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CONTENTS

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Using Digital Games in Technology Oriented STEM Education: The Examination of the Students' Game Designs

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Abstract

The purpose of this research is to examine the contents of the representations that students used while producing digital games in the scope of STEM education. The descriptive survey model among the other quantitative research methods has been used. Within the scope of this purpose, 300 games from the competition arranged throughout Turkey with the name of ''I encode my game'' have been examined in terms of different variables. Checklists were created by the researchers to analyze the data. In these checklists, mental structures (abstract, concrete, mixed and simple content), the use of violent content, the characters, the subject of the game, the type of points, the dominant colors were examined. Findings show that boys were more interested in the game production process than girls while the counselors were all females. it has been found that students intensively used concrete elements and gave more importance to the educational technologies such as educational-instructional games and quiz shows. Students used human figures, animals, objects and fantasy characters as the protagonists in their games. As for the representation of the human figures, it is seen that the proportions of boys and girls were equal. Digital games in technology-oriented STEM education promote students to join the production process on a large scale. At further researches, it is thought that providing students with educational content like game encoding is highly important.

Introduction

In the past, it was preferable to play games at real playgrounds, homes, or streets with real friends, but nowadays computer games, computerized virtual activities, or online games have become much more preferable (Horzum 2011). With the rapid advancement of the technology, the traditional game concept has changed, and a new concept called ''digital game'' has been created with the fact that digital tools has become an indispensable part of daily life. Increasing consumer interests towards the digital games and thus emerging market of digital games have shown itself in Turkey as well as all over the world. Increasing of popularity video games, make this video games current issue for educational games on the agenda.

Educational games are planned and purposeful games that provide the achievement of the objectives determined during the education process, develop knowledge and skills, and prepare the environment for reinforcing the previous learning (Coşkun, 2012). Çankaya and Karamete (2008) regard the importance of education technologies today as the result of the rapid development of technology and computer and regard as the new quest for solving the problems of education and training. Students demand and play with the digital educational content and thus loving to learn (İşman 2005). While the literature based on educational play is growing, a systematic review of the effectiveness of this new technology is still inadequate. Regardless of the complexity of a game and apart from the fact that technological integration of the game is its propulsive force, games could be propelling force in the process of learning for entitled as digital natives to achieve their 21st century skills.

Shin, Park and Bae (2014) state that the basic skills which the individuals of 21st century can be obtained through the education of computer and programming. In their study based on the effect of programming on the development of mathematical and technological thinking, Taylor, Harlow and Forret (2010) has found out that the education of programming has an effect on teaching of mathematical subjects, developing problem-solving strategies and improving collaborative, systematic and creative thinking. In digital game-based learning, students are expected to learn by playing educational computer games. Prensky (2001) states that students are willing to be a part of digital game-based learning, and also there are many different types of educational computer games like normal computer games which have a strategy or an action in them, and adds that these computer games combining different learning methods with many various types of games provide students with a broader sense of latent learning. Therefore, the students have fun playing these educational digital games and realize that they have learned new things when the game is over.

Educational digital games can be combined with other learning methods and provide a complete learning. Digital games are also classified in different groups. These groups mainly consist of abstract games, meaningful games, meaningless games, and progressive games. (Yenğin, 2010: 114). Mitchell and Smith (2004) differentiate the game types as action games, fighting games, platform games, adventure games, simulation games, modeling games, road games, logical games and math games. The games require that the complex and diverse capabilities should be brought together, focusing on the virtual world, thinking, strategy, planning, and most importantly, interacting with this world. (Bostan and Tıngöy, 2015) According to Prensky (2001), a game should have its own rules, goals, objectives, feedback, struggle, interaction, presentation and the story. The rules provide various ways for the players to reach their goal. The goals and objectives create a sense of duty in the players and make them spend their time and effort voluntarily. The feedback tells the players how far they have gone through their goals and provides some returns when the possible situations have changed in response to the players' reactions. Struggle / race / challenge / contrast are the basic problems that need to be dealt with during the game. The users can feel some fear and excitement during the game without facing any danger as in real life. This motivates and allows them to continue and complete the game. As for the interaction, two types of interaction can be mentioned. The first one is the interaction of the players or the computer, which can also be called as feedback. The second one is the social situation that the players create with each other while playing that game. The presentation or story is the subject of the game. The story of the game can be given directly at the beginning or in the course of the game. Many programs or tools can be used in the production of a game. One of the most common used software in primary, middle and high school levels is Scratch.

The Scratch programming platform was intended for the individuals between the age of 8-16 by the Massachusetts Institute of Technology (MIT) Media Laboratory in 2003. However, today, individuals of all ages use this platform. Since its opening to the public in May 2007, the Scratch Web site (http://scratch.mit.edu) has become a lively online community of people sharing, discussing and reinterpreting each other's projects. The users from around the world install more than 1500 new projects to this website every day, and it can be freely used to share and re-mix the source codes. This website's project collection includes video games, interactive stories, science simulations, virtual tours, birthday cards, animated dance competitions and interactive tutorials, which are all programmed in Scratch. Thanks to the interface that does not require any code-writing, users can create projects by dragging the code block from one place to another, and this website also offers a convenience for the newcomers. With more than 40 different language support, the users in more than 150 countries can easily communicate with each other and create collaborative projects (Resnick et al, 2009). Scratch program can also be used to create projects in different courses including the elements of music, pictures, simulations, games, presentations, videos, animations and many other multimedia elements (Çatlak, Tekdal and Baz, 2015).

Scratch has been used to enhance the development of technological fluency of young children at afterschool centers in economically disadvantaged communities (Peppler & Kafai, 2007) and to teach computer programming concepts in a college-level computer science class (Malan & Leitner, 2007). Apart from Algorithm and Programming Teaching, some subjects that are difficult to learn in courses such as Mathematics, Science, Foreign Language, Social Studies could be made enjoyable with Scratch projects and these subjects could be taught to students through playing games (Çatlak, Tekdal & Baz, 2015). Acording to Zhang, Yang, Luan, Yang, & Chua, (2014), Scratch not only serves as a programme learning tool but also contributes to high-level thinking skills. According to Marcelino, Pessoa, Vieria, Salvador and Mendes (2017), 'Scratch" is the most widely used program in teaching programming at the level of K-12. Çatlak, Tekdal and Baz (2015) suggest that Scratch should also be integrated with other courses besides the course of programming as almost all kinds of multimedia applications could be developed with the use of this programme. Yünkül, Durak, Çankaya and Mısırlı (2017) emphasize that it is important to expand the use of Scratch at the beginner and intermediate level in education programming, and for this program to be included in the curriculum. Yükseltürk and Altınok (2016) state that there are not any alternative methods and methodologies in teaching programming and the number of studies on this subject is very limited. Becta (2001) emphasizes the need for teachers to be involved in the process of educational game design.

In this age of rapid expansion of computer and educational technology, digital games have reached an attractive level. The gaming industry is growing rapidly, reaching millions of players very quickly. Science, technology, engineering and mathematics (STEM) education of digital games is also important for technology-oriented applications. Advancements in educational technology have provided various opportunities for supporting student learning, and they offer unique affordances for complex, integrated STEM learning environments. For example, learning experiences can be expanded to facilitate learning multiple subjects simultaneously. (Yang & Baldwin, 2020). STEM learning environment (Lunce, 2006; Smith and Mader, 2017). But what exactly does Technology mean from the concepts that make up STEM? Does it depict an electronic product? Or any product that makes our lives easier? Sivaraj, Ellis & Roehrig (2019) states that technology has three different meanings in STEM in its systematic literature review: 1. As educational technologies in STEM 2. Engineering product in STEM 3. Includes coding and computer thinking in STEM

Coding and computer thinking in STEM Education; There are various studies in which technology, coding, programming or computer thinking are included in science, engineering and mathematics activities (Swaid, 2015). Examples include designing digital works like websites and video games using applications such as Scratch. Learning and applying programming languages means using digital designs and computer technology in STEM learning process. The inclusion of coding practices into STEM-related practices can be seen as an effective tool "as students develop their design skills". In engineering applications involving computer thinking; for example, students develop mechatronic smartphone / Bluetooth-controlled 3D-design mobile vehicles, Kim et al. (2013) how to use robotics in engineering design based courses. Students using programming devices such as Raspberry Pi and Arduino combining programming and engineering applications can be given as examples. Interactive, immersive games that involve science, mathematics, engineering, and technology STEM learning (Lemke, 2013). The following sub-problems have also been dealt with in this research while searching an answer for the question ''which contents do the middle school students make use of in STEM educational technologies while developing their digital game coding skills?''.

- What are the contents that students use while producing digital games?
- What are the types in the games that students encode?
- What are the types of the characters that students use in the games they encode?
- What are the objects that students use on their interfaces in the games they encode?
- What are the awards students using in the games they encode?
- What colors students use intensively in the games they encode?

Method

Descriptive survey model, which is one of the quantitative research methods, has been used in this study. The general survey method has been used in the research process. The general screening models are screening arrangements applied on the whole universe or on a group of samples gathered from it in order to make a general judgement about the universe that consists of many elements (Karasar, 2003:79). Relational screening models in this group are between two and more variables. Since it is used for research models aiming to determine the existence or degree of change, it is considered appropriate for such research (Cohen, Manion & Morrison, 2000).

Data Collection and Analysis

In 2017-2018 academic year in Turkey, game coding competition was organized with the coordination of a government school and with the support by the government agencies in order to monitor students' coding skills. The data of this research were obtained from the games coded by the students who participated in the competition ''2018 National Encoding My Game". The students were asked to design a game using ''Scratch 2.0' program on a topic that they determined without any field constraint. The competitors were middle school students and they were asked to form a group of up to 3 students in their own schools and to encode their games under the supervision of a teacher. They were asked to use Turkish characters and contents, and they were also asked not to produce violent-based games.

There were 456 applications from 281 institutions all around Turkey. 456 works were identified as the universe of this research. The sample consisted of 300 randomly selected works. The data of this research were obtained from the works included in this competition. The data analysis was conducted by the researchers. The works in the competition were examined through the use of "Scratch 2.0" program. Checklists were created by the researchers to analyze the data. In these checklists, mental structures (abstract, concrete, mixed and simple content), the use of violent content, the characters, the subject of the game, the type of points, the dominant colors were examined. Then, information technologies experts were consulted about the appropriateness of the data provided. The findings were gathered about the contents over which a consensus was reached after getting the feedback.

Participants

In Table 1, it is seen that there are 281 applications from the participating schools. 60% of these schools (f = 182) are middle schools, 8% (f= 25) are imam hatip middle schools, 24% (f = 74) are colleges and 13% (f = 13) are science and art centers (BILSEM). As seen the participation in the competition is mostly from state schools, and at least in science and art centers.

Table 1. Distribution of works in the competition in terms of school type

School Type	f	%
Middle School	182	60
Imam Hatip Middle School	25	8
College	74	24
Science and Arts Center	13	4
Total	281	100

Table 2 shows the gender distribution of participants and consultants. 25% (f = 235) of the participants were females and 75% (f = 696) were males. 71% of the counselors (f = 212) were female and 29% (f = 85) were male teachers.

Table 2. Gender distribution of participants and consultants

	Gender	f	%
	Girl	235	25
Student	Boy	696	75
	Total	931	100
	Female	212	71
Consultant	Male	85	29
	Total	297	100

Table 3 shows the number of provinces where the participant institutions are located. It was observed that the participants were mostly from Ankara with %19 (f = 54), Istanbul with 16% (f = 47), Izmir with 4% (f = 4), Manisa with 4%, Bursa with % 3 (f = 3). It was also observed that the participations were generally from Turkey's three largest cities, and 57 of 81 provinces participated in the competition.

Table 3. Number of the provinces in which the applicant institutions are located

City	f	%	City	f	%	City	f	%
Ankara	54	19	Muğla	4	1	Aksaray	1	1
İstanbul	47	16	Adana	3	1	Bartın	1	1
İzmir	12	4	Amasya	3	1	Burdur	1	1
Manisa	12	4	Aydın	3	1	Çanakkale	1	1
Bursa	10	3	Bolu	3	1	Çorum	1	1
Kocaeli	8	2	Erzurum	3	1	Diyarbakır	1	1
Antalya	7	2	Hatay	3	1	Gümüşhane	1	1
Düzce	6	2	Mersin	3	1	Kahramanmaraş	1	1
Rize	6	2	Trabzon	3	1	Karaman	1	1
Tokat	6	2	Afyon	2	1	Kars	1	1
Denizli	5	1	Bilecik	2	1	Kırıkkale	1	1
Sakarya	5	1	Elâzığ	2	1	Kırklareli	1	1
Samsun	5	1	Eskişehir	2	1	Mardin	1	1
Tekirdağ	5	1	Isparta	2	1	Niğde	1	1
Uşak	5	1	Kastamonu	2	1	Ordu	1	1
Balıkesir	4	1	Konya	2	1	Şanlıurfa	1	1
Batman	4	1	Kütahya	2	1	Yalova	1	1
Gaziantep	4	1	Osmaniye	2	1	Yozgat	1	1
Giresun	4	1	Sivas	2	1			
Kayseri	4	1	Zonguldak	2	1			

Findings

In this section, the findings related to the sub-problems of this research are presented.

Game Contents Coded by Students

Figure 1 shows the basic features of the games produced by the students. (a) A skier, track, snow and trees are seen in concrete items. It is observed that student used only the concrete elements in the game design. (b) In the visual of abstract elements, it is seen that only the imaginary characters are used in the game. (c) In a complex content game, it is seen that the contents are used randomly. Two elephants are trying to wet a mouse by throwing some water on it. There are four Turkish flags in the edges of the visual. (d) In the violent element, a Ninja character is expected to break some boxes and reach the star. As the ninja progresses, it is understood that the rays will smash and damage him.

Figure 1. Visuals Contents

Table 4 shows the basic characteristics of the contents of the games that the students encoded. According to this table, students created a total of 300 games. They used concrete elements in 68 % (f = 205) of the games and used abstract elements in 27 % of the games (f = 83). Of the game contents encoded by the students, 49 % (f = 148) had a complex content and 47 % (f = 143) had a simple content. Violent elements were witnessed in 13 % (f = 50) of these contents.

Table 4. Basic features of the content of the games encoded by the students

Content	f	%
Concrete	205	68
Abstract	83	27
Complex content	148	49
Simple content	143	47
Violent elements	50	16

Game Types Coded by Students

Figure 2 shows the followings: (a) a visual of an educational-instructional game in which the player is asked to find the words associated with ''respect''; (b) a visual of a score collection game in which the rabbit is expected to collect fruits; (c) a male character to reach the orange area through the maze and collect the gold in this process;

(d) quiz show in which a girl character on the screen asks some questions and the player is expected to answer those questions by writing them in the given space.

(a) Educational - Tutorial (b) Score collection

(c) Maze (d) Quiz show

Figure 2. The visuals of Game Types

Table 5 shows the types of the games that students encoded. According to this table, of the 300 games encoded by students, 33% are score collection (f=100), 24% educational tutorial (f=74), 14% quiz show (f=44), 6% hurdle race (f=20), 6% maze (f=18), 4% concentration (f=14), 5% garbage pickup – recycling (f=16), 2% race (f=6), 1% advancement (f=4), 0.5% guessing (f=2), 0.5% following up (f=2)

Table 5. The types in the games that the students encoded

Subject	f	%
Score collection	100	33
Educational tutorial	74	24
Quiz show	44	14
Hurdle race	20	6
Maze	18	6
Garbage Pickup	16	5
Concentration	14	4
Race	6	2
Advancement	4	1
Guessing	2	0.5
Following up	2	0.5
Total	300	100

Characters Used in Coded Games

Figure 3 shows the characters that students created in the games. (a) In the category of human man, with the use of the arrow keys, a male character is expected to dance. (b) In animal category, a cat character is expected to pass obstacles. (c) A ball image in the object category is expected to pass obstacles with the use of the arrow keys. (d) In the category of fantasy character, a ghost image asks a boy various question.

(a) human-man character (b) animal-cat

(c) object-ball (d) fantasy character-ghost

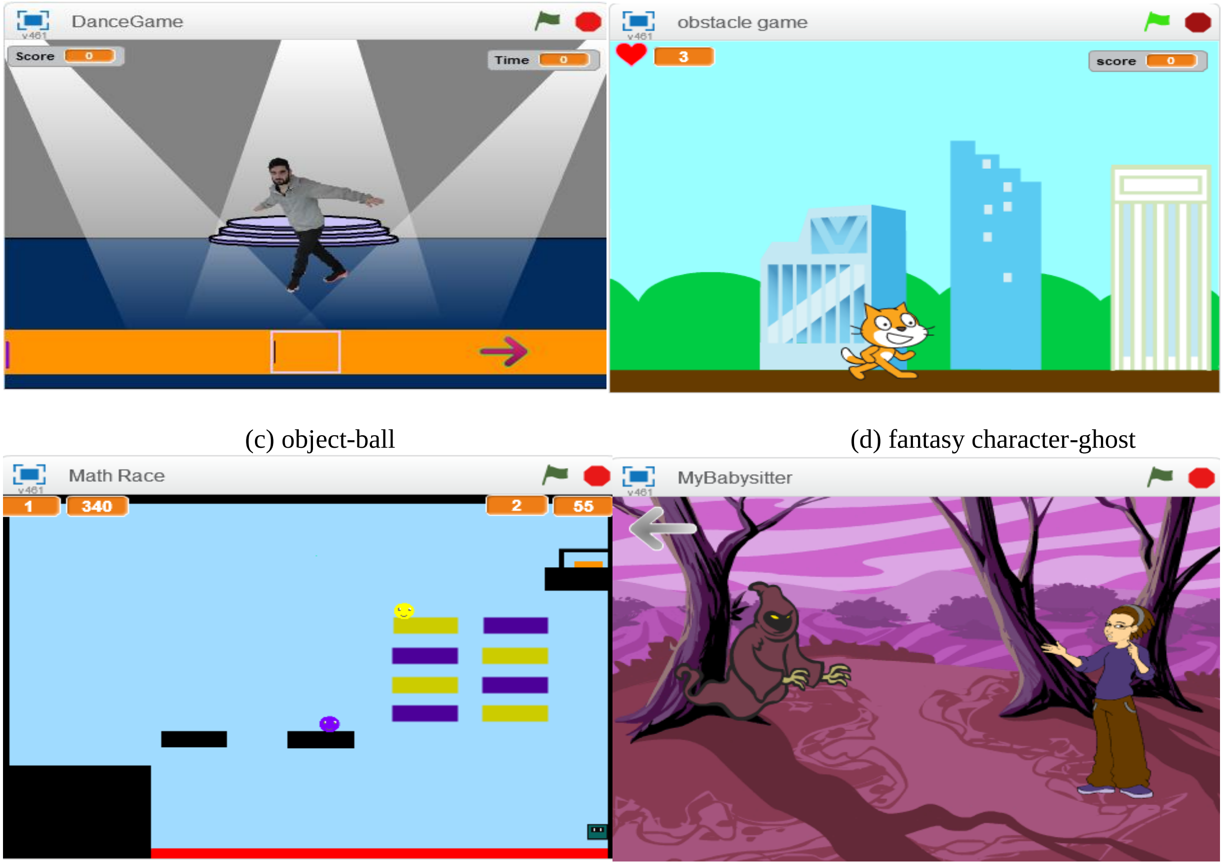


Figure 3. Visuals of the characters that students used in the games they encoded

Table 6 shows the characters students used in the games that they produced. It is seen that a total of 300 games were produced and students created 341 characters in total. However, in this table, only the characters with the frequency number of more than 1 have been issued.

Table 6. The contents of the characters that the students used in the games they encoded

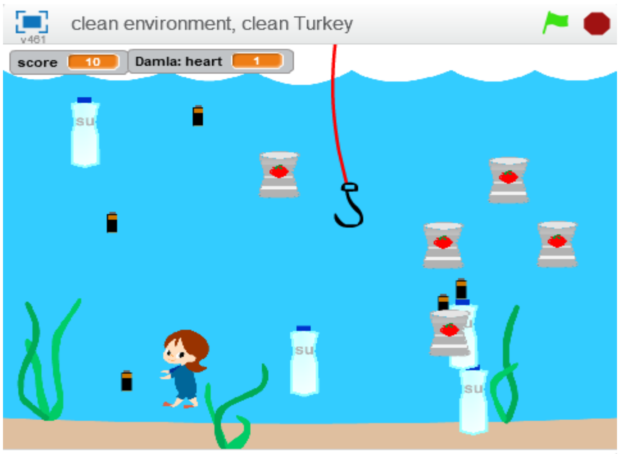
Human	f	%	Animal	f	%	Object	f	%	Fantasy	f	%
Female Character	18	26	Bat	23	36	Ball	19	27	Cartoon character	17	39
Male Character Child	17	24	Cat	10	15	Space craft	14	20	Puppet	16	37
Astronaut	9	13	Fish	6	9	Number	8	11	Witch	5	11
Farmer	9	13	Mouse	5	7	Picture	7	10	Monster	3	6
Man	4	5	Bug	4	6	Balloon	6	8	Ghost	2	4
Footballer	4	5	Bird	3	4	Fire	2	2			
Diver	3	4	Cancer	2	3	Flame	2	2			
Apple	2	2	Horse	2	3	Bomb	2	2			
Human	2	2	Dog	2	3	Wheel	2	2			
Shark	2	3	Jet	2	2	Jet	2	2			
Worm	2	3	Robot	2	2	Robot	2	2			
Rabbit	2	3	Rifle	2	2	Rifle	2	2			
Dice	2	2				Jet	2	2			
Total	69	100	Total	63	100	Total	70	100	Total	43	100

Therefore, the table shows only 245 characters in total. In terms of their characteristic features, these characters are divided into four groups as human, animal, object and fantasy characters. Out of 245 characters, 28 % (f=69) are human figures, 25 % (f=63) animals, 28 % (f=70) objects and 17 % (f=43) fantasy characters. It is seen that as a human character, participant students produced 26 % (f=18) female characters, 24 % (f=17) male characters, 13 % (f=9) astronauts and 13 % (f=9) farmers. Out Of the 245 characters, 63 are animal characters. It is seen that most preferred 36 % (f=23) are bats, 15 % (f=10) cats and 9 % (f=5) fish. Out of the 245 characters that were produced by the participant students, 70 of them are objects. It is seen that 27 % of these object characters are (f=19) balls, 20 % (f=14) spacecraft, 11 % (f=8) numbers. Out of the 245 games produced by the students, 43 of them consist of fantasy, that is, abstract characters. Of these characters, 39 % (f=17) are cartoon characters (abstract characters), 37 % (f=16) puppets and 11 % (f=5) witches.

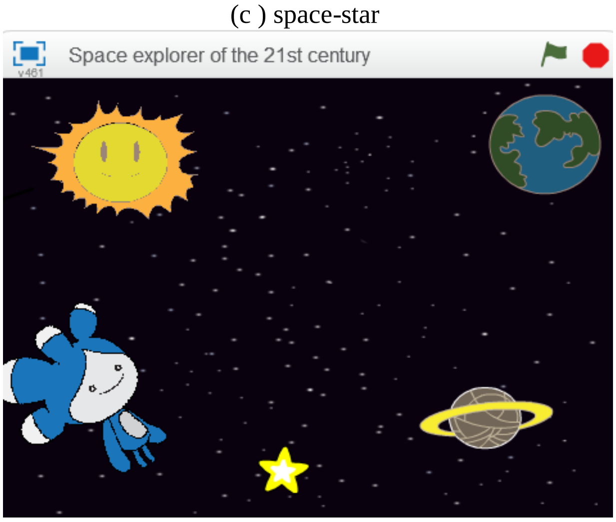
Objects Used in Coded Games

In Figure 4, there are the visuals of (a) human and animals, (b) environmental factors, (c) space, (d) object categories. (a) In the visual of humans and animals' category, a there is a character that cleans the environment. b) In the category of environmental factors, there is a girl character who is sensitive to environmental pollution. There are clouds and apples at the background of the visual. (c) In the category of space, there are stars, the Sun and the Earth at the background. (d) In object-numbers category, the numbers should be placed in a square which is divided into 9 parts.

(a) human and animal female character (b) environmental elements cloud and apple



(c) space-star (d) object-numbers



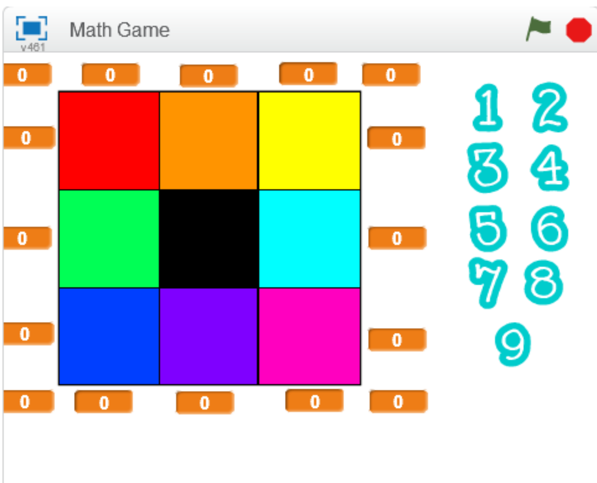


Figure 4. Visuals of objects used in coded games

Table 7 lists the objects that students used on their interfaces in the games they encoded. There were 1295 objects in the games that the students encoded. These codes are divided into six categories as humans and animals (f=312), environmental factors (f=304), space (f=110), technological objects (f=140), imaginary characters (f=74) and objects (f=352).

Table 7. Objects used coded games

Human and Animals			Environmental Factors			Space			Object		
	f	%		f	%		f	%		f	%
Boy	26	8	Cloud	36	11	Star	36	32	Ball	28	7
Child	26	8	Tree	26	8	Spaceship	22	20	Numbers	26	7
Cat	22	7	Apple	24	7	Meteorite	14	12	Letters	20	5
The fish	20	6	Sun	18	5	Rocket	14	12	Flag	18	5
Human	16	5	Banana	16	5	Meteor	8	7	Labyrinth	16	5
Dog	16	5	world	14	5	Moon	4	3	Arrow	16	5
Mouse	12	3	Water	14	5	Anthem	4	3	Tic	16	5
Bat	12	3	Watermelon	12	3	Saturn	4	3	Obstacle	12	3
Bear	10	3	Strawberry	10	3	Space	4	3	Money	12	3
Octopus	8	2	Orange	10	3	Total	110	100	Fire	10	2
Lion	8	2	Flower	8	2				Balloon	10	2
Bird	8	2	Cherry	8	2	Technological Elements			Building	10	2
Penguin	8	2	Peach	8	2		f	%	Recycle bin	10	2
Knight	8	2	Grape	8	2	Car	26	18	Question mark	10	2
Dinosaur	6	1	Home	6	1	Computer	16	11	Garbage	8	1
Elephant	6	1	Carrot	6	1	Glasses	10	7	Pen	8	1
Footballer	6	1	Fruit	6	1	Door	10	7	Hour	8	1
Cow	6	1	Moss	6	1	Ship	8	5	Key	6	1
Shark	6	1	Pear	4	1	Smiley Emoji	8	5	Basketball Ball	6	1
The monkey	6	1	Ice Mass	4	1	Telephone	8	5	Cake	6	1
Parrot	6	1	Grass	4	1	Headphone	6	4	Cookie	6	1
Police	6	1	Mountain	4	1	Battery	6	4	Eat	6	1
Princess	6	1	Thorn	4	1	Satellite	6	4	Glass	4	1
Rabbit	6	1	Tomato	4	1	Washing machine	4	2	Bezbol Ball	4	1
Man	4	1	Library	4	1	Notebook	4	2	Needle	4	1
Soldier	4	1	Mandarin	4	1	Bomb	4	2	Hammer	4	1
Fisherman	4	1	Market	4	1	Keyboard	4	2	Diamond	4	1
Whale	4	1	Egypt	4	1	Motorcycle	4	2	Castle	4	1
Insect	4	1	Pomegranate	4	1	radio	4	2	Bowl	4	1
Chick	4	1	Forest	4	1	Robot	4	2	Spoon	4	1
Farmer	4	1	Eggplant	4	1	Tablet	4	2	Book	4	1
Disabled Person	4	1	Milk	4	1	Sad Emoji	4	2	Aquarius	4	1
Woman	4	1	City	4	1	Total	140	100	Cup	4	1
Ninja	4	1	Chicken	4	1				Candle	4	1
Spider	4	1	Way	4	1	Fictional Characters			Race course	4	1
crab	4	1	Total	304	100		f	%	Pizza	4	1
Giraffe	4	1				Fantasy Character	58	78	Plastic bottle	4	1
Total	312	100				Witch	10	13	Rosette	4	1
						Dragon	6	8	numbers	4	1
						Total	74	100	Basket	4	1
									Hat	4	1
									Snare drum	4	1
									Bed	4	1
									Total	352	100

In the games that the students encoded, in human and animal category, 8 % were male children (f=26) , 8 % were female children (f=26) and 7% were cats (f=22). As for environmental factors, 11 % were clouds (f = 36), 8 % trees (f = 26), 7 % apples (f = 24). As for the space category, 22 % were stars (f = 36); 22 % were spacecraft (f = 20), and 14 % were meteorites (f = 12) and rockets (f = 12). In the technological item's category, 18 % were cars (f = 26), 11 % computers (f = 16) and 7 % glasses (f = 10). As for the imaginary characters, 78 % were fantasy characters (f = 58), 13 % witches (f = 13) and 8 % dragons (f = 6). In the object's category, 7 % (f = 28) were balls, 7 % (f = 26) numbers, 5 % (f = 20) letters.

Awards Used Coded Games

Figure 5 illustrates the visuals of the awards which the students used in the games they encoded. (a) In the Score category, the character is expected to choose the right foods for a healthy life. In return, the character earns points. In Not-used category, when the player clicks on the images, the English words for the fruits are heard. However, there are no scores assigned. (c) In the category of Life, the male character is expected to proceed without touching any garbage. If the character touches any garbage, its life (hearts) decreases. (d) In the Time category, a witch character is expected to travel in the city in a given period of time.

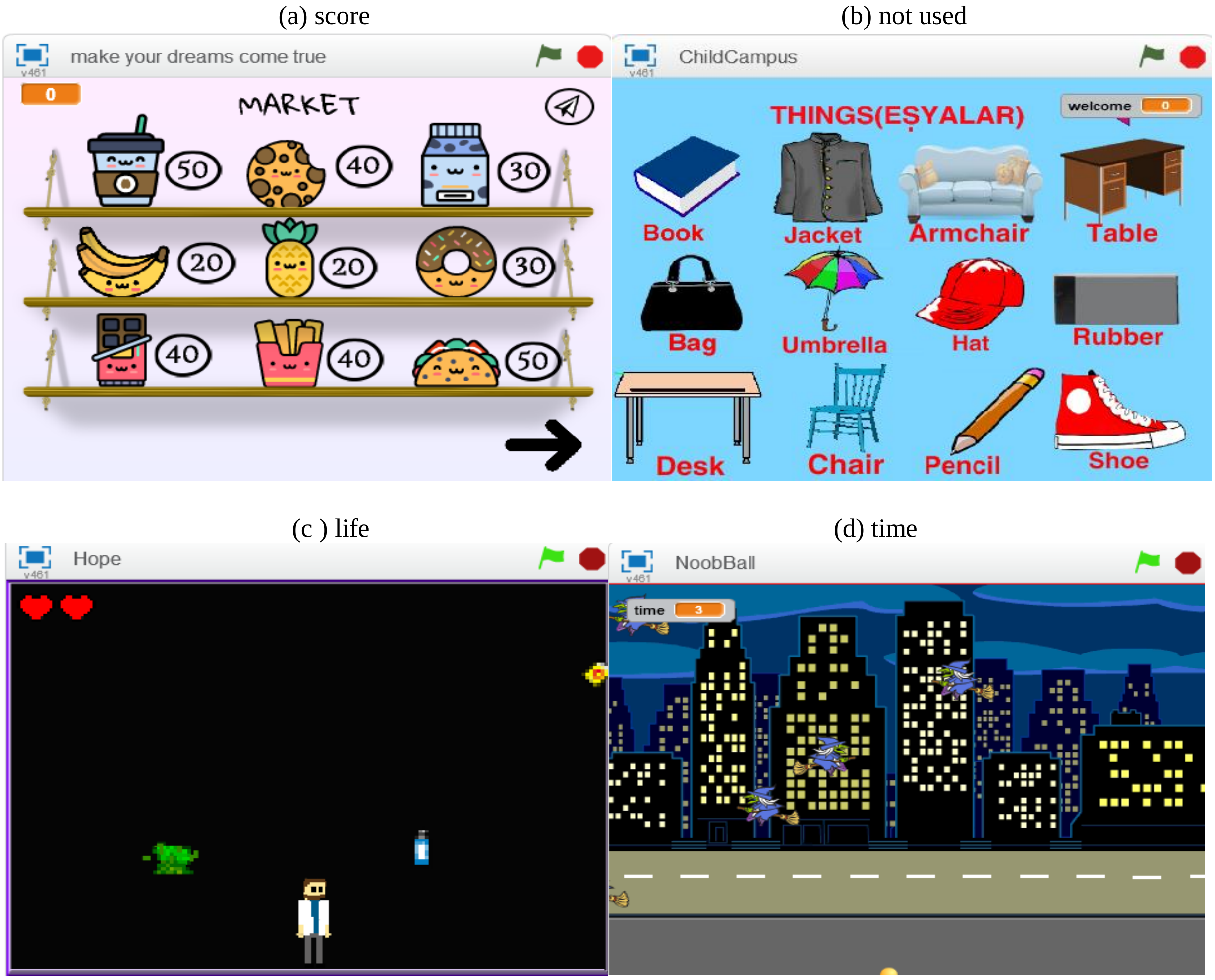


Figure 5. Images of the awards used by the students in the games they encoded

Table 8 shows the contents of the award used by the students in the games they encoded. It is seen that students mostly used 43 % (f = 130) points in the games they encoded. Beside this, there is not any award-winning criteria in the 19 % (f = 58) of the games. It is seen that 13 % (f = 41) of the awards were Life (hearts) and 4% (f = 13) were Scores. Other elements that the students used were listed as 2 % (f=7) for foods, %2 (f=6) for the number of correct answers, 2 % (f=6) for money, 1 % (f=3) for levels, 1 % (f=3) for hits, 1 % (f=3) for animals, 1 % (f=3) for the number of goals, 1 % (f=3) for keys.

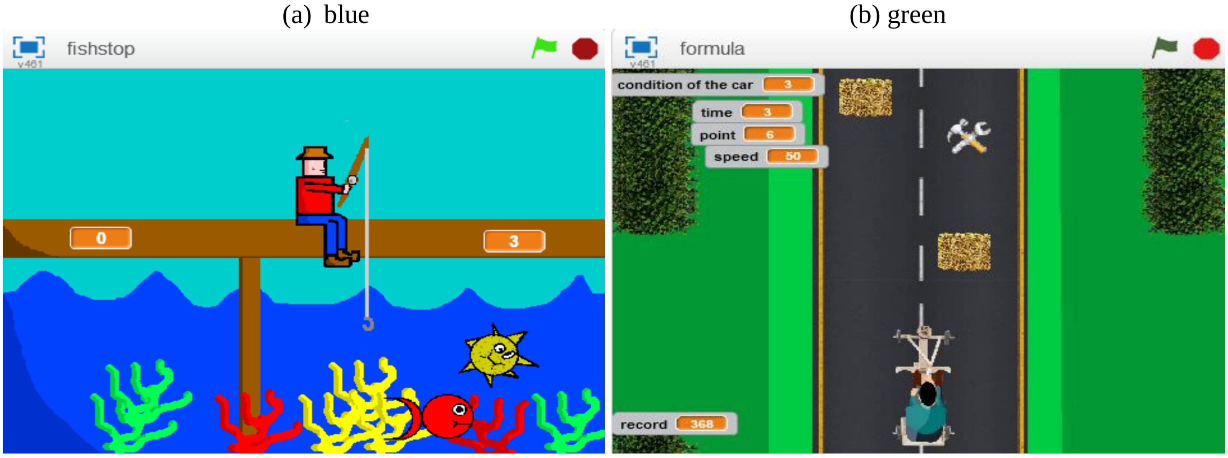
Table 8. The contents of the awards used by the students in the games they encoded

Award	f	%	Award	f	%
Point	130	43	Gold	3	1
Not used	58	19	Ammunition	2	1
Life (heart)	41	13	Member	1	1
Score	13	4	Tooth	1	1
Time	12	4	Winner	1	1
Food	7	2	Number of saved files	1	1
Number of correct answers	6	2	Completed game	1	1
Money	6	2	Badge	1	1
Level	3	1	Number	1	1
Hit	3	1	Wrong attempts	1	1
Animal	3	1	Star	1	1
Number of goals	3	1	Game completion	1	1
Key	3	1	Total	300	100

Colors Used Coded Games

Figure 6 shows the colors used intensively by students in the games they encoded. (a) in the Blue visual, a fisherman is fishing in a lake. (b) In the Green visual, it appears that a racer is moving on a road without hitting any obstacles. It is seen that the green color is used intensively in this visual. (c) In the No Dominant Color visual, water drops is expected to be collected through a bucket. However, there is no dominant color used in this visual. (d) In the Red visual, one or two players are expected to meet the ball. The Red color is used intensively in the background.

(a) blue (b) green



(c) no dominant color (d) red

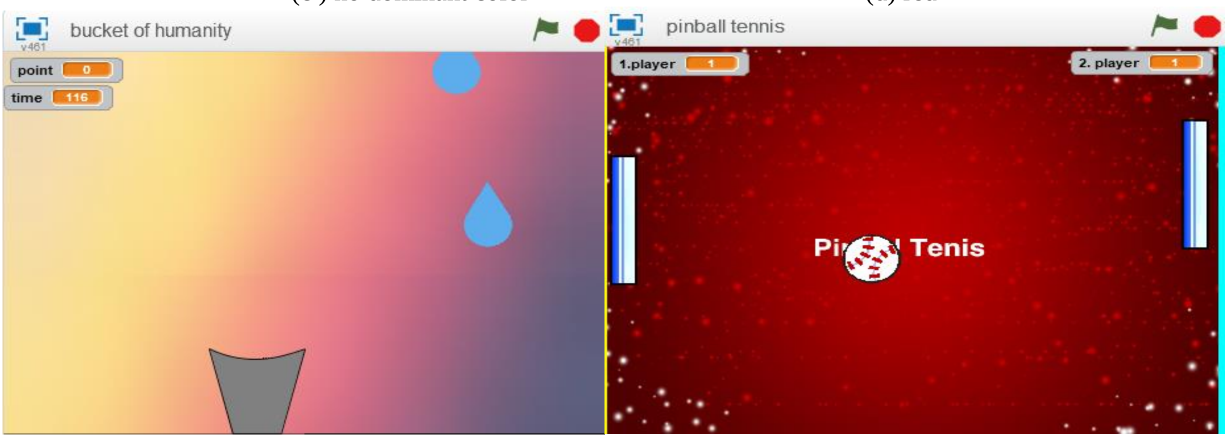


Figure 6. Intensive colors used by students in the games they encoded

Table 9 shows the contents of the colors that the students used in the games they encoded. It is seen that the students mostly used the color blue in their games, which is 21 % (f = 65). Following this, there comes the color green, which is 16 % (f=48). Then, 12 % (f = 36) appears to be not a dominant color. The other rates are as follows; 9 % (f=28) for red, 8 % (f=25) for white, 8 % (f=25) for black, 6 % (f=20) for magenta, 4 % (f=14) for grey, 3 % (f=9) for brown, 3 % (f=9) for pink, 2 % (f=6) for purple, 2 % (f=6) for yellow, 1 % (f=5) for orange, 1 % (f=3) for real pictures and 1 % (f=1) for lilac.

Table 9. Content related to the colors that students used intensively in the games they encoded

Color	f	%
Blue	65	21
Green	48	16
No dominant color	36	12
Red	28	9
White	25	8
Black	25	8
Magenta	20	6
Grey	14	4
Brown	9	3
Pink	9	3
Purple	6	2
Yellow	6	2
Orange	5	1
Real picture	3	1
Lilac	1	1
Total	300	100

Discussion and Conclusion

With the rapid advancement of the technology, the traditional game concept has changed, and digital items have become an indispensable part of our daily lives thanks to the ‘’digital games’’ concept. This study examines the variables which were used by the middle school students in creating digital games in the scope of technology-oriented STEM education. As Prensky (2001) stated before, what creates a game is the rules, goals and objectives, feedback, struggle / race / challenge / contrast, interaction, presentation and a story. Today, as a result of the rapid advancement in the technology, the Scratch-based game technologies increase the importance of technologies used in educational environments. Findings have shown that men were more interested in the game production process than females, and it is seen that counselors were all females. These findings support Becta’s (2001) conclusion that teachers should also be included in the process of an educational game production. It has been observed that the participants in the competition were mostly from Turkey’s first three largest cities. It has also been observed that of the 81 provinces, 57 of them took part in the competition. With all these findings, it could be said that computers created equal opportunities for coding and production process. It can be seen clearly that the students’ coding skills can be developed through such competitions.

As stated by Shin, Park and Bae (2014), Karabak and Güneş (2013), Monroy-Hernández and Resnick (2008), the students learn to produce digital games using their creativity, design some characters for the game, write stories, make feedbacks and use reward mechanisms, which are all essential for the improvement of their digital understanding. Therefore, they can gain some 21st century skills of systematical thinking such as computational thinking or lead them to STEM career paths In this study, it has been observed that students used concrete elements, abstract elements, complex content, simple and violent elements in digital games. According to Yengin (2010), digital games overlap with the expressions of abstract games, meaningful games, meaningless games and phased games. It has also been observed that while producing digital games, some of the students consciously or unconsciously used the violent contents such as weapons, bullets, rays and swords that will physically damage the character. It is stated that violent digital games cause aggressive behaviors, thoughts and physiological stimulation to increase, and also, they bring about desensitization against violence and low empathy for the long-time players and decrease the prevalence of benevolent behavior (Anderson, Shibuya & Ihori 2010). In the researches to be made in the future, the factors which make the students use the content of violence could be dealt with. Psychological effects of the digital games could be investigated.

In this study, the included game types were educational-tutorial, quiz, obstacle passing, maze, attention, garbage collection - recycling, race, progress, prediction, and follow-up. These results are to some extent similar to the classification by Mitchell and Smith (2004). In some of the games, it has been observed that students combined the course contents with digital games by using educational technologies or use of assessment STEM learning outputs. Educational-instructional games allow the students to learn the new concepts. Quiz shows integrate the knowledge with the technology. These results, as stated by Çatlak, Tekdal and Baz (2015), help integrate the technology with other courses besides programming.

The results show that the main characters the students used in the games they encoded were human figures, animals, objects and fantasy characters. However, Kan (2010) states that male and female roles are represented differently in computer games, considering the representation of the human figure in this study, it is seen the proportions of male and female representations were equal. Our ultimate goal should be to make games for learning more accessible and rich gaming experiences for all. Many of the changes in teaching and learning that came out of the gender equity movement improved the situation for all students, and not just for girls and women (Kafai, 2008). Exposing underrepresented students (e.g., females, minorities, and rural students) to pre-engineering skills through robotics and game design has the potential to increase their interest and to provide them with the skills needed to create a diverse workforce (National Research Council (NRC) 2011). Preparing students to succeed in STEM is crucial to ensuring that students have access to these and other STEM occupations in the future. (Leonard et al.,2016). In the interfaces that students produced, there were people and animals, environmental factors, space, technological elements, imaginary characters and various objects included. The results show that the students used the characters and infrastructures that the program already offered to them. Achievement systems or similar reward systems are becoming more and more popular in the games and they require for the addition of some scoreable targets to the game, apart from the inner mechanisms of the play such as meanings or purposes (Demirbaş, 2015). It has been observed that the students created some kind of reward systems for the games that they produced. They used the points most in their games. This result supports Prensky’s expression that these systems provide feedback and shows the dimension of the interaction between the players or the computers.

It has been proved via the experiments that colors make some psychological effects and the saturation of the colors gives information about the species, values, temperatures, coldness, activity, passivity, lightness, stimulation, relaxation, joy and sadness (Özdemir, 2005). It has been observed that students mostly used blue, green and red colors in the games that they produced. Blue represents coolness, calmness, loyalty, confidence and relaxation and it has a soothing effect (Madden, Hewett & Roth, 2000). Green represents freshness, coolness, growth, rebirth, peace, confidence, spring and vitality (Uçar, 2003, p.55). It appears that the students brought the calmness into the front in the games that they encoded.

Considering the concept of digital play, it has been observed that directing students to the game production process through competitions makes a great contribution to their 21st century skills in STEM education. From this point of view, encouraging students and their counselors in the game production process will provide an added value to our country within the scope of the growing game market. Within the framework of this research, the participation of males should be well-balanced with that of females. Students should be encouraged to use original characters or themes and to produce original contents. In educational technologies, digital games encourage students to game production. It is important to provide students with the necessary educational contents for the game encoding.

Leonardo et al (2016) found that game design and gaming developed children’s self-efficacy in technology, STEM attitudes/STEM careers, and computational thinking. In future studies, students' ability to produce games can be explored in depth, and the images used by students in producing games can be investigated through qualitative research in STEM education. The success of the games with high sales can be examined. With the use of these games, students' influence on STEM interest and STEM motivation can be investigated. Scratch 2 and the use of other educational tools in educational technologies, factors related to students' success can be examined in STEM education. Game design have not only been extolled for their role in learning but have also been identified as pathways to broaden participation in STEM and STEM-related careers (Caron 2010; Sheridan et al. 2013). This research is limited only to the game connected to this contest. The research can be repeated with field-specific content at primary, middle, high school and higher education levels.

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Preschool Children's Science Motivation and Process Skills during Inquiry-Based STEM Activities

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Abstract

STEM is an educational practice to integrate science, mathematics, engineering, and technology within the formal and informal context and it provides practical opportunities for the child to make sense of the world holistically. Moreover, the most important benefit of STEM activities for children, including engineering design, is to improve or support children's science and mathematics skills and social-emotional development. In this study, therefore, it was aimed to investigate children's science motivation as well as their usage of scientific process skills during inquiry-based STEM activities including engineering designs. Fourteen 5/6-years-old children included in the study and classroom observations, pre and post interviews were conducted to collect rich data. The findings revealed that children frequently engaged in STEM activities by employing at least one of the science process skills and they used engineering thinking apart from the science process skills. Moreover, following inquiry-based STEM activities, children have recognized science as an area of activity, and there have been positive changes in their motivation towards science.

Introduction

In educational policies, there are many ideas about critical times for students to increase their interest and success in STEM fields. Especially, a number of researchers have taken position that school levels including primary school and middle school (Wendell & Lee, 2010; Dabney, et al., 2012; King & English, 2016), high-school (Colakoğlu, 2016; Means, et al. 2017; Wang, 2013), college-level (Lai, 2018; Sass, 2015) have been influential for improving students' success and interest in STEM fields. However, in recent years, the idea STEM implementations should be started in early childhood education is increasingly accepted (Soylu, 2016; Tippett & Milford, 2017). Scientific findings, which show that children use their innate skills such as curiosity, questioning, and exploration to understand the world that they live in (French, 2004; Gelman & Brenneman, 2004; Katz, 2010; Schulz & Bonawitz, 2007), motivate policymakers, practitioners, and researchers to appreciate why STEM implementations should start at these ages. In fact, with these innate skills children offer a developmental potential for STEM education pedagogy. In other words, children already have a developmental trend or capacity which is an important requirement for STEM education pedagogy. Moreover, the early childhood education is appropriate to implement the academic subjects in STEM education by integrating since the integrated instruction, which is in the heart of STEM education, is an important learning standard for developmental appropriateness in early childhood education (Bredekamp & Copple, 2006).

The academic subjects of science, technology, engineering, and mathematics integrate in STEM education when they are implemented in classroom contexts. Particularly, science and mathematics, which are two important components of STEM education, are crucial in improving these skills. For example, inquiry-based science activities can improve children's scientific process skills, including observing, discovering, and problem-solving (Eshach & Fred, 2005; French, 2004; Gelman, Brenneman, Mcdonald, & Roman, 2009). The preschool mathematics also plays an important role in children's future school achievement, literacy development, and cognitive processes (Clements, Sarama, & Germeroth, 2016; Duncan et al., 2007; Nguyen, et al., 2016; Purpura, Logan, Hassinger-Das, & Napoli, 2017; Watts, Duncan, Clements, & Sarama, 2018). In recent years, there has been also an increasing interest in the field of technology. Researchers proved that in the early years of children, technology can contribute to their problem solving, mathematical concepts, computational thinking, and sequencing skills (Fessakis, Gouli, & Mavroudi, 2013; Kazakoff, Sullivan, & Bers, 2013; Sullivan & Bers, 2016). In early STEM education, engineering activities should be understood. The engineering was defined as the process of designing the human-made world by Katehi, Pearson, and Feder, (2009a, p. 27). While science tries to understand the world in which we live, engineering aims to modify the world to satisfy human needs. The scientific knowledge guides the engineering process, and it is also not possible to make much scientific progress without tools developed by engineers (Katehi, et al., 2009a, p. 27). In this respect, science and engineering cannot be separated from each other in learning environments. Engineering activities provide a natural context for children to experience scientific skills rather than abstractly learning concepts (Katehi, et al., 2009a; Schunn, 2009). These findings revealed that there is a lot to do about integrating the field of engineering into early childhood education environments to increase children's scientific gains. In this study, we expect that inquiry-based STEM activities including engineering designs present a learning environment that can help teachers to improve children's scientific process skills and their science motivation.

Science process skills are those that allow children to advance new information through concrete experiences. These skills are important in the daily lives of children as well as in their future lives (Charlesworth & Lind, 2010, p. 77). Young children's natural curiosity is crucial for learning science skills, and they not only learn skills but also build on a set of skills over time (Jirout & Zimmerman, 2014; Kuru & Akman, 2017). Moreover, these skills in the early years are also best predictors of children's science achievement in their next grades (Saçkes, 2013). Therefore, the researchers suggest that inquiry-based activities should be implemented in early childhood education to improve children's scientific skills and to increase their scientific achievement and their motivation (Alabay & Özdoğan, 2018; Saçkes, 2013; Samarapanguvan, Patrick, & Mantzicopoulos, 2011) because in inquiry-based activities, the child should take responsibility in the learning process by actively participating to obtain new knowledge (Pedaste, et al., 2015). Alfieri, Brooks, Aldrich, and Tenenbaum (2011) and Furtak, Seidel, Iverson, and Briggs (2012) reported that students' learning gains in the inquiry-based learning model were much more than traditional models.

This Study

The global economic competition has created the widely accepted STEM movement in the field of education (Katehi, et al. 2009b; Martín- Páez, Aguilera, Perales- Palacios & Vílchez- González, 2019; Soylu, 2016). STEM is an educational practice to integrate science, mathematics, engineering, and technology within formal and informal context and it provides practical opportunities for the child to make sense of the world holistically (Lantz, 2009; Marcus, Haden & Uttal, 2017; Marcus, Haden & Uttal, 2018). Moreover, the most important benefit of STEM activities for children, including engineering design, is to improve or support children's science and mathematics skills and social-emotional development (Katehi, et al. 2009b; Lippard et al., 2017). In recent years, thus, early STEM education has been a remarkable subject for researchers in Turkey and they have obtained various findings from their studies. For example, the findings of the study conducted by Akgündüz and Akpınar (2018) showed that STEM activities contribute to science, mathematics and 21st-century skills of children. Similarly, in another study, it was found that STEM activities improved children's 21st-century skills and STEM components (Günşen, Fazlıoğlu & Bayır, 2017). Uğraş (2017) also found that teachers emphasize the benefits, limitations, and practices of STEM in a study conducted to examine teachers' opinions about STEM education. However, there are not sufficient scientific data to support these findings. Martín- Páez, et al. (2019) in a literature review found that preschool was an educational stage when STEM studies were least conducted. Soylu (2016) also suggested that there should be more efforts to integrate STEM activities into the preschool education. This situation makes early STEM research particularly significant. The need for STEM activities in early education has been a point of inspiration for this study. Furthermore, the experts suggests that children acquire the scientific process skills at an early age and that this needs to be done through inquiry-based activities (Charlesworth & Lind, 2010; Jirout & Zimmerman, 2014; Saçkes, 2013; Samarapanguvan et al., 2011). To benefit from these activities, however, children need to participate in the educational process in a motivated way, as motivation is an important factor in children's academic success and school performance (Çeliker, Tokcan & Korkubilmez, 2015; Wigfield, Eccles & Rodriguez, 1998). Therefore, it is considered that this study is specifically important to determine whether inquiry-based STEM activities create a natural learning environment for the use of science process skills as well as the effects of these activities on children's science motivation. In this context, the following research questions were investigated:

1) Which science process skills were used by children at inquiry-based STEM activities including engineering design?
2) How did inquiry-based STEM activities influence children's science motivation?

Method

This qualitative study was designed following a case study methodology. The case study methodology (Moustakas, 1994) was used to explore how or why the actions occur within real-world contexts. Qualitative inquiries are powerful tools for enhancing one's understanding of learning and teaching process (Creswell, 2007). Correspondingly, kindergarten children's engaging in the inquiry-based STEM activities were investigated considering those activities as a case. In this study, science process skills that children used during the inquiry-based STEM activities and influence of children's engagement in these activities on their science perceptions were explored.

Participants

The study group was created by using homogeneous sampling, which is a purposeful sampling method. Purposeful sampling methods are the techniques to determine and select information-rich cases for the most effective use of limited resources (Patton, 2002). The purpose of this process with homogeneous sampling was to understand and describe a particular group in-depth through the data in relation to the aims of this study.

Table 1. The demographic data of the children in the study group

		f	%
Gender	Male	7	50
	Female	7	50
Age	5	8	57
	6	6	43
Attendance to school	1 year	7	57
	2 years	4	28
	3 years	2	14

This study was conducted in a public preschool in the center of Kırşehir. The school is located in the city center and families with an economic status range from low-to-high-level have their children enrolled in this school. There were ten groups in the school: five in the morning and five in the afternoon. The number of children in a classrooms varied between ten and sixteen. As the school was much in demand, teachers were eager to carry out the new practices. Moreover, the classes were less crowded. This was significant, because the small number of children in the classroom is very important for activities to be more effective and is an important element of the quality of education (Sheridan, Williams, & Samuelsson, 2014). Fourteen 5/6-years-old children (7 male and 7 female) and their teacher took part in the activities. Nearly half of the children were in their first year at school, four children were in school for two years, and two children were in school for three years. The teacher holds a bachelor's degree and gave her concept to implement Early Childhood Education Curriculum (MoNE, 2013) in the classroom. The classroom design was suitable for the Early Childhood Education curriculum and was adjusted according to the procedure of this study. Children were observed in small groups during the inquiry-based STEM activities.

Procedure

Three basic stages were followed when conducting this study. A general outline of the procedure was presented in Figure 1 below.

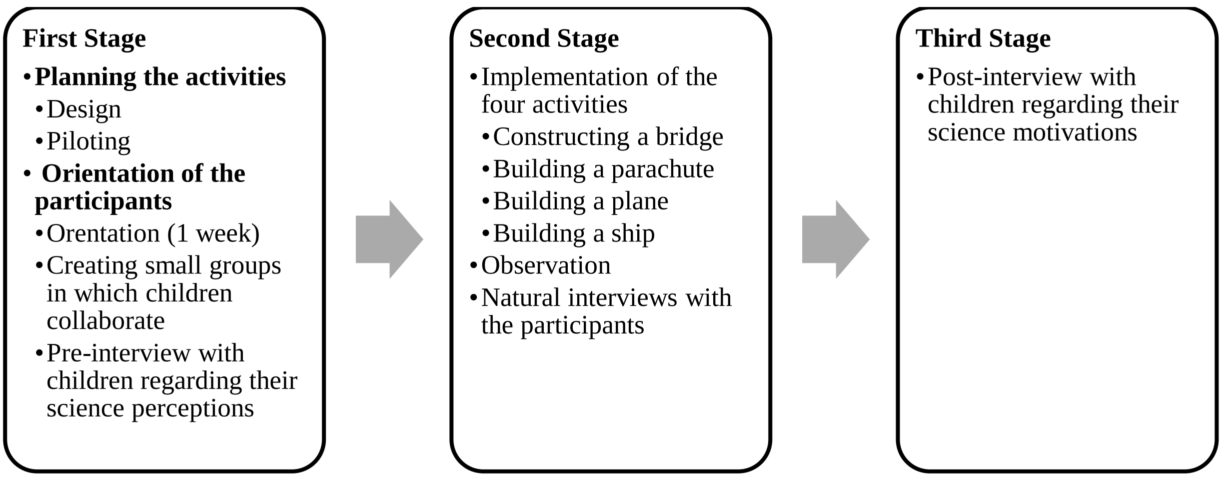

Figure 1. General Outline of the Procedure

In the first stage, four inquiry-based STEM activities were designed by the researchers. The activities were designed according to the inquiry-based learning framework of Llewellyn (2002). Besides, the activities were planned as integrated activities and satisfying properties of STEM activities. Moreover, the activities included "force" which is one of the contents to be taught in the preschool classrooms. In the process of creating activities, first of all, activities including the basic steps of the inquiry-cycle framework were arranged according to the subject of force in the solid, liquid, and gas. These activities were examined by three experts (two in the field of preschool education and one in the field of science education). Experts evaluated these activities according to content accuracy and developmentally appropriateness for preschoolers and then, activities were prepared for the pilot study by making arrangements according to experts' feedback. The pilot study was conducted in a different classroom to improve the structure and timeline of the activities. At the end of the pilot study, arrangements were made and the activities became ready for implementation. Although integrated activities were emphasized by the MoNE curriculum (2013), the teacher, children, and design of the classroom were not completely ready for conducting inquiry-based STEM activities. In the first stage of classroom sessions, therefore, a one-week orientation was conducted by the researchers to familiarize the participants with the activities. In addition, pre-interviews with children were conducted. The pre-interviews aimed at determining children's prior knowledge about science activities and their motivation towards science.

The second stage of this study included the implementation of the activities. While one researcher and the teacher conducted the activities, one researcher videotaped the classroom and collected data by recording field notes during the implementation of the activities. Engagement, exploration, explanation, elaboration, and evaluation (5E) processes were executed in each activity (*Figure II*). The third stage of this study consisted of conducting post-interviews with the children. These interviews were conducted to investigate how inquiry-based STEM activities influenced children's motivation toward science.

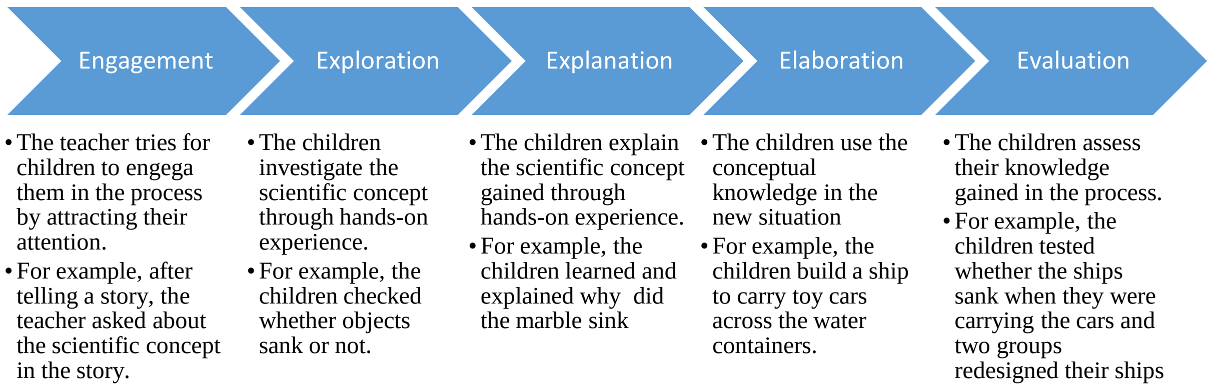

Figure 2. The inquiry-cycle with examples in the activities

Data Collection

Several data collection procedures were used in this study. Classroom observations, video recordings pre and post interviews were conducted to collect rich data. Although each data collection method had different characteristics, they provided useful information for understanding children's engagement in inquiry-based STEM activities. Classroom observations constituted the main data of this study. As mentioned earlier, one researcher both video-recorded and observed the classroom during the activities. A second researcher conducted activities in the classroom by getting help from the teacher. The role of both researchers was part-participant. The researchers who attended to the fieldwork used an observation form to record children's engagement in the activities. After conducting the activities, the video recordings were watched and analyzed by the remaining researchers. The observation form used in this study was developed by the researchers and was designed to record the activities performed by the children in each step of the inquiry cycle. After the initial version of the observation form was created, experts' opinion (one in field of preschool and two in field of educational sciences) was taken to determine whether the form was appropriate for this study. Moreover, a researcher used this form during the pilot study to determine whether the form is appropriate for the aims of this study. The form was redesigned with changes made as a result of feedback on its appropriateness. The final form consisted of each step of the inquiry-cycle and the starting-ending time of these steps. The observer noted what the teacher and the children do in these steps. In this way, the form was arranged in a semi-structured observation form model which the observer descriptively noted what he/she heard, saw and understood. (Rozsahegyi, 2019).

Semi-structured pre and post interviews with the children were conducted to explore the influence of the STEM activities on children's motivation towards science to obtain children's views more efficiently. The opinions of the three experts (one in the field of preschool education and two academicians in the field of educational sciences) were collected during the preparation of the draft of the interview form. Two questions were removed from the draft interview form by the feedback received from experts. Finally, the coefficient of agreement between the experts was calculated as .78 with the Fleiss Kappa coefficient. To reach the purpose of the study, the questions were asked to the children such as "Do you like science activities? What do you think of science activities? Do you think science activities are easy/difficult? Why?" During the interviews, additional questions were asked to children to broaden their answers.

Data Analysis

Observation notes, video recordings derived from the activities were collected to investigate children's use of science process skills during inquiry-based STEM activities. During the activities, the two researchers who participated in the fieldwork defined science process skills according to Charlesworth and Lind's (2010) categorization. Therefore, the collected data was coded around the following skills: observing, comparing, classifying, measuring, communicating, inferring, and predicting. These codes were used to analyze children's utilization of science process skills during the activities.

Additionally, the researchers were open to emerging new codes that were hidden in the data. During the analysis of observation notes and video recordings, apart from the science process skills, active engagement and emotion codes also emerged. These codes were used to interpret the influence of activities on children's science motivation. The data collected during pre and post interviews were analyzed according to Mantizicopolus, Patrick, and Samarapanguvan, (2008)'s categorization of science motivation of children. These codes were as follow;

- Don't know, no response, or irrelevant
- School activities or events not related to science
- Science content not included STEM activities
- Science content included STEM activities
- Science content and affect

Several procedures were used to eliminate validity and reliability issues. For the validity purpose, multiple sources of data were used for triangulation. Reliability and consistency of the results were also taken into consideration. The inter-rater reliability was calculated as .96 that showed acceptable reliability (Creswell, 2007) according to Miles and Huberman's (1994) formula. Besides, excerpts from video recordings, classroom observations, and interviews were presented in the related section. In the excerpts, pseudonyms were used to protect confidentiality.

Results

This section has two parts. The first part presented children's engagement in inquiry-based STEM activities and their use of science process skills during these activities. In the second part, the science concept of children was presented.

Children's Use of Science Process Skills during the STEM Activities

Children's engagement in STEM activities and their use of science process skills during these activities were analyzed in this part. We found that children frequently engaged in STEM activities by employing at least one of the science process skills. They actively participated in the activities and were motivated for reaching the goal of each activity cooperatively. However, children intended to use each skill in a different stage of the inquiry. The table below presented examples of children's use of science process skills in each stage.

Children used their observation skills in each stage of the activities. They frequently observed the teacher, their group-mates, and other group members. In the engagement stage, children observed the teacher. The teacher engaged them in the activities by telling a story, showing interesting pictures, and arranging a discrepant event to generate their interest. Children's observations of the discrepant event quickly attracted their attention. In the exploration stage, children observed their group-mates and worked cooperatively with them. Furthermore, they observed members of other groups to imitate strategies that they used and to understand how they used different materials in the designing process. In the explanation stage, children observed the teacher's explanation regarding the designs and groups' products that were created in the exploration stage. Especially, when teacher exhibited each group's product, children focused on the explanation of the teacher. Children's observations in the elaboration stage were similar to their observations in the exploration stage. They observed both their group-mates and members of other groups when refining their designs and products. In the evaluation stage, children observed how their and other groups' final products functioned. To sum up, children consistently used their observation skills for gathering information about the activity within the group and across groups. That is, their observations established a base for each stage. The excerpt below presented a variety of children's observation. Children also used comparison skills during their activities. They began comparing real-life situations and scientific concepts in the engagement stage (i.e., sinking-floating objects). For example;

> ….After the attention of the children was drawn to the scientific concept, the children were given some real objects (ping-pong ball, sponge, marble, mandarin, key, and woods). The teacher instructed the children how to record their predictions about whether these objects would sink in the water. To do this, children used the prediction chart prepared for this activity. The children then put the objects into large water containers and checked whether they sank or not, and then they marked the sunken objects into a new chart. The children explained the reasons for their first predictions by comparing their previous and subsequent chart. For example, Ahmet explained his opinion as; "I thought marble would sink because it was small, but it doesn't…. (Observation note from activity "Let's build a ship").

Moreover, they compared materials according to their properties, sizes, and intended purposes in the exploration stage. Each group compared members' proposals for designing the product. Besides, children compared components and different perspectives of the designs. In the explanation stage, children compared designs and products of the groups under the guidance of the teacher. Children compared the properties of the designs and materials that were used in the products. Children compared their prior knowledge with present understanding in the elaboration stage of the activities. Thus, they refined their designs according to their observations. Finally, children had the opportunity to compare their initial design and last design in the evaluation stage. They compared their designs with other groups' designs. In the evaluation stage, children also compared their prior knowledge and final understanding of the concepts. The excerpt below included children's comparisons of cardboards and papers during the design of an aircraft.

Classifying was widely used by children both in the design and evaluation processes. First, children classified real-life objects or events during the engagement process provided by the teacher. Next, they classified materials to design their models. They sorted materials according to their possible usages in the model. However, some children were not successful at classifying materials since they had to lack prior experiment on some materials and concepts. The teacher explained the concepts and materials in the explanation stage. Children classified each group's design and model following the teacher's explanation. In the elaboration stage, children classified materials to re-design and refine their models. They were generally successful at classifying at this stage since they had experienced during the activity. In the evaluation stage, children evaluated all groups' products and designs according to the purpose of the activity. They classified models such as floating-sinking or as solid-unstable. The excerpts below were a good example of children's classification of materials. Besides, children sorted materials according to their possible usages in the model.

> …Children chose materials themselves to design an airplane. They tended to use cardboards for their plane. They took cardboards and tried to put them onto other materials. Some children tried to fly cardboard by throwing. The teacher watched the children and groups for a while and instructed children how to design their airplanes… Children expressed their notions and drew their designs. Some groups drew more than one design, since children had different views… (Video note from activity "Let's build an airplane").

Measurement skill was another common science process skill that children used during the activities. When engaging children in the activities, the teacher provided children with opportunities to measure some concrete materials. In the exploration stage of the activity, children measured materials and collected data for their designs and models. They measured the length or weight of the materials for designing their models by using rulers, fingers, pencils, and so on. In the explanation stage, across groups, the teacher led children to measure some models' properties for comparison and classification purposes. Children used data from these measurements for refining their models in the elaboration stage of the activities. Finally, they measured some properties of the models when evaluating these properties. For example,

Table 2: Examples of children's use of science process skills during the STEM activities

Science Process Skills	Stage	Example
Observing	Engagement	Children's observations of discrepant events led them to quickly activate their attention and learning.
	Exploration	Children observed group-mates' behaviors, especially some children who did not have prior knowledge about the topic.
	Explanation	Children observed teacher's instruction and explanations.
	Elaboration	Children observed group members and other groups' modifying designs.
	Evaluation	Children observed how their products functioned.
Comparing	Engagement	Children compared real-life situations during discrepant events.
	Exploration	Children compared materials while designing. Comparing elements of the designs.
	Explanation	Children compared designs and materials created in the exploration stage.
	Elaboration	Children compared their prior knowledge and present understanding.
	Evaluation	Children compared their first and ultimate designs.
Classifying	Engagement	Children classified real-life situations through the help of a teacher.
	Exploration	Children sorted materials according to their intended use and intended parts of the design.
	Explanation	Children classified appropriate designs.
	Elaboration	Children classified materials according to the explanation of the teacher.
	Evaluation	Children evaluated models and classified them according to their properties.
Measuring	Engagement	Children conducted measurements during discrepant events.
	Exploration	Children measured materials and properties of designs and collecting data during the activities.
	Explanation	Children measured properties of designs to compare and classify.
	Elaboration	Children used their measurement skills to refine their designs.
	Evaluation	Children measured properties of final products.
Communicating	Engagement	Children explained prior knowledge.
	Exploration	Children shared observations and they communicated during the activities.
	Explanation	The teacher used a common language regarding scientific concepts.
	Elaboration	Children redesigned their products and discussed during the arrangement of materials.
	Evaluation	Children and teacher discussed the final products of the groups.
Inferring	Explanation	Children described their designs and investigations and deduced from teacher's comparison of the designs and materials. Children improved their understanding of using their experiences.
	Elaboration	Children observed explanation stage and made inference while redesigning their materials.
Predicting	Elaboration	Children made predictions about the properties of their designs such as floating in the water.
	Evaluation	Children evaluated products by predicting their properties.

> …The children tried to test how their parachutes landed when they threw them from a height. However, all groups saw that their parachutes did not work. The teacher also tried the parachute that he had prepared. The parachute slowly landed and the children were all excited and applauded teacher's parachute. After these trials, the teacher asked to the children, "Why did my parachute work, while yours didn't? I'm putting my parachute on the table so you can answer that question. Come and examine, compare it with your own". The children examined the teacher's parachute. The groups changed or reconstructed their parachutes. In a group, the children used a ruler to make the ropes the same length as the teacher's parachute ropes... (Observation note from activity "Let's build a parachute").

One of the common science process skills that children used was communication. It could be understood from the excerpts children frequently communicated with each other during the activities. Children frequently communicated with each other during their activities. Children shared their observations and ideas for the designs and products from the exploration to the evaluation stages. It should be noted that the teacher guided children for using their communication skills in the first activity. Therefore, it was ensured that each child collaboratively participated in the activities. They orally communicated ideas and directions. Children also drew figures of the designs so that other children could understand what they meant.

> ...The teacher showed the children the toy cars and asked how they could carry the toys cars across the water containers without sinking. One of the children (Berrak) said: "We could carry it by the ship". The teacher presented the children with a variety of materials to build a ship (ping-pong ball, pipette, cardboard, wood, paper, rope, sponge, bag, etc.). Children discussed in their group how to build a ship. The groups then took the materials they chose. They shared tasks. After building their ships, they tested whether the ships sank when they were carrying the cars. The teacher asked the children "Why did some ship sink at this stage". Furkan replied; "Because the cardboard was not water-resistant. If we had glued bags to our ship, it wouldn't have sunk". Two groups redesigned their ships by adding some materials such as bag, wood… (Observation note from activity "Let's build a ship").

Surprisingly, children used inference and prediction skills in the later stages of the activities. In the explanation stage, children began inferring when the teacher provided explanations of the events. For example, when the teacher provided information about how a ship could float, children inferred their designs' and products' properties regarding floating. Hence, they improved their knowledge of floating objects. Moreover, children used their inference skills while redesigning their products. Regarding the prediction skill, children made predictions in the elaboration and evaluation stages. As they gained scientific background through the activities, they predicted properties of the products and evaluated them in the evaluation stage.

The Effects of STEM Activities on Children's Science Motivation

In this section of results, we presented how inquiry-based STEM activities affected children's science motivation. Table 2 presents children's answers about science activities with examples in the pre and post interviews. The answers were arranged according to the coding scheme generated by Mantizocopolus et al. (2008). However, new categories including "science in-home and collaborative science" that are generated during the coding process are added to this coding scheme.

A comparison of the children's responses in the pre and post interviews showed that there were significant changes. Almost all of the children were not aware of their science activities before inquiry-based STEM activities were implemented. Children often considered science-related activities that were not relevant to science. For example, they talked about "cutting and painting activities" in art activities as a science activity. However, following inquiry-based STEM activities, children have recognized science as an academic subject, and there have been positive changes in their motivation towards science. Before the process, Berra had explained her view as;

> We cut things and paint them at the science activities.

But after the process, her view changed as;

> We built a ship and tried to see whether it was swimming.

Table 3: Children's answers and frequencies with examples by categories

Categories	f (Pre)	f (Post)
Don't know, No Response, or Irrelevant	49	2
School Activities or Events Not Related to Science	50	1
Science Content Not Included STEM activities	16	5
Science Content Included STEM activities	-	88
Science Content and Affect		
I like science	3	14
Science is difficult	3	1
Science is easy	-	9
Science is fun	-	13
Science is exciting	-	13
Science in Home	2	7
Collaborative Science	5	12

Children earlier reported that they don't like science activities as it is difficult. After the inquiry-based STEM activities, however, children thought that science is easy and they stated their reasons as;

> I can do it.

For example, before the process, Furkan had expressed his view as;

> I don't like science because it is difficult for children to cut over the line.

After the process, his view changed as;

> I like science because I can do it and it was easy for me. I had so much fun at the ship activity. It was fun and exciting to watch whether it sank or not.

The answers revealed that children's self-efficacy being engaged in science was effective, which led them to perceive science as an easy academic subject.

Another important finding was that children were able to transfer STEM activities from classroom context to home context. Before the process, irrelevant activities such as drawing, gluing, and paint printing was mentioned as home science activities. Following the process, the content of the home science activities changed. Children stated that they tried what they had done in the classroom at their home or that they told their parents about activities. After the process, Rümeysa expressed her experience as;

> I didn't do anything about science at the home, but I explained to my parents how to make a plane, ship, and bridge.

Also, Belinay expressed her experience as;

> I did an activity at home. I made the plane and ship with my mother

Besides, children recognized the importance of collaborative work in a STEM process. Abdulhalim explained his view like that;

> I like working in a group, because my friends help me and then, the tasks get much easier

Discussion and Conclusion

In this study, the purpose was to understand how inquiry-based STEM activities, including engineering designs, affect young children's scientific motivation and to determine which science process skills that they use in the activity settings. A purpose of the present study is to examine the effects of inquiry-based STEM activities on children's science motivation. Children's experiences in an academic subject are effective in terms of their motivation, and these experiences are crucial in the choice of future careers and interests (Caspi et al., 2019;

Eshach & Fried, 2005; Mantizicopolus et al. 2008). Motivation is an important field of study for social psychologists. They explained the psychological determinants effective in the motivation as follow: the individual's perception, beliefs and attitudes of the task or behavior (such as fun, exciting, useful), their self-competence (the individual feels competent of any task or behavior), perceived control of task or behavior (it refers to an individual's assessment of how easy a task or behavior is), and collaboration with others (the presence of people to help when the individual needs them) (Azjen, 1991; Wigfield, et al. 1998; Wigfield, Eccles, Schiefele, Roeser, & Davis-Kean, 2006). In this perspective, STEM activities in this study positively affected the children's science motivation, as the findings revealed that there were significant changes in the psychological determinants of children's science motivation after STEM activities. For example, when children were engaged in the STEM process, their perceptions toward science changed positively. Children hadn't developed any idea of what was done in science activity or they hadn't thought science as an academic subject before the implementation process. However, their views on science changed after implementation. Moreover, the children began perceiving science as fun, exciting, and easy after the STEM process. While these findings are similar to the findings of studies reporting that children's science motivation increase when they are exposed to science activities (Mantizicopolus et al. 2008; Patrick, Mantizicopolus, Samarapanguvan, & French, 2008), they also reveal that inquiry-based STEM activities have positive effects on children's perceptions of science. This might be because when children engaged in developmentally appropriate and inquiry-based engineering designs, they perceived science as an academic subject and science became fun for them. Self-competence is also one of the psychological determinants of motivation. As children were exposed to activities, they considered themselves as competent (Samarapungavan et al. 2011). In this study, it was understood that children felt sufficient about activities after the STEM process. Furthermore, this study suggested that children's preference to work in collaboration with their group mates is also an important factor in their motivation.

The findings based on classroom observations revealed that children actively used their science process skills including observation, comparison, classification, communication, measurement, prediction, and inference. STEM activities provided an environment for children to experience these skills in a collaborative atmosphere. Children used these skills in each stage of the inquiry-based activities. However, in each stage, their intentions for using these skills were varied. Moreover, while children used their observation, comparison, classification, measurement, and communication skills across all activities, they used inference and prediction skills mainly in explanation, elaboration, and evaluation stages. Inquiry-based learning aims to involve students in a real scientific discovery process (Pedaste et al., 2015). Thus, researchers suggest that inquiry-based learning process should be performed in a classroom context for children to improve their gains (Saçkes, 2013; Samarapanguvan et al., 2011). The findings of this study proved that these suggestions were justified. In early childhood education, besides, science process skills have been highlighted as promoting children's understanding of science as a way of knowing (Sackes, 2013). Therefore, children should be provided with opportunities for experiencing science process skills in a collaborative and inquiry-based atmosphere. Moreover, inquiry-based STEM activities could be developmentally appropriate for ensuring this atmosphere.

The current study revealed that children designed, tested, refined, and evaluated their designs and products within the circle of inquiry-based STEM activities. We observed that children used engineering thinking apart from the science process skills while engaging in the activities and understood that inquiry-based STEM activities provided useful opportunities for supporting children's engineering thinking. Our finding suggested that inquiry-based STEM activities could provide suitable and rich opportunities for enhancing children's engineering skills in early education as it required the correct direction for its introduction (Bagiati & Evangelou, 2009). This finding also extended the findings of Bagiati and Evangelou's (2016) and Lippard et al. (2018) by showing that children use engineering skills when they are actively involved in activities. The activities required both the inquiry of the preschool teacher and children's active engagement, motivation and collaboration. In this way, the activities will provide useful opportunities for supporting children's engineering thinking.

Parents are important partners and children's home environments can be rich resources for STEM in early childhood education. Therefore, the link between school and home environments is a significant factor for early STEM education. In this study, the findings showed that STEM activities were naturally transferred to the home by children. In the interviews, some of the children mentioned that they told their parents about the activities they conducted in the classroom, while others also mentioned that they repeated what they have done in the classroom in their homes. This finding was surprising for us since we did not attempt to express or imply the using of STEM in their home environments. It was well understood that inquiry-based STEM activities were effective in establishing a natural connection between school and home. A great deal of effort is needed to establish a link between school and home in early science education. The finding of this study may, in part, shed light on how to establish this connection. However, it should be noted that this study did not focus on what was done in children's home environments.

Recommendations

The findings of this study provided important information on the implementation of STEM activities in preschool education. Based on these findings, we provide the following recommendations. Since early STEM education provides the best opportunities for children to develop their 21st century and science process skills, policymakers in education, teachers and trainers may work collaboratively to integrate the engineering practices into preschool. Although STEM has been seriously taken up in preschool education, more information is needed on how to integrate STEM disciplines and how to implement engineering practices in the classroom context. Accordingly, professional development sessions including pedagogical information on the implementation of STEM disciplines can be planned for teachers. In particular, relevant courses may be integrate the curriculum of universities for teacher candidates to acquire their knowledge and skills for STEM during the pre-service years. Opportunities may be created for implementing STEM applications in informal contexts as well as formal contexts. Teachers may also generate "STEM activities in-home" by engaging families in the process. Moreover, STEM activities in formal context were implemented in this study. The studies may be planned to implement STEM in informal contexts such as museums, play-ground, laboratory. The finding that children reflect activities in various ways in the home environment may encourage researchers to investigate STEM practices in the home environment, their contributions to children, and parents' beliefs, attitudes and skills about STEM. This study was conducted over four weeks. However, future studies may be conducted to investigate how long-term STEM activities contribute to children's social, emotional, and language development.

Notes

This study was presented partially in the international conference on education in mathematics, science & technology (ICEMST, 2016).

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Pre-Service Science Teachers' Learning and Teaching Experiences with Digital Games: KODU Game Lab

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Abstract

The aim of this paper is to introduce Kodu Game Lab to pre-service science teachers through a method course based on MAGDAIRE framework and prepare them to design their own digital games. In accordance with this purpose, key factors towards using digital games in classroom are also observed. Convergent parallel design that is a type of mix method research design was used in this study. This study is performed with a total of 18 pre-service teachers (PSTs) who were senior students in a teacher education program of a public university in Turkey. PSTs voluntarily formed six groups and designed their own digital games collaboratively based on DGBL-ID Model. Technical Proficiency of Kodu Skills Test (TPKS-T), rubrics for group and personal assessment and observation form were used to collect data. According to analyses of data collected with TPKS-T, post-test mean of PSTs is significantly higher than their pre-test means. Findings of rubrics showed that PSTs' determined performance levels are directly proportionate to practices. Also, findings obtained with observation form are promoted this result. It can be suggested that knowledge and skills, pedagogical beliefs and culture have an effect on integrating digital games into learning process.

Introduction

Since the potential of technology to improve student learning and help change education in 1900s, researchers' interest in this field has increased day by day (Hew and Brush, 2007). In recent years, many researchers have examined the effectiveness of digital technologies in educational processes, and one of the researched topics in this area is the studies based on digital games (Liu and Chen, 2013). In fact, there is an increasing interest about using well-designed digital games that can promote learning in various disciplines (Gee, 2005; Shaffer, Halverson, Squire and Gee, 2005; Shute, Rieber and Van Eck, 2011). Various definitions towards digital games can be seen in related literature. For example, according to Granic, Lobel and Engels (2014), digital games been interactive engage players actively in game world and the world react to players agentive behaviors. Koster (2013) defined digital games as puzzles to solve and brain exercises. Vogel, Vogel, Cannon-Bowers, Bowers, Muse and Wright (2006) determined that digital games are activities had objectives and given feedback. Thus, we can say that digital games are explained with focusing different qualities. Whitton (2010) investigated the qualities of digital games that are suggested in the literature and stated the qualities of digital games that are especially used in learning environments. The researcher suggested that there are ten qualities of these games been presented in Table 1.

When these qualities of digital games are taken into consideration, it can be determined that digital game-based learning is one of the learning methods that can be used for effective learning. According to Bruner (1961), when learning process is active, goal directed, contextualized and interesting, effective learning occurs in the classroom environment. Also, feedback has a positive effect on learning (Ifenthaler, Eseryel and Ge 2012). It is clear that conditions for effective learning have parallels with qualities of digital games.

Theoretical Framework and Literature Review

Learning is connected with play closely (Amory, Naicker, Vincent and Adams, 1999). Digital games been used for educational purposes are absorbing and immersive implementations to attain specified learning objectives, outcomes and experiences (De Freitas, 2006). Prensky (2001) determined that fun and educational content must be balanced with each other to design an efficient educational game.

Table 1. Defining qualities of digital games (Whitton, 2010)

Quality	Definition
Competition	This quality requires winning the game with a higher score than the other player(s). Also, the player can compete with one's own by trying to get a higher score than his/her old score.
Challenge	This quality requires a task that has an unordinary process to win the game. Player should make an effort to achieve the outcome. Also, the task should have various difficulty levels.
Exploration	This characteristic is related to a game environment that can be real, virtual or simulated. The game environment should be discovered by the player. Discovery of the environment arouses player's curiosity since game world has different objects and characters.
Fantasy	This quality is about creating a fictional game world and game scenario that describes relationships between the characters and game environment.
Goals	Digital game should have clear purposes and objectives. Goals present explanations about actions to be taken to win or complete the game. Also, players are informed about goals what the game want and why they are playing the game.
Interaction	Players can influence the game situation by stepping into action and thus the game changes and gives directions/feedback to the players about deciding their next actions.
Outcomes	This quality is a mechanism that presents feedback which a goal is achieved, how far a player is accomplishing the goal or how far a player is close to achieving the goal in contrast with the other players. For example, scoring can be used for measurable outcomes.
People	This quality is about the players who join the game play. Players competitively play against each other in most of the games. Also, they can play collaboratively to achieve group goals.
Rules	Rules present instructions about playing game and constraints.
Safety	Outcomes of the game have no results such as penalties or rewards in the real world.

All qualities of designing digital games that are mentioned above such as challenge, exploration, outcomes (feedback) are in compliance with existed learning theories such as constructivism and flow theory (Qian and Clark, 2016). Prensky (2001) determined that presented challenging in flow state matches with almost perfectly individuals' solving skills of the challenging and individuals can gladly achieve most things been described as unachievable by them. In this regard, learners in a flow state are absorbed in activities and move away from irrelevant opinions and perceptions through a well-designed digital game (Chen, Wigand and Nilan, 1999).

Based on the qualities, it is important to emphasize advantages of digital games for learning environments. Digital games are user-centered activities (Gros 2007) and these activities give an opportunity about learning through experience to students (Baek 2010; De Freitas 2006; Kirriemuir 2002). In this context, digital games promote and increase learning (Natale 2002) and improve students' self-efficacy (Sitzmann 2011) and self-esteem (Ritchie and Dodge 1992). Also, these games establish learning environments that provide learning with fun (Prensky 2001), learning by discovery (Baek 2010) and cooperative learning (Gros 2007). In addition to these, digital games increase students' attendance to course (Gros 2007; Spires 2015) and provide immediate feedback to learners (Ifenthaler et al. 2012; Whitton 2010). Besides, digital games develop learners' skills such as problem solving (Akcaoglu 2013, Akcaoglu and Koehler 2014; Gros 2007; Spires 2015), decision-making (De Aguilera and Mendiz 2003; Spires 2015), spatial thinking (Feng, Spence and Pratt 2007; Uttal Meadow, Tipton, Hand, Alden, Warren and Newcombe 2013) and computer literacy (Natale 2002). Another important advantage of digital games is increasing learner's motivation (Alaswad and Nadolny 2015; Garris, Ahlers and Driskell 2002; Gee 2005; Mitchell and Savill-Smith 2004; Prensky 2001; Ray and Coulter 2010; Spires 2015).

When qualities and advantages of digital games are taken into consideration, it can be stated that digital games are seen as an important approach for science education since these games enable students to see representations of natural phenomena and interact with these phenomena, and promote students' developments towards explaining these phenomena scientifically (National Research Council 2011). Strengths of digital games in science field indicated as providing opportunities to students about observing, exploring, managing variables, and providing immediate feedback since these opportunities involve situations such as time-consuming, expensive or dangerous experiences in a traditional science course (Winn 2002). In this respect, pre-service science teachers were preferred for this study.

Purpose

The main purpose of this paper is to introduce Kodu Game Lab to pre-service science teachers through a method course based on MAGDAIRE framework and prepare them for designing their own digital games. After PSTs completed implementations of MAGDAIRE framework, they conducted their own digital game activities in real classrooms by means of traineeship process. In accordance with this purpose, this paper grounds on the following research questions:

(1) What are the effects of implementation process to developments of pre-service science teachers' skills towards using digital game-based learning to teach a particular topic?
(2) What are the effects of implementation process and traineeship process on PSTs' performance levels about usage of digital games in classroom?

Method

In this study, we used mixed method research design. In contrast with any method, using both qualitative and quantitative methods offer opportunity about developing a better understanding with respect to research problems and questions (Creswell, 2012). Convergent parallel design was used in this study. The purpose of this research design is to collect qualitative and quantitative data simultaneously, combine the data, and use results to comprehend determined research problem (Creswell, 2012). In this type of mixed method research design, researcher collects both qualitative and quantitative data, analyses both group of data independently, contrasts the findings and results obtained from the analysis, and makes comments about whether the results support or conflict with each other or not.

Participants

In this study, all participants were senior students in a teacher education program of a public university in Turkey. They were a total of 18 PSTs who took a course termed as special teaching methods and traineeship. 10 of all participants were female and 8 of them were male.

Procedures

In Turkey, the higher education system is supervised by the Council of Higher Education (CoHE) and the CoHE is responsible for designing, coordination and governance of higher education system. According to CoHE's system, the senior students who are in department of science education professional teaching knowledge courses such as educational psychology, teaching principles and methods, and instructional technologies and material design; general culture courses such as scientific research methods, and computer lessons; and complete major area courses such as environmental science (CoHE, 2016). It is aimed to make pre-service teachers recognize teaching methods and materials and prepare their own lesson plans and practice them with professional teaching knowledge courses. In this study, we termed this process as implementations of MAGDAIRE. Also, pre-service teachers experience teaching in real classroom environments with traineeship process. According to content of the course, pre-service teachers do traineeship in public middle schools during spring term. In our study, this process was started after MAGDAIRE implementations and was termed as traineeship process. In parallel with the curriculum of institutions for teacher training, subject matters about biological environment termed as people-environment relations and living creatures and energy relations take part in curricula of middle-school education.

In this paper, a science course subject of 7th grade of secondary school that is termed as "People-Environment Relations" was chosen to create lesson plan. Six main topics of mentioned course subject were determined as follows: (1) Explaining relations of living organisms between each other and lifeless organisms, (2) living diversity and climatic characteristics of ecosystems, (3) biological diversity and its importance, (4) indicating endangered species and offering suggestions protecting facilities for the species, (5) explaining environmental issues and their effects on environment, and (6) nutrition relationship in ecosystem.

In this study, we used Digital Game Based Learning-Instructional Design Model (DGBL-ID) that was designed by Zin, Yue and Jaafar (2009) and DGBL-ID was adapted for science teaching. DGBL-ID consists of five phases as analysis, design, development, quality assurance and implementation and evaluation as illustrated in Fig. 1. In analysis phase, problems that students face throughout learning course subject are determined and student readiness for DGBL is investigated. Also, digital game platform such as computer, smart phone and qualities of digital game are identified in this phase. Method and teaching strategies that will be used in instructional digital game are explained in design phase. Technical characteristics of digital game, characters, objects, game environment and game feedback are described, and features of characters and their movements are determined. Besides, course plan that will be integrated into digital game and kinds of teaching sources are stated. Digital game levels that involve some phases such as challenging, traps are designed in this phase. Type of game technology is clarified, and data pertained to user and scores of the user should be recorded at data source of prototype in development phase. Developed prototype is tested in the phase of quality assurance. By this means, first version of the digital game's quality can be controlled before implementation. In the last phase termed as implementation and evaluation, prototype that was completed the processes of testing and developing was installed into computers that will be used by the students and the prototype is used in the learning environments.

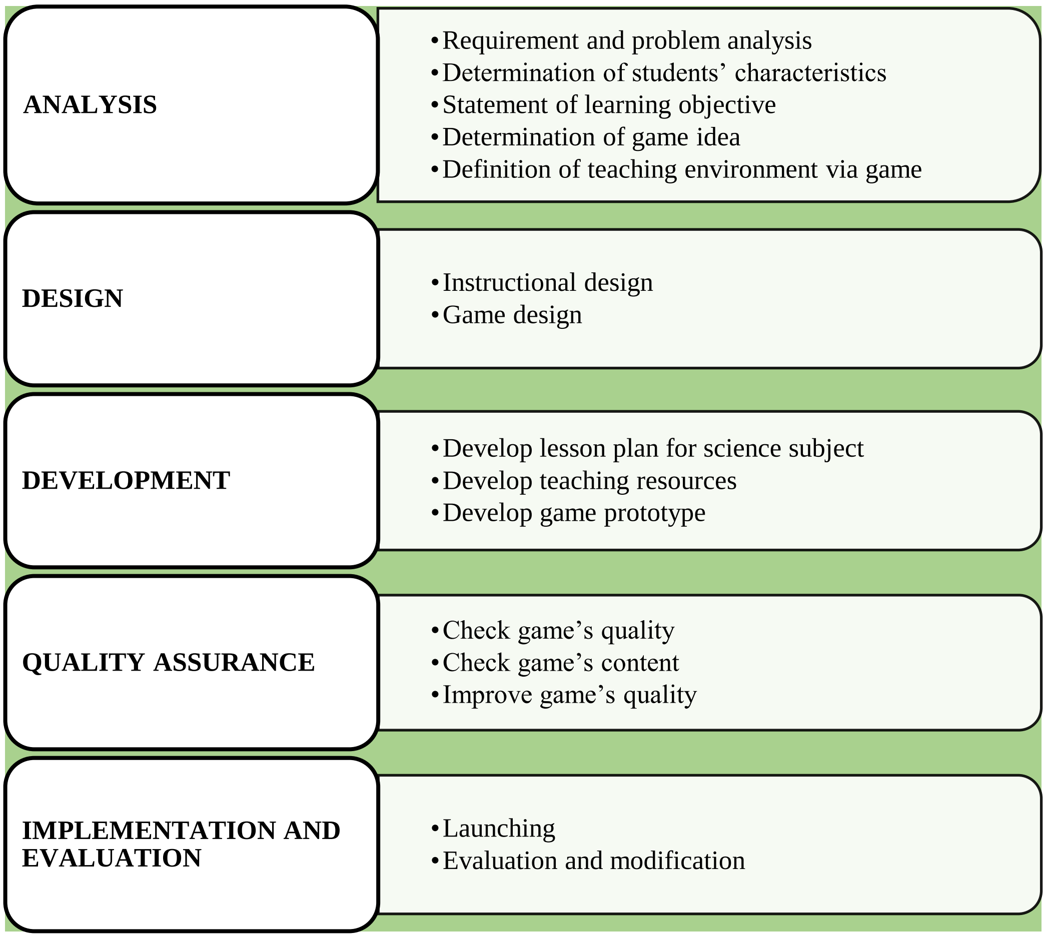

Figure 1. DGBL-ID model (Zin, Yue and Jaafar 2009)

We used Microsoft Kodu Game Lab to design digital games. Kodu is a visual programming that makes more specific creating a game (http://research.microsoft.com/en-us/projects/kodu/). Kodu is designed specifically for young children to learn through independent exploration (MacLaurin, 2011). Kodu has a simple language and entirely icon-based (http://www.kodugamelab.com/resources/). Kodu rules are regular expressions with a simple syntax (Touretzky, 2014). The software is integrated in a 3D game environment and it presents more appealing visual for students (Akçaoğlu, 2013). In addition to these, Kodu for the PC is free to download. Due to Kodu's accessibility, easier to use and visual appeal, as mentioned previously, we choose this software, because teachers are in need of reaching resources quite easily (Becker 2007).

Implementation Process

The present study's course plan was performed based on MAGDAIRE framework (Chien, Chang, Yeh and Chang, 2012). The framework consists of four phases termed as modeled analysis, guided development, articulated implementation, and reflected evaluation and the phases are respectively followed for one cycle. When first cycle is completed, it is returned to first phase (modeled analysis) and the cycle is repeated. Implementation process lasted a total of 12 weeks. Schedule of the implementation process is presented as follows:

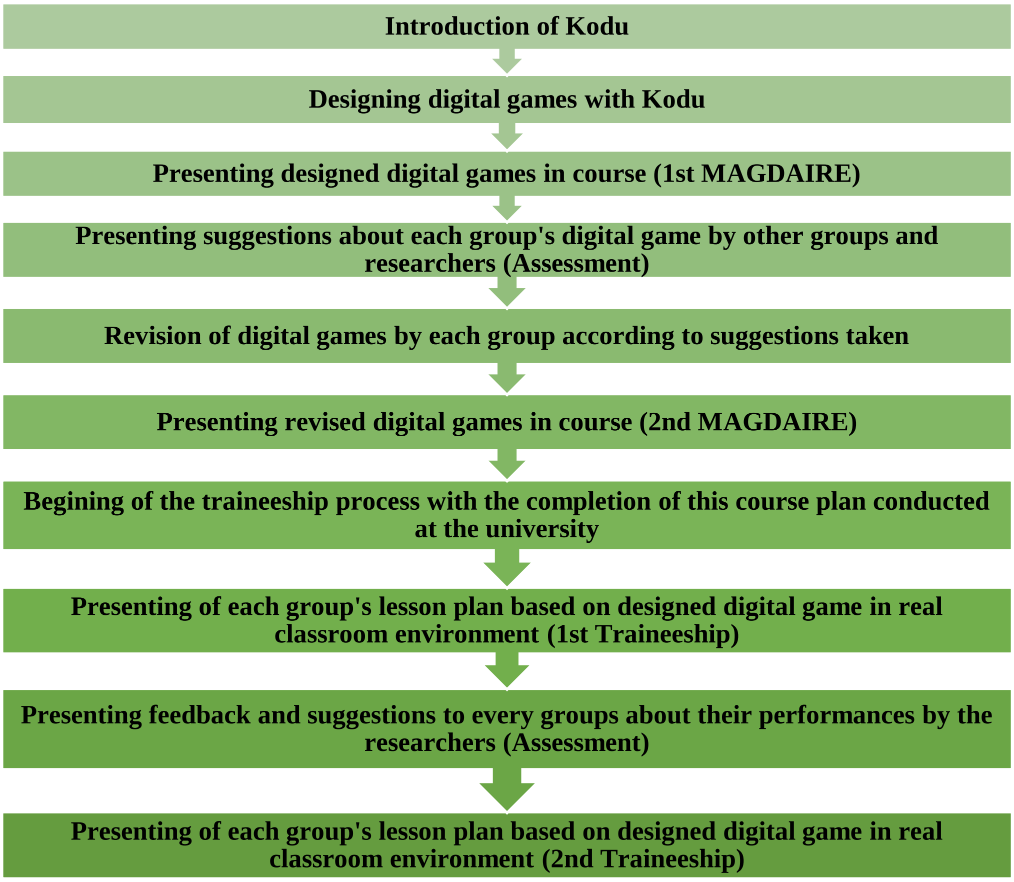

Figure 2. Schedule of the implementation process

18 of PSTs who participated in this course voluntarily formed six groups. In the process beginning, we introduce Kodu to PSTs respectively with the topics as follows: (1) Introduction about encountered first windows in start-up screen, (2) tools and objectives; and usage information about them, (3) painting, adding, or deleting ground, (4) adding or editing characters or objects, (5) programming, (6) adding or editing paths, (7) adding, removing, or tinting water, (8) scoring and winning the game, (9) adding a countdown or enumerative timer, (10) introduction about world settings tabs and objectives, and (11) creating a new world as an example. During the introduction process, we firstly presented the characteristics of mentioned phases and implemented all of them. As soon as we completed presentation of a phase, PSTs performed the same phase with their own laptops. By this means, they found opportunity about learning by doing and also, we could comprehend whether or not PSTs understand the use of any phase and were keeping up.

After the presentation process of Kodu was completed, each group started to create their own digital games that are associated with their own course subjects based on DGBL-ID Model. When they designed their digital games, implementations of the 1st MAGDAIRE cycle were performed. During MAGDAIRE implementations, instructor watched the PSTs' performances and didn't interfere in the course. Instructor took notes about presentations and after completing the MAGDAIRE phase, instructor used the notes to inform PSTs and made them notice their own mistakes. We also organized sessions to give feedback to each group about their activities. Also, PSTs were encouraged to evaluate other groups' activities. By this means, each group offered suggestions to other groups and at the end of the sessions PSTs and researchers introduced solution offers about diverse problems observed from each group's presentation. All groups improved their instructional plans and digital games in line with feedback gained. Similar with the 1st MAGDAIRE cycle, each group presented their enhanced digital game activities during the 2nd MAGDAIRE cycle. When the process was completed, we organized sessions again and groups were evaluated for the last time before traineeship process. Implementations of the 1st traineeship process and the 2nd traineeship process were performed in analogy to MAGDAIRE processes.

A digital game activity is introduced as an example. Goal of the activity is presenting environmental issues and their effects on environment. In accordance with this goal, Kodu will try to save his own world. Game content is presented below:

Rules	Assets	Scoring
• Kodu moves with arrow keys. • Kodu collects waste when he crashes into them. • Sputnik represents waste. • Heart represents air pollution filter. • Kodu launches Heart when S on keyboard is keystroked.	• Kodu • Sputnik • Fish • Turtle • Factory • Tree	• If Kodu collects Sputnik, he will gain 5 points. • If Sputnik crashes into fish and turtle, they will hit. • If Kodu can't collect Sputnik, trees will hit. • If Kodu can't attach filters to flues of factories,air pollution will occur.

Figure 3. Game content

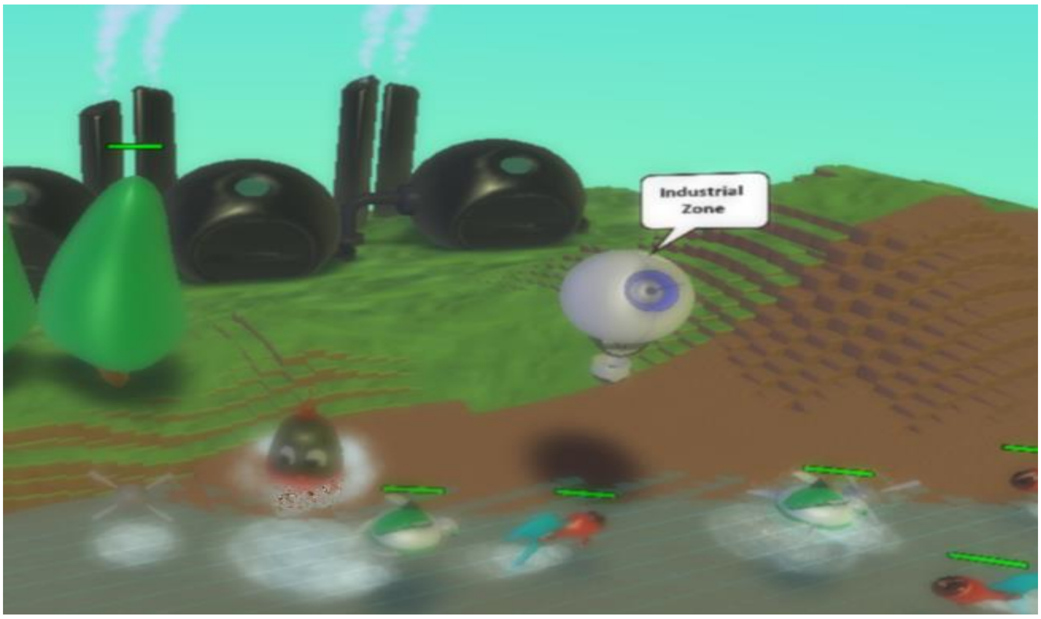

Figure 4. Screenshot from the game

Data Collection

Technical Proficiency of Kodu Skills Test

Technical Proficiency of Kodu Skills Test (TPKS-T) was developed as a practical assessment and evaluation instrument. Reliability studies of TPKS-T were performed with 35 PSTs (16 females, 19 males) who study department of Computer and Instructional Technologies. All of PSTs are seniors with an age average of 22.4, ranging from 22 to 23. IBM SPSS Statistics 20.0 software was used for data analysis. Cronbach’s alpha value was found as .801.

Table 2. Content of TPKS-T

	Implementation	Score
1	Creating an island and a lake; create hills and valleys	5
2	Adding characters/objects, adjusting their settings	5
3	Coding a character	5
4	Adding paths, moving on paths	5
5	Scoring with effects	5
6	Adding timers	5
7	Creating a game world by adjusting settings for water, sky and ground	5

Rubric and Observation

Rubric is an instruction for scoring to evaluate students' works (Montgomery 2000) and consists of criteria that are stated to measure students' levels of performances (Coffin 2002). A well-designed rubric can help both researchers and students to identify criterion for a successful process and/or product from beginning to end of a task, and also when a similar task is repeated in the future, it provide feedback that is specific to every student for achieving (Montgomery 2002). In this paper, we used two analytical rubrics that include criteria that are divided into different levels of performances (Luft 1999). Since every part of a performance or a product can be evaluated separately with an analytical rubric (Mertler 2001), we chose this type of rubric. By this means, we took the opportunity about evaluating severally all parts of process involved designing and presenting digital games by PSTs. In this context, one of the rubrics termed as "Rubric for Group Oral Presentation" was used to assess group works and second rubric termed as "Rubric for Student Exercise" was used for evaluating PSTs individualistically and both of the rubrics were developed by Montgomery (2002). Since the rubrics were in English, firstly they were translated into Turkish by three experts. Acquired three translations were evaluated by the researchers and two experts whose specialties are computer and instructional technologies. After completing the assessments, Turkish forms were organized by considering suggestions. Coordinated forms were examined by two experts whose specialties are Turkish philology and in the light of their suggestions final versions of the forms were prepared. In this study, we used an observation form that is adapted from Mento and Giampetro-Meyer (2000)'s research to follow group presentations and promote data sets of rubrics. The observation form has ten topics named as class beginning; student response; student participation; material (Kodu activities); pacing of material presentation/discussion; sense of the class; student involvement; pedagogical approaches; recurring student assignments; and sense of closure at end of class.

Results and Discussion

In this study, SPSS software was used to analyze quantitative data. Firstly, data acquired with TPKS-T was analyzed and independent samples t-test was used for the analysis. The effect sizes for t-test were determined and interpreted as Cohen (1988) stated (Cohen's d). Cohen's d is interpreted in the manner of following characterization: d = .20 is described as a small effect size, d = .50 as a medium effect size and d = .80 as a large effect size (Cohen 1988). Analysis results of t-test are illustrated in Table 3.

Table 3. Comparisons of pre-test and post-test scores of TPKS-T

Group	N	$\overline{X}$	s	SD	t	p
Pre-test mean	18	16.66	2.42	17	5.58	.000*
Post-test mean	18	19.55	2.03			

*p < .01

The results of independent samples t-test analysis deduce that PSTs' post-test mean ($\bar{x}$ = 19.55) is higher than PSTs' pre-test mean ($\bar{x}$ = 16.66) and there is statistically significant difference between means of pre-test and post-test ($t_{(17)} = 5.58$, $p < .01$). Effect size for this analysis was calculated as d = 1.86 that is evaluated as large effect size. Based on these findings, we can state that it is possible to improve PSTs' Kodu Game Lab skills about designing digital game activities with implementations of MAGDAIRE. After findings of TPKS-T were obtained, we investigated rubrics and observation forms. Firstly, rubrics for group oral presentations were examined and results of the rubric scores for each group (G1, G2, G3, G4, G5 and G6) are demonstrated in following figures.

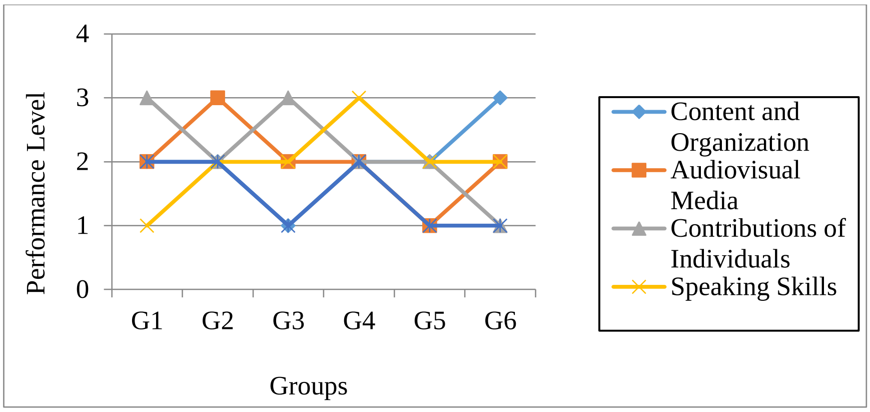

Figure 5. 1st MAGDAIRE cycle

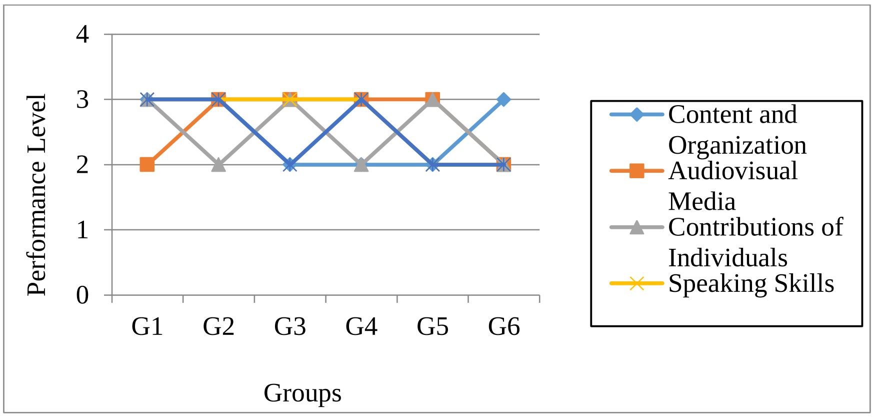

Figure 6. 2nd MAGDAIRE cycle

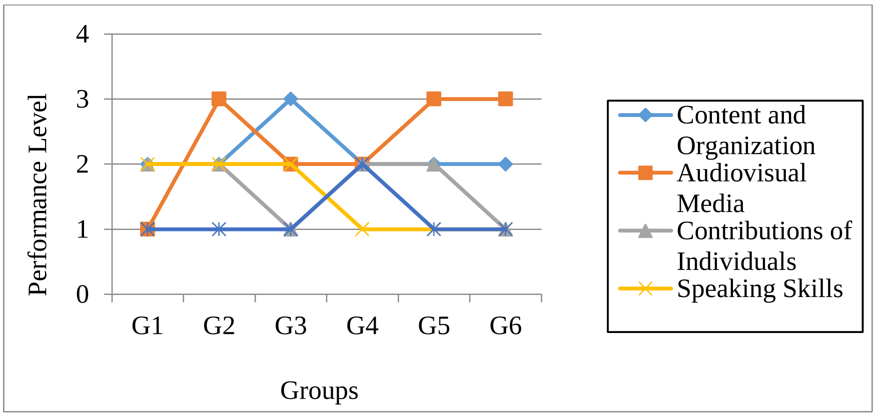

Figure 7. 1st traineeship process

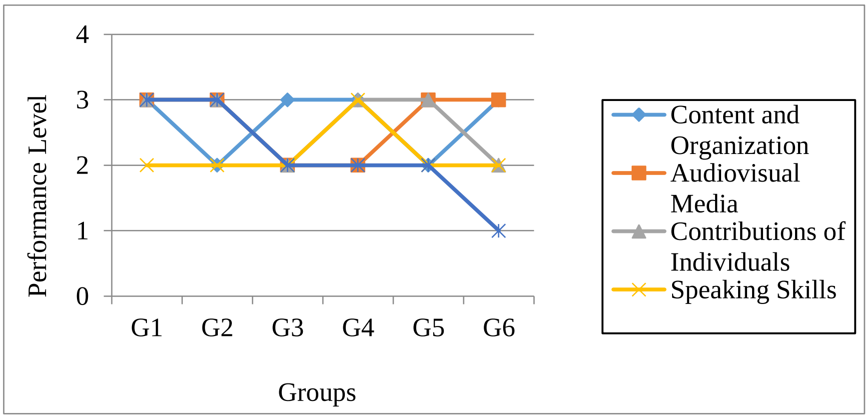

Figure 8. 2nd traineeship process

As illustrated in figures, it is seen that groups' rubric scores of the 2nd MAGDAIRE cycle performances are higher than their 1st MAGDAIRE cycle scores of performances assessment. After implementations of the 1st MAGDAIRE cycle were completed, the groups implemented their course plans during traineeship process. By the end of the processes, it is conspicuously noticed that groups' rubric scores were decreased again with the 1st traineeship process. When groups practiced their course plans for the second time, it was seen that their rubric scores increased and the 2nd traineeship process scores of performances assessment were higher than rubric scores of the 1st traineeship process. In this context, Wilcoxon Signed Rank Test was used to investigate whether there is a statistically significant difference between acquired rubric scores or not. Analysis results included scores of rubrics for group oral presentations about implementations of MAGDAIRE cycle and traineeship process are shown in Table 4.

Table 4. Analysis results of Wilcoxon Signed Rank Test

Implementation Pairs		N	Mean Rank	Sum of Ranks	Z	p
1st MAGDAIRE 2nd MAGDAIRE	Negative Ranks	0	.00	.00	2.232*	.026***
	Positive Ranks	6	3.50	21.00		
	Ties	0				
2nd MAGDAIRE 1st Traineeship	Negative Ranks	6	3.50	21.00	2.232**	.026***
	Positive Ranks	0	.00	.00		
	Ties	0				
1st Traineeship 2nd Traineeship	Negative Ranks	0	.00	.00	2.226*	.026***
	Positive Ranks	6	3.50	21.00		
	Ties	0				

*Based on negative ranks ** Based on positive ranks ***p<.05

Differences between each implementation pair are statistically significant since all of significance levels are less than .05 ($p < .05$). When mean rank and sum of ranks are taken in consideration, it is seen that the differences argue for positive ranks. In other words, scores of differences are in favors of implementations of the 2nd MAGDAIRE and the 2nd Traineeship Process. According to these results, it can be stated that the practices substantially have an impact on promoting PSTs' skills about developing course plans based on DGBL and presenting the plans.

To develop a more detailed point of view about analysis results of rubrics, we examined observation forms. According to our observations, PSTs seemed anxious, excited or unconfident while they were presenting their activities during their 1st MAGDAIRE experiences. Since they couldn't arrange the time, they exceeded the time limit and had to finish their presentations without coming to the end of their course plans. For example, PSTs who are in group 3 didn't greet students and didn't inform them on activities. Since Group 3 didn't invite students to join in the class discussion, students were passive during the process. Activity presentation was too fast, and students didn't have enough time to follow digital game activity being presented. At end of the class, the group had no time for reaching conclusions and providing summary handouts.

While implementations of the 2nd MAGDAIRE were performing, PSTs were sure of themselves compared to their first practices. When we examined performance of Group 3 again, they appeared to feel comforted. In class beginning, they greeted students and gave brief knowledge about the activity. They used the course time well and process of advertising activity was just about right. They encouraged participation of students in groups and encouraged them to class discussions. By this means, students were active during the implementation. Also, assignments of Group 3 seemed to prepare students for the activity. At end of the class, they reached the conclusions and provide summary handouts.

When groups' performances of traineeship process were observed, it was clear that PSTs were excited, stressful or diffident during the 1st Traineeship Process. Because of specified feelings, most of them had problems about classroom management and using the course time. For example, PSTs been in Group 1 created a very serious classroom environment. Students were too quiet and couldn't be part of the course. Group 1 completed the course too soon and they had to retell certain subjects. Contrary to this, Group 4 couldn't present the whole activity since they didn't make use of the time well. Although Group 5 was better than the other groups in the processes of presentation and organization, they had difficulties in communicating with students. Since they mostly mumped between each other, they lost control of the class.

PSTs were more relaxed and controlled during the implementations of the 2nd Traineeship Process. Also, it was seen that performances about group collaboration made progress and each PST was equally involved in the process contrary to the 1st Traineeship Process. Most of the groups provided a classroom environment for students' active participations. They made students work in groups and prepare cases in advance. For example, Group 2 that was the highest scoring group involved the students in their presentation and held their attention from beginning to end. By this means, they didn't encounter any classroom management problem. They had a good grasp of whether or not the students understand the activity and follow the phases. Also, they encouraged students to classroom discussion and listened students' opinions. At end of the class, they had enough time to make assignments and answer students' questions.

To support and detail the data obtained from rubric for group oral presentations, all PSTs' performances evaluated individually from the point of working within group by using "Rubric for Student Exercise". The data obtained from this rubric shows similarity with date set of rubrics for group oral presentations. Such in group performances, PSTs' performance levels of the 2nd MAGDAIRE are higher than rubric scores of the 1st MAGDAIRE.

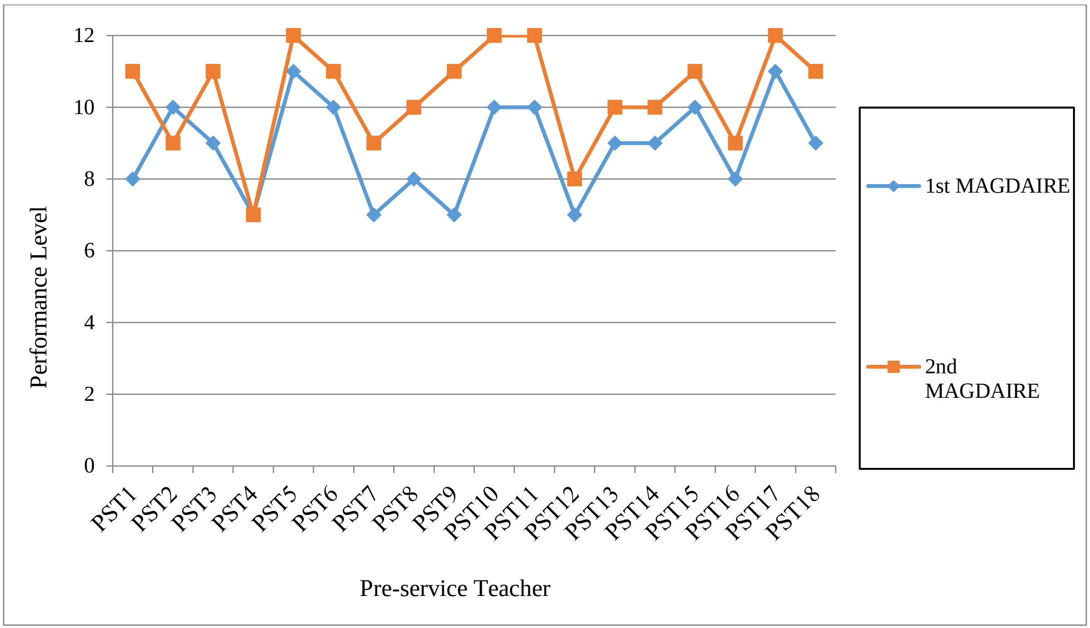

Figure 9. Rubric scores of the 1st MAGDAIRE and the 2nd MAGDAIRE

Each PST's scores are shown in Figure 9 and analysis results of Wilcoxon Signed Rank Test are presented in Table 5. Analysis results showed that statistically significant difference was found between PSTs' rubric scores of the 1st MAGDAIRE and the 2nd MAGDAIRE performances ($z = 3.46$, $p < .05$). According to difference scores of mean rank and sum of ranks, the differences argue for positive ranks. It means that the difference is for the benefit of the 2nd MAGDAIRE practices. In line with these results, designed course plan based on MAGDAIRE framework can be an important factor in developing PSTs' skills about use of digital games in classroom.

Table 5. Analysis results of Wilcoxon Signed Rank Test towards scores of the 1st MAGDAIRE and the 2nd MAGDAIRE

Implementation Pairs		N	Mean Rank	Sum of Ranks	Z	p
1st MAGDAIRE 2nd MAGDAIRE	Negative Ranks	1	5.00	5.00	3.461*	.001**
	Positive Ranks	16	9.25	148.00		
	Ties	1				

*Based on negative ranks **p<.05

According to observations of PSTs' personal experiences, we can determine that most of PSTs controlled their teaching processes in a professional way during the 2nd MAGDAIRE. PST 10 was one of the participants who scored full marks and revealed excellent performance towards system analysis and scientific literacy during the 2nd MAGDAIRE implementation. PST 10 took charge of his own behavior in the group during both 1st MAGDAIRE and the 2nd MAGDAIRE. PST 9 who showed the highest increase in gained total point of Rubric for Student Exercise made progress about working collaboratively with group friends and taking on various roles.

PST 4 whose rubric point of the 1st MAGDAIRE performance was equivalent to the point of the 2nd MAGDAIRE performance had problems on relating how Kodu system interacts with the curriculum. Total rubric point of PST 2 showed decrease in 2nd MAGDAIRE. Although he revealed excellent performance as a collaborative worker, he couldn't provide personal insight into the interaction of Kodu systems and couldn't offer an alternative option for received criticism.

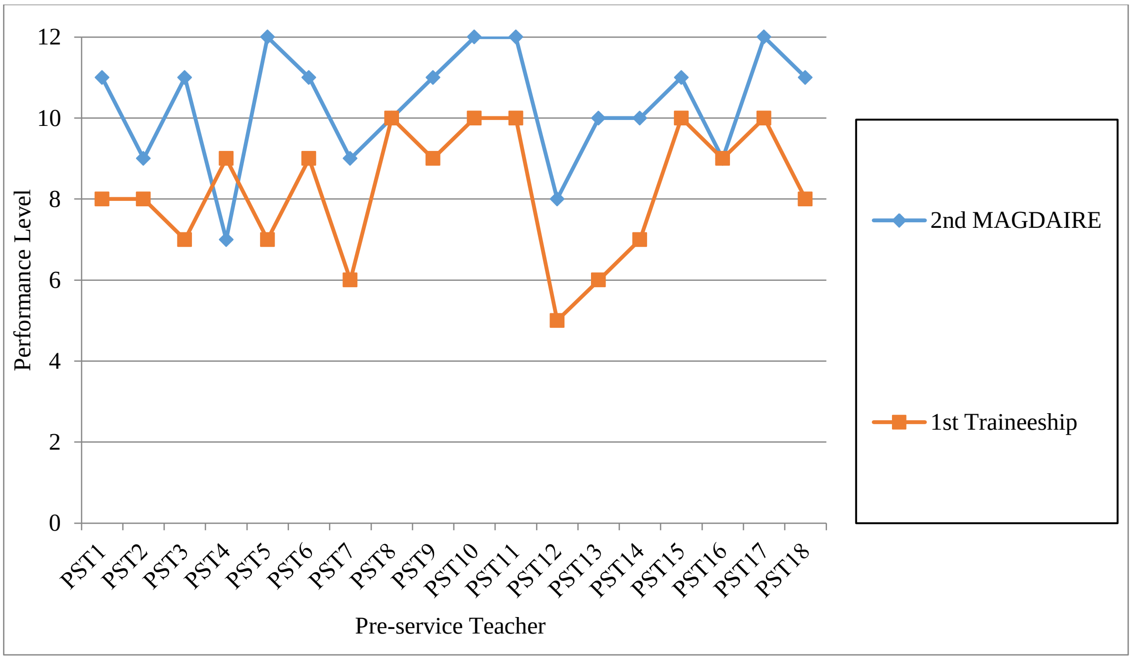

Figure 10. Rubric scores of the 2nd MAGDAIRE and the 1st traineeship process

As is the case with examination of group performances, PSTs' rubric scores decreased in practices of the 1st traineeship process. Each PST's scores are shown in Figure 10 and analysis results of Wilcoxon Signed Rank Test are presented in Table 6. When the rubric scores of the 2nd MAGDAIRE and the 1st Traineeship Process are compared with each other, it is seen that PSTs' scores been acquired from Rubric For Student Exercise of the 1st Traineeship Process are less than scores of the 2nd MAGDAIRE implementations with a statistically significant difference ($z = 3.26$, $p < .05$). It can be determined that the difference is in favor of negative ranks within the scope of mean rank and sum of ranks. Briefly, analysis results showed that the difference is against the 1st Traineeship Process.

Table 6. Analysis results of Wilcoxon Signed Rank Test towards scores of the 2nd MAGDAIRE and the 1st traineeship process

Implementation Pairs		N	Mean Rank	Sum of Ranks	Z	p
2nd MAGDAIRE 1st Traineeship	Negative Ranks	15	8.70	130.50	3.263*	.001**
	Positive Ranks	1	5.50	5.50		
	Ties	2				

*Based on positive ranks **p<.05

One of all PSTs' rubric score showed an increase. 15 of PSTs' rubric scores decreased and two of them remained unchanged. We investigated the data acquired from observation forms to explain reasons of the declines in the rubric scores. For example, PST 5 who was on the most decline didn't respond to the group and couldn't be part of the group. She followed a course plan been organized during her presentation and stuck to the plan. She didn't stray from the plan even if students asked questions to her. Instead of answering the questions, she merely gave directions been determined in the plan without showing flexibility in the limitations of the plan. PST 3 encountered classroom management problems since he behaved sympathetically students too much. Also, each member wasn't equally involved in the presentation in his group and for this reason PST 3 dominated the presentation. Since he lost control of the class, working collaboratively in groups and class discussion couldn't be conducted.

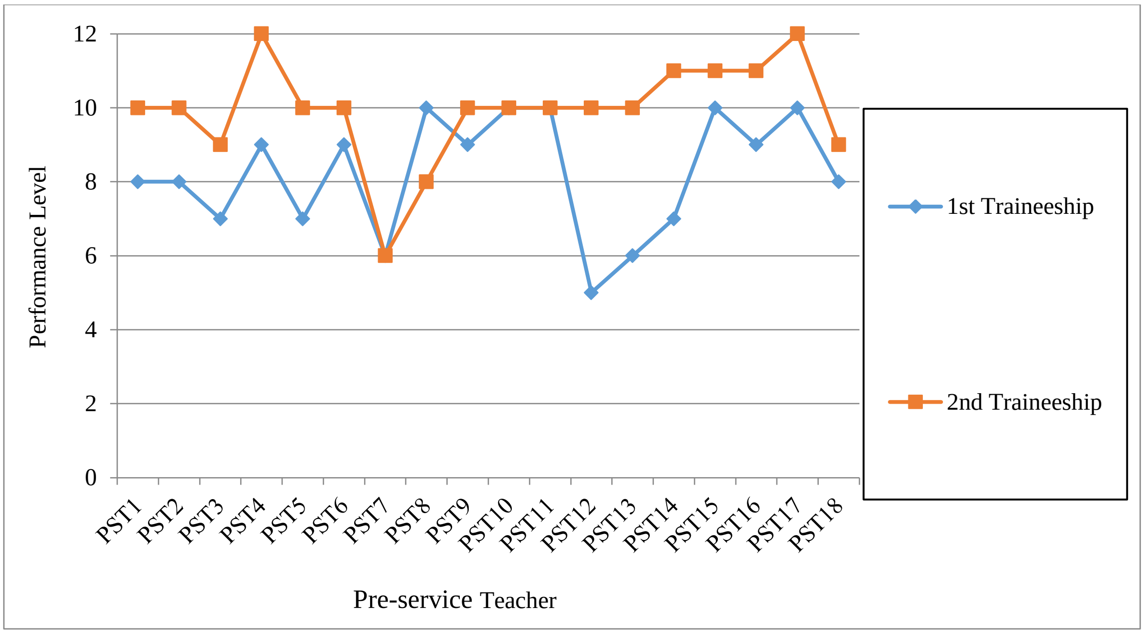

Figure 11. Rubric scores of the 1st traineeship process and the 2nd traineeship process

After these series of analysis were completed, we viewed lastly rubric scores of the 1st Traineeship Process and the 2nd Traineeship Process. Each PST's scores are shown in Figure 11 and analysis results are illustrated in Table 7. According to Table 7, statistically significant difference was found between PSTs' rubric scores of the 1st Traineeship Process and the 2nd Traineeship Process performances ($z = 3.01$, $p < .05$). When mean rank and sum of ranks are taken in consideration, it is seen that the differences argue for positive ranks and this result is in favor of the 2nd Traineeship Process. In the light of analysis results, practicing through traineeship process can influence PSTs' skills been concerned with integrating digital games into classrooms.

Table 7. Analysis results of Wilcoxon Signed Rank Test towards Scores of the 1st traineeship process and the 2nd traineeship process

Implementation Pairs		N	Mean Rank	Sum of Ranks	Z	p
1st Traineeship 2nd Traineeship	Negative Ranks	1	7.50	7.50	3.010*	.003**
	Positive Ranks	14	8.04	112.50		
	Ties	3				

*Based on negative ranks **p<.05

PST 12 who showed the highest increase in total rubric points developed a deep understanding about using Kodu and integrating it into curriculum. She listened actively to students and encouraged students to participate and discussion. She had a good grasp of whether or not the students understand the use of game and followed them with effective communication such as "Did I explain clearly?". PST 8 was the only participant who showed a decrease in total rubric points. Students were passive and didn't have enough time to grasp the information been introduced during her presentation. She didn't make any student assignment and didn't reach conclusions.

Discussion and Conclusion

The main purpose of this paper is to introduce Kodu Game Lab to pre-service science teachers through a method course based on MAGDAIRE framework and prepare them for designing their own digital games. In line with this purpose, a course plan based on MAGDAIRE was organized. Firstly, we made PSTs comprehend digital games integration into teaching processes and use of Kodu. Then, they started to design their own digital games in groups by using DGBL-ID Model.

In this paper, mixed method research design was used. TPKS-T been conducted to assess practically PSTs' skills about use of Kodu and rubrics aimed to evaluate levels of performances towards both groups' oral presentation and PSTs personal exercises in group works were used to collect quantitative data. Observation form consisted of ten main topics was used to collect qualitative data. Each implementation of all groups was evaluated separately and was given feedback to all groups about their performances. We evaluated data that was collected with TPKS-T to evaluate PSTs' skills about using Kodu. Analysis results of TPKS-T data showed that PSTs' post-test mean is significantly higher than their pre-test mean. According to this finding, it can be determined that PSTs' skills about designing digital game activities with Kodu can be developed by using MAGDAIRE cycle and working in groups.

When data been collected with rubrics termed as Rubric for Group Oral Presentation and Rubric for Student Exercise was investigated, it was seen that scores been gained from implementations of 2nd MAGDAIRE and 2nd Traineeship Process were respectively higher than total rubric scores of 1st MAGDAIRE and 1st Traineeship Process practices. According to analysis results, the differences between the rubric scores are statistically significant and the differences are in favors of implementations of the 2nd MAGDAIRE and the 2nd Traineeship Process. In light of these findings, it can be stated that rubric scores are directly proportionate to practices. As PSTs gain experiences, they start to transform into active users of digital games in classroom. Baek (2010) underlined that educators who are unfamiliar with digital games should learn about them and their contributions to education and this awareness is really important since educators can use digital games more easily in their classrooms, promoting learning can be actualized more effectively, and a factor oriented increasing motivation for students can be formed by means of it. We created a classroom environment where PSTs could get information about digital games and make practices with them. In this context, we think that one of the reasons about PSTs performance increase is experience. To identify the importance of experience, examination of barriers in technology integration into learning environment can be helpful. According to Ertmer (1999), experiencing is one of the barriers and PSTs should be given opportunities about using efficient technology tools throughout teacher education program in both content/method courses and field experiences (Ertmer and Ottenbreit-Leftwich 2010). Also, Bingimlas (2009) emphasized that PSTs should experience in self-organization and time management. In this paper, we observed that PSTs had problems about arranging course time and organization at the beginning of the process, but they overcame the problems in time.

Findings obtained from observation forms are consistent with aforementioned results. PSTs' performances such as classroom management, content and organization, pedagogical approaches made progress with implementations and their performance levels showed increases. In addition to experience, our observations showed that pedagogical beliefs have an effect on using digital games. Beliefs that feature in understanding teachers' behaviors (Kane, Sandretto and Heath 2002) are important factors of technology integration (Ertmer and Ottenbreit-Leftwich 2010). According to Hennessy, Ruthven and Brindley (2005), PSTs who use technology in their implementations move away from traditional beliefs effected negatively technology integration (Haney, Lumpe, Czerniak and Egan 2002) and they develop beliefs towards technology use. In our study, findings of pedagogical approaches and student response been topics of observation form showed that PSTs started to exhibit behaviors such as confident, organized, willing. According to Ertmer and Ottenbreit-Leftwich (2010), pedagogical beliefs can be changed by using current reflections and discussions. The mentioned change promotes our results.

In addition to all these, we can determine that knowledge and skills can be an important factor to integrate digital games into the classroom. Since courses involved subjects towards how digital games can be used and designed are quite few in curriculum of universities (Baek 2010; Becker 2007), teachers have absence of understanding about how digital games can be used (Becker 2007). This paper's results showed that PSTs' skills towards designing digital games were developed throughout the implementation processes as mentioned above. When PSTs started to use Kodu effectively, their activities were improved, and they presented well-organized activities wishfully in the classroom. This result is in accordance with the literature. Ertmer and Ottenbreit-Leftwich (2010) indicated that knowledge and skills are key concepts in technology integration and teachers need to feel sufficiently skilled about using technologies in their classrooms (Ashrafzadeh and Sayadian 2015). In light of these results, we can suggest that knowledge and skills, pedagogical beliefs and experience are important factors about integrating digital games into classroom environment.

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The Effect of Technology-Supported Inquiry-Based Learning in Science Education: Action Research

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Abstract

The general aim of this action research was to offer ways of making science and technology education more effective and solving problems in the related field. The specific purpose was to determine how inquiry-based learning supported by instructional technologies improves students' achievement and develops their scientific inquiry skills. Taking into consideration the literature and the interest areas of the researchers, the inquiry-based 5E instructional model was embedded in a new framework of 4W questions ("What will I learn?", "Why will I learn?", "With what will I learn?", and "What have I learned?") and supported by instructional technologies involving specific stages with standard applications for solving problems. The implementation was carried out at the seventh-grade level in a Turkish middle school in a semester. The participants were a researcher-teacher and six students (two girls, four boys). According to the results, the students' science achievement and scientific process skills developed. This implementation effectively addressed students' affective learning areas, such as their attitudes, motivation, sense of responsibility, and values in relation to the learning environment. It is hoped that the results of this research will offer insights for researchers and practitioners.

Introduction

With the advancement of science and technology, teacher-centered classical approach used in educational environments has been replaced by active learning approach. One of the active learning approaches is inquiry-based learning. Inquiry-based learning is based on the pragmatism philosophy developed by Charles Sanders Pierce, William James, and John Dewey in the early 20th century (Bakır, 2006). This learning approach, which has been included in science teaching programs for a long time (American National Research Commission [NRC], 1996) and maintains its popularity (Shahali, Halim, Treagust, Won, & Chandrasegaran, 2017), is defined by NRC as follows:

> Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations (NRC, 2000, p. 23).

Inquiry-based learning categorized as open-ended, guided, compound, and structured (Lustick, 2009; Martin-Hansen, 2002). Different types of inquiry-based learning are used in accordance with the characteristics and needs of the topics to be covered in science classes (Sadeh & Zion, 2012). The 5E Model, consisting of engagement, exploration, explanation, elaboration, and evaluation, is one of the ways of organizing inquiry-based science courses using inquiry-related skills (Melber, 2004; Kim, 2011). In this model, each step is built on the previous one (Warner & Myers, 2011). The details of the implementation of these steps are given below (Bybee, 2002):

(1) Engagement: The teacher tries to identify students' existing knowledge and misconceptions about the target subject. S/he introduces the subject in a way that draws students' attention and presents direct questions about the subject to be covered. The aim here is not to find the right answer but to engage students' minds. The question, "How can I explain this?", forms the basis of this stage.
(2) Exploration: Students conduct experiments either individually or through questions that engage their minds or utilize a source (e.g., books and computers). In this way, students have the opportunity to

share their ideas with others. As a result of the implemented activities, students may become aware of their deficiencies related to their pre-existing conceptualizations. Misconceptions can be remedied at this stage. Thus, at the basis of this stage is the question, “How can misconceptions be eliminated?”.

(3) Explanation: Based on their experience, students explain their scientific terms and concepts in formal language. In cases where students think they are inadequate, the teacher can provide explanations at the basic knowledge level. The basis of this stage is how to make scientific explanations.

(4) Elaboration: Students apply the knowledge and skills they have acquired to new situations. “How to apply what has been learned to different situations?” is the fundamental question underlying this stage.

(5) Evaluation: A short assessment is undertaken to reveal what students have learned. Students are encouraged to use the knowledge and skills they have acquired in future activities. The question, “How do students apply their scientific conceptualizations and skills?”, forms the basis of this stage.

The skills required for inquiry-based learning are called science process skills (SPSs). These skills appear not only in science but also in everyday life (Tan & Temiz, 2003). SPSs are defined as skills that facilitate students’ learning, provide them with the ability to research, allow them to be active in the learning environment and develop a sense of taking responsibility in their learning, and increase the retention of learned information. These skills are examined in the following three groups: Basic skills are related to observation, measurement, classification, data recording, and establishing numerical and spatial relationships. They provide the basis for the development of higher-level competencies. Causal skills concern prediction, identification of variables, and making inferences. These skills include the creation of testable hypotheses. Experimental skills require a high level of thinking, such as building hypotheses, constructing models, experimenting, changing and controlling variables, and decision making. These skills are a continuation of what has already been gained (Ayas, Çepni, Akdeniz, Özmen, Yiğit, & Ayvacı, 2005).

Although inquiry-based learning contributes to students’ cognitive and affective traits, such as their achievement and inquiry skills and attitudes (Acar Sesen & Tarhan, 2013; Cabe Trundle, Atwood, Christopher, & Sackes, 2010; Furtak, Seidel, Iverson, & Briggs, 2012; Hofstein, Navon, Kipnis, & Mamlok-Naaman, 2005; Lazonder & Harmsen, 2016), there are some difficulties in the implementation of this method, which results from lack of time, teacher beliefs, availability of materials and motivation, pedagogical deficiencies, administrative problems, overcrowded classes, and security problems (Cheung, 2011; Edelson, Gordin, & Pea, 1999). In addition, teachers face the challenge of needing to develop more skills to effectively implement inquiry-based learning. Since teachers are involved in students’ decision-making, inquiries, research and communication with their peers, they should have knowledge of the field and the ability to think quickly (Jarrett, 1997, p. 25). A recent study revealed that teacher candidates had difficulty in designing and implementing an inquiry-based learning process (Talanquer, Tomanek, & Novodvorsky, 2013). Similarly, other researchers reported that many inquiry-based activities undertaken in schools were not sufficient to capture the distinguishing features of authentic scientific research (Chinn & Hmelo-Silver, 2002), and scientific research widely conducted in schools differed from real scientific research in terms of qualitative aspects (cognitive processes and the underlying philosophy of knowledge) (Chin & Malhotra, 2000). Some researchers (Lederman et al., 2014; Schwartz, Lederman & Lederman, 2008) criticized the idea that merely performing inquiry-based activities would improve students’ understanding of how to conduct scientific research. In addition, it was found that providing students with an authentic research environment by engaging them in the process produced more effective results than a teacher-centered approach in which students were taught what research was and how it was undertaken (Lustick, 2009; Rendall, 1996).

Students need to possess certain knowledge and skills in order to understand the purpose of activities carried out in the inquiry-based learning process, obtain data, and analyze and interpret the collected data. Having an insufficient level of such knowledge and skills prevents meaningful learning (Edelson et al., 1999). At this point, technology can be incorporated into the learning process. In science courses at middle school level, digital images and videos, computer simulations, deepening software, online data acquisition for scientific analysis, web-based inquiry projects, and virtual science classes can be used (Bell, Gess-Newsome, & Luft, 2008). Beishuizen, Wilhelm, and Schimmel (2004) suggested that research skills students should have for effective learning; e.g., monitoring two or more variables when constructing a hypothesis, were difficult to understand for sixth-graders aged nine to ten years, and the development of these necessary skills could be supported using computer simulations. Similarly, de Jong (2006) stated that computer simulations could help improve skills utilized in the inquiry cycle, related to hypothesizing, determining variables and the relationships between them, making inferences, and interpretation. In cases where the classroom environment is not appropriate for data collection (Lee & Songer, 2003; Uçar & Trundle, 2011), the use of technology in the learning process promotes the visualizing of the lesson, facilitates the work of the teacher, and widens the perspective of students (Bozdoğan, 2011). Technology incorporates students into the learning process by allowing them to establish strong links between independent, cumulative information held in their mind and transfer this knowledge to new situations (Novak & Krajick, 2006).

Although technology-supported inquiry-based learning is considered to be more effective (Edelson et al., 1999; Uçar & Trundle, 2011; van Joolingen, de Jong, & Dimitrakopoulout, 2006), it is difficult to adopt this method, especially in rural areas due to the digital divide defined as regional inequality in the availability of information and communication technologies (Gündüz, 2010; Koyunlu Ünlü, Dökme, & Sarıkaya, 2014; Turkish Telecommunications Authority [TTA], 2002; Yang et al., 2013). Furthermore, financial hardships experienced especially in rural areas make it difficult for students to visit museums and science centers that offer authentic learning. Providing opportunities for these students to develop their scientific research skills and integrating scientific research into technology constitute the basis of the equality principle in education. Engaging in simple activities, such as showing an advertisement, a short video or pictures, can also help create an authentic learning environment.

The current research aimed to investigate the effects of the proposed technology-supported inquiry-based learning program on the science and technology course achievements and scientific research skills of middle school students in a rural area. It also aimed to reveal the changes in the students' views and perceptions concerning inquiry and technology following the implementation of this program. This study is important in terms of filling a gap in the literature related to research in rural areas in Turkey through its objective to provide a new perspective for in-service and pre-service teachers in similar contexts. Thus, the main research question was defined as, "What are the effects of the proposed technology-supported inquiry-based learning application on the science and technology course achievements and scientific research skills of middle school students in the rural setting?" Accordingly, the sub-problems of the research were defined as follows:

(1) How did this application affect the students' achievements in the science and technology courses?
(2) How did the students' scientific process skills change after the implementation?
(3) What did the participants (teacher and students) think about the implementation?

Method

Research Model

This study was designed as action research to improve the quality of the learning process. Action research can be defined as "any systematic inquiry conducted by teacher researchers, principals, school counselors, or other stakeholders in the teaching-learning environment, to gather information about ways that their particular schools operate, how they teach, and how well their students learn." (Mills, 2007, p. 5). In action research, both qualitative and quantitative data collection techniques can be used (Bogdan & Biklen, 1982). The stages used in the current action research used were identified from the relevant literature and are presented in Figure 1.

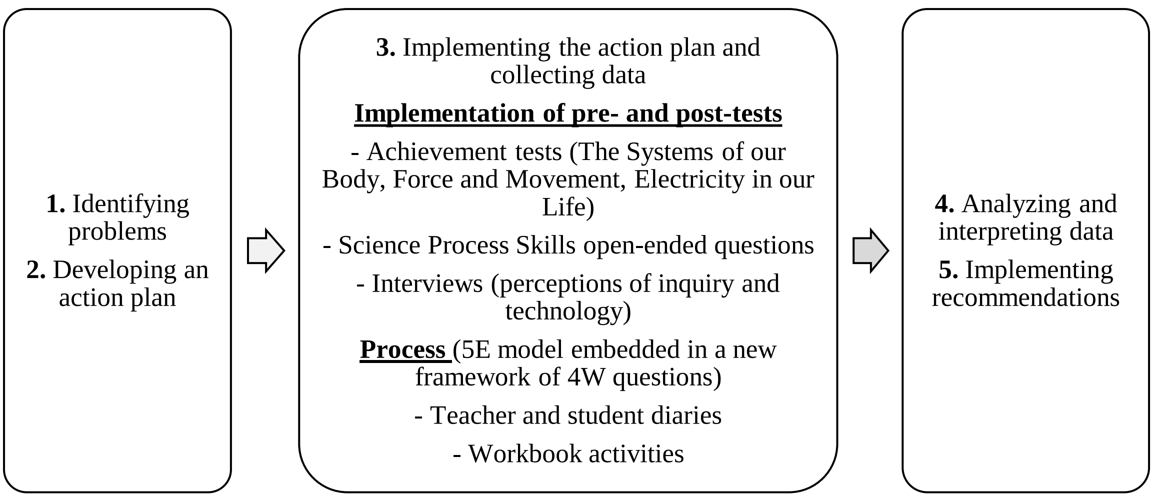

Figure 1. Stages of the current research

The stages presented in Figure 1 were specifically developed by the researchers of the current study. The research began with a focus on solving existing problems. The teacher, who had the role of both a researcher and a practitioner, had worked for six years in the school chosen for the research. She had taught the science and technology course for a year in the selected class according to the teacher's guide to teaching the sixth-grade lesson plans within the framework of the curriculum program developed by the Ministry of National Education (MoNE) and the Board of Education and Discipline. In the book, each unit is dedicated to a specific topic organized according to the 5E Model based on the constructivist approach. There are also suggested activities in the book. Based on her observation and experience, the teacher identified that she encountered the following problems in teaching in relation to this model:

(a) Students' awareness of what, why and with what to learn included in the 5E model proposed in the program is not at the desired level.
(b) Students are less motivated when only science and technology textbooks are used during course work.
(c) Students are not aware of the importance of conducting scientific research in science courses; the majority of students consider that research is merely about printing something or finding a picture somewhere related to the topic and gluing it on a piece of paper.
(d) Students are not familiar with the use of technological equipment due to the location of the school and their families having a low socioeconomic status; although they are very willing to use computers to access information when doing homework, they do not have sufficient resources to achieve this.

Table 1. Template lesson plan

What will I learn?
Engagement: 1. The name of the unit and subject and gains are presented to the students. Preliminary knowledge of the students is determined and any deficiencies are eliminated.
Why will I learn?
2. Students are asked why they will learn this subject. Examples are given from daily life related to the subject. Where appropriate, examples are brought to the class. Students are encouraged to engage in practice on these examples, create problems in their minds and think about these problems. For items that cannot be brought to the class, photos can be shown with a PowerPoint presentation to create a discussion environment for students. In this section, the teacher draws attention to the subject and motivates students to learn about the new subject by asking questions related to daily life that will increase their interest. **3.** Videos from daily life related to the subject are shown to generate the problem in students' minds. The identified problems are discussed through these videos.
With what will I learn?
Exploration: 4. The activities included in the science textbooks and organized by the researchers in accordance with the steps of scientific research specified by the National Science Teaching Association (NSTA) are undertaken by students. **5.** Videos, simulations and/or animations related to each activity are shown to students. **Explanation: 6.** Students are encouraged to provide written/verbal explanations based on their experiences in the exploration stage. **Elaboration: 7.** Students are encouraged to engage in activities to deepen their knowledge of the subjects they have learned. These activities are supported by visual materials, such as computer simulations, animations, photographs, films, and documentaries that are available to the researcher.
What have I learned?
Evaluation: 8. The changes in the knowledge of students throughout the implementation process are evaluated.

Table 1 shows the template of the lesson plan used in this research. In the development of an action plan, the problems identified by the researcher, her interest areas, and the related literature were taken into consideration. In light of this information, the following actions were taken to resolve the identified problems:

(a) The inquiry-based instructional 5E Model was reframed using the 4W questions of "What will I learn?", "Why will I learn?", "With what will I learn?", and "What have I learned?" and supported by instructional technologies (videos, animations, and simulations); then, the course plans were revised according to the updated model. This aimed to increase the students' awareness and motivation about what, why and how they would learn, reduce course work by relying solely on textbooks, and integrate technology with science.
(b) Tests were prepared to evaluate student achievements.
(c) Scientific research activities were performed to monitor the changes in the scientific research skills of the students.

(d) The teachers and the students recorded their thoughts and feelings about the implementation in a diary in the last 10 minutes of each class hour.

The data were collected during one academic term. Fifty-six hours of this period were devoted to the application of inquiry-based learning supported by instructional technologies, six course hours were allocated to achievement tests and two course hours to the administration of open-ended questions for SPS. Each lesson hour was 40 minutes.

Data Collection Tools

Quantitative Data Collection Tools

In this research, in order to evaluate student achievements, multiple-choice (four options) achievements tests were prepared for the following course units: the systems of our body, force and movement, and electricity in our life. The achievement tests developed were administered to the students at the beginning and end of each unit. In the development of these achievement tests, the following steps were undertaken (Atılgan, Kan, & Doğan, 2013): (1) Identifying the purpose of use for the test scores, (2) determining gains, creating the table of specifications, and preparing draft items, (3) reviewing the draft items, (4) preparing the draft test form, (5) implementing the draft test, and (6) selecting items for the final test based on the results of item analysis on the draft version. The test forms prepared for the systems of our body" (40 questions), force and movement (38 questions), and electricity in our life (37 questions) were administered to 187, 202 and 212 seventh-grade students, respectively and had measurement reliability (KR-20) values of 0.88, 0.87, and 0.86, respectively. During the development of the tests, 27% of the number of students who answered the test was calculated. The upper and lower groups were determined. The item difficulty index (p) and item discrimination index (r) of each item were calculated from the scores of the upper and lower groups. After the calculations, items with a substance discrimination index of 0.30 and above and a substance difficulty index between 0.20 and 0.81 were taken to the final test.

The SPS self-evaluation form consisting of six open-ended questions prepared by the authors to determine the students' SPS was applied to the participants before and after the application. These questions measured the students' ability to record data, process and model data, interpreting data and making inferences, identify variables, and construct hypotheses. In the process of developing open-ended questions related to SPS, the science subjects from the previous year and expert opinions (Ph.D. in science education) were taken into consideration. The experts did not change the number of questions and the skills measured by the questions. They only offered suggestions in terms of narration. The pilot implementation of the questions was conducted on a similar group. The students' responses to these questions were digitized by scoring. Through these questions, the changes in the students' ability to record data, process and model data, interpret data and make inferences, identify variables, and hypothesize were monitored.

Qualitative Data Collection Tools

Qualitative data were collected through the following documents: teacher and student diaries and the SPS self-evaluation form related to scientific research activities. The diaries kept by the teacher and the students aimed to reveal their thoughts on the implementation of technology-supported inquiry-based learning. The last ten minutes of each class was dedicated to this activity. During the implementation process, a total of seven, ten and 13 scientific inquiry activities were carried out in relation to the systems of our body, force and movement and electricity in our life units, respectively, and at the end of each activity, the students were asked to mark the SPS they used during each activity in the SPS self-evaluation form.

Data Analysis

As it was open-ended, the data obtained from the SPS test was first analyzed by content analysis and then digitized and converted into quantitative data. The data obtained from the achievement tests and SPS open-ended questions were analyzed at the significance level of $\alpha = 0.05$ using the Statistical Package for the Social Sciences (SPSS) v. 15. Since there were six participant students, as a non-parametric statistical analysis, the Wilcoxon signed-rank test values were calculated for the comparison of data (Wilcoxon, 1945). The responses to the open-ended SPS questions and the data from the teacher and student diaries were examined using content analysis. During this process, the logs were first dumped, read over and over again, and first codes and then categories were formed. The data obtained from the SPS self-assessment forms were digitized, and the average values of the skills used by all students in each scientific research activity were recorded.

Ethical Issues

Since the selected school was a public school operating under MoNE, the "Directive for the Approval and Implementation of Research and Research Support in Schools and Institutions Affiliated to the Ministry of National Education" (MoNE, 2006) was followed. Before the implementation of the program, official permission was obtained from MoNE, and the parents of the students were informed about the aim, duration and content of the research and signed a written informed consent form stating that they agreed to their children's participation in research. Similarly, the students provided their written consent as voluntary participants.

Validity and Reliability of the Research

The researcher had been engaged in this research field for seven years. The implementation took 4.5 months One of the strengths of this research was that the researcher conducted the study in her own school and class with her own students. Multiple data collection tools were used to provide data diversity and reliability in the study (Johnson, 2014; Patton, 2002). During the development of lesson plans and data collection tools, opinion was obtained from different experts with a PhD degree and experience in teaching. Two lecturers and two teachers were consulted at all stages of the implementation in order to minimize the bias of the researcher. Two researchers (authors) individually performed coding and met at specific time intervals to discuss and reach an agreement on the codes, categorizations, and themes.

Results

Effect of the Implementation on Student Achievement

The Wilcoxon signed-rank test was conducted to determine whether there was a change in the students' average scores in the pre- and post-tests related to their achievement in the systems of our body, force and movement, and electricity in our life course units. The results of these tests are presented in Table 2.

Table 2. Results of the Wilcoxon signed-rank test on the students' pre- and post-implementation achievement scores

Achievement tests	Post-test-pre-test	Mean rank	Rank sum	z	p	r
The Systems of Our Body	Negative rank	.00	.00	2.2	.028	0.63
	Positive rank	3.5	21			
	Tied					
Force and Movement	Negative rank	.00	.00	2.02	.04	0.58
	Positive rank	3	15			
	Tied					
Electricity in Our Life	Negative rank	.00	.00	2.2	.02	0.58
	Positive rank	3.5	21			
	Tied					

As shown in Table 2, there was a statistically significant difference between the students' pre-test and post-test scores in favor of the latter with the following values: $z = 2.2$, $p < .05$, and $r = 0.58$ for the systems of our body; $z = 2.02$, $p < .05$, and $r = 0.58$ for force and movement; and $z = 2.2$, $p < .05$, and $r = 0.58$ for electricity in our life. Thus, the implementation improved the participants' academic achievement.

Effect of the Implementation on the Participants' Views on Inquiry

The second sub-problem of the study aimed to reveal the effect of implementing technology-supported inquiry-based learning on the students' SPS. For this purpose, the SPS open-ended questions were administered to the students as pre- and post-tests, and the scores obtained were subjected to Wilcoxon signed-ranks test in SPSS software (Table 3).

Table 3. Results of the Wilcoxon signed-rank test on the students' pre- and post-test scores in the SPS evaluation form

SPS	Post-test-Pre-test	Mean rank	Rank sum	z	p	r
Data recording	Negative rank Positive rank Tied	.00 3	.00 15	2.07	0.3	0.6
Data processing and modelling	Negative rank Positive rank Tied	.00 6.5	.00 78	3.17	.00	0.91
Interpreting data and making inferences	Negative rank Positive rank Tied	.00 4	.00 28	2.42	.01	0.7
Identifying variables	Negative rank Positive rank Tied	.00 5.5	.00 55	2.87	.00	0.83
Constructing hypotheses	Negative rank Positive rank Tied	.00 4.5	.00 36	2.58	.01	0.74

There was a significant difference between the students' pre-test and post-test scores obtained from the SPS self-evaluation form, and this was in favor of the post-test scores. The values calculated for each investigated SPS were as follows: $z = 2.07$, $p < .05$, $r = 0.6$ for data recording, $z = 3.17$, $p < .05$, $r = 0.91$ for data processing and modeling, $z = 2.42$, $p < .05$, $r = 0.7$ for interpreting data and making inferences, $z = 2.87$, $p <.05$, $r = 0.83$ for identifying variables, and $z = 2.58$, $p <.05$, $r = 0.74$ for constructing hypotheses. Thus, the implementation improved the students' SPSs. Figure 2 shows the students' use of SPSs in scientific research activities by unit. This finding was obtained from the self-assessment form completed by the students after performing the activities.

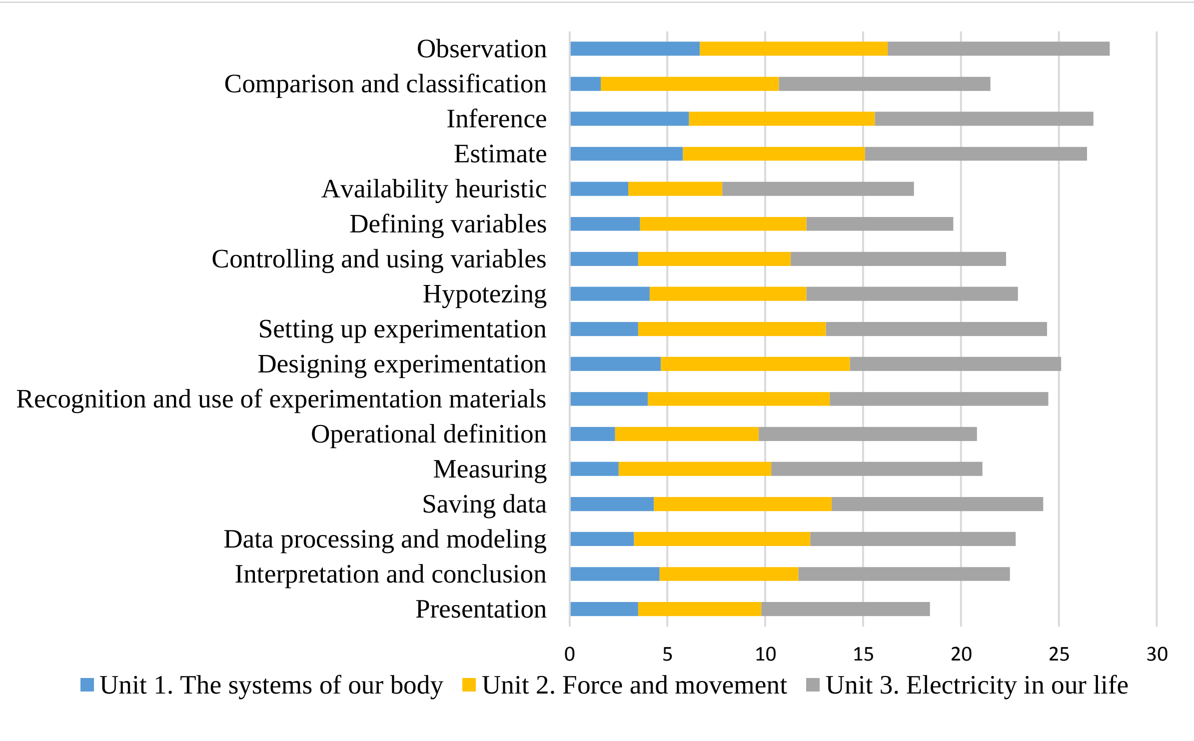

Figure 2. Students' use of SPSs according to course units

As shown in Figure 2, the students' use of SPSs in the activities of the systems of our body, force and movement, and electricity in our life units increased throughout the implementation.

Participants' Views on the Implementation

The third sub-problem of the study aimed to reveal the participants' views concerning the implementation of technology-supported inquiry-based learning. The teacher's views on the implementation were categorized under the headings of scientific research/activities, technology, workbook activities, and awareness of SPSs. The teacher (first author) stated that the students were willing to conduct scientific research activities, but the available course hours were not sufficient. In addition, she commented that technology used in the classroom increased students' interest in the lessons.

> There is limited time for practice in science lessons…The students liked the technology used. I think the final animation is more effective and enjoyable than the ones written in Power Point.

The teacher also reported that the students enjoyed watching animations, which provided more permanent learning, and using videos in teaching increased the students' motivation and quality of learning.

> The course went well. Students watched videos very carefully.

She considered that the students had difficulty carrying out the activities in the workbook, which she attributed to their lack of understanding of what they read.

> There is difficulty in reading and understanding activities. Even at guided events, they ask, How do we do that?

Table 4. Students' views on the learning environment

Category	Sub-category	Code	Frequency
Attitudes	General attitude toward the teaching of the course	Entertaining	29
		Enjoyable	7
		Understandable	2
		Desirable	33
		Good	30
		Excellent	2
		Exciting	1
		Moderate	1
	Attitude toward the scientific inquiry activities undertaken during the course	Reinforces learning	4
		Facilitates learning by doing	1
		Makes learning interesting	2
		Makes learning fun	2
		Satisfying	1
		Nice to create a product	1
		Not fun	1
	Attitude toward technology used in the course	Helps retention of learned information	1
		Entertaining	5
		Provides a better learning environment	3
		Makes learning fun	1
		Facilitates learning	2
Motivation	Willingness to learn about science and perform science-related activities		5
Values	Importance attached to the subject taught		7
	Importance attached to the course in general		6
Responsibility			6

At the same time, the teacher observed that the students easily conducted activities at the level of knowledge and understanding in the workbook, but it was difficult for them to perform those that required analysis-synthesis skills. She stated that during the implementation, the students understood the topics but needed extra time to successfully undertake the assessment activities in the workbook. The teacher also noted that although SPSs were included in the Secondary School Science Curriculum (MEB-TTKB, 2013), the students were initially not aware of these skills, but through conducting scientific research activities, they developed this awareness. As the implementation progressed, the teacher indicated that the students with moderate- and high-level achievements had better awareness of SPSs.

The students' views on the implementation were analyzed under the themes of the students' attitudes, motivation, values and sense of responsibility related to the science course concerning affective learning and comparison with the previous approach used in the teaching of the course. It was determined that the implementation of technology-supported inquiry-based learning helped the students develop positive attitudes toward the science course and enjoy learning science. Throughout the implementation process, the students were observed to be better motivated, more willing to learn the units, and more interested in the lessons. It was seen that supporting inquiry-based learning with technology appealed to the students' affective learning.

As shown in Table 4, the students generally described the implementation of technology-supported inquiry-based learning as entertaining (n = 29), enjoyable (n = 7), understandable (n = 2), good (30), excellent (n = 2), and moderate (n = 1), they mostly liked this implementation (n = 33), and the subjects covered were exciting (n = 1). For example, a participant stated:

> Today we learned the digestive system in science. We learned where it started, where it went through and where it ended. The course was very nice and I understood everything. I liked everything in class.

The students stated that the scientific inquiry activities carried out during the course provided the retention of information learned (n = 4) and encouraged learning by doing (n = 1). The students also considered that scientific research was interesting (n = 2), fun (n = 2) and satisfying (n = 1), and one student enjoyed creating a product. Only one student mentioned that scientific research was not fun (n = 1). A participant remarked:

> We learned very important things by scientific inquiry activities, we understood better. I'm looking forward to the next science class.

The students described the technology used in the course as providing retention of learned information (n = 1) and better learning (n = 3), and making learning easier (n = 2), entertaining (n = 5), and fun (n = 1). A participant stated:

> Technology is important not only for this course, but for all courses

and another participant commented:

> Today we watched videos again. Videos make it easy for us to learn.

Some of the students also referred to responsibilities they undertook by commenting on the work they had to undertake in order to be successful in the course (n = 6).

Discussion and Conclusion

The implementation of technology-supported inquiry-based learning was found to improve the participants' academic achievement, which is consistent with previous studies (Bell, Maeng & Binns, 2013; Bellflower, 2011; Cabe Trundle & Hobson, 2011; Eslinger, White, Frederiksen, & Brobst, 2008; Kim, 2011; Koyunlu Ünlü & Dökme, 2011; Lee, Linn, Varma, & Liu, 2010; Maeng, Mulvey, Smetana, & Bell, 2013; Uçar & Trundle, 2011). Bellflower (2011) reported that 21st century learning tools, such as online teachers, video games, YouTube, and virtual laboratories provided a greater positive contribution to student achievement and classroom performance compared to traditional teaching instruments. Kim and Hannafin (2011) argued that supporting scientific research with technology was an effective approach for problem solving. Some researchers also addressed the favorable effects of inquiry-based learning supported by software on concept teaching (Cabe Trundle & Hobson, 2011; Uçar & Trundle, 2011). In the current research, science was associated with daily life, and the proposed application was supported by technology, scientific research, and related activities. In addition, with the planning of lessons under 4W headings, it was aimed that the students would learn by inquiring about science topics. This implementation increased student motivation, allowing them to learn by doing, and thus positively influencing their success. Many scientists investigating the relationship between motivation and success have developed various theories. For example, Keller, Wlodkowski, Herzberg, Maslow, Mayo, McClelland, McGregor, Likert, Luthans, and Vroom all developed theories that focused on the important effect of motivation on students' learning (Dede & Yaman, 2008, p. 21). Over almost a century, many studies have been conducted on how inquiry-based learning with a constructivist approach increased students' success in science courses (Furtak, Seidel, Iverson, & Briggs, 2012). The most important factor that increased success in these studies was encouraging students to learn by doing things themselves. Similarly, the part of "With what will I learn" encouraged students to learn by doing.

Some researchers argue that Turkey's low level of achievement in the TIMSS-R test is due to the lack of emphasis on the nature of science and scientific research in education (Bağcı Kılıç, 2002). In the proposed implementation, the 5E Model was reframed under 4W headings and integrated into the lesson plans. Scientific research and activities were planned for the exploration and 'elaboration stages of the 5E Model. This allowed the students to learn how to perform scientific research and activities by inquiry and practice and become aware of their importance. According to the results obtained from this research and the literature, the students should be provided with the opportunity to personally undertake research in order for them to develop positive attitudes toward inquiry. The problems commonly encountered in primary education include teachers and students having sufficient knowledge concerning scientific research, the general belief that scientific research can only be learned by undertaking scientific research, and the teachers' not effectively applying scientific research in their class, not having a complete understanding of scientific research practices or attempting to perform scientific research in the class using traditional methods. For students to develop scientific perceptions, it is necessary to explore how they perceive scientific research and develop practices that will encourage them to learn more about scientific research (Lederman & Lederman, 2005).

In the current study, the technology-supported inquiry-based learning program positively affected the students' SPSs. Through scientific research and other activities conducted during the application process, the students' skills related to observation, comparison, inference, identification of variables, hypothesizing, designing and setting up experiments, recording data, and processing data and modeling developed. It can be stated that this development in the SPSs of the students stemmed from the scientific research and other activities undertaken during the exploration and elaboration stages of the 5E Model embedded in 4W. Previous studies also showed that technology-based inquiry-based learning contributed to the development of SPSs (Eslinger et al., 2008; Lin, Hsu, & Yeh, 2012; Trundle & Hobson, 2011). In this regard, the results of the current research are consistent with the relevant literature.

Research undertaken in science education at the national level emphasizes that SPSs are not sufficiently known by teachers (Türkmen & Kandemir, 2011) and teacher candidates (Ateş, 2005). These negativities can only be overcome if all scientific research and activities carried out are aimed at developing SPSs. Durmaz and Mutlu (2014) found that the science course designed with a focus on SPSs improved the seventh-grade students' related skills. The authors implemented the activities in the textbook with an SPS-centered approach and helped the students become aware of SPSs.

The teacher's views on the implementation were discussed under the headings of scientific research/activities, technology, workbook activities, and awareness of SPS. The teacher stated that the students were willing to perform scientific research activities, but the time allocated was not sufficient for such activities. The teacher also noted that the technology used in the course increased the students' interest toward the lesson. In addition, the teacher considered that the students enjoyed watching the animations, which provided a more permanent learning and using videos increased the motivation and learning quality of the students. According to the teacher, although SPSs were included in the Middle School Science Curriculum (MEB-TTKB, 2013), the students were not aware of these skills and conducting scientific research activities in the process helped them develop such awareness. The students' views on the implementation were addressed under the headings of their attitudes, motivation, values and sense of responsibility related to the science course concerning affective learning and comparison with the previous approach used in the teaching of the course. The technology-supported inquiry-based learning program led the students to develop positive attitudes toward the science course and enjoy the learning process. It was seen that the students had high motivation during the implementation process, they were eager to engage in the activities in the course, and they attached importance to the subjects covered and the overall course.

In this study, it was also determined that implementation of technology-supported inquiry-based learning with instructional technologies appealed to the students' affective learning. The views of the participant teacher and students about this learning approach were in parallel to the related literature (Kim, 2011; Li, 2014; Maeng, 2017; Ochsner, 2010; Waight & Abd-El-Khalick, 2007). In previous research in which a similar inquiry-based program based on technology use was undertaken, both the teacher described technology as a source of information and motivation, and the students similarly referred to technology as a source of information (Waight & Abd-El-Khalick, 2007). In another study, Ochsner (2010) found that using instructional videos in the lesson motivated the students to learn. Again, in research using a guided scientific research method enriched with technology, the students considered that technology made science teaching attractive, provided access to more accurate and scientific information, visualized the course, and thus facilitated the understanding of the subjects (Kim, 2011). Li (2014) also reported that using technology in science and mathematics education motivated the students. Maeng (2017) concluded that the use of technology in the science course played a complementary role, which is consistent with the results of the current research.

Limitations and Recommendations

This study has many strengths, including the use of multiple data collection tools, the relatively long study duration, and the program being implemented by one of the researchers. However, the limitations of the study are also acknowledged. For example, the achievements, skills and views of the students measured in the study were limited to the developed data collection tools. Similarly, the technology used was limited to the teacher's technological knowledge and skills, as well as the availability of technological tools. This research should be interpreted by the reader within the framework of these limitations.

Teachers use specific techniques in their class to provide better education. In order to systematize these implementations, teachers can be assigned the researcher role in action research to be conducted in the field of education to allow them to conduct research and be engaged in this process. Furthermore, in future studies, different dimensions of technology-supported inquiry-based research can be investigated. Teachers who want to avoid ordinary commonplace lessons can apply the action plan proposed and implemented in this research and develop similar plans for other course units.

Acknowledgements or Notes

This study includes a part of the first author's doctoral dissertation.

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Use of Educational Films in Environmental Education as a Digital Learning Object

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Abstract

The purpose of this study is to investigate the effects of educational movies that are used in teaching the chapter of Mystery of Earth Crust / Earth and Universe on the environment-related knowledge levels and attitudes of students. Another purpose of the study is to find out about the views of students in the experiment. As a result of the study, the knowledge test mean scores of the students after the implementation significantly differed between the groups in favor of the experiment group. Another finding in this study, no significant difference was found between the groups in terms of their mean post-test attitude scores before the implementation. For the first question, the students stated that the Mystery of Earth Crust / Earth and Universe chapter was distinct from other chapters because of some differences. For the second question, the students stated that they learned the definition, reasons, effects and types of environmental pollution, gained awareness and responsibility about the environment, learned about behaviors towards preventing environmental pollution and developed an attitude towards environmental pollution. Additionally, with the third question the students' emphasized educational movies had significant benefits for both individual outcomes and the instruction process.

Introduction

The rapid developments in science and technology today affect and change our lives to a significant extent. Increased amounts of individual science knowledge are needed for understanding the rapid developments in the field of science, and obtaining this knowledge is possible only by being scientifically literate individuals (Sürmeli, 2012). As also indicated in the curriculum, the science course aims to train all students as scientifically literate individuals. The science curriculum that was published in 2013 defined the characteristics of scientifically literate individuals in detail. Such individuals have basic skills regarding the sciences (biology, physics, chemistry, earth sciences, astronomy and environmental sciences, health and natural disasters) and skills towards discovering the natural environment, they inquire-question, are able to solve problems and learn throughout their lives by a consciousness of sustainable development. Additionally, these scientifically literate individuals have an understanding of the relationship between sciences and technology-society-environment, as well as psychomotor skills (MEB, 2013).

Accordingly, one of the important objectives of science instruction is to provide students with knowledge and awareness towards environmental problems that are increasing based on scientific and technological developments and train them to show attitudes and behaviors towards preventing these problems. This is possible only by planned environmental education with determined objectives (Güven, 2011). Environmental education is a continuous learning process that enables people to get to know concepts related to their environment, enables them to develop a positive attitude toward the environment and a high level of sensitivity and awareness to environmental problems, and also to acquire knowledge, skills, attitudes and values for solving environmental problems to leave a livable, clean and healthy environment for future society (Vaughan, Gack, Solorazano, & Ray, 2003).

The general aim of environment education is to raise awareness in and inform all individuals constituting the society. With this education, it is aimed to make individuals active in matters of the environment and provide them with positive and permanent behaviors (Kahyaoğlu, 2009). The science, environment education and biology curricula by the Ministry of National Education also aim to develop qualified nature and environment awareness, discuss topics of nature/environment and include teaching and training practices in relation to these (MEB, 2013; 2015; 2018). While providing learners with environment education, it is important to use different methods and techniques and visual and auditory elements instead of methods and techniques that make students depend on the textbook and limit them with what is taught by the teacher.

Developed science and technology have allowed access to several pieces of information and presentation of these in different formats (Peraya, 1998). Rapid mobility of change experienced in educational technologies has also diversified learning objects and instruction materials and made these more qualified and innovative (Koşar & Yüksel, 2005). Learning objects refer to all digital resources that may be reused to support learning (Polsani, 2003; Wiley, 2002). According to South and Monson (2000), learning objects are digital environments that are designed or used to achieve learning goals and they cover a broad area that extends from conceptual maps and graphics to videos and interactive movies. A digital learning object that shows a process or an operation is a short animation or video film, a piece of text, an image or a diagram and an interactive computer simulation (Cebeci, 2003). So, as digital learning objects, educational movies are some of the important learning materials that may be used for the success of education-training and need to be included in curricula (Wenger, 1943).

According to Bruner (2008), educational movies are tools that provide students with experience in indirect was and contribute to the process of learning-teaching. As learning objects, these movies are prepared with the purpose of informing learners on a certain topic, and they are highly effective tools of education, and therefore socialization (Birkök, 2008; Michel, Roebers, & Schneider, 2007). Educational research focuses on the benefits of educational movies. Usage of educational movies in learning environments eliminates mundaneness and provides motivation for the topics that are being taught (Weinstein, 2001). According to Demircioğlu (2007), educational movies increase the curiosity and attention of the student towards the subject, take students to places that are difficult to visit, bring dangerous practices into the learning environment, provide opportunities to assess examples from different perspectives, increase academic success and positive attitudes and leads to activation of more senses.

Gregg, Hosley, Weng and Montemayor (1995) stated that movies help better understanding of abstract and complex concepts in a both visual and auditory sense. Likewise, other researchers also stated that educational movies may be used as an effective tool in teaching certain subjects and acculturation, which is a social construct (İnce-Yakar, 2013; Osborne, 2002). For example, Takmaz, Yılmaz and Kalpaklı (2018) considered the movie Avatar as an effective instruction material due to its comprehensive emphases on the behaviors that are aimed to be taught by nature/environment education. According to Robles (1997), educational movies visually enrich a situation, eliminate problems that may occur in observation of fast-acting scientific events and provide opportunities for students to see what they are told verbally. This was also emphasized by the study conducted by Barnett, Wagner, Gatling, Anderson, Houle and Kafka (2006).

The researchers found that popular science-fiction movies contribute to the understanding of students on scientific concepts and development of their mental structures. The researchers also stated that educational movies may be used as effective tools in determining the views of students regarding the teacher, the curriculum and topics of science in daily life (Güven-Yıldırım, 2015; Güven-Yıldırım, Köklükaya, & Selvi, 2015; Köklükaya, 2014). According to Pekdağ (2005), when the visual scenes in the movie feel familiar and the auditory elements that accompany the visual presentation become known, activities that are carried out based on constructivism after watching the movie make the topic more understandable and easy to learn. That is, in a learning environment where movies are utilized, it is easier and more fun to reach targeted outcomes (Saraç, 2012). Hence, the purpose of this study is to investigate the effects of educational movies that are used in teaching the Mystery of Earth Crust / Earth and Universe chapter in the 5th-grade Sciences subject on the environment-related knowledge levels and attitudes of students. Another purpose of the study is to find out about the views of students in the experiment where educational movies are used on the movies they watched, the subjects they have learned in the process and the process of instruction. With these purposes, answers were sought for the following research questions:

1. Is there a significant difference between the mean preliminary knowledge test scores of the students in the experiment and control groups?
2. Is there a significant difference between the mean final knowledge test scores of the students in the experiment and control groups?
3. Is there a significant difference between the mean preliminary attitude test scores of the students in the experiment and control groups?
4. Is there a significant difference between the mean final attitude test scores of the students in the experiment and control groups?
5. What are the views of the students in the experiment group on the educational movies, the subjects they have learned in the process and the process of instruction?

Method

Study Model

To collect the data for the purposes of the study, this study employed a mixed design where qualitative and quantitative research methods were used. Mixed design studies are studies that allow the researcher to utilize both quantitative and qualitative data instead of a single type of data (Creswell, 2005). A quasi-experimental design was used to collect the quantitative data of the study, and in order to support and explain the results obtained about the quantitative data, the method of semi-structured interviews was utilized. Thus, with this, the study was carried out in compliance with the explanatory mixed design method. The logic of this approach is consideration of the quantitative data and the analysis results of these data as the focus and usage of the qualitative data and analysis results for refining the quantitative results in detail and explaining the quantitative results (Creswell, 2005; McMillan & Schumacher, 2010).

Study Group

The study group of the study consisted of a total of 44 students selected from two classrooms that were studying at the 5th-grade of a middle school in the Osmangazi district of the province of Bursa in Turkey in the spring semester of the academic year of 2016-2017. The experiment group of the study consisted of the students who received instruction with educational movies, while the control group consisted of those who received instruction without these movies.

As the study aimed to collect both qualitative and quantitative data, two types of participants were determined. All the students who participated in the study were included in the process of quantitative data collection (N= 44). During the process of obtaining qualitative data, the data collected from the students in the experiment group were analyzed, and the mean scores of the students were ranked as low, medium and high. After this, a total of volunteer 14 students were selected from these low, medium and high groups to carry out the semi-structured interviews.

Data Collection Tools

The study used the Environment Knowledge Test developed by Cömert (2011), the Environment Attitude Scale developed by Atasoy (2005), and a semi-structured interview form developed by the researchers.

Environment Knowledge Test: The test was developed Cömert (2011) with the purpose of determining the knowledge levels of students regarding Environmental Problems and Their Effects, which is within the scope of the Science and Technology course. The final form of the test was determined to have 23 after analyses, and the KR-20 reliability coefficient of the test was found as .75. For this research, the reliability value of the test was recalculated and the KR-20 reliability coefficient of the test was found to be .71.

Environment Attitude Scale: The scale was developed by Atasoy (2005) with the purpose of measuring 6th, 7th and 8th grade students' environmental thoughts, feelings and behaviors. The Cronbach's Alpha coefficient of the 25-item scale was calculated as .85. For this study, the reliability value of the scale was re-calculated and Cronbach Alpha reliability coefficient of the scale was found to be .74.

Semi-structured Interview Form: With the semi-structured interview questions prepared by the researchers, it was aimed to collect the views of the students towards the educational movies used in instruction, the subjects they learned during the process and the process of instruction. For this purpose, 6 semi-structured questions were prepared, and these questions were examined by 2 different experts that were not associated with the researchers for suitability in assessing the issues in question. As a result of receiving expert opinions, some questions that did not serve the objectives were removed, some questions were combined, and those that were not understood were reorganized. The data that were obtained from the interviews were audio-recorded by a recorder to be converted into text in the computer environment by getting permission from the participants. The explanations about how the qualitative data were analyzed are included in detail under the title of qualitative data analysis.

Data Collection Process

Before implementation, the Environment Knowledge test and the Environment Attitude Scale were applied in both groups as pre-tests. The experimental process covered the weeks (5 weeks) where the Mystery of Earth Crust / Earth and Universe chapter was taught in the spring semester of middle school 5th -grade. While the topics in the Mystery of Earth Crust / Earth and Universe chapter were taught with educational movies in the experiment group, these educational movies were not used in the control group. Attention was paid to obtain the selected movies from reliable sources and select those movies that are suitable for the age group and have suitable lengths. 13 educational movies that were considered to satisfy these criteria and provided content validity for the chapter were selected, watched by the researchers before implementation and utilized in the process of implementation. The films and the content of the films are given in Table 1.

Table 1. Educational films used in the experimental group

Topic	Educational Film Link	Content of the film	Screen time
Environmental pollution	https://www.youtube.com/watch?v=PGGHFTPuQMY	Environmental pollution	3.35 min
	https://www.youtube.com/watch?v=1mO19g9FHP8	Environmental problems	3.10 min
	https://www.youtube.com/watch?v=_J6k9MZab-w	Environmental problems	3.00 min
	https://www.youtube.com/watch?v=Dn_KJ1sb0LM	Recycle	3.45 min
	https://www.youtube.com/watch?v=l6E9TUY11HA	Water pollution	2.31 min
	https://www.youtube.com/watch?v=KdJxuQ0pof4	Air pollution	10.38 min
	https://www.youtube.com/watch?v=Wd0FzQTDM90	Air pollution	2.37 min
	https://www.youtube.com/watch?v=Muf8SMurYHI	Soil Pollution	5.29 min
	https://www.youtube.com/watch?v=NS-1lHWAr7E	Radioactive Pollution	2.32 min
	https://www.youtube.com/watch?v=MbCZoPb1PYg	Light pollution	6.26 min
	https://www.youtube.com/watch?v=i1La4xnwFHA	Noise pollution	3.16 min
	https://www.youtube.com/watch?v=5WMQIdFY9WI	Noise pollution	4.34 min

In the application process, the students in the control group were not watched educational films, and the gains of Mystery of Earth Crust / Earth and Universe chapter were given for 5 weeks by using question-answer technique, discussion and group work methods from the activities offered by the curriculum. After the implementation, the same test and scale were applied in both the groups as post-tests. In addition, at the end of the application process, semi-structured interviews were conducted with the students selected from the experimental group.

There are some factors that threaten the internal validity of the study. Factors such as participant characteristics, attitudes of participants and teaching activities, data loss, application of measurement tools, test implementation and unexpected events are factors that threaten internal validity (Fraenkel, Wallen & Hyun, 2012). In this study, there are some factors that threaten the internal validity such as the fact that the groups of students participating in the research cannot be formed by neutral assignment, pretest effect of test and scale used in research and the effect of students' expectations. However, the research design used in the research, the selection of measurement tools appropriates to the gains, the applications, observation of the course, prepared lesson plans. SPSS 21 analysis is the main measures taken to minimize the elements that threaten the internal validity of the study.

Data Analysis

The SPSS 21 statistical analysis software was used to analyze the data obtained in the study. Descriptive statistics (mode, median, mean, standard deviation) were utilized to determine the general distribution of the responses of the students to the test and the scale and test whether the quantitative data were normally distributed or not. The central tendency (mean, mode and median) and central distribution (standard deviation, variance, skewness and kurtosis) values for the test and the scale were reported. Independent-samples t-test was used to determine whether or not there was a significant difference between the mean pre-test and post-test scores of the students in the two groups. All analyses in the study accepted the level of significance as .05.

The qualitative data analysis method of content analysis was used to analyze the qualitative data that were collected in the study. This analysis followed the steps that were reported by Miles and Huberman (1994) and Yıldırım and Şimşek (2008). The documents that are obtained by writing down the interview responses were analyzed by the qualitative analysis software HyperRESEARCHTM 2.6.1. Then, themes which were able to explain the data generally through codes and gather those codes under certain categories were formed. In order to ensure the reliability of the study, the interviews made with the students were coded by an expert instructor. According to the measurements of consensus and dissidence in the codes which both two researchers made, the consensus correlation coefficient between the expert and the researcher was found as (.81).

Results and Discussion

For the purposes of the study that are stated above, both qualitative and quantitative data were collected from the student with a mixed research design. The findings obtained as a result of the analysis of the qualitative and quantitative data collected from the students and comments on these findings are given below.

Findings Regarding the Quantitative Data and Comments

The qualitative data of the study were obtained from the tests and scales applied with a total of 44 students including 22 in the experiment group and 22 in the control group before and after implementation. The quantitative findings regarding the research question and sub-questions of the study and comments are provided below.

Findings on the Sub-Questions 1 and 2 and Comments

Before going into the findings related to the sub-questions 1 and 2 of the study, the statistical method to be applied on the quantitative data was determined. For parametric analysis methods to be used in quantitative studies, the quantitative data collected by tests and scales must be normally distributed (Çepni, 2007; Sim & Wright, 2002). Because of this, some analyses were carried out on the data, and whether or not the data were normally distributed was controlled (See Table 2).

Table 2. Descriptive data on pre and post knowledge test scores

Tests	Group	N	M	sd	Var.	Med	Mod	Kurt.	Skew.
Pre-test	Experimental	22	6.73	2.25	5.06	7	6	-.39	-.60
	Control	22	6.36	2.30	5.29	6	5	-.58	.33
Post-test	Experimental	22	12.14	3.13	9.83	13	14	-.36	-1.04
	Control	22	8.36	3.03	9.19	9	8	-1.54	-.02

Table 2 shows the descriptive information on the mean knowledge pre-test and post-test scores of the groups. According to the information on the table, the mean knowledge pre-test score of the students in the experiment group (M= 6.73) was close to that of the control group (M=6.36), while the mean pre-test scores of both the groups were relatively low. The mean knowledge post-test score of the students in the experiment group (M= 12.14) was higher than that of the control group (M= 8.36). It is seen that the success levels of the students in both groups increased, while the increase was higher in the experiment group.

As seen in Table 2, the mean, mode and median values of both groups for the pre-test results were close to each other. Again, these values for both groups for the post-test results were almost equal to each other. Such close values of mean, mode and median scores obtained for the data collected from all the tests are interpreted as that the data are normally distributed (Köklü, Büyüköztürk, & Bökeoğlu, 2006). The skewness and kurtosis values in Table 1 were also suitable for normal distribution. Skewness and kurtosis values in the range of -2 to 2 show that the data are normally distributed (George & Mallery, 2003). As the sample sizes for both groups were n > 20, based on the central limit theorem, the data are assumed to be normally distributed (Büyüköztürk, 2010). Parametric tests were used to analyze the data that were found to be normally distributed based on descriptive statistics. Based on this, it was firstly aimed to determine whether or not there was a significant difference between the mean knowledge pre-test scores of the students in the experiment and control groups, and independent-samples t-test was applied on the knowledge pre-test scores (See Table 3).

Table 3. Independent sample t-test results of pre-test knowledge scores

Group	N	M	sd	*t*	*p*
Experimental	22	6.73	2.25	-.53	.60
Control	22	6.36	2.30		

Based on the results, there was no significant difference between the mean knowledge pre-test scores of the students (experiment group: M = 6.73, control group: M = 6.36) before the implementation (p > .05, t = -.53). The finding that there was no significant difference between the scores of the students before the implementation was suitable for the purpose of determining the effectiveness of educational movies.
The results of the independent-samples t-test regarding the difference between the mean knowledge post-test scores of the groups are provided in the table below (See Table 4).

Table 4. Independent sample t-test results of post-test knowledge scores

Group	N	M	sd	*t*	*p*
Experimental	22	12.14	3.14	-4.05	.00
Control	22	8.36	3.02		

According to Table 4, the mean post-test score of the experiment groups was M = 12.14, the mean post-test score of the control group was M = 8.36, and the difference between the groups was significant (p < .05, t = -4.05).

Findings on the Sub-Questions 3 and 4 and Comments

Before going into the findings related to the sub-questions 3 and 4 of the study, the statistical method to be applied on the quantitative data was determined by carrying out analyses on the data to see whether or not the data were normally distributed (See Table 5).

Table 5. Descriptive data on pre and post attitude scale scores

Tests	Group	N	M	sd	Var.	Med.	Mod	Kurt.	Skew.
Pre-test	Experimental	22	83.13	8.49	72.12	83	82	1.45	-.17
	Control	22	84.68	11.24	126.23	86.5	84	-1.52	-.73
Post-test	Experimental	22	90.59	6.13	37.68	92	92	-.58	-.53
	Control	22	89.59	9.90	98.06	92	92	1.34	-.13

According to Table 5, the mean attitude pre-test score of the experiment group (M= 83.13) was close to that of the control group (M=84.68). In the post-test results, the mean score of the experiment group (M= 90.59) was again close to that of the control group (M= 89.59). It is seen that there were increases in attitude scores in both groups, but there was no noticeable difference in the post-test scores.

According to Table 5, the mean, mode and median values of both groups for the pre-test scale results were close to each other. Again, these values for both groups for the post-test scale results were almost equal to each other. Close mean, median and mode values and the skewness and kurtosis values regarding the data show that they are normally distributed (George & Mallery, 2003, Köklü, et al. 2006). Likewise, according to the central limit theorem, it is assumed that the data are normally distributed (Büyüköztürk, 2010). It was decided to use parametric tests in the analysis of the data that were determined to be normally distributed based on descriptive statistics, and independent-samples t-test was used to test whether the difference between the pre-test attitude scores of the groups was significant (See Table 6).

Table 6. Independent sample t-test results of pre-test attitude scale scores

Group	N	M	sd	*t*	*p*
Experimental	22	83.13	8.49	.515	.609
Control	22	84.68	11.24		

According to the information in Table 6, the mean attitude scale pre-test scores were M= 83.13 and M= 84.68 for the experiment and control groups respectively. The difference between the groups was not significant (p > .05, t = .515). After this, the post-test scores of the groups were compared by independent-samples t-test (See Table 7).

Table 7. Independent sample t-test results of post-test attitude scale scores

Group	N	M	sd	*t*	*p*
Experimental	22	89.59	6.13	-.403	.689
Control	22	90.59	9.90		

According to the table, the mean attitude scale post-test scores were M= 89.59 and M= 90.59 for the experiment and control groups respectively. The difference between the groups was not significant ($p > .05$, $t = -.53$).

Findings Regarding the Qualitative Data and Comments

The qualitative data of the study were collected with 14 students selected from the experiment groups through semi-structured interviews to explain and support the findings obtained from the quantitative data. The students were asked to answer 3 open-ended questions to collect the qualitative data. The responses of the students to the questions were examined in detail and codes and themes for each question were derived. The qualitative data were analyzed by qualitative research methods by using these codes and themes, and the findings on each question were included by direct quotes from the responses of the students. As the students' own sentences would be presented without changing them, the students were given code names such as S_1, S_2, S_3… to protect their identity. Regarding the qualitative data, the following sections include findings on the direct quotes from the responses of the students, percentage and frequency tables about the questions and codes and themes, as well as comments on these findings.

Findings Regarding Differences in Teaching of Chapters and Comments

The students were first asked the question "what was the most important difference that distinguishes the classes where the Mystery of Earth Crust / Earth and Universe chapter was taught from other science classes?" and the study investigated why they found the class different without emphasizing the subject matter or the educational movies or the instruction process. The codes and themes were established after examining the students' responses to question 1 in detail. These codes and themes, and the percentage and frequency distributions are presented below (See Table 8).

Table 8. Percent-frequency distributions of theme and codes for question 1

Main Theme	Theme	Code	f	%
Differences of teaching Mystery of Earth Crust / Earth and Universe chapter from teaching of other chapters	Differences of unit	Frequent encounter in everyday life	9	33.3
		Addressing environmental issues	5	18.5
		Providing useful information	4	14.8
	Differences of educational films	Using visual and video	3	11.1
		Providing retention	3	11.1
		Better understanding	2	7.4
		Providing fun lesson processing	1	3.7

Table 8 shows that the students answered this question with responses that could be collected under 2 themes. 33.3% of the students responded as that the Mystery of Earth Crust / Earth and Universe chapter is intertwined with our lives and the knowledge acquired in this chapter will frequently appear in our daily lives. For example, student 2 (S_2) commented on this code as follows:

> S2:...I think, the difference that separates the Mystery of Earth Crust / Earth and Universe chapter is that what I learn from this chapter may turn up every day, while the other science chapter(s) may appear when they are needed (40.526, 25.05.2017).

18.5% of the students stated that this class talks about environmental issues, and 14.8% said the information they gathered in this class is very useful. Student 5 (S_5) explained this code as follows:

> S5: This chapter has become mentally more permanent. This chapter will be useful for me and for those I love throughout my life (84.712, 25.05.2017).

In addition, 11.1% of the students who explained the difference that distinguished the class from other classes emphasized the visuals and videos used during classes. Again, 11.1% of the students stated that the class was more permanent because of the educational movies, 7.4% said they understood the class better with the help of the educational movies and 3.7% said the class was very entertaining. For example, student 7 (S_7) and student 12 (S_{12}) commented on these codes as follows:

S7:…helps me understand better. It does not stay in my mind much when the professor teaches it. I understand better by visuals and videos. There is a great chance that I will forget the subject when the professor teaches it (111.985, 25.05.2017).

S12: The most important difference that separates the Mystery of Earth Crust / Earth and Universe chapter from other science classes is that science classes teach scientific subjects, while the Mystery of Earth Crust / Earth and Universe chapter talks about social lives, and nature-human relationships (198.320, 25.05.2017).

Findings Regarding Topics That Students Get Knowledge and Comments

The students, who revealed the reasons in their opinion on why the class was different from other classes with their responses to the first question of the interview, were asked the second question "Which subjects have you gathered knowledge on in our class?" This way, the subject titles that they learned were investigated. The codes and themes were established after examining the students' responses to question 2 in detail. These codes and themes, and the percentage and frequency distributions are presented below (See Table 9).

Table 9. Percent-frequency distributions of theme and codes for question 2

Main Theme	Theme	Code	f	%
Topics that students get knowledge	Environmental pollution	Causes of environmental pollution	11	20
		Types of environmental pollution	10	18.2
		Effects of environmental pollution	6	10.9
		Definition of environmental pollution	4	7.3
	Removal of Environmental Pollution	Environmental awareness	11	20
		Behavior to removal of environmental pollution	7	12.7
		Attitudes towards environmental pollution	3	5.5
		Waste and recycling	3	5.5

While answering the question, as seen in Table 9, the students provided responses that could be gathered under the themes of environmental pollution and eliminating environmental pollution. A large part of the students responded to the question about forming explanatory sentences about the reasons for and types of environmental pollution. For example, student 1 (S_1) commented on this code as follows:

S1: In the class, I learned not to litter, how long it takes it do degrade in nature, forest fires, exhaust gasses produced by cars and the need to install filters for those, and that the wastes and gasses that are released by volcanic eruptions harm the environment. As an example to environmental pollution, the biggest reason for it are people, as I learned, there is excessive population increase, unplanned industrialization and irresponsible hunting, soil pollution, need to avoid soil pollution, careless littering, water pollution, drainage waters, agricultural chemicals, acid rains, household waste, etc. (252.635, 25.05.2017).

Similarly, the student 9 (S_9) and student 14 (S_{14}) explained issues as follows:

S9: I learned that people are like the enemy of nature. Because we buy a phone, a higher model is released in a couple of days, and if we throw the old one in the environment, there is nature pollution.

S14: In the class, I learned about air pollution, water pollution, soil pollution, light pollution, visual pollution and noise pollution. I obtained the most amount of knowledge on air pollution. Everything like factory chimneys and exhaust smoke coming from cars may pollute the air. (615.056, 25.05.2017).

Another part provided views on the effects and definition of environmental pollution. Student 5 (S_5) explained this code as follows:

S5: Then, in air pollution, the smoke that comes out of heating stoves and factories makes us sick, but if we install filters, we protect our health. (476.426, 25.05.2017).

Under the theme of eliminating environmental pollution, the students stated that they gained responsibility and awareness for the environment in this class. Again, a very large proportion of the students emphasized that they learned about behaviors towards preventing environmental pollution and developed attitudes towards it. 3

students talked about the information they gained about wastes and environmental pollution. Some of the responses by the students were as the following:

> S13: A learned a lot that I did not know. I believe these will contribute to my life and in solving problems. For example, it is harmful to pour waste oils into the sink. We can prevent this by throwing them into the bins made by our government. Global warming also harms us much. It puts the lives of all living being in danger. For example, stores turn all the lights up at night to draw attention, everywhere is lit up like it is daytime. (577.802, 25.05.2017).

> S6: For example, I was a person who litters before observing these classes. …who excessively sprays perfume, pollutes the environment. However, after seeing these, I quit all these. I said I will not do these and warned those who did. (393.426, 25.05.2017).

> S11: We should avoid wasting water, plant trees in nature, install filters on factory chimneys, avoid pouring oil in sinks, throw batteries into battery collection boxes instead of regular thrash, construct buildings with the same heights, and avoid turning the volume up too much while listening to music. (491.802, 25.05.2017).

Findings Regarding the Use of Educational Films in Lessons and Comments

Lastly, the students were asked the question "what are your views on the educational movies that were used in the class?" With this question, it was aimed to learn about what they thought about the educational movies that were used I the class, whether or not they liked educational movies, and if any, the negative aspects of educational movies. Another purpose of asking this question was to achieve explanation of the findings obtained from the quantitative data and reveal the reasons for the investigated effects of educational movies on different variables. The codes and themes were established after examining the students' responses to question 3 in detail. These codes and themes, and the percentage and frequency distributions are presented below (See Table 10).

Table 10. Percent-frequency distributions of theme and codes for question 3

Main Theme	Theme	Code	f	%
Thoughts about the use of educational films in lessons	Contribution to the student	Providing permanent learning	13	31.7
		Providing meaningful learning	9	22
		Usefulness	4	9.8
	Contribution to the teaching process	Providing more effective learning	7	17.1
		Providing detailed information about the topic	5	12.2
		Providing fun learning aptitude	3	7.3

According to Table 10, the students provided responses under themes that emphasized the effects of educational movies on both individual outcomes and the instruction process. For example, the vast majority of the students, 31.7% emphasized that educational movies provide more permanent learning. Student 4 (S_4) and student 10 (S_{10}) explained this code as follows:

> S4: ..I am a person who understands better with visuals. If the teacher did not show these movies and just taught the subject, I would not remember it. (741.308, 25.05.2017).

> S10: ...was very helpful for me to hold the classes with movies. For example, if we write it down, it will stay in our mind for at least a day. But it can stay in our mind for a couple of years when we watch a movie or a video.(877.132, 25.05.2017).

Again, a significant portion as 22% stated that educational movies lead to meaningful learning. According to 9.8% of the students, educational movies were very helpful in their learning of the subject. While explaining the contributions of educational movies in the instruction process, 17.1% of the students stated that educational movies provide a more effective learning. 12.2% stated that movies help explain the subject in more detail, while 7.3% said classes are held in a very fun way with the help of educational movies. Some of the responses by the students were as the following: For example, student 8 (S_8) commented on this code as follows:

> S8: I think the classes were really fun with these movies. In addition to being fun, they were informative. This is because the movies told us what we can and cannot do against these pollutions. (826.541, 25.05.2017).

Discussion and Conclusion

As a result of the study, there was no significant difference between the mean pre-test knowledge scores of the students in the experiment group who were given environment education with educational movies and those in the control group who were given environment education without educational movies ($p > .05$, $t = -.53$). Additionally, the knowledge test mean scores of the students after the implementation significantly differed between the groups in favor of the experiment group ($p < .05$, $t = -4.05$). The literature review showed that there is a limited number of studies where educational movies are used in environment education. For example, Takmaz, Yılmaz and Kalpaklı (2018) aimed to investigate what the movie Avatar as an instruction material makes people think in terms of nature and environment education. As a result, it was concluded that the movie Avatar may provide significant contributions as an effective instruction material due to its comprehensive emphases on behaviors that are aimed to be created by nature/environment education. Demirkuş, Bozkurt and Gülen (2017) provided virtual materials to establish popular environmental concepts and sets of concepts in the mind properly and achieve accurate learning of these. In the material prepared by the researchers, a movie DVD with 712 concepts was created by using popular environmental concepts from 90 scientific movies viewed on documentary channels. The results of another study by Selanik-Ay (2010) were directly in parallel with those in this study. In the study, it was revealed that educational movies contribute to students' acquisition of knowledge on topics related to the environment, awareness on environmental issues, information on environmental issues and development of environmental awareness. Likewise, Barbas, Paraskevopaulos and Stamou (2007) investigated the effects of movies related to the natural environment on the effects of students' views regarding the environment. Their study used slides and educational movies with subjects of the natural environment, environmental pollution and the damages people inflict on nature. As a result, it was concluded that movies related to the natural environment had positive effects on sensitivity for the environment. Alım (2006) also emphasized the role of auditory and visual media in environment education. Moreover, the results of several studies in the literature have revealed positive effects of educational movies on the knowledge and success in classes. As reported by Birkök (2008), by usage of educational movies in the instruction process, complex information is understood more easily, the entirety of the organized information is transferred dynamically, visually and auditory, and in addition to instruction, behavioral models can also be provided to the student. The results of other studies reported that movies have positive effects on knowledge and success about the classes (Birkök, 2008; Pekdağ & Le Marechal, 2007; Watts, 2007; Woelders, 2007), experiences of watching movies change the scientific understanding of students towards science and science subjects (Frank, 2003), and movies contribute to the cognitive development of students (Anderson, Huston, Schmitt, Linebarger, & Wright, 2001; Rice, Huston, Truglio, & Wright, 1990).

Another finding in this study was about the effects of educational movies on the attitudes of middle school students towards the environment. As a result of the analysis, no significant difference was found between the groups in terms of their mean pre-test attitude scores before the implementation ($p > .05$, $t = .515$). There was also no significant difference between the post-test mean scores ($p > .05$, $t = -.53$). The researchers could explain this outcome by some important points in changing attitudes. Attitudes are formed as a result of the experiences, reinforcements, imitations and social learnings throughout people's lives, and the root of many attitudes is in the person's childhood. These attitudes that are acquired in childhood years do not change easily unless there are significant experiences and memories on the subject (Kağıtçıbaşı, 2010). Considering especially the characteristics of the age group in the study and the short time of implementation, it is believed that the attitudes resisted change as it was reported in the literature. Moreover, as attitudes are implicit, they are difficult to measure. Thurstone (1931) and Likert (1932) stated that most methods in attitude scales are based on the assumption that people's attitudes can be measured through their views and beliefs on the object of attitude (Arkonaç, 2001). That is, attitudes are highly difficult to measure as they are implicit, and it is also difficult to determine the functional relationship between the "measured attitude" and the attitude on which a conclusion is drawn (Eren, 2001). On the other hand, the literature contains studies that, in contrast to the results of this study, reported positive effects of educational movies on attitudes (Birkök, 2008; Cavanaugh & Cavanaugh, 1996, 2004; Çemrek, Anılan, Anılan, Balbağ, & Görgülü, 2005; Kaşkaya, Ünlü, Akar, & Özturan-Sağırlı, 2011; Laprice & Winrich, 2010; McCormick, 2007; Sürmeli, 2012).

The study reached its qualitative results by the semi-structured interviews carried out with the students. The responses provided by the students not only explained the reasons for the quantitative results but also provided ideas about the educational movies that were used in the process. The responses provided by the students were examined and it was found that their views gathered around a few points. For the first question, the students stated that the Mystery of Earth Crust / Earth and Universe chapter was distinct from other chapters because of this difference. A large part of the students stated that the chapter is intertwined with our lives, we would encounter the information we have learned in this chapter frequently, and environmental issues were discussed in the class. Again, for the second question, the students stated that they learned the definition, reasons, effects and types of environmental pollution, gained awareness and responsibility about the environment, learned about behaviors towards preventing environmental pollution and developed an attitude towards environmental pollution. This shows that the environment education reached its purpose and it was provided in compliance with the targeted outcomes of the chapter. This is because with environment education provided to students, it is expected that they recognize the values, attitudes and concepts related to their environment, and this education allows individuals to develop responsibility, sensitivity and awareness about their environment. Environment education is a life-long process of learning where individuals obtain knowledge, values and experience towards solving environmental problems to leave a healthy and clean environment for future generations (Doğan, 1997; Vaughan, Gack, Solorazano, & Ray, 2003). In the sciences course curriculum prepared by the Board of Education and Discipline of the Ministry of National Education, environmental topics are included in abundance with the aims of better understanding of the environment by students, their display of behaviors that are useful for the environment, awareness of environmental issues, their responsibility about these issues and increasing sensitivity about the environment (MEB, 2013).

Additionally, the students emphasized the educational movies that were used in teaching the chapter while providing their responses and made some explanations. According to the students, educational movies had significant benefits for both individual outcomes and the instruction process. Firstly, the students stated that educational movies made it possible to hold classes by visuals and videos. Bruner (2008) also emphasized this situation and defined educational movies as tools that provide students with indirect experiences through videos and enrich the learning and instruction process. According to Birkök (2008), by using educational movement in the instruction process, the entirety of the organized information is provided dynamically, auditory and visually, and in addition to instruction, behavioral models can also be given to students. The students reported that educational movies were beneficial for their learning of the topic, contribute to better understanding of the course and the class that was held this way was more permanent. When the literature is reviewed, it may be seen that this result that was revealed by the views of the student was in agreement with those of several studies. Barnett, Wagner, Gatling, Anderson, Houle and Kafka (2006) reached the conclusion that popular movies were effective for students to make sense of scientific concepts and develop their mental structures. Likewise, several researchers reported that educational movies affected learning positively (Beuscher, Roebers, & Schneider, 2005; Birkök, 2008, Linebarger, Kosanic, Greenwood, & Sai Doku, 2004; Pekdağ & Le Marechal, 2007; Stoddard, 2009) and provided permanence for classes (Akbaş, Canoğlu, & Ceylan, 2015; Butler, Zaromb, Lyle, & Roediger, 2009; Sullivan-Kerber, Clemens, & Medina, 2004; Walker, 2006; Watts, 2007; Woelders, 2007). Finally, the students stated that the classes that were held with educational movies were very entertaining. Akridge and Balkanski (1990) found that students had much fun as a result of using educational movies in the learning environment, and their attitudes and motivations towards the course increased. Similarly, researchers defined educational movies and videos as a very good educational tool that may be used to make learning more fun in formal and informal education and achieve permanent and effective learning (Hébert & Peretz, 1997).

Recommendations

Educational movies have been found in education environments for about half a century (Depover, Giardina, & Marton, 1998), and they are defined as some of the important learning objects in achieving success in education-training (Wenger, 1943). In this sense, it is believed that research results that determine the effects of educational movies in learning environments on different variables will be effective in filling the gap in the literature. Based on the results of the study, it is recommended to include different samples in future studies and investigate the effects of educational movies on different variables.

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The Digital Story of Science: Experiences of Pre-Service Science Teachers

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Abstract

The purpose of the study is examination of the quality of digital stories developed by pre-service science teachers and deeply investigating pre-service teachers' experiences related to scientific concepts, the characteristics of scientific knowledge and the ways of reaching scientific knowledge in the stages of exploration, storytelling and digitalization. A case study design is used in the research. Criterion sampling was used from the purposeful sampling methods. The research was carried out with the 3th year 36 pre-service teachers who study at a public university in Turkey during the fall semester of 2018-2019. Rubric for Evaluation of Digital Stories, semi-structured reflection form and digital diaries form developed by researchers were used for data collection. Content analysis technique was applied to analyze the reflections and dairies, and the digital stories prepared by the participants were evaluated using the *Digital Storytelling in Educational Context Rubric (DSECR)* form. According to the findings, most of the digital stories prepared by pre-service science teachers were at high quality level. Participants stated that they used scientific concepts in their digital stories and transferred the characteristics of scientific knowledge to digital environment and scenarios. Additionally, science teachers' experience of preparing digital stories supported 21st century skills.

Introduction

It has been always critical helping students to understand the nature of science and it is a common goal of the scientists especially in the last century (Abd-El-Khalick, Bell, & Lederman, 1998; Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). However, research suggests that pupils and teachers do not have a consistent understanding of science from preschool to the end of secondary school (Lederman, 2007; Lederman et al., 2002). In the programs and studies about understanding the nature of science, it is seen that besides teaching the content to the students, teaching the working principles of the scientists, the stages they experienced in the process of producing scientific knowledge and their contribution to understanding the nature of science are all critical (Akerson, Morrison, & McDuffie, 2006; Bati & Kaptan, 2017; Ministry of National Education [MEB], 2013; National Research Council [NRC], 1996). In addition, several studies indicate that teachers have a positive effect on the development of scientific thinking skills of the students if they correctly convey the characteristics of scientific knowledge and scientists, as well as the society-science and science-society relationship (Dogan, Cakiroglu, Cavus, Bilican, & Arslan, 2011; Khishfe, 2008; Zeidler, Walker, Ackett, & Simmons, 2002).

It has been a necessity for modern people to follow scientific and technological developments and use contemporary technology. Technological tools are entering our lives in almost every area and we have to take decisions and make choices as individuals and society (Kilic, Haymana, & Bozyilmaz, 2010). Scientific developments trigger technological developments, technological developments incite scientific developments, and therefore all these affect society and the environment. Therefore, the concepts of science, technology, society and environment closely interact with each other. It is also important to teach this dynamic interaction in science teaching (Kilic et al., 2010).

The new generation faces technological devices such as iPods, iPads, tablets, mobile phones and smartphones beginning from the moment they are born (Morgan, 2014). Some skills that are expected from today's generation and that became a necessity are called 21st century skills. These features, which are generally given under the headings of technology literacy, information literacy, communication skills, creativity, simulation, multitasking, collaborative working, problem-solving and social responsibility. These are some of the skills emphasized in today's educational settings and should be acquired by the learners (Leonard, Elizabeth, & Marta, 2010). The digital story approach appears to be a modern practice in developing the mentioned skills (Malita & Martin, 2010).

In addition, following and using the latest technologies play an important role in the academic success of the learners. New methods and techniques are widely used in education in order to increase the effectiveness of learning activities. Many studies on digital storytelling emphasized that this approach is a powerful and effective tool that can be used in educational environments (Clarke & Adam, 2011; Nilsson, 2008). Story and storytelling is an important strategy for teaching and learning, and stories help to express experiences (Lowenthal & Dunlap, 2010).

"Digital storytelling", which is built by bringing the video, picture, audio or written narrative or dialogues and music together in a story-building framework, has become a mean of expression. Use of digital stories has accelerated in different areas with the development of Web 2.0 technologies (Hartley & McWilliam, 2009; Robin, 2008). Digital storytelling was first introduced in California in the late 1980s by Dana Atchley and Joe Lambert (Hartley & McWilliam, 2009; Kocaman-Karaoglu, 2015; Robin, 2008). The Center for Digital Storytelling, founded by Lambert and Atchley in U.C. Berkley, in 1993, has been guiding and supporting the creation of digital stories and the studies conducted in this field (Robin, 2008). According to Robin (2008), with today's technologies creating a digital story is very easy and fast, which has been effective in the increase of the use of this method in schools.

In general, storytelling shapes the basis of digital story creation (Gocen, 2014). What distinguishes the digital story method from traditional storytelling is that it is supported by visual and audio materials in digital media. The use of digital story in teaching is an educational technology that includes many basic 21st century skills such as, technology literacy, creative thinking, effective communication and productivity (Jakes, 2006). Taking an active role in the digital story preparation process plays an important role in gaining mentioned skills (Jakes & Brennan, 2005). The process of digital story creation includes creative skills such as determining the topic, investigating this topic and creating scripts (Karatas, Bozkurt, & Hava, 2016). The different ideas available in the literature enrich the learning experiences by maximizing the interaction with the content they prepare. Digital storytelling practices can be used within a single lesson and subject; on the other hand, it is particularly a suitable approach to combine different disciplines (Benmayor, 2008; Robin, 2008). For example, according to Lederman and Niess (1997), the interdisciplinary approach signifies an undivided whole and they likened it to the formation of compounds in chemistry. The compounds show different properties than single elements that form them. When the disciplines are combined, a very different and clearer picture emerges (Lederman & Niess, 1997; MEB, 2016). In this study, the nature of science and the use of digital technology in science education were discussed together and digital stories were used as a teaching method.

Studies investigating the effect of digital storytelling on educational outcomes show that this activity has the potential to increase students' creative thinking skills, imagination, academic achievement and motivation (Duveskog, Tedre, Sedano, & Sutinen, 2012; Karatas et al., 2016; Wang, He, & Dou, 2014). In addition, digital storytelling also provides digital literacy skills (Karatas et al., 2016). Digital storytelling offers various opportunities such as diversity in classroom practices, personalization of the learning experience, supporting student-centered teaching, helping to explain complex issues, and creating easy and inexpensive learning environments (Xu, Park, & Baek, 2011; Yang & Wu, 2012). Thus, it is important to use digital storytelling in classroom practices.

Regarding the studies in science education area, there are not many studies related to the use of digital story (Hoban, Nielsen, & Shepherd, 2015; Robin, 2016; Valkanova & Watts, 2007). This study will contribute to the field about the use of digital story, which is a relatively new application for science education. In this study, it is planned that third grade pre-service science teachers will develop digital stories featuring the striking sections of scientists' lives, blending the knowledge and experience that they have gained in their fields and in the field of technology. The purpose of the study is examination of the quality of digital stories developed by pre-service science teachers and deeply investigating pre-service teachers' experiences related to scientific concepts, the characteristics of scientific knowledge and the ways of reaching scientific knowledge in the stages of exploration, storytelling and digitalization. For these purposes, the following questions will be addressed:

- What is the quality level of the digital stories developed by pre-service science teachers in terms of different dimensions?
- What are the experiences of pre-service teachers on scientific concepts, characteristics of scientific knowledge and the ways of reaching scientific knowledge in the stages of exploration, storytelling and digitalization?

Method

Research Model

This study was designed as a qualitative case study. According to Creswell (2007) case study is a research approach in which the researcher examines one or more of the situations delimited over time using multiple data sources, and describes the situations and contextual themes. In this study, the holistic single case design was used to investigate the experiences of pre-service science teachers while developing digital stories on life stories of scientists and to examine the quality of digital stories developed by pre-service teachers.

Study Group and Role of the Researchers

The study was carried out with 36 third year pre-service science teachers studying at a public university in Turkey during the fall semester of 2018-2019 academic years. Criterion sampling from purposeful sampling methods was employed to choose participants. The main criterion was taking Special Teaching Methods I course and have taken Computer II course. Thirty-three of the participants were female and three of them were male.

There are some important factors in choosing this group of students. Firstly, since the pre-service teachers study at the same department of the same higher education institution and at the same grade level, the content of the courses they take at the undergraduate level is considered to be appropriate for the purpose of the study and to comprehend the courses they will take during the study. Science pre-service teachers take various courses in general education, science education and technology and computers during their university education. However, they are not usually provided a supportive context in which they can apply these skills together for a common purpose. In this study, they were provided an opportunity for blending these different knowledge and skills gained in their teaching lives and also examining various aspects of scientific concepts and different aspects of scientific knowledge through concrete examples in this process.

Two researchers also participated in the data collection process of the research. In this process, the researchers informed the participants about the purpose, scope and duration of the study, avoided being intrusive and adopted a neutral role. The role of the researcher in qualitative research appears as an important factor affecting the study. Therefore, in this process, researchers tried to explain the whole research process in detail. The data collection process took place in a quiet environment, and the researcher became someone who observed the participants from the outside. Researchers have been empathic listeners throughout the process and have avoided behaviors that may affect the study negatively.

Research Process

The digital stories to be prepared should have been related to striking parts of life stories of scientists who had worked on the subjects covered in the secondary school science curriculum. At the beginning of the research, a four-hour training was given to pre-service teachers, on science, the characteristics of scientific knowledge, and the approaches to teach the nature of science. In addition, another four hours of training was provided on digital story content and digital story creation process. Pre-service teachers were provided help and feedback by two researchers throughout the process. The implementation period of the project was approximately three months. First participants did some research and prepared scenarios about striking parts of life stories of scientists who they have chosen. This process took around two weeks. Then they submitted draft scenarios and got feedback from the first researcher. Then they started to convert their scenarios to the digital form. They used templates and free images from PowToon, the Web 2.0 tool that they used to prepare their digital stories; and they also used other images as needed. They also made voice recordings for their scenes. Finally, they combined their video with voiceover and/or music.

Data Collection Tools

Digital story section of Digital Storytelling in Educational Context Rubric developed by Sarica and Usluel (2016) was used to determine the quality of digital stories developed by pre-service science teachers and Reflection Form for Digital Story Preparation Experiences was employed to determine pre-service science teachers' experience on scientific concepts, characteristics of scientific knowledge and the ways of reaching scientific knowledge in the exploration, storytelling and digitization processes. In addition, digital logs were also used in order to deeply investigate digital story preparation experience of pre-service teachers. Different methods are used by researchers to ensure the validity and reliability of qualitative case studies. One of them is collecting data from multiple data sources to ensure internal validity and to synthesize and support each other with the triangulation method (Mills, Durepos, & Wiebe, 2010). In this study, triangulation method has been used by obtaining data at different stages of the application with multiple data collection tools.

Digital Storytelling in Educational Context Rubric

Digital Storytelling in Educational Context Rubric developed by Sarica and Usluel (2016) is comprised of three sections and 30 criteria related to the digital story-telling process in educational context. The sections are defined as “story”, “storyboard” and “digital story”, where the “story” section consists of eight criteria (purpose, use of language and grammar, authenticity, emotion, sincerity, conciseness and fluency), the "storyboard" section consists of four criteria (organization, content, integrity and fluency) and the "digital story" section consists of 18 criteria (purpose, use of language and grammar, clarity, length, authenticity, emotion, conciseness, suitability of visuals, effectiveness of visuals, suitability of sound, sound speed, sound quality, suitability of music, music speed, music-sound volume compatibility, integrity, fluency, copyright). The validation study of the developed rubric was conducted by experts in terms of content, structure and criteria dimensions. For the reliability of the rubric, Cohen`s Kappa index was calculated using interrater reliability coefficient = number of agreements / (total number of agreements + disagreements) (Miles & Huberman, 1994). A minimum of .60 value should be reached for reliability (Cohen, 1960). In this context, regarding the weighted Kappa coefficients of the criteria, it was determined that the majority of the criteria showed substantial or almost perfect agreement between two raters. According to these results, it can be stated that the developed rubric was valid and reliable (Sarica & Usluel, 2016).

Reflection Form for Digital Story Preparation Experiences

In the process of digital story preparation, pre-service teachers carried out exploration, storification and digitalization stages. A semi-structured reflection form has been prepared by the researchers to determine the experiences pre-service teachers had about scientific concepts, characteristics of scientific knowledge and the ways of reaching scientific knowledge. Reflection form aimed to elaborate the experiences of the pre-service teachers for each dimension of the digital story preparation process, and they were asked to express their thoughts in written form under the relevant heading with detailed explanations. The semi-structured nature of the form is intended to remind pre-service teachers their experiences in the process, but it is not as a short-answer questionnaire on which they can simply mark the answers, it is in a form allowing them to express their thoughts in their own words. The reflection form was applied to all pre-service teachers who participated in the study at the end of the research.

Digital Logs

In this study, digital logs were also used as a data collection tool. The digital log form was comprised of nine questions regarding the exploration of the scientist, the digitalization of the scenarios, the problems experienced in this process, the opinions and suggestions about the process of digital story preparation. Participants answered these questions electronically after their digital story preparation experience.

Data Analysis

Within the scope of the research, 19 digital stories produced by pre-service science teachers were evaluated using the Digital Storytelling Rubric developed by Sarıca and Usluel (2016). Digital stories were evaluated under 17 categories except the copyright category by two independent raters from 1 to 3. Weighted kappa coefficients were calculated, then the reliability of the two raters was checked. In Cohen’s Kappa index, the reliability coefficient between raters was calculated by using the following formula: (K) = Agreement / (Agreement + Disagreement) (Miles & Huberman, 1994). If the raters gave the same score for an item, it was taken as “Agreement”, if they gave different scores it was taken as “Disagreement”. Regarding the values of Kappa coefficient, <.20 is interpreted as slight, .21–.40 as fair, .41–.60 as moderate, .61–.80 as substantial, and

.81–1.00 as almost perfect agreement (Cohen, 1960; Landis & Koch, 1977). Between the two raters, it was found that the majority of the criteria showed almost perfect and substantial agreement.

Content analysis was used to analyze the data obtained from digital logs and from the reflection form for digital story preparation experiences. There are two major types of content analysis: inductive and deductive (Armat, Assarroudi, Rad, Sharifi, & Heydari, 2018). Inductive content analysis is usually applied for the cases there are no studies/limited studies about the research topic (Elo & Kyngäs, 2008), then categories and themes emerge from the text. When the researcher adopts deductive content analysis, analysis starts with pre-existing categories that were adopted from a conceptual framework, theories, or earlier research findings (Armat et al., 2018). Then the researcher looks for whether predetermined categories exist or not in the text. For the analysis of this study, deductive method was applied for analysis of both digital logs and the reflection forms. For the digital logs, first, each researcher read the participants' answers separately and coded under predetermined themes. The opinions of the pre-service teachers included in the logs were reviewed in terms of 21st century skills, Partnership for 21st century learning (2015): Learning and innovation skills, knowledge, media and technology skills, and life and career skills. Then, at the end of the analysis process, the two researchers' separate analyzes were reviewed and the codes and themes were found to be coherent. Nvivo 12 pro software was utilized during these analyzes. For the reflection forms, the data obtained were grouped under the themes based on the study objectives. The identity of the participants was kept confidential in the direct quotations taken from the opinions in the reporting process. At the end of the analysis period, the analyses of the two researchers were reviewed and the codes and themes were adapted.

In order to ensure internal validity in this research, pre-service teachers' experiences on the digital story-building process were first defined from the direct quotations and then interpreted. For the reliability of the study, multiple data collection tools (rubrics, reflection form and digital logs) were utilized and both researchers analyzed the data independently and the results they obtained were compared.

Findings

Findings about the Quality of Digital Stories Developed by Pre-Service Science Teachers

Nineteen digital stories developed by pre-service science teachers individually and in groups were reviewed independently by two raters. The qualities of digital stories were evaluated (weak, medium, good) using Digital Storytelling Rubric, consisting of 17 items in three categories. It has been found that pre-service teachers achieved at least 50% points from the majority of 18 scale items for 19 digital stories. As seen in Table 1; For 16 rubric categories, at least 11 of 19 stories were rated as “good”. The number of stories rated as "medium" ranges from 1-8. For another rubric category (purpose), all of the stories were rated as “medium”. There is no story with a "weak" score in any category, which is also seen in the Table 1. As a result, it was concluded that on average 58% of the prepared stories were at high quality level and 42% of them were at "medium" quality level.

Table 1. Frequencies of mean of ratings for digital story quality (N=19)

Rubric categories	Weak	Medium	Good
Purpose	0	19	0
Language	0	0	19
Clarity	0	2	17
Length	0	2	17
Originality	0	1	18
Affect	0	0	19
Plainness	0	1	18
Proper visuals	0	5	14
Effective visuals	0	6	13
Proper audio	0	1	18
Audio speed	0	3	16
Audio quality	0	1	18
Proper music	0	7	12
Music speed	0	7	12
Music level	0	8	11
Integrity	0	2	17
Fluency	0	5	14

Pre-Service Teachers' Experiences related to Scientific Concepts, the Characteristics of Scientific Knowledge and the Ways of Reaching Scientific Knowledge in the Stages of Exploration, Storytelling and Digitalization

As a result of the analysis performed on the data obtained from the reflection forms: the scientific concepts, the characteristics of scientific knowledge, and the ways of reaching scientific knowledge themes emerged. The categories included under the theme of scientific concepts are: concepts and taking part in the story (Table 2).

Table 2. Frequencies related to categories and codes in the theme of scientific concepts

Themes	Categories	Codes
Scientific Concepts	Concepts	scientific knowledge DNA electricity the earth is round solar system-space gene audio atmospheric pressure solenoid bacteria natural selection buoyancy microscopic organisms penicillin radioactivity telephone
	Taking part in the story	content of the scene study of scientists basic concepts visualization getting attention dubbing

The opinions that are mostly mentioned by pre-service science teachers under the *concepts* category were the concepts related to the characteristics of scientific knowledge. One of the participants (P) expressed his/her idea as:

> Scientific knowledge is based on observations and inferences. He observed the piece of mushroom left in his pocket and made inferences by examining this piece (P24),

whereas another opinion supporting this one was:

> Imagination and creativity occupy an important place at every stage of the development of scientific knowledge. This concept can be associated with seeing porous structure of the mushroom and likening it to the cells in the monastery where the monks stay (P35).

Another code that was frequently repeated by the participants under the *concepts* category was DNA. A participant stated his/her opinion about DNA as:

> I have encountered scientific concepts related to the structure of DNA (P5),

another participant stated that he/she had chosen Aziz Sancar as the scientist of his/her digital story and said the following about the concepts he/she encountered:

> My digital story was about the DNA repair work that he had found; the scientific concepts in this study were: DNA, nucleotide, gene, cancer cell, enzyme, ultraviolet rays, and DNA damage (P16).

Pre-service teachers often included scientists working on electricity in their digital stories. One of the participants who went through the concept of electricity in his/her digital stories mentioned the concepts that he/she encountered as:

> In the digital story about Nikola Tesla we faced with scientific concepts of electricity (P11).

whereas another participant stated the concepts that he/she faced as:

> Electricity is the concept that Franklin works on. Positive charge, negative charge, neutral took place as the particles forming materials. Electrical attraction force and push-pull concepts were also included (P10).

Pre-service teachers stated that they mostly included concepts as scene content in their digital stories. As seen in Table 2, the findings under the category of *taking part in the story* are grouped under six separate codes. A participant stated his opinion on this issue as:

> The concepts in our digital story are based on Torricelli's experiment. We tried to story and explain Torricelli experiment in which he made open air pressure measurable using mercury (P2).

A screenshot from the digital story describing Torricelli's experiment is shown in Figure 1.

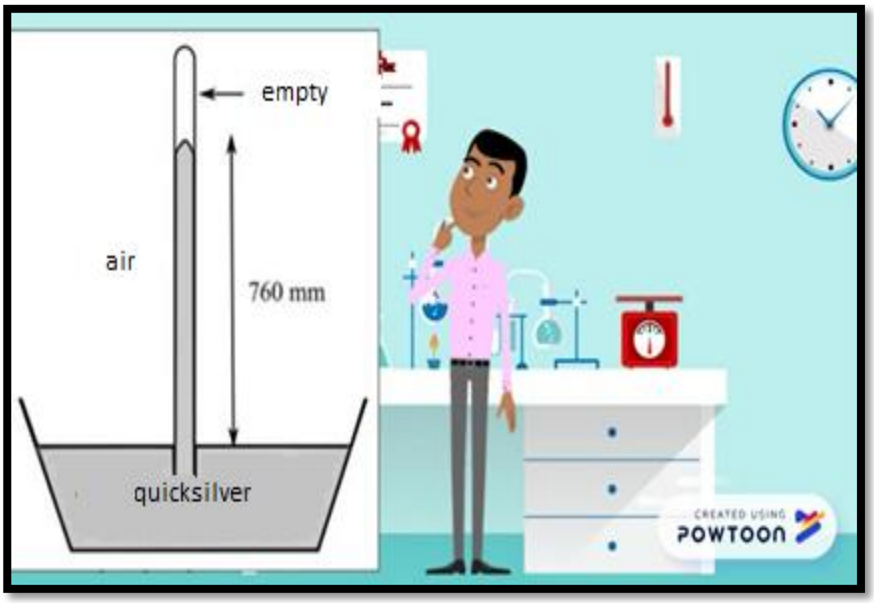

Figure 1. A digital story example describing the experiment by Torricelli

Another participant said that:

> Earth, diameter, trigonometry, tangent, cotangent, measurement, etc. Biruni has measured the diameter of the earth using a formula. We covered these concepts in this part (P31).

The other recurring view under this category is that the concepts mentioned in digital stories were the ones included in the work of scientists. An opinion mentioned under this code was as follow:

> The subject of my story was the life of a person who was engaged in science, and this person was the inventor of telephone, one of the technological devices. Developmental characteristics of science were mentioned. As an example, Graham Bell developed his invention and then proceeded to open up a long-distance phone line. In doing so, naturally he used technology and this product emerged as an accumulation of his work with his friend Watson (P13).

The categories under the characteristics of the scientific knowledge theme were perception of scientific knowledge process, scripting process and digitalization process. The characteristics of scientific knowledge have been included in the perception of scientific knowledge process (see Table 3).

Table 3. Frequencies related to categories and codes in the theme of the characteristics of scientific knowledge

Themes	Categories	Codes
Characteristics of Scientific Knowledge	Perception of scientific knowledge	*SK2 *SK4 *SK6 *SK5 *SK3 *SK7 *SK1
	Scripting process	utilize the features of scientific knowledge stages of research process utilization of visuals simplification work of the scientist determining important parts
	Digitizing digital stories	use of visual media preparing scenes visualization of scientific knowledge using characters appropriate for student level research

*SK1: These aspects include teaching students that scientific knowledge, its “facts,” “theories,” and “laws” are both reliable and tentative.
*SK2: Empirically based (based on and/or derived from observations of the natural world).
*SK3: Subjective and/or theory-laden.
*SK4: Partly the product of human imagination and creativity.
*SK5: Subject to a distinction between observations and inferences.
*SK6: Influenced by social and cultural factors.
*SK7: That theories and laws are different kinds of knowledge.

Scientific knowledge (SK) includes logical, mathematical or empirical inferences, which is one of the characteristics of nature of science, is frequently emphasized by pre-service teachers under this category. An opinion stated under this code is:

> Biruni mathematically formulated the diameter of the earth with trigonometry and proved it via experiment (P23).,

whereas another opinion supporting this was:

> Hook made reasoning about the thing that he saw in his pocked but cannot make sense of as it might be the mushroom he eats before. He made experimental inferences by conducting an examination in the microscope to obtain a clearer result (P24).

In this category, another prominent characteristic of nature of science, which was frequently repeated by the pre-service teachers, was imagination and creativity have an important role in the acquisition of scientific knowledge. A participant expressed his opinion related to this topic as:

> Galileo looked at Saturn constantly, making observations, he used his own creativity to name Saturn Rings as the Saturn Ears (P27).

Whereas another opinion supporting this was:

> I have seen this characteristic of scientific knowledge in the part where Robert Hook and his wife examined the mushroom tissue, likened it to the cells of the priests in the monastery and named them as the cell (P33).

Another nature of science characteristic mentioned by pre-service teacher under this category was:

> The scientific knowledge is influenced by the social and cultural surrounding at the stage of development and practice.

An opinion stated under this code was:

> Mendel's father engagement in agriculture and Mendel's interest in plants were influential in this study (P20).

another opinion supporting this was:

> The church opposed the books published by Galileo and he was accused of influencing the people. He was eventually put under house arrest (P27).

Another nature of science characteristic expressed by pre-service teacher under this category was:

> Observation and inference are different things.

One of the opinions mentioned under this code was:

> Franklin has taken many pictures of DNA and has observed these pictures abundantly. However, he could not connect his observations to an idea. The people who interpreted these pictures and made inferences were Watson and Crick (P34).

Another nature of science characteristic stated by pre-service teachers under this category was: Scientific knowledge is subjective. An opinion mentioned under this code was as follow:

> The best example of it is Watson and Crick believed that DNA has a double spiral structure when Pauling was thinking that it has a triple helical structure (P34).

The nature of science characteristic less frequently mentioned by pre-service teachers under this category was: Scientific theories and laws are different types of knowledge. An opinion stated under this code was:

> Theory is the information without a definitive conviction, which may be changed in some cases. However, the law is the information accepted by everyone, which cannot be changed. Mendel has enacted his hypotheses. They are still accepted today (P36).

The nature of science characteristic that was least mentioned by pre-service teachers under this category was:

> Scientific knowledge is changeable.

The participant explained his/her opinion related to this code as:

> As time progresses, technology is evolving. Science is progressing by this means. Aziz Sancar has now achieved DNA repair with today's technology. But in the future, new solutions will be found with the technology that is continuing to develop (P22).

The following codes were achieved in the *scripting process* category: utilizing the characteristics of scientific knowledge, stages of research process, utilization of visuals, simplification, works of the scientists and determining important parts. Pre-service teachers emphasized that scientific knowledge includes logical, mathematical or experimental inferences. A participant expressed his/her opinion as:

> Fleming used experiments and calculations while working on penicillin and in other studies. We talked about these works in detail in the scenario (P29).

Pre-service teachers stated that they used the stages of the research process while preparing a scenario. Regarding the stages of the research process, a participant stated that:

> Scientific knowledge is systematic and methodical. Such as measuring the diameter of the world through certain stages and methods (P23),

whereas another said:

> Rachel Carson's narration of her life took place in the scenario as describing the stages in the process of conducting her research (P1).

Pre-service teachers stated that they mostly used visual media when *digitizing digital stories*. A participant expressed his/her opinion on this code as:

> Since we covered it in the script, it wasn't too hard. We've included it by adding in the event and supporting it with pictures and sounds (P10).

whereas another stated:

> For the information that I transferred to the script, I created scenes via the Powtoon application in digital format. I prepared the scene related to the topic and used visuals. Then I transferred this information to the digital media with voiceover (P21).

Another opinion supporting these was:

> We put into the screen a short summary about Galileo and the scenario we prepared from it via Powtoon. We transferred the pictures of the observations that he had made to the scenes with the characters (P27).

Pre-service teachers declared that while digitizing their digital stories they prepared the scenes first. A participant expressed his/her opinion as:

> I took scientific information into consideration when preparing the scenes and arranging the objects in the scene (P14),

and another said:

> We created the script and then we started to create the scenes. In most cases we had problems in reflecting the background and the basic parts of the invention, we had to change the scenes we made constantly, but we didn't remove any scene from the scenario or added a scene contrary to the scenario (P19).

The ways of reaching scientific knowledge theme was comprised of scientists' ways of reaching knowledge, pre-service teacher's ways of reaching knowledge, the contribution of creating digital stories, and the contribution of digitalizing. Observation, experiment, research and inference were the most mentioned codes by the pre-service teachers under the category of *scientist's ways of reaching knowledge* (Table 4).

Pre-service teachers stated that scientists often made observations to reach scientific knowledge. A participant expressed his/her opinion about observation as:

> Leeuwenhoek has first identified the issue that attracted his attention, in other words the problem: Why do spectacle lenses show objects larger (P9)?

He then went to the optician's shop and worked with the craftsmen, in other words he made observations about the problem and collected data. The opinion of a participant suggesting that the scientist reaches scientific knowledge through experiment was:

> He was a scientist who makes experiments and observations, who is able to observe different situations directly, we also mentioned in our story, he was someone constantly making experiments in his laboratory, who was working dispersed, and penicillin was found because of this (P29).

Participants also emphasized that scientists make inferences when reaching scientific knowledge. A participant stated that:

> He studied previous studies conducted on cancer cells and proceeded with deductions (P22).

whereas another expressed his/her opinion as:

Watson and Crick have reached scientific knowledge by reviewing previous studies and making logical inferences (P34).

Table 4. Frequencies related to categories and codes involved in the ways of reaching scientific knowledge

Themes	Categories	Codes
The Ways of Reaching Scientific Knowledge	Scientist's ways of reaching knowledge	observation experiment research inference curiosity imagination mathematical calculations disciplined work collaboration trial reasoning produce theory method daily life hypothesis testing law cause and effect relationship training systematic study socio-cultural environment changeable
	Pre-service teacher's ways of reaching scientific knowledge	research collaboration reviewing the work of scientists
	Contribution of creating digital stories	research skills review of the process of acquiring knowledge understanding the properties of scientific knowledge learn about scientists questioning skills feeling like a scientist gaining technical skills gaining a scientific perspective inference material development no contribution
	Contribution of digitalizing category	technical skills understanding the properties of scientific knowledge collaboration learning systematic study ensure the reliability of scientific knowledge contribution of the prepared material to students understand the ways of reaching scientific knowledge experience entertainment visualization comprehending concretization of scientific knowledge decision-making professional development questioning no contribution

Pre-service teacher's ways of reaching scientific knowledge category is consisted of conducting research, collaborating and reviewing the work of the scientists. While pre-service teachers offered a variety of ways through which scientists reach scientific knowledge, they did not mention this diversity for themselves. Pre-service teachers stated that they mostly do exploration to reach scientific knowledge. A participant expressed his/her opinion on this issue as:

> We explored Kepler's life and inventions (P12).

whereas another stated that:

> We have reached this information by reading Fleming's life story (P29).

Another opinion supporting these was:

> While I was exploring the life story of the scientist I made a systematic source search. I took care to conduct my work in a plan (P28).

Regarding the *contribution of creating digital stories*, pre-service teachers mostly stated that it contributed to their exploration skills. A participant expressed his/her opinion on this issue as:

> Creating a story about a scientist has contributed a lot to me on the ways of reaching scientific knowledge. In order to create this story, I explored scientific knowledge by conducting a detailed search (P11).

whereas another participant said that:

> Yes, I think it contributed on me. Because before we decided to the scientist, we explored and worked on many scientists. As we read the lives of many scientists until we reached the decision-making stage, we had a lot of information at hand (P35).

Under *the contribution of digitalizing category*, pre-service teachers often stated that digital stories strengthen their technical skills. An opinion on this issue is as follows:

> As we know, recording scientific information is a necessity for the performance of the science process. Any data that I transfer to digital media paves the way for potential scientific methods that I will use in the future. The data that I transfer to the digital media will always be there, and maybe one day they may even directly influence my life. I now understand how important technology is in accessing information. I think we have to catch the new age in these days that we call Industry 4.0 (P13).

Findings Obtained from Digital Logs

Findings obtained from digital logs were reviewed in terms of 21st century skills. The logs were grouped under the themes of information, media and technology skills, learning and innovation skills, and life and career skills. Information literacy, information and communication technology literacy, and media literacy categories were the items under the theme of information, media and technology skills. The frequencies related to the themes, categories and codes of 21st century skills are listed in Table 5.

Under the *information literacy* category, the most mentioned opinion was analyzing the learning objectives. Pre-service science teachers said that they were examining the objectives covered in the 2018 Science Course Curriculum while preparing the life stories of scientists in the digital story preparation process. A participant said that:

> Regarding the scientist, we decided to choose Johannes Kepler considering the objectives in the science curriculum (P30).

Another opinion mostly mentioned under *information literacy* category was research skills. Pre-service science teachers stated that in the digital story preparation process, they investigated the life stories of scientists in detail. A participant expressed his/her opinion as:

> Firstly, I started to work by exploring Nikola Tesla's childhood. It was not difficult to create my script after exploring the interesting events he has experienced during his childhood and his business life and the beautiful inventions that he has made (P12).

whereas another participants stated his/her opinion as:

> First, we explored the life of Marie Curie in detail and thoroughly internalized it, we insisted on her works and designed a scenario (P19).

However, pre-service science teachers stated that they wanted to choose a different scientist during the digital story preparation process.

Table 5. Frequencies related to themes, categories and codes in twenty-first century skills

Themes	Categories	Codes
Information, Media and Technology Skills	Information literacy	review of learning objectives research being different and native
	Information and communication technology literacy	digitization recording recording process experiences during digitization affordances of the program
	Media literacy	visual media audio recording software audio
Learning and Innovation Skills	Critical thinking & Problem solving	problems experiences
	Collaboration	support support type
Life and Career Skills	Flexibility & Adaptability	making choice
	Productivity & Responsibility	opinions about the process professional development use of technology productivity use different materials imagination & creativity

Under *information and communication technology literacy* category, the opinions mostly mentioned by the participants were about transferring to digital media. Regarding transferring the script that they prepared to the digital media a participant stated his/her opinion as:

> First of all, we wrote our script and prepared in Powtoon using the characters suitable for the subject, tools, backgrounds, visuals and the appropriate vocalization options (P16).

Whereas another participant said that:

> In this process, we first created our scenes. Then we made the character selection and determined the character movements. After this stage, we carried out voice recording and transferred it to the program (P20).

Another opinion mostly mentioned under *information and communication technology literacy* category was related to the recording process. It is seen that pre-service science teachers performed their recording in different ways. A participant said that:

> I used YouTube to save the story. I shared my story with Powtoon and uploaded it to YouTube and recorded it by downloading to my computer using mp4 converters on internet sites (P14),

whereas another one explained it as:

> After all the scenes, pictures and sound recordings were completed and our mistakes were corrected, I started the video on Powtoon. At the same time I started to record the video on the Bandicam program that I downloaded on my computer. Bandicam recorded the video screen while Powtoon video was playing (P26).

Another participant said:

> After completing our story, we recorded it via Active Presenter program (screen capture program) (P27).

Another opinion mentioned by the participants was what happened during the digitalization. It is seen that pre-service science teachers experienced different problems related to this subject. A participant expressed his/her opinion on this issue as:

> It did not take much time to write our script in this process, however it took quite a while for us to find the visuals and to create audio recordings and to insert them in the program while transferring the script to digital media (P8).

The facilities of the program that pre-service science teachers used while utilizing information and communication technologies have also affected their work. A participant reflected his/her opinion as:

> I wanted to animate an eagle's chasing a rabbit in that scene, but Powtoon didn't allow it, I couldn't find the necessary characters and movements. Again, I wanted to create this scene in a cloud of thought, but the visual could not be placed on the speech cloud. In short, I couldn't do what I imagined in a scene (P1).

Under *Media Literacy* category, pre-service science teachers stated that they mostly used visual media while digitalizing the scenarios they prepared. The opinion of a participant on this issue is as follows:

> Some characters and pictures in the Powtoon application were not sufficient, so we used pictures of Nikola Tesla found from external sources. We found the pictures that fit our script. We paid attention the scenarios and the pictures being compatible (P12).

Another opinion mostly mentioned under *media literacy* category, was audio recording software. Pre-service science teachers explained that they performed the audio records of their digital stories by the Powtoon. A participant stated his/her opinion on this issue as:

> We added it directly, using the voice recording feature the Powtoon program. We took some sounds via WhatsApp sound recording, we converted them by a program and added it to the Powtoon program (P27).

However, there are also participants who recorded audio using WhatsApp (P24) and the phone's voice recorder feature (P32). They preferred a quiet environment while performing audio recording and managed the process. A participant expressed his/her opinion as:

> We made sound recordings in a quiet environment, because when we insert it to the program, sometimes it sounds like there are other sounds in the background and we didn't let it happen (P16).

Learning and innovation skills theme consisted of *critical thinking and problem-solving* and *collaboration* categories. The problems and the experiences in the process were put under *critical thinking and problem solving* category. Pre-service science teachers experienced a number of problems while preparing the digital stories and they were able to solve these problems. Regarding the problems of pre-service science teachers, it is seen that they mostly stemmed from the program they use. The opinion of a participant on this issue is as follows:

> The biggest problem we experienced in this process was the character and visual elements. In Powtoon, we didn't find the appropriate visual and character for our script, so we had to export pictures and videos. In addition, both character types and the properties of the character we selected were limited, for example we could only use a single sitting character on a scene showing that he was doing a microscope examination and his hands were on the keyboard. Therefore, we couldn't create most of the scenes we dreamed for our script in Powtoon (P40).

Another participant expressed his/her opinion as:

> It was a very tiring and instructive process (P15).

Support and support types codes were under *collaboration* category. Pre-service science teachers received help from friends in this process. A participant stated his/her opinion on this issue as:

> Usually we took care of everything together with my friends from the group, we consulted with other close friends in only a few points (P33).

They stated that they got support from the teachers along with the friends from the group as follows:

> We got support from our lecturer and computer teacher in cooperation with our group friends (P21).

Regarding the type of support that pre-service science teachers needed, it is seen that it was technical. A participant stated his/her opinion on this issue as:

> We got help from our computer teacher on adding sound. The sounds we inserted were present in all the scenes. We couldn't add sound to each scene separately. We got help on how to add the sounds we recorded to the relevant scene (P34).

Life and career skills theme consisted of *flexibility and adaptation* and *productivity and responsibility* categories. Making choice was a code included under *flexibility and adaptation* category. In the process of digital story preparation, pre-service science teachers have decided about the scientist to work on in a flexible way. A participant explained his/her choice as:

> While reviewing various scientists, we've seen Edmund Halley. We wondered and decided to explore his life. Later, the life story of scientist attracted our attention. We said “we should make the digital story of this scientist” (P20).

whereas another one explained it as:

> I've been curious about Nicola Tesla since I was a kid. I chose Nikola Tesla for this homework because I thought it would be both fun and useful for me (P12).

Under the category of *productivity and responsibility*, opinions about the process were mentioned. A participant stated his/her opinion as:

> The process was quite disciplined. We tried to do our best. We laughed at some point, but we never left our seriousness and made an educational, interesting video (P38).

Another opinion mentioned under *productivity and responsibility* category was that this process contributed to their professional development. A participant expressed his/her opinion on this issue as:

> We both got the experience of writing stories in digital media, and we learned a lot of new and innovative programs that can be used in our teaching life in the future. We implemented many activities in the programs and I think it contributed to our development in this respect (P7).

A participant explained his/her opinion that the digital story preparation process supported the use of technology in their courses as follows:

> Because of our field, we have to know the technology and use it in the most effective way. We used the technology efficiently by preparing a digital story (P5).

Pre-service science teachers stated that digital story preparation process provided productivity. A participant stated his/her opinion on this issue as:

> Most importantly, I think it is one of the first steps in creating something for another age group, not for ourselves (P14).

whereas another participant expressed his/her idea as:

> Powtoon is an application very enjoyable to use. I have both learned and created a very instructive story (P12).

Under the category of *productivity and responsibility*, pre-service science teachers emphasized that digital stories can be used as a different material in the classroom. A participant said on this issue:

> Their contribution to me is, it may be a material that can be used in the courses (P31).

Pre-service science teachers also pointed that digital story preparation process provided them the opportunity to use their imagination and creativity. The opinion of a participant on this issue was:

> Narrating the process of the invention of our scientist allowed us to use our imagination (P27).

Discussion and Conclusion

With this research, it was intended that pre-service science teachers prepare digital stories about scientists' lives, bringing their field knowledge and technology skills together. Investigation of the experiences gained and the quality of the final product in terms of different variables were conducted at the end of the process. For this purpose, Digital Storytelling Rubric in Educational Context, Reflection Form and Digital Logs were used as data collection tools. This section contains the discussions and suggestions developed based on the findings.

Nineteen digital stories, which have been developed by pre-service science teachers individually and in groups, were reviewed independently by two raters. The features required in digital stories were evaluated according to the Digital Storytelling Rubric in Educational Context (weak, medium, and good) that consists of 17 items, in three categories. Weighted Kappa coefficients of the categories developed by Sarica and Usluel (2016) showed a substantial or almost perfect agreement between the two raters in most of the criteria. According to this result, it can be said that product evaluation results were valid and reliable. More than half of the digital stories prepared by pre-service science teachers were found to be at high quality level.

The analysis of the data obtained from the reflection forms revealed that pre-service science teachers used the characteristics of scientific knowledge in their digital stories and they included DNA, electricity, round form of the world, solar system-space and gene concepts most. In addition, pre-service teachers stated that they used these concepts in their digital stories mostly as the scene content. In the literature, it was also reported that digital storytelling is effective in increasing students' knowledge about the topics they investigate (Gakhar, 2007; Koltuk & Kocakaya, 2015). *Scientific knowledge includes logical, mathematical or experimental inferences* theme, which is one of the nature of science themes in the perception of scientific knowledge process, has been frequently emphasized by pre-service teachers. The nature of science theme that was least mentioned by pre-service teachers was *Scientific knowledge is changeable*. The review of the literature revealed that students cannot understand that scientific knowledge can change (Griffiths & Barman, 1995; Griffiths & Barry, 1993; Ryan & Aikenhead, 1992). Moreover, there are many studies in the literature indicating that science teachers and pre-service science teachers has naïve views about the nature of science (Abd-El-Khalick, 2005; Abd-El-Khalick & Lederman, 2000; Dogan-Bora, 2005; Yakmaci, 1998). Teachers' understanding of the nature of science is parallel to the students' understanding of the nature of science. There are also studies that show that the changeability of scientific knowledge is a characteristic that can be developed rapidly (Abd-El-Khalick & Akerson, 2004; Morrison, Raab, & Ingram, 2009).

Pre-service science teachers mostly stated that they used the characteristics of scientific knowledge and visual media when transferring their stories to digital media. Studies indicating that digital stories improve students' media skills are available in literature (Ohler, 2006; Robin, 2008). This finding of the research seems to support the literature. Participants emphasized that scientists often made observations, experiments, research and draw inferences to reach scientific knowledge. While pre-service teachers presented a variety of ways through which scientists reach scientific knowledge, they did not reflect this diversity for themselves. Pre-service teachers stated that they mostly do research to reach scientific knowledge. Regarding the contribution of creating digital stories, pre-service teachers mostly stated that it contributed to their research skills.

Pre-service teachers also stated that digital stories provided them technical skills. According to the results of the study conducted by Koltuk and Kocakaya, (2015), students stated that they were doing research about the subjects in modern physics and the scientists who were dealing with physics, using computer, making audio-visual-music-graphics search from the internet, sharing videos in YouTube and using technology effectively. In a study by Dogan (2012), it was reported that digital stories improve students' technology skills. The findings of the study by Dogan (2012) and Koltuk and Kocakaya (2015) are consistent with the findings of this study.

Findings obtained from digital logs were reviewed in terms of 21st century skills. The logs were grouped under the themes of *information, media and technology skills*, *learning and innovation skills*, and *life and career skills*. *Information literacy, information and communication technology literacy, and media literacy* categories were under the theme of *information, media and technology skills*. Pre-service science teachers stated that in the preparation of digital story, they reviewed science course curriculum in terms of learning objectives and they researched life stories of scientists in detail. The participants explained that in the process of digitizing their scenarios, they first created scenes, then they looked for appropriate visuals and they performed a voiceover in the final stage. Regarding the products prepared by pre-service teachers, it is observed that the used media items (text, sound, visual) were directly related to the content and supported the content. The studies in the literature also support that the images, sounds and texts unrelated to the scenario should not be used in the digital story; if used, it would decrease the effectiveness of the prepared content (Kilinc & Yuzer, 2015; Uslu-Pehlivan, Erden, & Cebesoy, 2017).

Another finding from digital logs is that pre-service science teachers performed their voice recording in different ways. They stated that they used visual and audio media to digitalize the scenarios they prepared about scientists. Participants explained that their digital stories were recorded using Powtoon program. They preferred a quiet environment while making sound recordings. They had some problems while preparing the digital story and they were able to solve these problems. In a study conducted with the high school students by Koltuk and Kocakaya (2015), it was found that they had some difficulties while creating the digital stories, developed suggestions to solve these problems. This shows that digital stories contribute to the development of problem-solving and critical thinking skills of 21st century skills.

The literature review also showed that digital stories contribute to critical thinking skills (Robin, 2008; Yang & Wu, 2012) and problem solving ability (Yuksel, Robin, & Mcneil, 2011). Regarding the problems of pre-service science teachers, they stated that some of the problems they faced stemmed from the features of the program they used. In a study conducted by Uslu-Pehlivan et al. (2017), pre-service teachers experienced some difficulties in the process of creating digital stories. These problems were grouped as technical difficulties, problems experienced in the story-building process and the difficulties experienced in terms of time. In addition, in a study conducted by Kobayashi (2012) most of the pre-service teachers reported that they have experienced technical difficulties. The findings of this study support the literature (Kobayashi, 2012; Uslu-Pehlivan et al., 2017). In this process, pre-service science teachers received help from their friends and technical support from the researchers. These findings of the study are in line with the findings of the studies by Koltuk and Kocakaya (2015) and Sadik (2008).

Analysis of the data from digital logs also suggest that, in the process of digital story preparation, pre-service science teachers have decided about the scientist to work on in a flexible way. Pre-service science teachers stated that the digital story preparation process contributed to their professional development, provided support for the development of their technological competences, provided productivity, and provided different materials preparation experience. In a study by Bullock (2013), it was reported that experiences that are clearly positioned around digital technologies can greatly reinforce a positive bias towards the use of technology for teaching. In the literature, there are several studies emphasizing that the development of digital story improves the productivity skills (Jakes, 2006; Koltuk & Kocakaya, 2015; Robin, 2008). In addition, pre-service science teachers also stated that the digital story preparation process provided them the opportunity to use their imagination and creativity. In a study by Uslu-Pehlivan et al. (2017), pre-service teachers stated that preparing digital stories was educative, fun and creative. The findings of the study by Uslu-Pehlivan et al. (2017) support the findings of this study.

In conclusion, from the data, it was found that the digital stories prepared by science pre-service teachers were at "high" or "medium" quality level. This finding coincides with the finding obtained from the reflection form that digital story preparation provides research and technical skills. In addition, the findings obtained from diaries that digital story preparation help participants gaining 21st century skills support this result. In the reflection form findings, the participants stated that they used scientific concepts in their digital stories and transferred the features of scientific knowledge to digital media and scenarios. When the scenarios and products prepared by the participants were examined, it was seen that they confirmed this finding.

Recommendations

Findings from digital logs are in line with the existing literature in terms of supporting the development of 21st century skills (Karatas et al., 2016; Koltuk & Kocakaya, 2015; Robin, 2006; Tunc & Karadag, 2013). Similar studies can be conducted with different working groups and compared with this study. Studies can be carried out by using rubric which is one of the alternative measurement and evaluation tools. In addition, experimental studies can be carried out in which the digital stories prepared by pre-service science teachers are applied in the science courses in the related units at different grade levels and the effects of these applications in terms of various variables can be analyzed. Further studies on the use of digital stories produced by pre-service teachers in real classroom settings can be conducted and student outcomes might be analyzed.

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