Indonesian Society for Science Educators

Journal of Science Learning

journal homepage: ejournal.upi.edu/index.php/jslearning

Augmented Reality and Animation Supported-STEM Activities in Grades K-12: Water Treatment

Necla Dönmez Usta[1]*, Neslihan Ültay[1]

[1]Faculty of Education, Giresun University, Giresun, Turkey

*Corresponding author: necla.donmezusta@giresun.edu.tr

ABSTRACT Animation is used to increase the interest and engagement of students in the learning environment. Animation is exciting and fun, and using animation, abstract concepts are easy to present, display, and convey to students. Augmented reality, like animation, can help make it easier to understand abstract concepts. In many areas, augmented reality is used in education since it perfectly integrates virtual content with the natural world. STEM education is one of the areas where augmented reality can be used effectively. In this context, this research aimed to reveal the fourth-grade students' opinions about augmented reality and animation-supported STEM activities on the "Water Treatment" topic. These STEM activities were carried out with 15 (7 females, 8 males) fourth-grade students from a primary school in Turkey and lasted for 6 lesson hours. This study is a case study. As data collection tools in the study, the Know-Want-Learned chart, and the Application General Evaluation Form, which consists of eight open-ended questions developed by the researchers, were used. Based on the study's findings and the researchers' observations, it was determined that the augmented reality and animation-supported STEM activities are appropriate for acquisition, content, application, active participation, duration, and student level. In addition, the activities were enjoyable, humorous, engaging, and exciting. It is recommended in this context to conduct similar studies on different disciplines or concepts.

Keywords Animation, Augmented Reality, STEM Activity, Primary School Students, Water Treatment

1. INTRODUCTION

In the twenty-first century, having creative, innovative, and productive individuals who are curious, questioning, researching, analytical thinking, problem-solving skills, and able to transfer what they learn to real life is more important than having a labor-based workforce. These skills are called 21st-century skills, and these skills (Partner 21st-century century learning (P21, 2007) are expressed in three basic dimensions: learning and innovation, digital literacy, and career and life. In the twenty-first century, with changes made in education programs in recent years to train the human resources that countries require, these P21 skills are being attempted to be gained by individuals ranging in age and education level from pre-school to higher education. Interdisciplinary teaching comes to the forefront in acquiring these skills, particularly when science, technology, engineering, and mathematics disciplines are attempted to be taught by integrating. In this way, the concept of STEM arising is an educational approach that integrates the teaching of science, technology, engineering, and mathematics at all educational levels, beginning with pre-school (Gonzalez & Kuenzi, 2012). In addition to the objectives stated above, STEM education aims to provide the necessary human resources to compete in the long term, particularly on the PISA global scale, and to raise Turkey's average (Uştu, 2019).

For this reason, the Ministry of National Education (MNE) issued a report on STEM education in 2016 that stated that steps should be taken to conduct STEM education research, establish STEM education centers, train STEM-competent teachers, and update the curriculum (MNE, 2016). As a result, the theme 'Science, Engineering, and Entrepreneurship Practices' was added to the Science Curriculum to respond practically to the needs of students from fourth to eighth grade and real-life problems with a product they designed. STEM education aims to educate students in science, mathematics, engineering, and technology, with activities ranging from

Received: 22 January 2022
Revised: 29 May 2022
Published: 27 November 2022

pre-school to post-doctoral. However, it appears that STEM education is mentioned in Turkey's new curriculum under the heading of scientific and engineering applications. It takes place from fourth to eighth grade (Hiğde, 2018), although STEM education is appropriate for all grades. The foundations of the scientific process abilities necessary for STEM activities are created at a young age (Ültay et al., 2020). Therefore, it is more crucial to undertake STEM activities at an early age, for instance, in the 4th grade at this point. This study is significant because it focuses on fourth-grade students.

There are numerous findings on the effectiveness of STEM activities in Turkey and abroad when reviewing the literature on science education. Many of these have a positive impact on students' academic performance and scientific process skills (Cotabish, Dailey, Robinson, & Hunghes, 2013; Kong & Huo, 2014; Ormancı, 2020; Sarıca, 2020; Sırakaya & Alsancak-Sırakaya, 2020; Ültay, Balaban, & Ültay, 2021). Furthermore, STEM-focused studies show that students successfully create a positive attitude toward STEM and STEM disciplines (Chen, Huang, & Wu, 2021; Hackman, Zhang, & He, 2021; Karahan, Canbazoğlu Bilici, & Ünal, 2015). When students' attitudes toward STEM disciplines are examined separately, it is discovered that the most significant improvement is from high to low in engineering, science, technology, and mathematics (Tseng, Chang, Lou, & Chen, 2013).

In STEM activities, it is required that at least two STEM disciplines are included in the activity (Kennedy & Odell, 2014). Interestingly, the commonly preferred discipline is "engineering" in STEM activities (Moore et al., 2014; Ültay et al., 2021). It is an expected result because formerly, it was mentioned that students' attitude towards engineering has mostly increased among STEM disciplines. However, in today's world, especially after the Covid-19 pandemic, technology has become an essential part of the educational system. During the pandemic period, most courses were based on online learning after April 2020, and most teachers had no experience designing their courses for online teaching (Marek, Chew, & Wu, 2021).

Additionally, STEM-based online learning activities are carried out, and remarkable results are seen. For example, Sarnita, Fitriani, Utama, and Suwarma (2021) reported that online STEM courses had increased students' creative thinking skills. Similarly, Benli Özdemir (2021) found that online STEM activities improved students' 21st-century skills. From this, it is clearly understood that technology is an indispensable part of our lives. Even though STEM activities include technology as a discipline, using technology as a complementary pedagogy in STEM activities can still be viewed as a modern-day necessity. In this research, technology is not a separate discipline but a complementary pedagogy. This study used augmented reality and animation in STEM activities. Augmented reality (AR) has been widely used in the last ten years, depending on smart devices such as smartphones, tablets, etc. (Schiavi, Havard, Beddiar, & Baudry, 2022). AR contributes to better structuring of concepts/subjects (Turan-Güntepe & Dönmez-Usta, 2021). With AR being used in the learning environment, abstract concepts can be transformed into visible, audible, and visual dynamic concrete concepts (Cai, Liu, Wang, Liu, & Liang, 2021). Many studies have concluded that AR improves student achievement and significantly contributes to STEM education (Hsu, Lin, & Yang, 2017; Wu, Hwang, Yang, & Chen, 2018). The fact that AR is a technology that today's students can easily use means that the use of AR in STEM education supports the learning and teaching process (Sırakaya & Alsancak-Sırakaya, 2020). AR in science is a simulation that could involve learners more deeply in the investigatory project activity than traditional simulations could (Hwang, Wu, Chen, & Tu, 2016). For this reason, AR can significantly impact STEM Education (Phon, Ali, & Halim, 2015). Considering the advantages mentioned earlier of AR in the learning environment, many applications such as "Anatomy 4D, Quiver 3D, Animal 4D+, Elements 4D, and Octaland 4D" were designed to use AR in science education (Buluş-Kırıkkaya & Şentürk, 2018). One of the applications of AR, "Quiver 3D," is used in this study.

Animations have been used as educational resources to support science teaching and learning for several decades in science education. Animations of dynamic views and abstract events/subjects positively affect learning (Lowe, 2003). The animations used in learning environments significantly affect students' attitudes towards the course and academic success (Powell, Aeby Jr, & Carpenter-Aeby, 2003). In addition to speeding up and slowing downtime, it can be said that it provides many contributions, such as being able to be analyzed, simplifying complex systems, being valuable and inexpensive, and motivating in learning environments (Daşdemir & Doymuş, 2012). Ceylan (2014), in her study on STEM education, concluded that the methods and techniques she used for the technology discipline, such as slow transition animation techniques, collaborative groups, and the engineering design process, contributed to students' scientific creativity skills. AR and animation-based materials help students to visualize, experiment, and collect data on STEM subjects by enabling them to apply what they have learned and use computers with special applications such as computer simulations and animations (Lantz, 2009). In this respect, this study is also essential.

This research aimed to reveal the fourth-grade students' opinions about AR and animation-supported STEM activities on the "Water Treatment" topic in the "Human and Environment" unit. At this point, the following questions form the focus of the study:

- What are the students' opinions on what they know about the topic, what they want to learn, and what

they learned at the end of the AR and animation-supported STEM Activities?
- What are the students' opinions about augmented reality and animation-supported STEM activities?.
- What are the students' opinions about the designed water treatment system?

2. METHOD

Based on the general characteristics of case studies, Yin (2003) distinguishes four patterns: single holistic case, embedded single case, holistic multiple cases, and embedded multiple cases. The holistic single case pattern can be applied to situations involving individuals or institutions (Creswell, Plano Clark, Gutmann, & Hanson, 2003). Researchers reveal the situation described as the heart of the study in case studies and clearly express the underlying reality and boundaries (Miles & Huberman, 1994). The holistic single-case design is used to study unique situations that do not meet the standards of a single analysis unit. Because the unique situations mentioned in the design cannot be numerous or even multiple, they can be the subject of independent research (Yıldırım & Şimşek, 2018). At this point, it was determined that it was appropriate to conduct the case study, one of this study's qualitative research designs, which is about AR and animation-supported STEM activities on water treatment, within the framework of a holistic single case pattern. The study employed the embedded single-case methodology to focus on a single instance where AR and animation-supported STEM activities were considered vital. Thus, students' perspectives on AR and animation-supported STEM activities were solicited, and an attempt was made to shed light on these interlaced concerns concerning the water treatment mechanism and application process.

2.1 Sample

AR and animation-supported STEM activities were carried out with 15 (7 females, 8 males) fourth-grade students from a primary school in the Eastern Black Sea Region in Turkey, selected as a STEM primary school in the second term of the 2020-2021 academic year. Students are between the ages of 9-10 and have participated in STEM activities on different subjects in previous years.

The primary school teacher has 23 years of experience, is skilled in STEM activities, and is eager to put her knowledge into practice. The school is a STEM practice school. Therefore, primary school teachers have a certain level of theory and practice in STEM. The STEM activities were explained to the primary school teacher in detail before the application and discussed. The primary school teacher also examined the applications of animation and AR in STEM activities. The primary school teacher wanted the activities to be done by the researchers since they were technological applications. She said that we could also benefit from the materials in the class regarding the water purification system. Thus, the researchers and the primary school teacher jointly created the materials such as cotton, coal, newspaper, pet bottles, etc. The students were divided into groups of 2-3 people by their primary school teacher, and a total of six groups were formed. The primary school teacher guided the homogeneous distribution and

Mert's Water Treatment System

When Mert awakens in the morning, he goes to the bathroom to wash his hands and face, and when he turns on the bathroom faucet, he notices a difference in the color of the water. As the water continues to flow, it becomes completely cloudy. As a result, Mert believes he is late for school and arrives without washing his hands and face. When he walks into the classroom, his teacher notices Mert is sleepy and thoughtful, and he asks.

Teacher: Mert, did you sleep late last night?
Mert: Not at all, teacher. I could not wash my face in the morning because the water was very cloudy when I turned on the faucet.
Teacher: So, children, have you ever had this problem in the morning?
A few students who lived near Mert's house reported having a similar problem. When the teacher returned to the classroom, he said, "You've heard about the problems your friends are having."
So, how can we help them?
What solution can we offer?

Figure 1 Mert's water treatment system dynamism of the groups, was present in the classroom throughout all applications, and allowed students to carry out activities in their natural environment. On the other hand, the primary school teacher preferred that the researchers carry out the application.

2.2 Designing and Creating AR and Animation Supported STEM Activities

This section presents the points to consider when designing the event in detail. Furthermore, a worksheet has been developed so teachers and students can quickly implement AR and animation-supported STEM activities. In the Turkish science lesson curriculum (MNE, 2016), the "Human and Environment" unit is in the 4th grade and is recommended for 6 lesson hours. The outcomes of the "Human and Environment" unit of the Turkish science curriculum (MEB, 2018) are listed as "*F.4.6.1.1. Students pay attention to behaving economically in the use of resources. a. It emphasizes the importance of saving resources such as electricity, water, and food. b. Emphasis is placed on the importance of reuse. F.4.6.1.2. Students realize the importance of resources and recycling necessary for life. Resources such as water, food, and electricity are mentioned*" as examples suitable for daily life situations were investigated in the environment where the students would apply the activity for their outcomes. Within the scope of the researched examples, a context related to water treatment was chosen because of the importance of water awareness, saving water, and decreasing water resources in our daily lives. When selecting this context, consideration was given to the fact that it is a problematic situation encountered in everyday life.

When determining the problem, the researchers' prepared story titled "Mert's Water Treatment System" is intended to be given to the students as a problematic case. Therefore, the relevant story is depicted in Figure 1.

In the preceding story, students will be asked to assist Mert in setting up a water purification system to purify water. Soil, gravel, coal dust, filter paper, cotton, fine cloth, newspaper, funnel, water, pet bottle, plastic container, scissors, and towel paper are required for a water treatment setup.

At the stage of presenting solutions to the problem situation, consideration has been given to the criteria, limitations, and multiple solutions of the water treatment system they are expected to design and the ability to test it. However, because testing the given problem situation in real life is impossible, the criteria and limitations are given in accordance with the prototype they can apply in the classroom. Similar applications can also be found in the literature (Hacıoğlu, 2020). The design, which allows for the clean treatment of contaminated water, is structured as an engineering design problem. Therefore, the criteria and limitations of the prototype they designed for solving the students' problems are also included. It was also noted that the given problem has multiple solutions and that the solutions can be tested. Furthermore, it is hoped that they will require engineering design skills that demonstrate science and design abilities while solving the problem. For this, instructions have been created on the worksheet.

Students are given opportunities to use the discipline of mathematics while creating and testing the prototype they create for the problem solution. For example, students are expected to generate the amount of balanced cotton or coal dust used and increase or decrease the amounts after testing the setup and using mathematical modeling. Students are also expected to test and evaluate the setup. Here, they are allowed to evaluate the instructions and mechanisms in the 7th section of the worksheet.

2.3 Implementation

The implementation was carried out in 6 lesson hours (2 * 3 weeks) as recommended in the curriculum by the researchers.

Problem identification (1 lesson hour)

The students were shown Mert's One Day Animation-I, prepared by the researchers, during the first stage of the lesson. This animation was created with the Vyond application ("VYOND", 2022), which allows users of all skill levels to create animations. Mert's mistakes in using resources such as water, electricity, and food in his environment are depicted in the animation. Figure 2 contains animation sample screenshots. In addition, incorrect behaviors are depicted in the images with an arrow.

Figure 2 Sample screenshots of Mert's One Day Animation-I

Following the viewing of the relevant animation, the students discussed animation. Then, the students attempted to identify incorrect behaviors in the animation. Unfortunately, researchers have not provided any scientific guidance in this case. Following that, the researchers attempted to determine/define the problem situation by reading the story titled Mert's Water Treatment System (Figure 1).

Presenting potential solutions and determining the best solution (1 lesson hour)

At this point, students were introduced to the materials needed for the water purification system and brought to the classroom. Figure 3 shows a sample image from related materials.

Figure 3 Example materials required for a water treatment setup

The students arrived at the material table in groups formed by the primary school teachers, examined the materials, and designed by debating the suggestions and the best solution for the proposal. The students were asked to draw the relevant suggestions for the mechanism in the third section of the worksheet.

Water treatment system design, testing, and revision (2 lesson hours)

The students attempted to make the two-dimensional mechanisms they designed for the solution proposals in their worksheets testable in three dimensions. Figure 4 contains sample images of the mechanisms created by the students

Figure 4 Sample images of the prepared water treatment system

Water treatment system presentation (1 lesson hour)

Students were asked to present the water purification systems they created. During the presentation, they were questioned about how they used science, mathematics, and engineering knowledge and skills in the design of the mechanism and how they used this knowledge.

Process evaluation (1-course hour)

Mert's One Day Animation-II was shown after the student presentations. This animation was also created with the Vyond application, which allows users of all skill levels to create animations. Mert's mistakes in using resources such as water, electricity, and food in his environment are corrected in the animation. Sample screenshots of the animation are included in Figure 5.

Figure 5 Sample screenshots of Mert's One Day Animation-II

Following the viewing of the relevant animation, the students discussed animation. A comparison with Animation-I has been made. Following that, the proper and efficient use of resources such as water, food, and electricity, as well as recycling and being a conscious consumer, were discussed. Next, students were instructed to draw pictures depicting the subject or concept/concepts they learned during these activities. Students were given empty frames that could be used for free on QuiverVision 3D Augmented Reality coloring apps, and they were asked to draw pictures on them. This app provides high-quality Augmented Reality (AR) experiences by combining amazing 3D graphics and digital technologies. Combining traditional coloring and cutting-edge technology helps to make learning fun and exciting for people of all ages. Quiver uses augmented reality to bring drawing or coloring pages to life in 3D animation ("QuiverVision", 2022). Figure 6 includes sample images of students making their two-dimensional drawings three-dimensional, viewing, and coloring them. Following the visualization of the students'

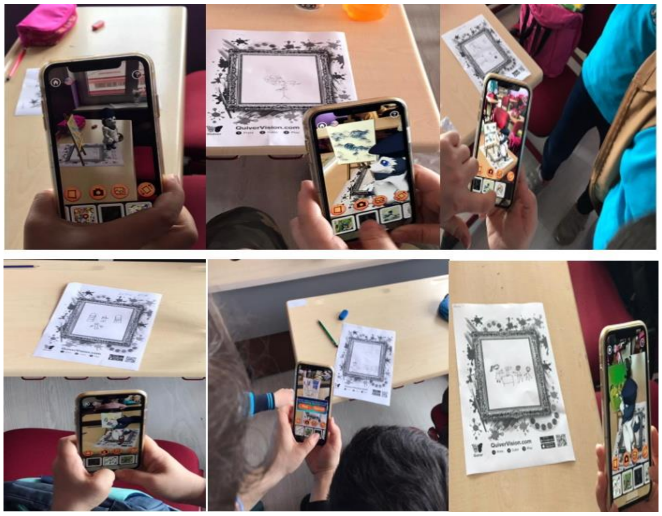

Figure 6 Sample images of 3D displays of students' drawings

drawings in 3D, the implementation was completed using data collection tools.

2.4 Data Collection Tools

As data collection tools in the study, the Know-Want-Learned (KWL) chart, and the Application General Evaluation Form, which consists of eight open-ended questions developed by the researchers, were used. The Application General Evaluation Form includes questions about what students learned, their struggles, the water purification system they designed, activities, and the learning environment they experienced during the activation process. During the development of this form, the perspectives of two science educators with experience in STEM activities were solicited. The application general evaluation form was finalized after receiving feedback from the relevant experts.

2.5 Data Analysis

The information gathered from the data collection tools was analyzed using content analysis. The basic process in content analysis is to collect similar data within the framework of specific concepts and themes, then organize and interpret it so the reader can understand (Bauer, 2003). Both researchers thoroughly examined the data during the data analysis process and created appropriate codes. The codes created were combined based on their similarities and differences, and subcategories/categories were determined by grouping the codes under different headings. The themes were reached through the created categories and continued until the themes were fixed. The percentage of compliance was calculated by Miles and Huberman (1994) with the percentage of agreement formula (% of agreement = [agreement/disagreement + agreement] * 100) as .89 was founded to determine the reliability of the study.

2.6 Ethics in the study

Within the bounds of ethical principles, the researchers personally followed the application process. Data was collected at every study stage, following the principles of follow-up and respect for people. The study did not include private conversations between researchers and students during the data collection due to privacy and confidentiality concerns (Drew, Hardman, & Hart, 1996). Furthermore, the students were informed that some demographic information would be shared with the readers, and their permission was obtained. To ensure confidentiality, students who participated in the data collection process within the research ethics framework were coded as S1, S2, S3,..., S15.

3. RESULT AND DISCUSSION

The results of the first study question are shown in Table 1: "What are the students' opinions on what they

Table 1 The results of the KWL chart

Know	*f*	Want	*f*	Learn	*f*
Conscious consumers (S1, S3, S4, S5, S9, S10, S12, -, 15)	10	Recycling (S7, S8, S10, S11, S12, S15)	6	How we should clean the water (S1, S2, S3, S4, S5, S6, S7, S8, S9, S10, S11, S12, S13, S14)	14
Saving and recycling (S5, S6, S7, S8, S9, S10, S11, S12, S13, S15)	10	How to be a conscious consumer (S5, S6, S7, S8)	4	How to be a conscious consumer (S1, S4, S5, S8, S11, S12, S13, S15)	8
Environment concept (S2, S8, S9, S11, S12)	5	Saving (S2, S3, S5, S8)	4	The importance of saving (S1, S2, S6, S11, S12)	5
		The importance of the environment (S4, S6, S8, S12)	4	Recycling (S4, S7, S13, S15)	4
		The consequences of human impact on the environment (S4, S6, S9, S13)	4		
		How to get drinking water from seawater (S9)	1		
		What is inside the soil? (S1)	1		
		Technology (S1)	1		

know about the topic, what they want to learn, and what they learned at the end of the AR and Animation-supported STEM Activities?"

As seen in Table 1, the first column shows what students know about the topic, and the students said that they know some knowledge about "conscious consumers (10), saving and recycling (10) and environment concept (5)."

The second column shows what students want to learn. Furthermore, students said that they want to learn about "recycling (6), some said how to be a conscious customer (4), saving (4), the importance of the environment (4), how to get drinking water from seawater (1), what is inside soil (1) and technology (1)".

The third column shows what students learned at the end of the AR and animation-supported STEM Activities. For example, Al Students said that they learned about "how we should clean the water (14), how to be a conscious consumer (8), the importance of saving (5), and recycling (4)".

The results of the second and third study questions are shown in Table 2: "What are the students' opinions about Augmented reality and animation-supported STEM activities" and "What are the students' opinions about the water treatment system they designed?". Table 2 summarizes the students' answers to The Application General Evaluation Form.

As seen from Table 2, the students were asked eight questions. Some questions (1, 2, 3, 8) were about the students' general thoughts on AR and animation-supported STEM activities, while others (4, 5, 6, 7) were about the water treatment system project.

Students said active participation (9) and fun (7) during AR and animation supported-STEM activities. Furthermore, they said that "positively affected (12), enjoyable (5) and exciting (4) your motivation towards the lesson. Moreover, they indicated that these STEM activities were enjoyable (8) and lovely (8). In general, positive feelings appeared in students' minds.

The student said that she/he paid attention to the "filtration method (11)" while designing his/her water treatment system project. Besides, they indicated that "separation of dirty water (4) and while setting up the mechanism in the filtration method (4)" had trouble learning with their your project. Moreover, they said that they were "very pleased (14), clean water from dirty water made me happy (9) and enjoyable (2)," satisfied with the project they prepared. They indicated that they "improve the separation mechanism (5), obtain different dirty water (4), and obtain potable water (3)" to prepare it again.

Table 2 The results of the application general evaluation form

1. Explain whether you feel active or not, along with the reason during this STEM activity.			
Codes	*f*	Codes	*f*
Active participation (S3, S4, S5, S7, S8, S9, S11, S12, S13)	9	Intriguing (S1)	1
Funny (S1, S2, S4, S6, S10, S14, S15)	7	Exciting (S3)	1
Experiment (S6, S7, S13)	3	Creative (S8)	1
Instructive (S2, S10)	2		
2. Would you like to use applications similar to this STEM activity in your different courses? Explain.			
Codes	*f*	Codes	*f*
Yes (S1, S2, S3, S4, S5, S6, S8, S9, S10, S11, S12, S13, S14)	13	No (S15)	1
Enjoyable (S1, S5, S6, S8, S11, S13, S14)	7	It takes too much time (S15)	1
I wish that all courses were taught through experiments (S4, S9)	2		
In all courses (S7, S12)	2		
In Mathematics and Turkish (S2)	1		
In science courses (S10)	1		
Active participation (S12)	1		
3. How do you think this STEM activity affected your motivation toward the lesson? Explain.			
Codes	*f*	Codes	*f*
Positively affected (S1, S4, S5, S6, S7, S8, S9, S10, S11, S12, S13, S15)	12	Carefully listened (S2)	1
Enjoyable (S4, S5, S7, S11, S15)	5	Instructive (S11)	1
Exciting (S1, S2, S3, S10)	4	Experiments (S12)	1
Eager to learn (S6, S13)	2		
Happy (S8, S10)	2		
Learning with playing (S4)	1		
4. What did you pay attention to while designing your project during the activity?			
Codes	*f*	Codes	*f*
Filtration method (S1, S2, S4, S5, S6, S7, S8, S9, S10, S12, S15)	11	Everything (S3)	1
The weight of water (S1)	1	Acting with thoughts (S11)	1
Experiment (S13)	1		

Table 2 The results of the application general evaluation form (*continued*)

5. What were you having trouble learning with your project?			
Codes	*f*	Codes	*f*
No trouble (S3, S4, S5, S6, S7, S8, S11)	7	While setting up the mechanism in the filtration method (S1, S12, S13, S15)	4
Separation of dirty water (S2, S9, S10, S14)	4		
6. Are you satisfied with the project you prepared?			
Codes	*f*	Codes	*f*
Very pleased (S2, S3, S4, S5, S6, S7, S8, S9, S10, S11, S12, S13, S14, S15)	14	Enjoyable (S5, S7)	2
Clean water from dirty water made me happy (S1, S6, S8, S9, S10, S12, S13, S14, S15)	9		
7. If you had the chance to prepare it again, what would you like to change in your new project?			
Codes	*f*	Codes	*f*
Improve the separation mechanism (S3, S5, S6, S7, S15)	5	Nothing (S1, S4)	2
Different dirty water (S2, S8, S11, S14)	4	More fast system (S9)	1
Obtaining potable water (S10, S12, S13)	3		
8. What do you think about these STEM activities in general? Explain in detail.			
Codes	*f*	Codes	*f*
Enjoyable (S1, S2, S4, S6, S8, S9, S11, S15)	8	Difficult (S2)	1
Lovely (S1, S3, S5, S7, S10, S12, S14, S15)	8	A useful project in daily life (S13)	1
Instructive (S8, S9, S11)	3	Improve social skills (S5)	1
Improve motivation (S6, S9)	2		
Exciting (S10)	1		

Figure 7 Opinions about the AR and animation-supported STEM Activities

Figure 8 Opinions on the water treatment system

Two figures are created from the codes to get a clearer picture. The first figure summarizes student opinions on STEM activities in general (Figure 7), while the second summarizes student opinions on water treatment systems (Figure 8). These figures are made with Word Art (“WordArt”, 2022).

As summarized in Figure 7, students have positive feelings and opinions about the AR and animation-supported STEM activities. For example, an S2-coded student stated, "I did the activity feeling excited and happy." An S4-coded student stated, "I felt active myself, so it was enjoyable." Finally, an S6-coded student stated, "The activities directed us to learn, and we learned while having fun."

As can be seen in Figure 8, the majority of them were happy to be able to get clean water from dirty water. For example, the S15 code student stated, "To obtain crystal clear water from dark water was impressive." S10, S12, and S13 coded students stated, "If we had the opportunity to change something in our projects, we would change it to obtain potable water because the water in this activity could not be consumed due to the presence of microscopic bacteria." Some students added a lot of coal dust to get dirty water, so it was challenging to get clear water for them. Therefore, S2, S8, S11, and S14 stated, "If we had the opportunity to change something in our projects, we would form a different dirty water."

The findings from the KWL chart showed that the majority of the students stated that they were aware of conscious consumers (f = 10) and saving and recycling (f = 10) and that they wanted to learn more about recycling (see Table 1). The students stated at the end of the application that they learned how to clean the water and to be a conscientious consumers. Most students (f = 9, see Table 2) stated that they actively participated in AR and animation-supported STEM activities and found them entertaining (f = 7, see Table 2). This situation may be related to the student's active participation in the process and their design of suitable products for potential solutions. Hacıoğlu and Dönmez Usta (2020), in their research on digital game design-based STEM activities, stated that working as engineers to solve the problem situation and designing appropriate products aided the students' more active involvement in the process. In his study, Morrison (2006) stated that STEM education allows learners to learn subjects or concepts more cheerfully and entertainingly. Dönmez (2017) discovered that students enjoyed the activities in his study on robotic tournaments within STEM education. According to Ensari (2017) 's research, the lessons are more enjoyable with STEM activities, and the subjects/concepts become more understandable with these activities requiring active participation. Similarly, Pekbay (2017) discovered that students enjoy STEM activities and learn science concepts through group work. In this context, the findings of the literature support the study's findings.

Almost all of the study's students (f = 13) expressed a desire to use AR and animation-supported STEM activities in various lessons. Students can gain knowledge in various areas by combining design, experimenting, analyzing, interpreting, and natural phenomena with STEM activities (Wang, 2012). It is claimed that science and mathematics lessons are rich in content and that technology material such as AR and animation make them more interesting for students (Schaefer, Sullivan, & Yowell, 2003). Besides, teaching materials by integrating teaching materials with STEM, it is expected that student learning motivation will increase. Teaching materials with STEM require text, graphics, animation, simulation, and video because the use of STEM-integrated teaching materials also can improve students' thinking skills (Zahara, Abdurrahman, Herlina, Widyanti, & Agustiana, 2021).

Moreover, it can be said that teaching materials and environments containing AR technology contribute positively to students' learning. Sobrino, Vallejo, Morcillo, Redondo, & Schez (2020) found that AR-supported learning material positively affects the student's motivation in learning environments. This could have stemmed from students' intense interest in AR, which positively affects their motivation and increases their desire to learn. This study found that AR and animation technology-supported STEM activities brought together more than one discipline in an interconnected way by contributing to students' knowledge in various fields and their thinking skills. Moreover, it was determined that animation-based teaching materials prepared using AR technology increase students' interest and motivation in the subject and their use in lessons that include teaching problem-solving skills, such as mathematics, physics, and chemistry in literature (Cevahir, Özdemir, & Baturay 2022). This situation may be related to the students' desire to use activities similar to those used in different lessons within the scope of the study. Most students (f = 12) reported that AR and animation-supported STEM activities increased their motivation for the lesson. STEM education has increased students' interest and motivation in science classes (Green, 2012; Kang, Ju, & Jang, 2013; Park & Yoo, 2013; Yamak, Bulut, & Dündar, 2014). It is stated that science-based STEM education can be a helpful pedagogy for teaching students science and creating excitement and motivation for them to learn science (Siew, Amir, & Chong, 2015). In many studies in which students view the use of animation in science lessons, a positive relationship was found between students' use of animation and their attitude towards technology, and their knowledge transfer and motivation towards science and technology lessons (Rosen, 2009; Önal & Söndür, 2017). In this context, it is clear that AR and animation-supported STEM activities positively impact students' motivation. Furthermore, it is believed that there is a directly proportional relationship between students' motivations and their active participation in the process and creating ideas and products consistent with these ideas.

When designing the water purification system in AR and animation-supported STEM activities, students stated that they focus primarily on the filtration method (f = 11). This situation can be explained by the fact that students with AR and animation-supported STEM education will create a goal not only as a way of learning but also with an attitude toward science (Douglas & Strobel, 2015).

STEM activities encourage students to learn, research, and ask questions about potential and existing problems (Tabaru, 2017). In this regard, the problem encountered in Mert's Water Treatment System story is a situation that anyone can face in everyday life. To solve Mert's problem, students divided into groups and designed various water purification systems. In view of Akgündüz and Akpnar (2018), the product design stage in students' STEM activities is the most challenging stage. Separation of dirty water and setting up the mechanism in the filtration method as the point at which some students (f = 4) have difficulty in the activity is consistent with the literature in this study. The fact that some of the students (f = 7) also stated that they had no trouble can be explained by their familiarity and experience with STEM activities. The

STEM school was chosen from the school where the application was submitted. As a result, the fact that students are used to and experienced in STEM activities helps to explain why some students do not struggle with design. At this point, it is possible to state that the study improves problem-solving and solution-generation skills by supplementing the students' experiences. Specifically, the students stated that they would like to improve the separation mechanism, and different dirty water is allowed to design products. In this case, it indicates that students' ability to solve problems encountered in everyday life has improved. It is claimed that STEM activities help students become aware of real-world problems, as well as their knowledge and skills (Kanadlı, 2019), generate solutions (Roberts, 2012; Ültay et al., 2020), and contribute to problem-solving abilities (Barak & Doppelt, 2000). According to Fortus, Dershimer, Krajcik, Marx, and Mamlok-Naaman (2004), science education practices and engineering design activities should be used to help students develop skills such as problem-solving and solution generation. By incorporating engineering design activities into science education applications, this study added to the body of knowledge.

Almost all students (f = 14) expressed satisfaction with the devised water purification system. Furthermore, using the purification devices they created, the students obtained clean water from dirty water and were relieved that they had found a solution to the problem. Furthermore, Uyar, Canpolat, and Şan (2021) found that students were very satisfied with the STEMactivities, which made the lesson fun and allowed for active participation, in a study in which they examined the opinions of teachers and students in the STEM center on STEM education. These findings corroborate ours. Namely, students stated that they provide active participation in AR and animation supported-STEM activities and that they find it funny. Furthermore, students' satisfaction with the water treatment system they designed can be attributed to the fact that STEM education is an educational approach that improves students' problem-solving skills (Roberts, 2012) and allows the transformation of remaining knowledge into products, applications, and discoveries (TÜSİAD, 2014, p.16).

The students responded to the question of what they would change if they had the opportunity to re-prepare the water purification systems by saying they would improve the separation mechanism (f = 5), use different dirty water (f = 4), and obtain potable water (f = 3). These answers are related to students' ability to examine the problem, find solutions to problems with unique ideas, communicate in group work (Sparkes, 2017), and improve their ability to find solutions to daily life problems (Roberts, 2012). It can also be explained by the fact that AR and animation-supported STEM applications help students develop 21st-century skills by encouraging scientific thinking, imagination, self-expression, and self-confidence (Ültay, Dönmez Usta, & Ültay, 2021; Young, House, Wang, Singleton, & Klopfenstein, 2011).

Students stated that AR and animation-supported STEM activities are generally enjoyable, fun, active participation, exciting, improve motivation, and are so good. In STEM education applications, there is an emphasis on technology and engineering; this allows students to gain a multidisciplinary perspective and put their knowledge into practice (Akgündüz et al., 2015). Due to this situation, STEM is in a crucial position in today's information and technology age. Given the importance of STEM education in a country's ability to lead in science and technology while also becoming economically strong (Lacey & Wright, 2009), it is thought that AR and animation-supported STEM activities should be included more in the lessons so that students can develop different solutions to the daily life problems they encounter and holistically evaluate the events. Painting according to learning objectives in augmented reality applications in education, multimedia materials such as text, audio, 3D objects, 2D or 3D animation, and video can be used together (Wang, Kim, Love, & Kang, 2013). In this study, augmented reality applications were used together with animation. Thus, it has contributed to students actively participating and helped to learn to be effective in the learning process.

The students focus on the filtration method, obtaining clear water, obtaining potable water, a different separation system, a different dirty system, and the difficulty in setting up the mechanism. These points of view are consistent with the students' status as members of Generation Z. Since this generation grew up with the Internet, it is a generation that can quickly access information, is tech-savvy, does not adhere to formalities, learns quickly, and embraces diversity (Twenge, Campbell, Hoffman, & Lance, 2010). These characteristics, in general, can be said to support their views on the water treatment system.

4. CONCLUSION

Based on the study's findings and the observations of the researchers who were putting the process in place, it was determined that the AR and animation-supported STEM activity is appropriate in acquisition, content, application, active participation, duration, and student level.

Within the scope of the study, it was determined that AR and animation-supported STEM events are enjoyable, humorous, engaging, and exciting. Therefore, the study designed STEM activities with AR and animation support. This activity is a trailblazer in demonstrating how technology such as AR and animation in science education can be integrated with STEM education.

Given that STEM activities should be structured according to at least two disciplines (Pitt, 2009), it is clear that this AR and animation-supported activity employs three to four disciplines. At this point, it appears that three to four disciplines can be carried out in a coordinated manner in STEM activities. The students' water purification system designed and tested is said to meet the learning outcomes.

5. RECOMMENDATION

When the results of the study were evaluated, the following suggestions were made:

Studies should be conducted on developing and implementing AR and animation-supported STEM activities for various subjects and concepts such as traffic lights, substance, and properties, separation methods of substances, intensity, etc.

Studies should be conducted to design and implement studies in which various technologies such as virtual reality and simulation are integrated into STEM activities.

It is recommended in this context to conduct similar studies on different disciplines or concepts. In addition, studies focusing on different sample groups or research methods (such as the experimental method) should be conducted.

REFERENCES

Akgündüz, D., & Akpınar B. B. (2018). Okul öncesi eğitimde fen eğitimi temelinde gerçekleştirilen STEM uygulamalarını öğrenci, öğretmen ve veli açısından değerlendirilmesi [Evaluation of STEM applications based on science education in pre-school education in terms of students, teachers, and parents]. *Journal of Education for Life*, *32*(1), 1-26.

Akgündüz, D., Aydeniz, M., Çakmakçı, G., Çavaş, B., Çorlu, M. S., Öner, T., & Özdemir, S. (2015). *STEM eğitimi Türkiye raporu* [STEM education Turkey report]. İstanbul: Scala Basım.

Barak, M., & Doppelt, Y. (2000). Using portfolios to enhance creative thinking. *Journal of Technology Studies*, *26*(2), 16-25.

Bauer, M. W. (2003). Classical content analysis: A review. In M. W. Bauer & G. Gaskell (Eds.), *Qualitative researching with text, image and sound* (pp.131). London: Sage Publication.

Benli Özdemir, E. (2021). Views of science teachers about online STEM practices during the COVID-19 period. *International Journal of Curriculum and Instruction*, *13*(1), 854-869.

Buluş-Kırıkkaya, E. & Şentürk, M. (2018). The Impact of Using Augmented Reality Technology in The Solar System and Beyond Unit on The Academic Achievement of The Students. *Kastamonu Education Journal*, *26*(1), 181-189.

Cai, S., Liu, C., Wang, T., Liu, E., & Liang, J. C. (2021). Effects of learning physics using augmented reality on students' self-efficacy and conceptions of learning. *British Journal of Educational Technology*, *52*(1), 235–251.

Cevahir, H., Özdemir, M., & Baturay, M. H. (2022). The Effect of Animation-Based Worked Examples Supported with Augmented Reality on the Academic Achievement, Attitude and Motivation of Students towards Learning Programming. *Participatory Educational Research*, *9*(3), 226-247.

Ceylan, S. (2014). *A study for preparing an instructional design based on science, technology, engineering, and mathematics (STEM) approach on the topic of acids and bases at secondary school science course.* (Unpublished Master Dissertation). Uludağ University, Bursa.

Chen, Y. L., Huang, L. F., & Wu, P. C. (2021). Preservice pre-school teachers" self-efficacy in and need for STEM education professional development: stem pedagogical belief as a mediator. *Early Childhood Education Journal*, *49*(2), 137-147.

Creswell, J. W., Plano Clark, V. L., Gutmann, M. L., & Hanson, W. E. (2003). Advanced mixed methods research designs. *Handbook of mixed methods in social and behavioral research*, 209-240.

Cotabish, A. Dailey, D., Robinson, A., & Hughes, G. (2013). The effects of a STEM intervention on elementary students" science knowledge and skills. *School science and Mathematics*, *113*(5), 215-226.

Daşdemir, İ., & Doymuş, K. (2012). The effect of using animation on primary science and technology course students' academic achievement, retention of knowledge and scientific process skills. *Pegem Journal of Education and Instruction*, *2*(3), 33-42.

Dönmez, I. (2017). The views of students and team coaches about robotic competitions on the STEM education framework (Case of first Lego league). *Journal of Research in Education, Science and Technology*, *2*(1), 25-42.

Douglas, K. A., & Strobel, J. (2015). Hopes and goals survey for use in STEM elementary education. *International Journal of Technology and Design Education*, *25*(2), 245-259.

Drew, C. J., Hardman, M. L., & Hart, A. W. (1996). *Designing and conducting research: Inquiry in education and social science (2nd Ed.).* Boston: Allyn and Bacon.

Ensari, Ö. (2017). *Pre-service Teachers' Views on STEM Education and STEM activities.* (Unpublished Master Dissertation). Yüzüncü Yıl University, Van.

Fortus, D., Dershimer, R. C., Krajcik, J., Marx, R. W., & Mamlok-Naaman, R. (2004). Design-based science and student learning. *Journal of Research in Science Teaching*, *41*(10), 1081-1110.

Gonzalez, H. B., & Kuenzi, J. J. (2012). Science, technology, engineering and mathematics (stem) education: a primer. Library of Congress. Congressional Research Service. Retrieved from https://fas.org/sgp/crs/misc/R42642.pdf Access date: 08.04.2021.

Green, A., (2012). *The integration of engineering design projects into the secondary science classroom.* (Unpublished Master Dissertation). Michigan State University, Michigan.

Hacıoğlu, Y. (2020). 'Implementation of Thematic STEM Education: Friction Force Example. *Boğaziçi University Journal of Education*, *37*, 3-21.

Hacıoğlu, Y., & Dönmez-Usta, N. (2020). Digital game design-based STEM activity: Biodiversity example. *Science Activities*, *57*(1), 1-15.

Hackman, S. T., Zhang, D., & He, J. (2021). Secondary school science teachers" attitudes towards STEM education in Liberia. *International Journal of Science Education*, *43*(2), 1-24.

Hwang, G. J., Wu, P. H., Chen, C. C., & Tu, N. T. (2016). Effects of an augmented reality-based educational game on students' learning achievements and attitudes in real-world observations. *Interactive Learning Environments*, *24*(8), 1895–1906. https://doi.org/10.1080/10494820.2015.1057747

Hiğde, E. (2018). *The Investigation of the effect of the STEM activities prepared for 7th class students in terms of different variables.* (Unpublished doctoral dissertation). Aydın Adnan Menderes University.

Hsu, Y. S., Lin, Y. H., & Yang, B. (2017). Impact of augmented reality lessons on students' STEM interest. R*esearch and Practice In Technology Enhanced Learning*, *12*(1), 1-14.

Kanadlı, S. (2019). A Meta-summary of qualitative findings about STEM education. *International Journal of Instruction*, *12*(1), 959-976.

Kang, J., Ju, E. J., & Jang, S., (2013). The effect of science-based STEAM program using a portfolio on elementary students' formation of science concepts. *Elementary Science Education*, *32*(4), 593-606.

Karahan, E., Canbazoğlu Bilici, S., & Ünal, A. (2015). The integration media design processes in STEM education. *Eurasia Journal of Educational Research*, *15*(60), 221-240.

Kennedy, T., & Odell, M. (2014). Engaging students in STEM education. *Science Education International*, *25*(3), 246-258.

Kong, Y. T., & Huo, S. C., (2014). An effect of STEAM activity programs on science learning interest. *Advanced Science and Technology Letters*, *59*, 41-45.

Lacey, T. A., & Wright, B. (2009). Employment outlook: 2008-18-occupational employment projections to 2018. *Monthly Lab. Rev.*, *132*, 82.

Lantz, H. B. (2009). Science, technology, engineering, and mathematics (STEM) education what form? What function? *Report, CurrTech Integrations*, Baltimore.

Lowe, R. K. (2003). Animation and learning: Selective processing of information in dynamic graphics. *Learning and Instruction*, *13*(2), 157-176.

Marek, M. W., Chew, C. S., & Wu, W. C. V. (2021). Teacher experiences in converting classes to distance learning in the COVID-19 pandemic. *International Journal of Distance Education Technologies (IJDET)*, *19*(1), 40-60.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook*. Sage.

Milli Eğitim Bakanlığı (MEB). (2018). *Fen Bilimleri Dersi Öğretim Programı (İlkokul ve ortaokul 3, 4, 5, 6, 7 ve 8. Sınıflar* [Science Cirriculum: Elementary and middle schools 3,4,5,6,7 and 8th grades.]. Ankara, Turkey: Talim Terbiye Kurulu Başkanlığı https://mufredat.meb.gov.tr/ProgramDetay.aspx?PID=325

Ministry of National Education (MNE). (2016). *STEM education report*. From http://yegitek.meb.gov.tr/STEM_Egitimi_Raporu.pdf Access date: 31.12.2017.

Moore, T. J., Stohlmann, M. S., Wang, H. H., Tank, K. M., Glancy, A. W., & Roehrig, G. H. (2014). Implementation and integration of engineering in K–12 STEM education. In, S. Purser, J. Strobel, & M. Cardella (eds.), *Engineering in Precollege Settings: Research into Practice* (pp. 35-60). West Lafayette, IN: Purdue University Press.

Morrison, J. (2006). Attributes of STEM education: The student, the school, the classroom. *TIES (Teaching Institute for Excellence in STEM)*, *20*, 2-7.

Ormanci, Ü. (2020). Thematic content analysis of doctoral theses in STEM education: Turkey context. *Journal of Turkish Science Education*, *17*(1), 126-146.

Önal, N. T., & Söndür, D. G. (2017). I like technology usage in lessons and animations in science!. *The Journal of Academic Science Studies*, (55), 97-118.

Park, S. J., & Yoo, P. K. (2013). The Effects of the learning motive, interest and science process skills using the "Light" unit in science-based STEAM. *Elementary Science Education*, *32*(3), 225-238.

Partnership for 21st Century Learning (P21). (2007). *Framework for 21st century*.

Pekbay, C. (2017). *Effects of science technology engineering and mathematics activities on middle school students.* (Unpublished Doctoral Dissertation). Hacettepe University, Ankara.

Phon, D. N. E., Ali, M. B., & Halim, N. D. A. (2015). Learning with augmented reality: Effects toward student with different spatial abilities. *Advanced Science Letters*, *21*(7), 2200–2204.

Pitt, J. (2009). Blurring the boundaries STEM education and education for sustainable development. *Design and Technology Education: An International Journal*, *14*(1), 37–48.

Powell, J. V., Aeby Jr, V. G., & Carpenter-Aeby, T. (2003). A comparison of student outcomes with and without teacher facilitated computer-based instruction. *Computers & Education*, *40*(2), 183-191.

QuiverVision. (2022). Retrieved from https://quivervision.com/

Roberts, A. (2012). A justification for STEM education. *Technology and engineering teacher*, *71*(8), 1-4.

Rosen, Y. (2009). The effects of an animation-based on-line learning environment on transfer of knowledge and on motivation for science and technology learning. *Journal of Educational Computing Research*, *40*(4), 451-467. https://doi.org/10.2190/ec.40.4.d

Sarica, R. (2020). Analysis of postgraduate theses related to stem education in turkey: a meta-synthesis study. *Acta Didactica Napocensia*, *13*(2), 1-29.

Sırakaya, M., & Alsancak-Sırakaya, D. (2020). Augmented reality in STEM education: a systematic review. *Interactive Learning Environments*, 1-14.

Sarnita, F., Fitriani, A., Utama, J. A., & Suwarma, I. R. (2021, March). Application of STEM-based online learning to train creative skills of students in covid-19 pandemic periods. In *Journal of Physics: Conference Series* (Vol. 1806, No. 1, p. 012039). IOP Publishing.

Schaefer, M. R., Sullivan, J. F., & Yowell, J. L. (2003). *Standard-based engineering curricula as a vehicle for K– 12 science and math integration*. Frontiers in Education, 2, 1–5.

Schiavi, B., Havard, V., Beddiar, K., & Baudry, D. (2022). BIM data fow architecture with AR/VR technologies: Use cases in architecture, engineering and construction. *Automation in Construction*, *134*, 104054.

Siew, M. N., Amir, N., & Chong, C. L. (2015). The perceptions of pre-service and in-service teachers regarding a project-based STEM approach to teaching science. *Springer Plus*, *4*(1), 1-20. doi:10.1186/2193-1801-4-8

Sparkes, V. P. (2017). *What is the STEAM?.* Ayrıntı Publishing İstanbul.

Sobrino, S. S., Vallejo, D., Morcillo, C. G., Redondo, M. A., & Schez, J. C. (2020). RoboTIC: A serious game based on augmented reality for learning programming. *Multimedia Tools and Applications*, *79*, 34079–34099. https://doi.org/10.1007/s11042-020-09202- z

Tabaru, G. (2017). *İlkokul 4. sınıf öğrencilerine fen bilimleri dersinde uygulanan STEM temelli etkinliklerin çeşitli değişkenlere etkisi* [Elementary school 4th grade the effects of STEM-based activities applied in science lessons to primary education students in terms of various variables]. (Unpublished master thesis). Niğde Ömer Halisdemir University (In Turkish).

Tseng, K. H., Chang, C. C., Lou, S. J., & Chen, W. P. (2013). Attitudes towards Science, Technology, Engineering and Mathematics (STEM) in a Project-Based Learning (PJBL) Environment. *International Journal of Technology and Design Education*, *23*(1), 87-102.

Turan-Güntepe, E., & Dönmez-Usta, N. (2021). Augmented Reality Application based Teaching Material's Effect on Viscera Learning Through Algorithmic Thinking. *Journal of Science Learning, 4*(4), 365-375.

TÜSİAD. (2014). *STEM (Science, Technology, Engineering and Mathematics, Fen, Teknoloji, Mühendislik, Matematik) alanında eğitim almış iş gücüne yönelik talep ve beklentiler araştırması* [For the STEM-trained workforce demand and expectations research]. https://tusiad.org/tr/yayinlar/raporlar/item/8054-stem-alaninda-egitim-almis-isgucune-yonelik-talep-vebeklentiler-arastirmasi

Twenge, J. M., Campbell, S. M., Hoffman, B. J., & Lance, C. E. (2010). Generational differences in work values: Leisure and extrinsic value increasing, social and intrinsic values decreasing. *Journal of Management*, *36*(5), 1117-1142. Doi: 10.1177/0149206309352246.

Ültay, E., Balaban, S., & Ültay, N. (2021). Content analysis of the studies examining the teachers' and pre-service teachers' views on STEM education. *Turkish Journal of Primary Education*, *6*(2), 109-125. DOI: 10.52797/tujped.953385

Ültay, N., Dönmez Usta, N., & Ültay, E. (2021). Descriptive content analysis of studies on 21st century skills . *SDU International Journal of Educational Studies*, *8*(2), 85-101. DOI: 10.33710/sduijes.895160

Ültay, N., Zıvalı, A., Yılmaz, H., Bak, H. K., Yılmaz, K., Topatan, M., & Kara, P. G. (2020). STEM-Focused Activities to Support Student Learning in Primary School Science. *Journal of Science Learning*, *3*(3), 156-164. DOI: 10.17509/jsl.v3i3.23705

Uştu, H. (2019). *Preparing and implementing successful STEM/STEAM activities in primary schools: A participatory action research with primary school teachers.* (Unpublished Doctoral Dissertation). Necmettin Erbakan University, Turkey.

Uyar, A., Canpolat, M., & Şan. İ. (2021) Views of Teachers and Students in Stem Center on STEM Education: The Sample of PayaSTEM Center". *MANAS Journal of Social Studies*, *10*(1), 151-170.

VYOND. (2022). Retrieved from https://www.vyond.com/

Wang, H. H. (2012). *A new era of science education: Science teachers' perceptions and classroom practices of science, technology, engineering, and mathematics (STEM) integration*. University of Minnesota.

Wang, X., Kim, M. J., Love, P. E., & Kang, S. C. (2013). Augmented reality in built environment: classification and implications for future research. *Automation in construction*, *32*, 1-13.

WordArt. (2022). Retrieved from https://wordart.com/

Wu, P. H., Hwang, G. J., Yang, M. L., & Chen, C. H. (2018). Impacts of integrating the repertory grid into an augmented reality-based learning design on students' learning achievements, cognitive load and degree of satisfaction. *Interactive Learning Environments*, *26*(2), 221–234.

Yamak, H., Bulut, N., & Dündar, S. (2014). The Impact of STEM Activities on 5th Grade Students' Scientific Process Skills and Their Attitudes Towards Science. *Gazi University Journal of Gazi Educational Faculty*, *34*(2), 249-265. doi: https://doi.org/10.17152/gefd.15192

Yıldırım, A., & Şimşek, H. (2011). *Qualitative Research Methods in Social Sciences (8th ed.).* Ankara: Seçkin Publishing.

Yin, R. K. (2003). *Case Study Research Design and Methods* (3rd ed.). London: Sage Publications.

Young, V. M., House, A., Wang, H., Singleton, C., & Klopfenstein, K. (2011, May). Inclusive STEM schools: Early promise in Texas and unanswered questions. In *Highly Successful Schools or Programs for K-12 STEM Education: A Workshop. Washington, DC: National Academies* (Vol. 1, p. 2014).

Zahara, M., Abdurrahman, A., Herlina, K., Widyanti, R., & Agustiana, L. (2021, February). Teachers' perceptions of 3D technology-integrated student worksheet on magnetic field material: A preliminary research on augmented reality in STEM learning. In *Journal of Physics: Conference Series* (Vol. 1796, No. 1, p. 012083). IOP Publishing.