grade students‘ interest on scientific creativity?
- What are the remarks of 6th grade students on digital game-based STEM activities?

Method

Research Method

In this research, ―the effects of digital game-based STEM activities on students' interest in STEM fields and scientific creativity" in 6th grade science classes were examined with sequential explanatory design as of a mixed-method. Creswell and Clark (2017) define the mixed-methods research as collecting, analyzing, and correlation of both quantitative and qualitative data for a single study or a study sequence. In this method, it is emphasized that the fundamental assumption in applying both quantitative and qualitative approaches together and to correlate them with one another is to comprehend the problem statement of the researches better. In the study, primarily the quantitative data were collected and then the qualitative data were obtained by receiving students' opinions of the application. According to Creswell (2012), in studies where a new lesson module is developed and applied, it is more convenient to prefer one-group experimental design by definition of the research. Therefore, by forming a single group selected by the criterion sampling method which is a purposive sampling method, one-group pretest-posttest design was used in this study as of an experimental method.

Participants of the Study

In determining the study group of this research, the criterion sampling method as a purposive sampling method was used. Purposive sampling allows a detailed and in-depth examination of the subjects (Patton, 1987). Considering the students that are selected by the criterion sampling method can be studying in distinct divisions while determining this study group in the survey, this research is conducted on a voluntary basis for that the survey is planned to be performed after school hours. In the selection of the participants, it was determined that the volunteer participation form should be completed by both the parent of the student and the student and that the participant should be a 6th grade student as a criteria. In accordance with these criteria, the study was conducted with a total of 25 students, 18 boys, and 7 girls, studying in 6th grade during the 2017-2018 academic year (n = 25).

Data Collecting Tools

In the research, while the Science, Technology, Engineering, and Mathematics Career Interest Survey (STEM-CIS) and Scientific Creativity Scale (SCS) were used for the quantitative part of the study, a semi-structured interview form was used for the qualitative part.

STEM Career Interest Survey

For the first sub-problem of the study, STEM-CIS developed by Kier, Blanchard, Osborne, and Albert (2014) was used. STEM-CIS consists of four sub-dimensions as science, technology, engineering, and mathematics. For each sub-dimension, there are 11 items. The distribution of these 11 items in reference to six different social cognitive profession factor as self-efficacy (2), personal purpose (2), outcome expectation (2), interest (2), conceptual support (2), and personal inclination (1). The scale consisting of a total of 44 items is a 5-point likert type scale. For sub-dimensions of the scale as science, technology, engineering, and mathematics, Cronbach α values are calculated as 0.77; 0.89; 0.86 and 0.85 (Kier, Blanchard, Osborne & Albert, 2014). STEM-CIS has been adapted into Turkish by Pekbay (2017). As a result of the analysis, the reliability coefficient of Turkish translation of the scale was found to be α = 0.94. For each dimension of the scale, an internal consistency coefficient was calculated. Cronbach α values are calculated as 0.85; 0.86; 0.90 and 0.87. Following the validity and reliability analysis during the scale adaptation process, a final form of STEM-CIS consisting of four sub-dimensions and 36 items was formed.

Scientific Creativity Scale

For the second sub-problem of the study, the SCS developed by Hu and Adey (2002) was applied. The reliability of the original test is calculated a=0.893. The test consisting of seven open-ended questions evaluates of all sub-dimensions of the process (imagination, thinking), trait (fluency, flexibility, originality), and product (technical product, science knowledge, science phenomena, science problem) which are the principal dimensions of the Scientific Creativity Structure Model process (see Figure 1).

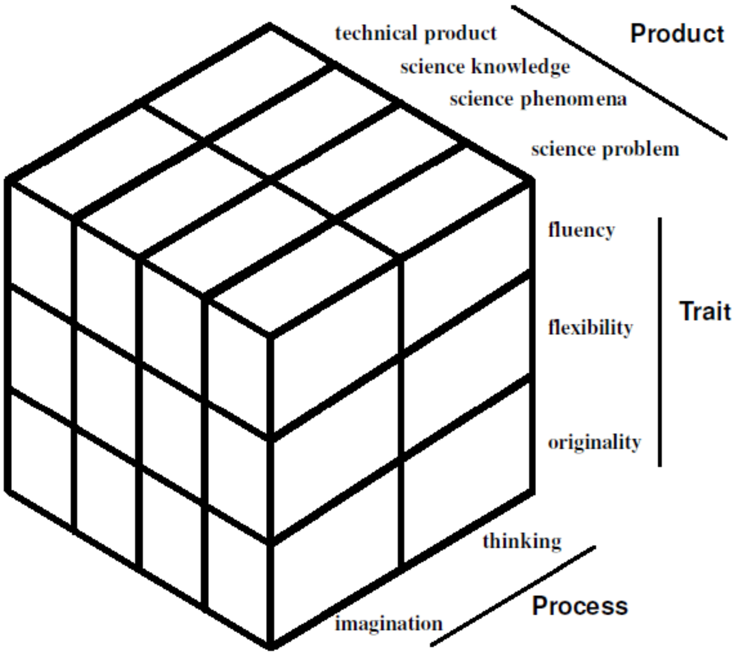

Figure 1. Scientific Creativity Structure Model (Hu & Adey, 2002)

Every question in the test evaluates multiple sub-dimensions. Answers given to the questions are graded with respect to their fluency, flexibility, and authenticity (Hu & Adey, 2002). Scientific Creativity Scale is adapted into Turkish by Kadayıfçı (2008). The reliability of the Turkish translation of the test is calculated as α=0.735.

Semi-Structured Interview Form

For the purpose of determining the expediency of digital game-based STEM activities and collecting student remarks, a 10 question semi-structured interview form was prepared by the researcher in order to obtain qualitative data. The prepared interview form was controlled by two different experts besides the researcher. For the interview, a total of two students, one male, and one female with an average score, were selected considering their posttest scores alignment of STEM-CIS and then were interviewed.

Application of STEM Education and the Process Steps

Published in 2018 by the Ministry of Education, STEM activities in the science curriculum are submitted with the addition of the ―entrepreneurship" concept to its status in the 2017 curriculum. Within this framework, students are required to define a problematic case they face in daily life in compliance with learning outcomes partaking in all units. Furthermore, they are also asked to plan materials, budget and time to be used for solving the problem case. Students are expected to develop alternative solution suggestions and to choose the most convenient solution for solving problems in groups. Once the solution is decided, they are promoted to initially do the planning and then to design the product in the school environment and share it. Students are anticipated to develop marketing strategies and promotional materials that can sell the product to the market in order to enhance their entrepreneurship skills in the last stage which is the product sharing stage and to share the designed products through science festivals at the end of the semester (MoNE, 2018).

In this research, taking curriculum objectives into consideration STEM lesson plans were prepared by researchers with reference to STEM Cycline developed within the scope of STEM Integrated Teaching Project by Bahcesehir University STEM Center (BAUSTEM). STEM Cycline is divided into two sections consisting of cognitive process and social product (see Figure 2). It is important that the teacher and students perceive the cognitive process prior to the social products that they will be exhibiting as a solution towards APoKS as an essential preparation (Aşık, Doğança Küçük, Helvacı & Çorlu, 2017).

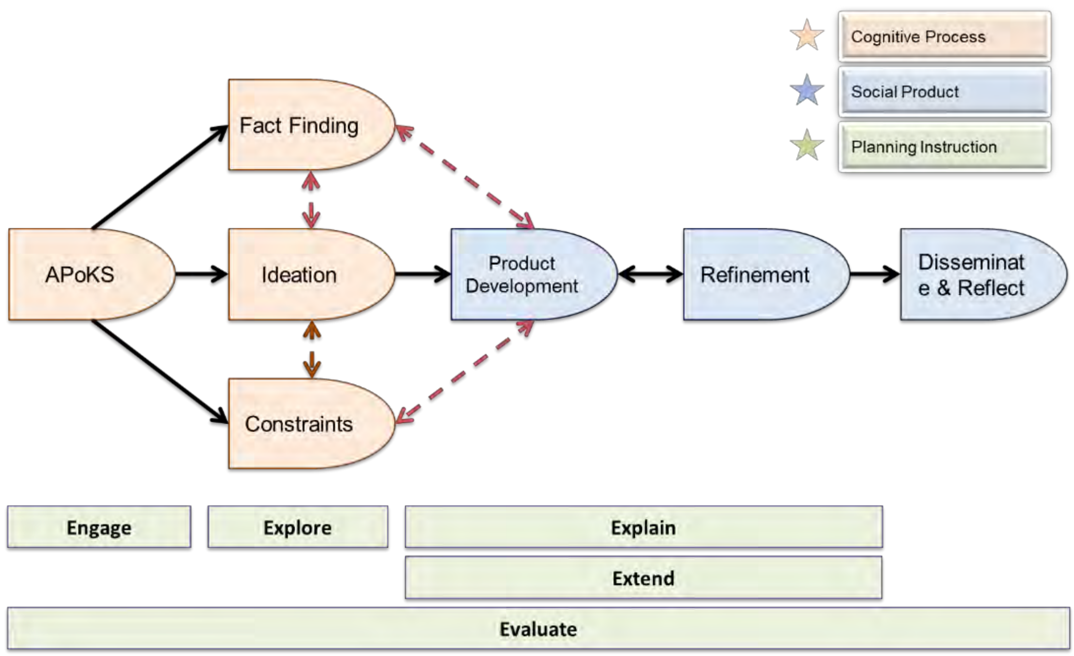

Figure 2. STEM Learning Cycline (Çorlu, 2017)

STEM lesson planning starts with determining the targeted outcomes. Initially, acquisitions related to the centered discipline are registered. For example; a science teacher should write science acquisitions as the center discipline. Subsequently, acquisitions regarding other STEM disciplines are written down. Secondly, used materials and then the referenced sources used for designing the lesson plan are indicated. At the beginning of the STEM Cycline, there is Authentic Problems of Knowledge Society (APoKS) based on fields of interest of teachers and students concerning the 21st century. It is suggested that this problem should be conducive to examination of the dynamic and complex structure of multiple variables, and thus not leading students to a predetermined single solution but be a well-defined problem with certain limitations that concentrates on the 21st century life. As to these limitations, they are the criteria to prevent stipulated errors in developing solution ideas to the problem.

An example of an APoKS prepared by the researcher:

AUTHENTIC PROBLEMS OF KNOWLEDGE SOCIETY (APoKS)

In 1977, NASA had designed Voyager 1 and Voyager 2 spacecrafts for the use of examining Jupiter. In response to astrophysicist Carl Sagan's proposal, a team was organized and a golden record was placed to the rocket's capsule section by this team. The content of the record was formed by the committee that Carl Sagan was the chairman of. This record contained the following for the extraterrestrial life forms or future humanity to find out about the diversity of life in earth and cultures;

- *Various photographs,*
- *Various natural sounds like wind, thunder and animal noises and greeting messages in 55 languages,*
- *In order to present life in the world, there are a lot of information ranging from our DNA helix to our internal organs, from what we eat and where we live to what technologies we can use.*

Recently, NASA has decided to launch a new space programme and claims to send many information back to deep in the space like the Voyager spacecrafts.

You and your team have been selected to add a few photos to this spacecraft representing the basic parts and functions of plant and animal cells. You are expected to design your own plant and animal cell models using Minecraft.

I wish you a successful mission…

CONSTRAINTS

- *You have to calculate how many blocks you use in Minecraft.*
- *The width of the animal cell you will design should be 20 blocks-long maximum.*
- *The outer parts of the cells that you will design should be produced through creating an algorithm by the "Agent" inside the Minecraft.*

Primarily APoKS and limitations are presented to students. In the meantime, it is important to draw students' attention, motivate them and arouse their curiosity. The students form a team before proceeding to the information acquisition section.

In this section, students should be provided the time and environment to conduct researches free and without interference. Therefore, in order that they can start to discuss the topic, open-ended questions are prepared by the teacher. In information acquisition section, students collect information for solving APoKS. However, the teacher can summarize the problem by addressing the class and explain the theoretical information on the board, if necessary. Subsequently, the ideation development section is preceded. In this section, the teacher supervises the process through frequent visits to the groups. The teacher should provide a democratic environment for students to defend their opinions. Furthermore, the teacher should try to stipulate some ideas that students may develop and be prepared for questions that may be asked to students over these ideas or be present abiding by students' possible need for new information. Students then proceed to the product development section once the information and idea development sections are finished. In this section, the teacher asks the students to draw their design sketches with precise measurements. In this section, the teacher can share the theoretical information on the board with the whole classroom, and solve sample or multiple-choice problems regarding the subject, if required. In the testing section, students test the products that they designed key to the suitability to APoKS and the limitations. Concurrently, in this section, the teacher can plan various activities, questions, discussions according to students' interests and levels. The testing section should be planned according to what kind of information and skills students require beyond the objective acquisitions. In the dissemination and reflection section which is the final one, students share the products they designed suitable for society. The teacher plans activities to encourage students for their sharing (Çorlu, 2017).

Research Design and Implementation

Experimental processes of the research were carried out with 25 students studying in 6th grade science lesson during the 2017-2018 academic year. Four different STEM activities were prepared and also applied by the researcher at the science lesson center. While preparing STEM activities, ―STEM Lesson Plan Template" developed by Çorlu (2017) was used. Digital game-based STEM activities are considered appropriate to be performed in the computer laboratory by researchers. Because the students selected by one of the purposeful sampling methods called criterion sampling method were from different classes, they performed their studies in the computer laboratory after school time.

STEM-CIS and SCS were applied to students as a pretest in order to determine their interest levels towards STEM fields prior to application. Subsequently, the application process began. The application process lasted for four hours per week, a total of 16 hours four weeks. Each student had a laptop computer, mouse, headphones and internet access in the computer laboratory. Additionally, each computer had a local network connection with each other. Therefore, students are able to create designs as groups within Minecraft. Two images of the designs of the groups are given in Figure 3 and Figure 4.

Figure 3. Students are working on a Task in Minecraft

Figure 4. A Sample of Students' Work in Minecraft

The application of each lesson plan lasted an average of four hours. The teacher reads APoKS and its limitations in the classroom out loud before sharing them, and then hand activity papers to the groups. Students tried to create solutions by using Minecraft Education Edition, to find information about the given APoKS, to develop ideas; and then tested and shared the results with their classmates.

At the end of the fourth week, students were subjected to the STEM-CIS and SCS as a posttest. Moreover, a semi-structured interview form was applied by the researcher to obtain qualitative data in order to determine the application's expediency and attain students' opinions. Reviewing the posttest scores of the STEM-CIS were selected two students with an average score. These students (a male and a female) were performed a semi-structured interview.

Science lesson learning outcomes used in the application are indicated in Table 1.

Table 1. Science Lesson Learning Outcomes Applied in STEM Lesson Plans

1. Lesson Plan	▪ Compares animal and plant cells regarding their basic parts and functions.
2. Lesson Plan	▪ Defines velocity and expresses its unit. ▪ Demonstrates the relationship between distance, time and velocity on a graphic and interprets them.
3. Lesson Plan	▪ Explains the differences between physical and chemical alteration by observing various events.
4. Lesson Plan	▪ Explains the layer model which represents the structure of the world and compares these layers according to their general features.

As STEM education is an interdisciplinary education model, other STEM learning outcomes in addition to science lessons are present in STEM lesson plans prepared by the researchers. Some parts of the acquisitions regarding other STEM disciplines prepared for STEM lesson plans are shown in Table 2.

Table 2. Other STEM Outcomes Applied in Lesson Plans

Tech	▪ The student uses simple steps for solution design when solving an algorithmic problem. ▪ The student describes a software development process that can solve software problems (design, coding, testing and verification). ▪ The student evaluates what kind of problems can be solved by using modeling and simulation.
Engineering	▪ The student assumes oneself as a team member in different roles in the project study and completes the necessary practices for that role. ▪ The student expresses and discusses ideas and findings clear and consistent to the target group by using visual, written and verbal communication methods. ▪ The student sorts design process steps and explains the performed activities at each stage. ▪ The student prepares painting drafts with the purpose of developing the ideas in the process of design, problem-solving and understanding correlation in between.
Math	▪ Determines the center, radius, and diameter by drawing a circle. ▪ Solves problems requiring four operations with natural numbers.

Data Analysis

STEM Career Interest Survey (STEM-CIS) Analysis

The total scores of the students were analyzed through the statistical program. Primarily, a normality analysis was applied to the data obtained from the research. As the Shapiro-Wilk test provides better results in small groups consisting of less than 35 participants (Shapiro & Wilk, 1965), Shapiro-Wilk test values were surveyed.

In response to the data incompatibility to normality distribution, nonparametric Wilcoxon Signed Rank Test was applied for the analysis and the results were interpreted.

Scientific Creativity Scale (SCS) Analysis

In SCS, every question is analyzed one by one. Table 3 was used in order to perform scoring for this analysis.

Table 3. Evaluation Criteria for SCS

Question	Sub Content	Fluency Point	Flexibility Point/Classes for Flexibility Point	Authenticity Point
Question 1	Unconventional Usage	1 point for each generated answer	1 point for each interesting answer (1) general use tools (2) glass varieties (3) physics (4) chemistry (5) biology / health / medicine (6) technology / gadget	2 points for each answer found in less than 5% of the people, 1 point for answers found between 5%-10% of people
Question 2	Discovering the Problem	1 point for each generated answer	1 point for each interesting answer (1) planet history (2) structure of the planet (3) aliens (4) benefit (5) considering as a habitat to live	2 points for each answer found in less than 5% of the people, 1 point for answers found between 5%-10% of people
Question 3	Product Development	1 point for each generated answer	1 point for each interesting answer (1) aesthetics (2) safety (3) speed / energy (4) functionality (5) comfort / ease	2 points for each answer found in less than 5% of the people, 1 point for answers found between 5%-10% of people
Question 4	Scientific Imagination	1 point for each generated answer	1 point for each interesting answer (1) living creatures (2) general life and physics laws (3) planet and environment (4) human and life (5) social life (6) transportation, tools and inventions	2 points for each answer found in less than 5% of the people, 1 point for answers found between 5%-10% of people
Question 5	Discovering the Problem	3 points for each answer found in less than 5% of the people, 2 points for answers found between 5%-10% of people, 1 point for over 10%		
Question 6	Science Experiment	A maximum of 9 points for each given method (3 for tools, 3 for the principle, 3 for the procedure). If two perfect method is suggested for a single answer 18 points in total		4 points for methods less than 5%, 2 for those between 5%-10%
Question 7	Product Design	3 points for each function indicated of the machine		Score from 1 to 5 key to the name, visuality, statement, functionality, analogy features

Students could give multiple answers to the questions of the scale, if they wish so. Each student's test was converted into a total score, obtained scores were analyzed. Since the pre-test-post-test total scores of the Scientific Creativity Scale and the pre-test-post-test total scores of the Authenticity dimension, which is one of the sub-dimensions of the scale, showed normal distribution (p> 0.05), the related groups t-test from the parametric tests was used to analyze the data. The non-parametric Wilcoxon Signed Ranks test was used to analyze the data, since the pre-test and post-test data of the sub-dimensions of Fluency and Flexibility did not show normal distribution.

Analysis of Semi-structured Interview Form

The data obtained through the interview form applied in the research were analyzed using descriptive analysis method. The answers students gave during the interviews were converted into text. Thereafter, the texts were given to the participants to verify the accuracy and the exactness of the records and thus the reliability of the data was ensured. The answers given by the students are presented and described in tables in the findings section.

Results

The first sub-problem of the survey is stated as; ―Do digital game-based STEM activities have an effect on 6th grade students' interest in STEM fields?" The nonparametric Wilcoxon Signed Rank Test was applied in order to analyze the data and the results of STEM-CIS tests were given in Table 4.

Table 4. Wilcoxon Signed Rank Test Results of STEM-CIS Pretest-Posttest Total Scores

		N	Order Ort.	Order Top.	Z*	p
Pretest-Posttest	Negative Order	1	1.5	1.5	-4.245	0.000
	Positive Order	23	12.98	298.50		
	Equal	1				
Science Dimension Pretest-Posttest	Negative Order	1	10.50	10.50	-3.777	0.000
	Positive Order	21	11.55	242.50		
	Equal	3				
Math Dimension Pretest-Posttest	Negative Order	2	12.25	24.50	-3.169	0.002
	Positive Order	19	10.87	206.50		
	Equal	4				
Technology Dimension Pretest-Posttest	Negative Order	1	1.5	1.50	-4.064	0.000
	Positive Order	21	11.98	251.50		
	Equal	3				
Engineering Dimension Pretest-Posttest	Negative Order	3	9.33	28.00	-3.053	0.002
	Positive Order	18	11.28	203.00		
	Equal	4				

*Based on Negative Order Substructure

When Table 4 Wilcoxon Signed Rank Test results are analyzed, it is seen that there is a significant difference between pretest and posttest scores abiding by the STEM-CIS (Z =-4.245, p<.05). When the sub-dimensions of STEM-CIS were examined, it could be observed that there is a significant difference between pretest and posttest scores of science dimension (Z =-3.777, p<.05); mathematics dimension (Z =-3.169, p<.05); technology dimension (Z =-4.064; p<.05) and engineering dimension (Z =-3.053; p<.05).

The second sub-problem is emitted as ―Dodigital game-based STEM activities have an effect on 6th grade students' interest on scientific creativity?" It is analyzed through a t-test for correlated pairs which is a parametric test for data analysis and the results of SCS tests were given in Table 5. Looking into Table 5, the SCS pretest score average was found as = 27.68 and the average of posttest scores was found to be = 52.44. According to t-test analysis results for correlated pairs, there is a significant difference between pretest and posttest scores of the SCS (p<.05).

Table 5. Paired Samples t-Test Results of SCS Pretest-Posttest Total Scores

	N		SS	t	sd	p
Pretest	25	27.68	7.94	-15.646	24	0.00
Posttest	25	52.44	10.63			

When Table 6 is reviewed, the average of pretest scores of the SCS's Authenticity sub-dimension is = 7.28 and the average of posttest scores is = 16.04. According to t-test analysis results for correlated groups, there is a significant difference between pretest and posttest scores of the SCS (p<.05).

Table 6. Paired Samples t-Test Results of SCS Authenticity Dimension Pretest-Posttest Total Scores

	N		SS	t	sd	p
Authenticity Pretest	25	7.28	2.84	-10.564	24	0.00
Authenticity Posttest	25	16.04	4.35			

As Shapiro-Wilk test probability values were surveyed, due to the fact that pretest and posttest data of Fluency and Flexibility sub-dimension were incompatible to normality distribution (p<0.05), data were analyzed through nonparametric Wilcoxon Signed Rank Test and the results were given in Table 7 and Table 8. As seen in Table 7, the posttest score regarding one of the sub-dimension of the SCS that is the Fluency dimension is higher than its pretest score. When Wilcoxon Signed Rank Test results are examined, it is seen that there is a significant difference between pretest and posttest scores of the Fluency dimension of SCS (Z =-4.391; p<.05).

Table 7. Wilcoxon Signed Rank Test Results of SCS Fluency Dimension Pretest-Posttest Total Scores

		N	Order Ort.	Order Top.	Z*	p
Fluency Pretest-Posttest	Negative Order	0	0.00	0.00		
	Positive Order	25	13.00	325.00	-4.391	0.000
	Equal	0				

*Based on Negative Orders

Table 8. Wilcoxon Signed Rank Test Results of SCS Flexibility Dimension Pretest-Posttest Total Scores

		N	Order Ort.	Order Top.	Z*	p
Fluency Pretest-Posttest	Negative Order	0	0.00	0.00		
	Positive Order	25	13.00	325.00	-4.378	0.000
	Equal	0				

*Based on Negative Orders

A sub-dimension of the SCS, the flexibility dimension‘s posttest score turned out to be higher than its pretest score as it is observed in Table 8. When the Wilcoxon Signed Rank Test scores are examined, it can be seen that there is a significant difference between SCS‘s Flexibility dimension pretest and posttest scores (Z =-4.378; p<.05).

The frequency and percentage values of students‘ given answers in reply to SCS‘s 1st question ―Please write down as many as possible scientific uses as you can for a piece of glass?" is given in Table 9.

Table 9. Frequency and Percent Values of Pretest-Posttest Answers Given in Response to Question 1 of SCS

Pretest			Posttest
Answers	f	f	Answers
Test equipment can be made (beaker, slide, graduated cylinder...)	6	13	Test equipment can be made (beaker, slide, graduated cylinder...)
Magnifying Glass can be made	4	7	Telescope can be made
Telescope can be made	3	5	Magnifying Glass can be made
Microscope can be made	3	4	Microscope can be made
Used in windows	3	4	It can start a fire
It can start a fire	2	4	Used in windows
It can make hologram	1	4	Glasses can be made
Glasses can be made	1	2	It can be used as accessories
It can be used for protection	1	2	We can acquire lighting in different colors by changing the glass color
It can be used as accessories	1	1	It can make hologram
It is used for producing screen (monitor, television...)	1	1	It can be used for protection
		1	It is used for producing screen (monitor, television...)
		1	We can create rainbow by the help of light refraction
		1	We can create a vacuumed ambience can be created
		1	Printer glass can be made
		1	Insulating material can be made
		1	Mirror can be made
		1	It can be used in health industry
Total	26	54	

Five students did not answer the first question in the pretest, they answered all of the questions in the posttest. According to Table 9, there were 26 responses in the pretest and 54 responses in the posttest. The most given response is the same one both for the pretest and the posttest. 6 students in the pretest, 13 of them in the posttest gave the answer ―Test equipment can be made (beaker, slide, graduated cylinder...)". The frequency and percent values of student answers for the second question of the scale ―If you had a spacecraft to travel through space and went to a planet, what scientific questions would you want to research?" is stated in Table 10.

Table 10. Frequency and Percent Values of Pretest-Posttest Answers Given in Response to Question 2 of SCS

Pretest Answers	f	f	Posttest Answers
Is there any water on the planet?	11	15	Is there any water on the planet?
Is there life on the planet?	9	13	Is there life on the planet?
What gases are there on the planet? (Oxygen, carbon dioxide...)	7	8	Is the planet suitable for human life?
Is the planet suitable for human life?	7	6	What gases are there on the planet? (Oxygen, carbon dioxide...)
Is the planet's soil arable?	4	6	Which substances can be found on the planet?
How many degrees is the temperature of the planet?	3	4	What are the planet's features?
How are the landforms of the planet?	3	4	How are the landforms of the planet?
Are there any plants on the planet?	2	4	How many layers is the planet formed of?
What is the diameter/size of the planet?	2	3	Are there aliens?
What are the planet's features?	2	3	What are the minerals on the surface of the planet?
Which substances/minerals can be found on the planet?	2	3	Which natural sources are existing on the Planet?
Is food available on the planet?	2	2	How many degrees is the temperature of the planet?
How many satellites does the planet have?	1	2	Is food available on the planet?
What kinds of mines does the planet have?	1	2	Which of the materials we bring from the Earth can be used here?
What is the orbit of the planet?	1	2	Does the planet have an atmosphere
How similar is the planet to Earth	1	1	Are there any plants on the planet?
Which animals can live on this planet?	1	1	Is the planet's soil arable?
Which of the materials we bring from the Earth can be used here?	1	1	How many satellites does the planet have?
		1	What is the diameter of the planet?
		1	How is the gravity on the planet?
		1	What kinds of mines does the planet have?
		1	Does the planet contribute to humanity?
		1	Is there any researched object on the planet?
		1	How many researches I should conduct on the planet?
		1	How big is the core of the planet?
		1	By melting the solid form of water, can we create a water cycle?
		1	How was the planet formed?
Total	60	89	

Two students did not answer the second question in the pretest, all of the students answered it in the posttest.

According to Table 10, there were 60 responses in the pretest, 89 responses in the posttest. The most given response is the same one both for the pretest and the posttest. 11 of them in the pretest and 15 of them in the posttest responded as ―Is there any water on the planet?"

The frequency and percent values of student answers for the third question of the scale ―Consider possible readjustments that can make a normal bicycle more interesting, more useful and more beautiful" is stated in Table 11.

Table 11. Frequency and Percent Values of Pretest-Posttest Answers Given in Response to Question 3 of SCS

Pretest Answers	f	f	Posttest Answers
I would make it move with a motor	4	10	I would make it move with a motor
I would make sure it is not touching to the ground	3	6	I would install lighted tires
I would make an emergency automatic brake system	3	5	I would make sure it is not touching to the ground
I would paint the bicycle	3	4	I would install a more comfortable and bigger seat
I would install grand tires	2	3	I would install a wheel
I would install lighted tires	2	2	I would make an emergency automatic brake system
I would add a charging station	2	2	I would add a charging station
I would install a comfortable seat	2	2	I would install a sound system
I would install a solar panel	1	2	I would install a navigation system
I would ensure the bicycle to run on water	1	1	I would install a solar panel
I would install a speed indicator	1	1	I would install grand tires
I would install a wheel	1	1	I would install an umbrella
I would install an umbrella	1	1	I would paint the bicycle
I would add seat heating	1	1	I would add seat heating
I would enable it change colors key to the ambient	1	1	I would enable it change colors key to the ambient
		1	I would add suspension
		1	By creating a magnetic field, I would make sure it won't touch the ground.
		1	I would make it luminous so that it can be noticeable in the dark too
		1	I would add on more gears
		1	I would produce the basic parts of the bicycle out of recycled materials
		1	I would install a windmill
		1	I would install brake and gas pedals
		1	I would install off-road tires for easy movement on all grounds
		1	I would make the tip sharp in order to reduce air resistance
		1	I would install a system that produces electric energy
		1	I would add small pieces of plastic for a better grip of the rear wheels to the ground
		1	I would make it a folding bicycle
		1	I would condition it as dirt-resistant and dustproof using nanotechnology
		1	I would transform it to be able to run automatically when necessary
		1	I would install more tires
		1	I would optimize its aerodynamic
		1	I would add wings
Total	28	59	

Five students did not answer the third question in the pretest, all of the students answered it in the posttest.

According to Table 11, there were 28 responses given in the pretest, 59 answers in the posttest. Students‘ answers for the fourth question; ―Consider that there is no gravity and describe what the world would be like.” is given in Table 12. The most given response is the same one both in the pretest and the posttest. 4 students in the pretest and 10 students in the posttest answered: ―I would make it move with a motor”.

Table 12. Frequency and Percent Values of Pretest-Posttest Answers Given in Response to Question 4 of SCS

Pretest Answers	f	f	Posttest Answers
Everything would lift-off (buildings, people, etc.)	12	12	Everything would lift-off (buildings, people, etc.)
Living would get difficult	7	7	Eating would get difficult
Eating would get difficult	3	6	Moving would get difficult
Moving would get difficult	2	6	Living would get difficult
We would get to places by jumping	1	4	We would have a hard time drinking liquids
Using aircrafts would become obligatory	1	2	We would get to places by jumping
Oceans would not exist	1	2	Using aircrafts would become obligatory
We could not grow plants	1	2	Oceans would not exist
We would sleep on air	1	2	We could walk with magnetic shoes
		1	Climate event would change (rain, snow, etc.)
		1	We could not grow plants
		1	People could not build houses
		1	We would sleep on air
		1	Air traffic would increase
Total	29	48	

Two students did not reply to the fourth questions in the pretest, they all replied it in the posttest. According to Table 12, there were 29 responses in the pretest, 48 in the posttest. The most given response is the same one both in the pretest and the posttest. 12 students in the pretest and 12 in the posttest gave the answer as ―Everything would lift-off (buildings, people, etc.)”. Answers are given for the fifth question of the scale ―Use possible methods to divide a square into four equal parts.” are given in Table 13.

Table 13. Frequency and Percent Values of Pretest-Posttest Answers Given in Response to Question 5 of SCS

Pretest Answers	f	f	Posttest Answers
1 distinct method	10	8	4 distinct method
2 distinct method	8	6	5 distinct method
4 distinct method	7	4	6 distinct method
		2	3 distinct method
		2	7 distinct method
		2	8 distinct method
		1	2 distinct method
Total	25	25	

All students gave answers to the fifth question in the pretest and posttest. According to Table 13, it is observed that seven students at the utmost used 4 distinct methods in the pretest, maximum of 2 students used 8 distinct methods in the posttest.

Answers are given for question six, ―There are two kinds of a napkin. How would you test which one is better? Please write possible methods, tools, principles, and simple procedures that can be used." is stated in Table 14.

Table 14. Frequency and Percent Values of Pretest-Posttest Answers Given in Response to Question 6 of SCS

Pretest Answers	f	f	Posttest Answers
I will prefer the one wiping a wet floor better	7	8	I will wet it, choose the one drawing more water
I will wet it, choose the one which is leaking less	4	6	I will prefer the soft one
I will prefer the soft one	3	4	I will wet it, choose the one which is leaking less
I will wet it, choose the one drawing more water	3	4	I will choose it depending on how hard it is to be torn
I will choose it depending on how hard it is to be torn	2	4	I will have the exact amount of water on two napkins, choose depending on which can absorb better
I will check its thickness, pick the thicker one	2	3	I would prefer the one wiping a wet floor better
I will wet it, choose the one which is harder to be torn apart	2	2	I would prefer the water-resistant one
I will put ice on both napkins, choose the one which can hold the ice longer	1	2	I will check its thickness, pick the thicker one
I will examine it with a microscope	1	2	I would wet it, choose the one which is harder to be torn apart
		2	I will choose the one absorbing liquids faster
		1	I will put ice on both napkins, choose the one which can hold the ice longer
		1	I will examine it with a microscope
		1	I would wet it, choose considering which is more solid
		1	I will calculate the mass and volume, choose the one which is the highest valued.
		1	I will check its absorption duration for different liquids
		1	I will examine it with a magnifying glass
		1	I will check the component materials and search
Total	25	44	

One student did not answer the sixth question in the pretest, all the students gave answers in the posttest. According to Table 14, 25 answers in the pretest, 44 in the posttest were obtained. The most given answer in the pretest was ―I will prefer the one wiping a wet floor better" by 7 students, and ―I will wet it, choose the one drawing more water" in the posttest by 8 students.

The last question is ―Please design an apple-picking device. Draw a picture, give it a name and specify the functions of each part." And the given answers are indicated in Table 15.

Table 15. Frequency and Percent Values of Pretest-Posttest Answers Given in Response to Question 7 of SCS

Pretest Answers	f	f	Posttest Answers
1 Function	6	7	3 Function
3 Function	6	4	4 Function
4 Function	6	4	5 Function
2 Function	3	3	6 Function
7 Function	1	2	2 Function
		2	7 Function
		1	1 Function
Total	22	23	

Three students did not answer the seventh question in the pretest, and two students did not answer it in the posttest. According to Table 15, 6 students indicated 1, 6 students indicated 3, six students indicated 4, 3 students indicated 2, and 1 student indicated 7 functions in the pretest. In the posttest; on the other hand, seven students indicated 3, 4 students indicated 4, 4 students indicated 5, 3 students indicated 6, 2 students indicated 2, 2 students indicated 7, and one student indicated 1 function.

The third sub-problem is as, ―What are the remarks of 6^{th} grade students on digital game-based STEM activities?" Data collection was performed through a semi-structured interview form. The questions asked during the interview and the answers of the students are directly given in Table 16.

Table 16. The Answers Given by the Students during the Interview

Interview Questions	**Answer of student #1**	**Answer of student #2**
1- ―Doyou think that digital game-based STEM activities are suitable for the objectives of the course? Explain.	*I think it is suitable, it is a fun and educational activity, I think it creates a difference.*	*Yes, I think it is suitable. The lessons were quite fun lessons and it was enjoyable.*
2- ―What have you learned coming up with solutions to Authentic Problems of Knowledge Society (APoKS)?"	*I learned what to be careful about when doing researches. I learned about plant and animal cells, layers of the earth, constant speed movement and ratio and proportion.*	*I learned to do researches, group working and task sharing more actively. I learned new things while designing cell generals in Minecraft. For example, we designed the*

		structure of the cytoplasm by imitating it to a slime block. This was very interesting to me. I think to shape the generals with blocks improved my imagination.
3- ~~"~~Working as a team helped you develop yourself in what aspects?"	*I learned to create new ideas as a team, respect and tolerance within the group, how to make the group work effectively. I learned to respect other people's ideas and to be respectful to new ideas.*	*I learned that I shouldn't be afraid to ask for help. I learned not to hesitate asking for my friends' help. I started as a bit hesitative because I do not play games on the computer at all, but I defeated this fear by working as a team.*
4- ~~"~~Which professions of people do you feel more comfortable talking to? Why?"	*Engineer, doctor, scientist (Science)*	*Engineering. I am very interested in the plans engineers to draw. I think my science and mathematics are good and I'm not afraid to talk about it. I also like to talk to professionals from these fields.*
5- ~~"~~Do you think it is necessary to use digital game-based STEM activities in classes? Why?"	*I think it is necessary; because I feel that I would communicate easier with teachers. Lessons become more fun and active. I learn through having fun. I wish we could have such lessons taught in our classes too.*	*Yes, I think so; because it makes the lessons more fun and enables us to use technology. I think it would be more enjoyable and fun to perform STEM activities using Minecraft in our classes. I believe it is interesting and this attraction will increase my scores in exams.*
6- ~~"~~In general, what are the positive aspects of the digital game-based STEM activities that you use in the lessons?"	*Use of technology, fun and because it is fun we can be more involved in classes. We can learn easily*	*It is a good opportunity for those who are not used to computers like me. As we start the lessons with a problem, I think that my problem-solving skills increased and that we can complete data collecting and product developing sections as a team more actively.*
7- ~~"~~When evaluated in general, what are the negative (compelling) aspects of the digital game-based STEM activities you use in the lessons?"	*I had a bit of a hard time using Minecraft, but then I improved as I kept using it. I don't think there is any other negative aspects of it.*	*I don't think its negative aspects are too many. I think that it is a bit short in terms of time. I wish that time would be extended*

8- —What are the differences between science teaching enhanced with the use of digital game-based STEM activities in the classroom with science teaching supported by normal activities?”	*The differences are: Fun and educative It measures our capacity to comprehend. In the Minecraft world where the only limit is our imagination, we can do whatever we want but in classes, we only listen, memorize and write. We get stressful. It is like we only study for the exams.*	*We only see it on board in the class but in STEM lessons we learn by doing, experiencing through our own research.*
9- —Would you like Minecraft Education Edition, a digital game, to be used in lessons? If yes, which courses would you like it to use in?”	*Yes, we can use it in Physical Sciences, Mathematics, Robotic, Turkish and Social Sciences classes. In social sciences, we can learn north, south, east and west concepts on the map.*	*Yes, I would want to, Yes, I would want to, I want it to be used in Science and Social sciences classes I believe that it is very entertaining and educative in the science lessons than what we did in the previous weeks and in social studies classes it will be easier to memorize by seeing their geographical position.*
10- —Which of the STEM lesson plans you applied did you like the most? Why?”	*I liked the plan about layers of the earth much better. I really like to do researches on earth and space.*	*I really liked the lesson plan about speed-time graphics. Because the lesson plan was about speed-time which is one of the subjects that we could calculate in both science and mathematics classes*

When we evaluate the findings stated, for both students to emphasize that it is an entertaining and educative, interesting and pleasing application especially in relation to the application implemented, and also to point out that they have learned by doing and experiencing in the interview consisting of ten questions are significant results. Moreover, they stated that they benefited from studying in groups in terms of both affective and cognitive aspects of group work.

Discussion

In this study, the effects of STEM activities using digital games on 6th grade science courses on students' interest level in STEM fields and their scientific creativity were examined. For this purpose, four different lesson plans prepared by the researcher was applied for four hours per week, a total of 16 hours four weeks. While the scales were applied before and after the application process, two students were interviewed and their remarks on the application were obtained. At the result of the study, it could be observed that there was a significant difference in consequence of STEM CIS scale pretest-posttest score analysis, which is carried out to see digital game-based STEM activities effects on 6th-grade students in terms of their interest level in STEM fields, statistically in favor of the posttest. Moreover, according to the results of the analysis conducted towards science sub-dimension, mathematics sub-dimension, technology sub-dimension and engineering sub-dimension of this scale, it was seen that there were significant differences between the pretest and posttest scores of the students in favor of the posttest. Correlatively to the results of this study, there are surveys establishing STEM education‘s positive effects on the interest towards STEM fields (Gallant, 2011; Honey et al., 2014). Gülhan (2016) also concluded that STEM activities applied in science courses increased the students' interest in STEM fields, as they were in this study.

In the research, SCS is used and analyzed in an attempt to determine the effect of digital game-based STEM activities on 6th grade students‘ scientific creativity. As a result of the research, it was perceived that there was a statistically significant difference between the pretest and posttest Scientific Creativity levels in favor of the posttest. Moreover, it was seen that there was a significant difference between the pretest and posttest scores of students in fluency and authenticity sub-dimensions of SCS in favor of the posttest. Similar to the results of this study, Oh, Bae and Park (2016) discovered in a research they conducted with preeminent potential students that STEM activities applied in science courses increased students‘ creative thinking skills and emotional intelligence dramatically. Likewise, Ceylan (2014) indicated in a research conducted with 8th grade students that STEM activities contributed to students‘ creativity skills as is in this study. Karisan, Macalalag and Johnson (2019) have shown too that STEM activities contribute to skills of students as creativity, innovation, problem solving, critical and divergent thinking.

Some of the lessons to be focused on teaching 21st century skills are mathematics and science education. 21st century skills include creativity, innovation, critical thinking, and the ability to solve complex problems (Fadel, 2008). Findings of a similar research conducted by Rasul, Halim and Iksan (2016) exhibit that STEM activities enhanced the 21st century skills of students. The data obtained in this study show that digital game-based STEM activities have a similar positive effect on students' scientific creativity.

In the study, a semi-structured interview was conducted with a selected male and a female student with the average score based on the STEM-CIS posttest scores. The students expressed that digital game-based STEM activities support working in teams for the sixth-grade students, they learned by experiencing things, they find it very entertaining and educative and that they want them to be used in other courses. Accordingly, in a study conducted by Short (2012), it was concluded that Minecraft supported science and mathematics education; moreover, it improved students‘ teamwork and product development processes. Correlatively, in a research done by Hamari and others (2016), it was concluded that digital games increase students' effective participation (focus, interest, and entertainment) and thus they participate in learning activities effectively. There are many studies proving that educational digital games have positive effects on many variables, such as learning performance, academic achievement, and learning persistence (Greenblat, 1973; Green & Bavelier 2003, Griffiths 2002; Mayo, 2009; Prot et al., 2014; Karsenti & Bugmann, 2017). In addition, there are many studies showing that STEM activities can increase many features of students such as learning motivation, creativity, curiosity, responsibility and imagination (Batdi, Talan, & Semerci, 2019). The most significant divergence of this research from other studies stated is that it combines the digital game Minecraft: Education Edition with

STEM education and as a result of this study, it was determined that this teaching increased students' interest in STEM fields, had a positive effect on creativity and students enjoyed it quite much.

Conclusion

The purpose of this study is to investigate the effects of digital game-based STEM activities on students‘ interest in STEM fields and scientific creativity in 6th grade. STEM activities with Minecraft increased students' interest in STEM fields and improved their scientific creativity. According to the results of the qualitative part of the study, the students stated that thanks to their tasks in the Minecraft world, they cooperated and communicated as a team, made common decisions, and learned to respect different ideas and perspectives. Students also indicated that the learning processes were both educational and instructive. In addition, it can be said that participation in digital game-based STEM activities further encourages and motivates students to interest science.

Recommendations

Based on the results of the study, the following recommendations are presented:

- For the researchers wanting to implement these activities in their own classes should organize a spare time activity prior to the application process for a certain period of time in order for the students to comprehend the mechanics of the digital game to be used and increase their player experience. By this means, it is considered that the students will be able to use the digital game‘s functions faster and more efficiently.
- The researcher may invite a person or people working in STEM fields to their classes within a certain period of time during the implementation process so that the students can get an expert opinion.
- The researcher may use these activities for not only science lessons but branches like mathematics, informatics by planning the application process and completing the necessary arrangements.
- The researcher may increase activity application duration considering that students can complete the activities in different periods of time.
- It can be suggested that these kinds of teaching materials prepared for students are organized not just oriented to certain units but to be prepared inclusive of more units with more units.
- Gender factors may be researched in terms of scientific creativity and interest in STEM professions of STEM activities developed based on digital games.
- The research can be repeated with different educational digital games besides Minecraft Education Edition that is used as a digital game in this study.
- It can be recommended to examine the effect of digital game-based STEM activities on the scientific creativity of students in each education stage.
- Concerning the recent increase in player and audience numbers, online game playing has emerged as a brand-new sports branch and recognized as an electronic sport. E-sports (electronic sports) became a sport branch that approximately 380 million people grow interested in recently (Newzoo, 2019). Therefore, integrating e-sports into education may be a subject to research.

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Author Information

Uğur Sarıçam	Mehtap Yıldırım
https://orcid.org/0000-0002-0330-884X	https://orcid.org/0000-0001-7398-8396
PhD Student	Marmara University
Marmara University	Turkey
Turkey	Contact e-mail: *mehtap.yildirim@marmara.edu.tr*