GAMIFIED-INTEGRATED STEM: EXPLORING 8TH GRADE STUDENTS' PROBLEM-SOLVING SKILL PERCEPTIONS AND CRITICAL THINKING DISPOSITIONS ABOUT GLOBAL CLIMATE CHANGE

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ABSTRACT

GAMIFIED-INTEGRATED STEM: EXPLORING 8TH GRADE STUDENTS' PROBLEM-SOLVING SKILL PERCEPTIONS AND CRITICAL THINKING DISPOSITIONS ABOUT GLOBAL CLIMATE CHANGE

Gamified-integrated STEM is one of the techniques that combines integrated STEM stages with gamification elements and can engage individuals in climate change communication (Rajanen & Rajanen, 2019). The main purpose of this study is to investigate gamified-integrated STEM-based instruction on global climate change causes a significant change in 8th-grade students' perceptions of problem-solving skills, critical thinking dispositions, and climate change views. In this quasi-experimental study, the sample consisted of sixty-nine 8th grade students from a public school in Turkey. Three classes of twenty-three participants each were named as the traditional group, experimental group 1 (integrated STEM group), and experimental group 2 (gamified-integrated STEM group). The data was collected in the 2022-2023 academic year. Problem-solving skill perceptions scale, critical thinking disposition instrument, and interviews were used to examine the research questions. According to the findings of the study, statistically significant differences were found between the pre & post-test scores of both scales in the lessons taught with gamified-integrated STEM instructional design compared to the other groups. When all groups were compared, the highest difference was found between the gamified-integrated STEM group and the control group. In addition, when taking the students' views on global climate change, it was found that the students in the gamified-integrated STEM group had higher levels of hope about global climate change and a desire to take action. The results revealed that gamified-integrated STEM activities on global climate change could be used, especially in subjects considered difficult to learn. It is expected that the results obtained from this research will create an opportunity for improving global climate change education within the scope of gamified-integrated STEM education.

ÖZET

OYUNLAŞTIRILMIŞ BÜTÜNLEŞİK STEM: 8. SINIF ÖĞRENCİLERİNİN KÜRESEL İKLİM DEĞİŞİKLİĞİNE İLİŞKİN PROBLEM ÇÖZME BECERİSİ ALGILARI VE ELEŞTİREL DÜŞÜNME EĞİLİMLERİNİN İNCELENMESİ

Oyunlaştırılmış entegre STEM, entegre STEM aşamalarını oyunlaştırma unsurlarıyla birleştiren ve bireyleri iklim değişikliği iletişimine dahil edebilen tekniklerden biridir (Rajanen ve Rajanen, 2019). Bu çalışmanın temel amacı, küresel iklim değişikliği konusunda oyunlaştırılmış entegre FeTeMM temelli öğretimin 8. sınıf öğrencilerinin problem çözme becerileri, eleştirel düşünme eğilimleri ve iklim değişikliği görüşleri üzerinde anlamlı bir değişime neden olup olmadığını araştırmaktır. Bu yarı deneysel çalışmanın örneklemi, Türkiye'deki bir devlet okulunda öğrenim gören altmış dokuz 8. sınıf öğrencisinden oluşmaktadır. Her biri yirmi üç katılımcıdan oluşan üç sınıf geleneksel grup, deney grubu 1 (entegre STEM grubu) ve deney grubu 2 (oyunlaştırılmış entegre STEM grubu) olarak adlandırılmıştır. Veriler 2022-2023 akademik yılında toplanmıştır. Araştırma sorularını incelemek için problem çözme becerisi algı ölçeği, eleştirel düşünme eğilimi ölçeği ve görüşmeler kullanılmıştır. Çalışmanın bulgularına göre, oyunlaştırılmış entegre STEM öğretim tasarımı ile işlenen derslerde her iki ölçeğin ön ve son test puanları arasında diğer gruplara kıyasla istatistiksel olarak anlamlı farklılıklar bulunmuştur. Tüm gruplar karşılaştırıldığında en yüksek fark oyunlaştırılmış entegre STEM grubu ile kontrol grubu arasında bulunmuştur. Ayrıca, öğrencilerin küresel iklim değişikliğine ilişkin görüşleri alındığında, oyunlaştırılmış entegre STEM grubundaki öğrencilerin küresel iklim değişikliğine ilişkin umut düzeylerinin ve harekete geçme isteklerinin daha yüksek olduğu görülmüştür. Sonuçlar, küresel iklim değişikliği konusunda oyunlaştırılmış-entegre STEM etkinliklerinin özellikle öğrenilmesi zor olduğu düşünülen konularda kullanılabileceğini ortaya koymuştur. Bu araştırmadan elde edilen sonuçların, oyunlaştırılmış-entegre STEM eğitimi kapsamında küresel iklim değişikliği eğitiminin geliştirilmesi için bir fırsat yaratması beklenmektedir.

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LIST OF ACRONYMS/ABBREVIATIONS

OECD	Organization for Economic Co-Operation and Development
STEM	Science, Technology, Engineering, Math
APoKS	Authentic Problem of Knowledge Society
NRC	National Research Council
InTeach	Integrated Teaching
ESA	Entertainment Software Association
NGSS	Next Generation Science Standards
IPCC	Intergovernmental Panel on Climate Change
GCC	Global Climate Change
ÇEİD	Çevre Eğitimi İklim Değişikliği
MoNE	Ministry of National Education

1. INTRODUCTION

Gamified integrated STEM education is a new concept that combines integrated STEM framework with gamification elements and can engage individuals in climate change communication (Rajanen & Rajanen, 2019). Education is to promote long-term and lifelong learning, holistic development, and well-being, and to develop students' skills for sustainable living (Halinen, 2018). The concepts of integrated STEM and gamification, which are tools of education, are effective in students' skill development, whereby students acquire new skills as well as knowledge and use these skills in various aspects of their lives. Skills such as creative thinking, teamwork in multidisciplinary projects, networking, technological skills, and literacy are central to education (Thompson et al., 2018). In this education process, the individuals are responsible for identifying and finding solutions to existing problems, developing a critical perspective, being open to innovation, and creating, producing, and collaborating (Organization for Economic Co-Operation and Development, 2020). Science, technology, engineering, and mathematics (STEM) education (National Research Council, 2011) is a program of integrated education centered on science and mathematics that uses the opportunities provided by technology and engineering design processes to improve students' skills (Capraro et al., 2013). It is advantageous to provide problem-solving and critical thinking skills through STEM education (Asigigan & Samur, 2021; Akgündüz et al., 2015).

In STEM education, students can realize STEM concepts and perform tasks and activities that seem too challenging to overcome in an enjoyable active learning environment (Zaki et al., 2020). Therewithal, educational games, and gamification have become a rapidly developing field in STEM learning (Novia et al., 2021), because bridging what students do outside of school with what they do in the classroom is a critical step in achieving STEM education goals (Annetta et al., 2013). Using gamification, in other words, games and game elements (such as badges, points, rules, stories, teams, collaboration, challenges, rewards, and feedback) in the classroom support learners' holistic understanding of scientific concepts, develop their cognitive function, enhance learning outcomes, and promote intercultural communicative competence (Zhonggen, 2019), all of which promote learners' problem-solving and critical thinking skills.

In the world we live in, one of the most critical socially relevant scientific topics (i.e., socio-scientific issues) that overlap with STEM, that we feel the inevitable effects of, and that needs to be urgently addressed by every citizen in the world is global climate change (Toriz, 2019). However, studies show that teachers are less effective than they could be in educating the next generation about climate change and its causes (Plutzer & Hannah, 2018). If information is still provided with factual, conceptual, encyclopedic, or too much on abstract concepts (Talanquer & Pollard, 2010), students may not understand the connections between concepts and ideas offered when addressing major course topics such as climate change, and instruction may become excessively fragmented (Reid, 2000).

Since traditional methods do not meet the skills of the new generations, whom we call digital natives, it is considered necessary to add some elements that may attract their attention to the lesson and enrich it with STEM content, even for students preparing for the high school entrance exam who are exposed to challenging content (Özkan & Samur, 2017; Vu & Feinsteim, 2017). Gamification is one technique that could engage individuals and diverse stakeholders in climate change communication through interactive, participatory, and meaning-making communication (Rajanen & Rajanen, 2019). Therefore, the current research aims to explore the effects of gamified-integrated STEM instruction about global climate change on 8^{th}-grade middle school students' critical thinking disposition levels, problem-solving skills perceptions, and their views about global climate change.

1.1. The Purpose of the Study

The purpose of the present research is to investigate whether gamified-integrated STEM instruction about global climate change causes a significant change in 8^{th}-grade students' problem-solving skill perceptions and critical thinking disposition levels. The other purpose of this research is to analyze students' views in terms of problem-solving skill perceptions, critical thinking disposition levels, and learning about global climate change.

1.2. The Significance of the Study

It is essential to develop new approaches in education for both teaching and learning because the knowledge accessible in cultures living in the digital age is continuously changing (Çavaş et al., 2004). STEM education is recognized as one of the most effective ways to acquire skills such as creativity, critical thinking, collaborative work, and problem-solving skills, which are also accepted as 21st-century skills (Akgündüz et al., 2015). Well-integrated STEM instruction may engage students towards the lesson and attract their attention, as well as may have a role in increasing their critical thinking levels and developing problem-solving skills, thus may increase the rate of retention of the learning outcomes (Stohlmann et al., 2012). In addition, gamification is one of the effective teaching techniques in education (Novia et al., 2021). Moreover, it is known that students engage in activities and develop skills such as problem-solving, strategic, and creative thinking, and decision-making through games (Orak et al., 2020; Şirinkan & Şirinkan, 2011). In this regard, there is a need for creating an environment where students can develop 21st-century skills, comprehend both daily life problems and global problems such as global climate change, and explore reasonable solutions, as well as benefit from the power of gamification.

The concept of gamified-integrated STEM has currently aroused repercussions on education, and there is a limited number of studies in the literature (Alsawier, 2018; Fiş Erümit, 2016; Şahin, 2015; Taşkın, 2020; Tunga, 2016; Türkan, 2019;). There are some studies that examine the teachers' views about gamification (Bolat et al., 2017; Flores-Aguilar et al., 2023; Hebebci & Usta, 2018; Karaoğlan Yılmaz & Yılmaz, 2019; Kılıçel & Ertaş Kılıç, 2021). Moreover, the research focus on gamification is generally on elementary school students, and some studies investigated students' motivations (Alsawaier, 2018; Asigigan & Samur, 2021; Fantazir, 2020; Hawkins et al., 2019; Hung et al., 2014; Hursen, 2019; Papadakis et al., 2023), academic achievements (Güner, 2018; Hung et al., 2014; Lawton, 2020; Kam & Umar, 2023; Stanley-Yolgeçen, 2018;) critical thinking dispositions and problem-solving skills (Almutairi & Almassaad, 2023; & Asigigan & Samur, 2021; Hermita et al., 2022), engagement (Alsawaier, 2018; Baiden, et al., 2022; Fantazir, 2020; Stanley-Yolgeçen, 2018; Playfoot, 2016; Terrell, 2016), attitudes towards gamification (Ertan, 2020; Türkan, 2019), self-efficacy beliefs (Annetta et al., 2013; Hung et al., 2014), and their views about gamification (An, Y., 2023; Asigigan & Samur, 2021; Bolat et al., 2017; Bozkurt, 2021; Chan & Lo, 2022; Hebebci & Usta, 2018; Hursen, 2019; Juuti & Lavonen, 2006; Karaoğlan Yılmaz & Yılmaz, 2019; Kılıçel & Ertaş Kılıç, 2021; Mert & Samur, 2018; Zhumasheva et al., 2022). However, since there is a gap in the literature in the gamification studies conducted with upper-grade middle school students, there is a need for research on gamification with this grade level (Asigigan & Samur, 2021).

On the other hand, it is unclear how educators can use games and social platforms to implement gamification approaches, as there is no common design framework (Fiş Erümit, 2016). Moreover, climate change gamification can highlight the unseen urgency of the issue, raise awareness of climate change so that today's actions may change the future. Recently, there has been an increase in studies investigating the potential of gamification in the context of climate change, but these are not numerous (Rajanen & Rajanen, 2019). This study is critical because it can be helpful for teachers to enter students' worlds and make their lessons fun to attract the attention of children who see life as a game (Yıldırım, 2018). For these reasons, the results of this study will shed light on the literature about 8^{th}-grade students' critical thinking disposition levels and problem-solving skill perceptions with the help of different instructional designs on global climate change.

1.3. The Research Questions

Considering the purpose of the current study, there were four main research questions that this study aimed to answer.

Research Question 1: Are there any statistically significant differences in 8^{th} grade students' problem-solving skill perceptions and critical thinking dispositions that resulted from interventions?

Research Question 2: Are there any statistically significant differences in 8^{th} grade students' problem-solving skill perceptions and critical thinking dispositions between control and experimental groups?

Research Question 3: How do students express their problem-solving skill perceptions and critical thinking dispositions after the interventions?

Research Question 4: What are the students' views on learning about global climate change through gamified-integrated STEM instruction?

2. LITERATURE REVIEW

Since the purpose of the study was to explore the problem-solving skill perceptions and critical thinking skill dispositions of 8th-grade students with gamified-integrated STEM education, problem-solving, and critical thinking skills were first included in the literature. Then, the connection between integrated STEM education and these skills is mentioned. Since the problems of global climate change and the melting of glaciers were addressed in the research using the gamified-integrated STEM model, the gamified-integrated STEM concepts arising from the combination of gamification and integrated STEM education were explained in detail. Finally, the literature review was completed by incorporating the main issues of the research on global climate change and the melting of glaciers.

2.1. Problem-Solving

A problem is defined as a question raised for inquiry, consideration, or solution in the Merriam-Webster Dictionary (2023). A problem is also defined in the Cambridge Dictionary (2023) as a situation, person or thing that requires attention and needs to be addressed or resolved. When the literature is examined, it is seen that there are different definitions of the problem. For example, Dewey (1997) defined the problem as the thing that occupies the minds of individuals, while Yavuz et al. (2010) defined it as the difficulties people face. According to Dörnyei (1995), a problem has three meanings which are the undesirable initial state of the current situation and the prospective future expectation, a desirable state of how the future should look, and an obstacle that prevents today's undesirable situation from turning into a desired one. According to these definitions, a problem can be anything that does not fit into the generally accepted body of knowledge. Thus, the problem originates as a relational concept; it is based on a question we ask about a difficulty we confront, a series of events that need to be resolved, or a connection between two or more statements (Schmidt et al., 2011).

Problem-solving is the process or act of finding a solution to a problem. Problem-solving is an inevitable aspect of human life and is critical for survival (Mayer, 2013; Tambychik & Meerah, 2010). Problem-solving is also referred to as 21st-century skills (Güven & Alpaslan, 2022). 21st-century skills include the abilities and learning tendencies, literacy, and competencies that educators, academics, and government have collectively created to succeed and meet the needs of 21st-century societies (Gonzalez-Perez & Montoya, 2022). Skills that enable individuals to be effective and productive have made knowledge for solving a problem applicable (Dede, 2010). Problem-solving is a complex concept and process. The underdetermination of the concept of the problem is shown by Karl Popper's statement as cited in the article of Schmidt (2011) that life is a constant problem-solving (Popper, 2000).

One of the most important tools in gaining skills is education (Gonzalez-Perez & Montoya, 2022). School is one of the areas where problems are encountered, and students are expected to develop these skills at school. Therefore, problem-solving is one of the most crucial skills required of students in all areas of learning and accomplishment, including both in-school and out-of-school learning and achievement (Rahman, 2019). Problem-solving can also be expressed as a cognitive process that aims to solve a problem that students have encountered for the first time or have not thought about deeply before and find solutions to this problem (Haladyna, 1997). Students with problem-solving skills should be able to ask and clarify fundamental questions in both traditional and new approaches, explain different perspectives, develop better answers to all kinds of unknown situations, and make successful and inventive use of what they know throughout their lives (Dede, 2010; Gürsoy, 2006; Yalçın, 2018). Problem-solving in science learning can improve these cognitive abilities (Baran & Maskan, 2010; Sumarni et al., 2022), science process skills (Özer & Özkan, 2012), and effective learning (Cook et al., 2012; Movahedzadeh et al., 2012). Because solving problems is a scientific concept, it becomes the fundamental concept of scientific literacy, which comprises scientific inquiry and scientific knowledge (Abd-El-Khalick et al., 2004; Nentwig et al., 2009).

Integrated STEM education, which is a STEM teaching framework, based on the problems we encounter in daily life, places the Authentic Problem of Knowledge Society at its center, and all other branches and subjects develop around this problem (Çorlu, 2017). Applying effective STEM learning based on problem-solving becomes one of the scopes of science skills (Adlim et al., 2015; Afriana et al., 2016; Nugraheni & Suyanto, 2017). Gamification is another method used to gain such skills, and with gamification, students are provided with better, independent, and logical problem-solving abilities (Oliveira Biazus & Mahtari, 2022; Stohlmann et al., 2012). Gamified-integrated STEM education using both integrated STEM teaching framework and gamification also starts the player's journey around the problem and consists of the solution processes of this problem (Morschheuser et al., 2017). The perception of problem-solving skills is the perception that students create towards the solution process of the problem they encounter (Ekici & Balım, 2013). Regardless of their perception of problem-solving skills, individuals need to acquire problem-solving skills to solve the problems they encounter. Because individuals need to use problem-solving skills to deal with problems in their daily lives (Guven, 2010), in this research, using instructional design prepared with gamified-integrated STEM education, aims to both confront students with the global climate change problem that has global effects. At the same time, they encounter in their daily lives, as well as to identify and improve the perception they have created to solve this problem.

2.2. Critical Thinking

Problem-solving requires the use of critical thinking because critical thinking and problem-solving skills are closely related (Shanta & Wells, 2022). Critical thinking is a way of thinking based on the ability and tendency to effectively obtain, evaluate, and use information, that influences and improves the quality of an individual's thinking about a subject, content, or problem (Gandi et al., 2021; Paul & Elder, 2013; Tartuk, 2015). Critical thinking skills need to be cultivated in order for students to grasp how to solve the problem using the alternative solutions available to them (Gandi et al., 2021).

Critical thinking is defined in psychology as the mental processes, strategies, and representations that people utilize to solve problems, make decisions, and acquire new concepts (Sternberg, 1986). In other words, it means evaluating situations and problems from all angles, thinking objectively, being open to new ideas and facts, and being inquisitive (Willingham, 2007). Critical thinking, according to Facione (1990), is a self-regulated judgment that is made with a specific goal in mind and produces interpretation, analysis, evaluation, and inference, as well as an explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations that underlie the judgment.

Critical thinking requires evaluating events and situations from different perspectives and examining a problem in depth (Altıntaş, 2019). It enables people to improve their thinking about topics, materials, or problems by expertly confronting thought-specific constructions and attaching intellectual criteria to them. Regarding content applicability, instructional strategies that encourage memorization do not promote critical thinking. Critical thinking instruction emphasizes questioning techniques that push students to analyze, synthesize, and evaluate knowledge to solve problems and make decisions rather than just copy facts (Snyder & Snyder, 2008). Because critical thinking is a mental habit that enables students to think about their thinking and how to improve the process, it requires the use of higher-order thinking skills (Schafersman, 1991).

Critical thinking is thus the result of education and practice. For students to become effective thinkers, they should be provided with learning environments in which they can do so (Swartz et al., 2008). To teach students such skills, the learning process should be modified to be more flexible, creative, active, and challenging (Fisher et al., 2022). Students should learn by thinking and acting through engaging lessons, mapping information to everyday life, thinking as integration, and living critically (Waddel, 2019). Science educators create several approaches and techniques for creating an effective learning environment in their classrooms to teach critical thinking skills in science (Gencer & Doğan, 2020; Nugraheni & Aji, 2022).

A wide range of studies from several countries describes how design-based STEM learning activities engage students in solving real-world problems by exploring and collaborating with their peers to create an effective learning environment that fosters critical thinking skills (Gencer & Doğan, 2020; Hiğde & Aktamış, 2022; Mater et al., 2022). Within the framework of integrated STEM education, students analyze the facts, generate ideas about them, defend their results, and encounter opposing ideas by considering all the conditions (Lau, 2011). Individuals work on an authentic design problem of an interdisciplinary nature and thereby controlling the design process (Moore et al., 2014). It comprises establishing a link between scientific inquiry and engineering design, confirmatory research inquiry, and problem-solving, as well as being an essential component of traditional science education (NRC, 2012). Gamified-integrated STEM education using this framework may also help individuals produce practical solutions to the difficulties they encounter in their own lives (Aslan, 2018).

2.3. Integrated STEM Education

In today's world, where information is increasing in untraceable ways, both the educational environments and the characteristics that individuals should have been changing significantly (Gadot & Tsybulky, 2023; Manyika et al., 2017). Today, in such learning environments, individuals are expected not only to acquire knowledge or use ways of producing knowledge but also to critically process information, participate in discussions on social issues, and be active citizens (Şardağ, 2020). These characteristics are closely related to 21st-century skills, such as creativity, critical thinking, problem-solving, decision-making, communication, collaboration, and information literacy (DeCoito & Briona, 2023; Herdem & Ünal, 2018; Maass et al., 2019).

Science, technology, engineering, and mathematics education, also known as STEM education, has emerged as an approach that was introduced in the United States in the 1990s (Kelley & Knowles, 2016), and is becoming more widespread every day, and includes the integration of science, technology, engineering, and mathematics (Granovskiy, 2018). Integrated STEM education is considered as an effort to bring together some, or all of the science, technology, engineering, and mathematics disciplines in a course, unit, or subject based on the connections between the subjects and real-life problems (Çorlu et al., 2014). Therefore, the STEM approach is considered as an integrated education program (NRC, 2011). Technology and engineering in integrated STEM education directly cover problem-solving, innovation, and design, and the engineering component provides students with the opportunity to explore mathematics and science in real-life contexts by helping them develop their critical thinking skills (Herdem & Ünal, 2018; Hernandez et al., 2014).

When the literature is examined, it is found that there are different definitions for integrated STEM education (Bender, 2018; Bybee, 2013; Çorlu, 2013; Erdoğan, 2014; Kelley & Knowles, 2016; Moore et al., 2014; Sanders, 2009; Wang, 2012; Yıldırım, 2018). To give an example, Wang (2012) defined STEM as an instructional strategy that brings together the disciplines of science, mathematics, technology, and engineering, thus determining the approach to teaching knowledge, skills, and values more semantically. Bender (2018) also defined STEM as scientifically grounded student-centered teaching based on real-world problems for students to solve in groups and to use scientific methods. Therefore, integrated STEM aims to enable people to solve real-world problems with STEM literacy, engage in employment, and foster personal development by establishing different connections with other disciplines (Kelley & Knowles, 2016; Chesky & Wolfmeyer, 2015; NRC, 2011).

The STEM: Integrated Teaching Framework (InTeachFramework) (Çorlu 2017) provided a theoretical path for STEM education practitioners, teacher educators, and researchers for enhanced instruction based on many sources of knowledge and data (Çorlu et al., 2014; 2017). The goal is to integrate STEM applications into the classroom by combining the holistic approach. The framework's focal point is Authentic Problems of Knowledge Society (APoKS). The STEM education approach is interdisciplinary because a single discipline is usually not sufficient to solve problems in daily life (Capraro, & Capraro, 2014; Çorlu et al., 2014; Moore et al., 2014). With a real-life problem, the lesson should be well-structured, and the subject must arouse the curiosity and interest of the students (Akarsu et al., 2020).

The theoretical framework developed and widely used in the United States, where the STEM education approach originated, is the engineering design process (Moore et al., 2014). In the process leading to the design, the students must decide on a solution by thinking critically in accordance with the evidence, testing whether the solution is possible, and discussing the problem and solution proposals repeatedly during each task

(Topsakal et al., 2022). In the solution, that is, in the ideas discussed, it should be noted that there is not a single truth. It is aimed to developing both creativity and critical thinking skills by presenting real-life problems to students with alternative solutions. In addition, group work promotes both communication skills and peer learning (Akarsu et al., 2020).

APoKS and constraints, fact-finding, ideation, product development, testing, dissemination, and reflection are included in STEM instructional designs. In integrated STEM education, the lesson begins by presenting a real-world problem in a scenario. In this process, students try to understand the problem based on the scenario and understand why solving the problem is essential. At these stages, student questions are fundamental, and the teacher should encourage students to think with open-ended questions (Moore et al., 2014). Students first individually try to find a solution to the problem they encounter. Then, they decide on a solution proposal from brainstorming supported by group work.

At the product stage, they learn to take and manage risks, solve real-world problems by effectively using the given materials, think about different solution methods, utilize, and develop their creativity, and practice teamwork and collaboration throughout the whole process (Akarsu et al., 2020; Jeong & Kim, 2015). Integrated STEM education is also considered a way for students to think about significant problems, generate solutions, and acquire such skills in environments where they feel comfortable and stay in the flow of the lesson (Wang & Chiang, 2020). Therefore, this study will utilize the integrated STEM education framework to promote students' problem-solving skill perceptions and critical thinking dispositions. Through this framework, it is aimed to guide students to explore the problem of melting glaciers, which is a crucial global issue.

2.4. Gamification

In this section, gamification will be examined under the subheadings of game & play, and game mechanics & game elements.

2.4.1. Game & Play

Children find ways to play in their natural surroundings for pleasure, exploration, practicing what they already know, and gaining new knowledge and skills even in the absence of structured systems for play, often known as games (Vygotsky, 1978). As can be seen from the meanings used in this sentence, the words "play" and "game" have different meanings. Play is defined as enjoyable activities based on enjoyable actions (game mechanics) that have no goal or rule (Ishak et al., 2022; Landers & Sanchez, 2022). It is a way for children to acquire new skills in their own environment and gain experience in absorbing new approaches (Guyton, 2011; Samur, 2016). A game, which is the best way to gather and apply motor skills, is an activity that the player does for a purpose within the framework of specific rules (Samur, 2016), and the player is emotionally attached to the result (Juul, 2010). The game is an enjoyable activity in which the player struggles with one or more game mechanics, following the rules to achieve the goal and reaches an objective outcome, and solves a problem at the end of this struggle (Arkün-Kocadere & Samur, 2016; Tekinbas & Zimmerman, 2004).

Play is an activity that helps to address some of the needs of individuals (Peng et al., 2012). Needs are the desires that motivate people to act in various situations; they are the building blocks required for the health, development, and well-being of the organism (Ryan & Deci, 2008). Games are useful in addressing children's psychological and physiological needs (Deci & Ryan, 2000; Ilies et al., 2017; Maslow, 1943). Similarly, games are essential in terms of affective development as they are environments where individuals and especially children, can express themselves freely (Taşkın, 2020). While learning with games, the child could learn by gaining different experiences and having fun (Habgood & Ainsworth, 2011). This is because the child finds a solution to a problem through the game, thinks strategically, and makes various decisions. Thus, students' knowledge, skills, and behaviors desired to be acquired can be quickly gained in the game (Şirinkan & Şirinkan, 2011).

Traditional education has been criticized for being insufficient or ineffective in terms of meeting students' psychological and physiological needs as well as developing certain skills (Ivanic et al., 2007; Rooney, 2014; Tapscott & Williams, 2010). Educators, who realized that the game has an important place in the learning environment, developed methods that appeal to more senses by concretizing and gamifying the subjects instead of explaining the topics theoretically to meet the children's needs and make the teaching more efficient (Güner, 2018). Although the games are not designed for any educational purpose, they contain all the elements necessary for effective learning to take place, such as giving players frequent feedback with the right timing, moving to increasingly difficult levels, having a goal at the same time, communicating with other people (Gee, 2003).

2.4.2. Game Mechanics & Game Elements

The game mechanics and elements, which are preferred in different ways in each game design, affect the game's fun (Samur, 2016).

2.4.2.1. Game Mechanics. Game mechanics are the rules, procedures, and actions that guide players through the game, which are fun, skill-based, and have uncertain consequences. In the literature, game mechanics are defined as player actions that must be performed to complete the game, progress in the game, and make the game enjoyable (Apperley & Beavis, 2013; Samur, 2016; Trefry, 2010; Zagal et al., 2007). The actions that the player performs to progress in the game, achieve the goals of the game, and complete the game are the basic mechanics. Some exemplary game mechanics are to open, to find, to draw, to change, to pass, to escape, to save, to sell, to ask, to give, to burn, to walk, and to jump (Burgun, 2015).

2.4.2.2. Game Elements. In the game, the features that make the game more difficult, more organized, more fun, and more purposeful are defined as game elements (Werbach et al., 2012). Some game elements are listed below.

1. Character: It is the tool that initiates the game experience, chosen by the player, that enables the player to reveal the decisions and actions taken toward the problem and goal in the game (Fullerton, 2014; Tavinor, 2017). It allows the actor to identify more with the characters (Fullerton, 2014; Klimmt et al., 2010).

2. Goal of the Game: The goal is the work that needs to be done or the last point to be reached, making the game interesting and unique (Bulut et al., 2022). Games should have a clear goal (Crawford, 1984). Giving learners a goal in the learning process can support learners' performance (Kitsantas et al., 2004). Goals are also the way for the player to gain experience in the game and involve the player (Fullerton, 2014).

3. Rule of the Game: Rules define actions, constraints on actions and their consequences, goals, areas, and objects in the game (Fullerton, 2014; Shell, 2008; Swartout & Lent, 2003; Tekinbas & Zimmerman, 2003). Although the most basic element that makes the game a game is a rule, the game cannot be defined only by its rules; the game itself is a rule (Schell, 2008).

4. Game Obstacle: Obstacle is the elements that make the player's actions, progress, and development in the game difficult, limit, stop, physically included in the game or event, situation, rule, time, puzzle, riddle, doubling, etc. (Perry & DeMaria, 2009). In both physical and digital games, obstacles such as opponents, time pressure, speed, restriction, playing as a team, puzzles to be solved in the game, game environment, and non-player characters can be created in the steps the player takes to achieve his/her goal (Fullerton, 2014).

4.1. Level: Each game starts with an easy goal or task to introduce the player to the game world and allow the player to play the game again. As each goal or task is completed, the player encounters the increasingly challenging goal-task in a hierarchical structure to reach the major goal of the game (Zackariasson et al., 2010).

4.2. Time: It can appear in 6 dimensions in the game: duration, sequence, temporal location, deadline, cycle, and rhythm.

5. Feedback of the Game: Feedback is accepted as an important factor influencing the performance of learners in the process of acquiring knowledge and skills (Shute, 2008). Although the concept of feedback is used in many fields, from science to social sciences, feedback is basically a result of knowledge (Dökmen, 1982). Feedback gives

individuals the opportunity to correct their mistakes and helps them to improve themselves (Hattie & Timperley, 2007). For this reason, feedback should be motivating, directing, and reinforcing (Dökmen, 1982).

5.1. Reward: The game is a system in which an individual is rewarded when his/her goal is achieved, or the obstacle is overcome. A reward in a game is any game element or feature of the game that supports and strengthens the behavior of the player in the game. (Bateman & Boon, 2005; Fullerton, 2014; Mckerman et al., 2015; Perry & DeMaria, 2009).

5.2. Punishment: After a behavior is done, giving a warning from the environment, or removing a pleasant stimulus is punishment (Erden, 1985). The balance in the game and the progress of the game may change with these penalties. In games, punishment is an element that complicates the game and makes the game experience more enjoyable. It is an important alternative for teachers who need to renew their education, as it creates the behavior of continuing the game even if the mistakes in the games are punished and makes the process more enjoyable (Nolan et al., 2014).

5.3. Progress Bar: A progress bar is feedback containing indicators for the completion or progress of a task (Conrad et al., 2010).

5.4. Badge: A badge is a game element that helps the learner quickly visualize the results of their assessments prepared for each goal (Frost et al., 2015).

5.5. Leaderboard: It is a table board showing the names and positions of the leading competitors. The leaderboard brings competition to the game. At the same time, it allows both to set long-term goals, such as being the best player in the game, and to set short-term goals, such as making any goal or scoring better (Nebel et al., 2016).

2.5. Gamification in Education

It can be said that when children start school, they find many of the learning activities offered to them boring and even unnecessary. They come to the point where they lose their high learning motivation, sense of curiosity, and willingness to ask questions (Cordova & Lepper, 1996). In this case, solutions such as preparing content according to students' readiness and learning speed, cooperative learning, and presenting abstract content in context are suggested. Educators prefer games to bring these suggested solutions into the learning environments (Crawford, 1984; Hong & Chu, 2017; Hsu et al., 2017; Kurapati et al., 2017).

One of the effective ways for students to find solutions to real-world problems and establish direct connections with different disciplines is gamification which has emerged as a popular trend in education in recent years (Hanus & Fox, 2015). "Gamification refers to a process of enhancing a service with affordances for gameful experiences in order to support user's overall value creation" (Huotari & Hamari, 2012, p. 19). The gamification method aims to educate individuals enjoyably, increase students' motivation, and improve their problem-solving skills while having fun (Mert & Samur, 2018). Gamification encourages users to perform a task and enables them to make the task more effective by using game elements (Asigigan & Samur, 2021; Boyce, 2014). In gamification, game elements such as avatars, rules, awards, progress bars, and leaderboards are included, while no game mechanics are used. For this reason, it is possible to define gamification as game-like activities without game mechanics (Özkan & Samur, 2017). Moreover, gamification activities have the potential to improve learning when they are well-designed and used correctly (Seabron & Fels, 2015).

Although it is known that the use of gamification in education increases students' engagement (Fantazir, 2020; Stanley-Yolgeçen, 2018), motivation (Asigigan & Samur, 2021; Fantazir, 2020), and 21st-century skills (Asigigan & Samur, 2021); gamification in the classroom is a difficult task to master (Bruke, 2014). There are some issues teachers who will include gamification in their lessons should pay attention to:

- Students should be a part of every step of the design.
- Skill-oriented goals should be set.
- The success of the whole class should be targeted.
- Regular and continuous feedback should be used.
- Students should be given a second chance.
- Level and progress bars should be used.
- Barriers should be included.
- Rewards and badges should be used.
- The student should be presented with power and options.
- Technology should be used.
- All probabilities should be calculated and piloted (Samur & Cömert, 2022, p. 176 180).

For gamification to be applied successfully in education, game components should be appropriately incorporated (Şahin & Samur, 2017; Yıldırım & Demir, 2016) into the instructional designs to find reasonable solutions to daily life problems with an interdisciplinary approach like STEM. This study aims to contribute to the literature using gamification in the integrated STEM Education framework with middle school students, which is not commonly found in the literature (Asigigan & Samur, 2021).

2.6. Gamified-Integrated STEM Education

Time is changing. In this changing age, the words students use to describe each other have also changed (Dou, 2014). Students who used to identify each other with the music they listened to now do so with the games they play (Comulada et al., 2011). Although in the popular perception in society is that boys play more games than girls, the reality is that girls play as much as boys (Entertainment Software Association, 2010). Games contain many factors that can be of interest to students, some of which are getting instant feedback, a sense of achievement, and progressing through the chapter (Dou, 2014). Students learn through activities where they can see the results of their best efforts. Vygotsky's zone of proximal development is no different. Students get bored when they do not make an effort or push too hard, but they enjoy tasks that appeal to their developmental areas (NRC, 2000).

The use of obstacles is a well-known method for making games more interesting. Undoubtedly, difficult but surmountable obstacles contribute to the enjoyment of games (McGonigal, 2011). Students will encounter obstacles as they progress through the course (e.g., projects, tests, assignments, etc.). Students will overcome these challenges to collect and win as many points as possible (Dou, 2014). Students benefit substantially from open-ended, inquiry-based learning methods because they are engaged in developing knowledge rather than consuming it and they engage in higher-order thinking (Tekinbas et al., 2010), active learning as opposed to passive learning (NRC, 2000). Gaming challenges provide a common platform for students to cooperate and learn together. Game design concepts may change the direction of a classroom and the way students think. Gamifying the classroom is about more than just STEM; it is about learning (Dou, 2014).

Students learn by participating in disciplinary practice. This is, predictably, identical to the open inquiry literature that pervades every fiber of the Next Generation Science Standards (NGSS) - the practice of science. Students should be “doing” science. An exercise, rather than assimilating learning from lectures or textbooks, should be an exercise in which it is about generating knowledge. Identifying a problem, structuring research, gathering evidence, analyzing evidence, developing results, and communicating information (NRC, 2000; 2012). These are activities that students need to master. In addition, it is like the game structure that students take an active role and receive and give feedback on what they are doing (Squire, 2003). Activities emerging from play environments should include independent activities and group tasks (Dou, 2014).

Science should be "done" by students. An activity, rather than assimilating knowledge through lectures or textbooks; it should be an exercise in scientific discovery. Identifying a problem, organizing research, collecting evidence, evaluating evidence, producing results, and sharing information (NRC, 2000; 2012). Students need to master these activities. Furthermore, it is inherent in the game structure that students take an active role and receive and provide feedback on their performance (Squire, 2003).

Activities arising from play environments should include both individual and group tasks (Dou, 2014). Collaboration is also a proven and effective learning method (Gillman, 1990). Getting students out of the classroom paradigm and into a play environment is important and requires some imaginative naming. For example, instead of using terms like homework or exam, teachers can use tasks, explorations, achievements, and treks. While students may understand that a rose by any other name is still a rose, it is the suspension of disbelief, the sense of illusion provided by honoring the new nomenclature, that will enable them to engage in learning quests (Dou, 2014).

Gamified-integrated STEM education is a teaching method created by using the integrated STEM framework and incorporating gamification elements into this framework. Gamified-integrated STEM education pedagogically includes problem-based and project-based learning, where active learning is central, and students use various techniques and resources (Bourazeri et al., 2017). Many different game elements are used in gamified-integrated STEM instructional design, such as stories, rules, goals, awards, points, badges, leaderboards, and materials. A real-life problem based on knowledge, which is the first place in STEM studies, is conveyed through a story in the integrated STEM designs. The story is a game element that enables the player to learn and experience the game and is used to reveal the player's purpose in a well-designed educational game (Fiş Erümit, 2016). In STEM practices and activities, tasks, rules, and restrictions are given in the story (Fullerton, 2014; Morgan & Slought, 2013). STEM project-based learning and inquiry-based learning basically involve using materials; besides that, the material is used to contribute to the game's story (Kiili, 2005). At this stage of tasks, engineering designs or presentation ways are tested by feedback, which is one of the basic requirements of gamification (Fiş Erümit, 2016). The primary goal of feedback is to improve students' knowledge, abilities, and comprehension of a specific topic or general skills (Shute, 2007). At the same time, effective teaching should allow students to reflect on their own ideas, receive feedback from other students on their ideas, and alter their thinking as a result of this new knowledge (Slough & Milam, 2013).

Although the game, gamification, and STEM education have been studied separately in the literature, studies on gamified-integrated STEM education, which forms the basis of this study, are limited (Alsawier, 2018; Taşkın, 2020; Türkan, 2019). In Bozkurt's (2021) study on the opinions of pre-service teachers on gamification application, pre-service teachers stated that gamification provides fun, interesting, effective, and permanent learning experiences. Hebebci and Usta (2018), who took the opinions of teachers on the use of badges, one of the important components of gamification, in educational environments, found that teachers had predominantly positive opinions about the use of badges, such as gaining positive behavior, increasing motivation, active participation in lessons and making lessons interesting. Similar to the findings of Bozkurt (2020), Karaoğlan Yılmaz and Yılmaz (2019), who took the opinions of pre-service teachers on the use of Kahoot, one of the tools of gamification, for educational purposes, found that the use of Kahoot made the lessons interesting for students, increased students' motivation, and reinforced the subjects.

Asigigan and Samur (2021), who conducted gamified STEM activities with 3rd and 4th grade students, found a significant difference between the pre-test and post-test scores in the critical thinking levels of the students in their study, while they did not find a significant difference in their perceptions of problem-solving skills. The study found that students had high levels of intrinsic motivation and were motivated by the awards and badges they received at the end of the activities (Asigigan & Samur, 2021). Kılıçel and Ertaş Kılıç (2021) aimed to determine the views of teachers and students about the gamification technique in science courses. According to the findings of the study, teachers and students stated that gamification increased their course success and motivation as it enabled internalization, peer learning, active participation, learning without getting bored, learning with love and permanent learning (Kılıçel & Ertaş Kılıç, 2021).

Insights gained from previous literature contribute to our understanding of the influence of gamified-integrated STEM activities on the outcomes of integrated STEM education (Asigigan & Samur, 2021; Bozkurt, 2021; Kılıçel & Ertaş Kılıç, 2021). There is still much to learn about the use of gamified-integrated STEM education. Understanding how students shift from performing tasks for enjoyment to doing them for intrinsic value will also help us understand how games assist learners in engaging and developing their knowledge of STEM topics. After all, if a student is simply not engaged, he or she is really not learning (Dou, 2014). Specifically, more research is necessary for the gamified-integrated STEM activities of upper-middle school students to further understand the nature of their experiences, which may be crucial for improving the benefits of STEM education programs (Asigigan & Samur, 2021). Moreover, this study will shed light and provide more empirical evidence on gamified-integrated STEM education on global climate change, which is one of the most crucial global crises that have both global and local effects.

2.7. Global Climate Change

The term global climate change (GCC) refers to any change in climate that occurs over time, whether caused by natural variability or human actions (Intergovernmental Panel on Climate Change, (IPCC), 1995). GCC is a critical concern in science, technology, and society. The necessity of raising awareness of this issue, as well as its possible origins and observed or expected impacts, is cited as the motivation for using GCC in investigations (Ceyhan & Mugaloglu, 2020). The IPCC (2021) stated that the human impact on the current GCC is apparent, and that human-induced climate change has had profound consequences on weather and climate extremes worldwide. Teaching about GCC gives future citizens a natural setting for future citizens to study science and develop responsibility and understanding of this threat to our world through personal and societal actions (Shepardson et al., 2015).

One purpose of educating children about the GCC and the human impact on the environment is to raise responsible citizens who will make future environmental decisions based on their knowledge (Christensen & Knezek, 2015). Whether children continue to work in a STEM-related field or just live in a world touched by STEM, cultivating an early understanding of the environment is crucial to improving their attitudes toward the environment around them as adults (Christensen & Knezek, 2015; Lester et al. 2006). However, GCC is challenging for both instructors and students because it involves complicated scientific systems and contradictory messages from popular media (Svihla & Linn, 2012). According to researchers, due to a lack of climate change curriculum in schools, children are more likely to acquire their knowledge from the media than from instructors (Christensen & Knezek, 2015; Robertson & Barbosa, 2015; Tibola da Rocha et al., 2020).

Teachers play an important role in shaping the future of the world. In shaping the future, it is the teachers' responsibility to encourage students to explore solutions to global problems by using different disciplines and confronting students with difficulties (Garcia-Gonzalez et al., 2020). According to studies, instructors are not as effective as they may be in educating the next generation about climate change and its causes with the methods and programs they currently use (McNeal et al., 2017; Plutzer & Hannah, 2018). Teachers must be able to handle complicated scientific conceptions to enable learners to make judgments about climate change that are supported by science (Hestness et al., 2014). While some science instructors are well-versed in these topics, many teachers feel unable to properly discuss climate change science in their classes due to their lack of experience in the field (Hestness et al., 2014). For instance, many biology teachers claim that they are not well-equipped to teach climate-related topics ((Hestness et al., 2014; NRC, 2012).

In the literature, previous studies support the need for new models of climate change education (Moser & Dilling 2004). Many educators believe that, in addition to teaching science, they should engage students and promote positive environmental sensitivity (Cordero et al., 2008). Today, everyone must take action to combat GCC; it is not just the responsibility of scientists (Bäckstrand, 2003; Hoffmann et al., 2022; Valdez et al., 2018). There is an imbalance between the level of knowledge about GCC and scientific literacy (Kolenatý et al., 2022), and this situation reveals the need for science educators who are equipped to provide education about GCC and its impacts. For this reason, it is included an environmental education course under the name "Environmental Education and Climate Change" in the curriculum for the middle school level in Turkey (Ministry of National Education, (MoNE, 2021). In this curriculum, the objective of "ÇEİD 4.4. Students interpret the effects of global climate change through case studies" includes an acquisition directly related to the melting of glaciers (MoNE, (Environmental Education and Climate Change Curriculum), 2022, p. 12).

The effects of GCC are more pronounced in other parts of the world (such as the polar regions) (Monroe et al., 2017). The consequences of sea level rise are already being felt around the world, and sea levels are expected to rise by 1 to 4 feet by 2100 (IPCC, 2022). For example, more than half of the population of the United States now lives in cities that will be affected by rising sea levels if GCC continues unchecked (Strauss et al., 2015). As a result, sea level rise is an important and relevant topic for students (Breslyn et al., 2016). As a direct result of the GCC, media outlets are increasingly reporting that sea levels are rising (Roy et al., 2023). Sea level rise is a strong and useful concept that is observable and accessible to middle school students. In this regard, sea level rise is a significant concept in science education, not only because of discipline-based concepts but also because of its effects on humanity (Breslyn et al., 2016).

Systematic scientific research on the causes, processes, magnitude, and implications of the complex and dynamic process of sea level rise has been beneficial. About 75% of the observed global mean sea level increase is caused by two main causes (IPCC, 2022). The first process involves Earth's land ice melting, which is most obviously manifested in the melting of glaciers and ice sheets and the subsequent flow of ice into the oceans. The Antarctic and Greenland ice sheets are the major contributors to the sea level rise. Sea ice, such as floating ice shelves, does not directly cause sea levels to rise because it already moves the mass of water it contains according to Archimedes' Principle. However, the loss of sea ice may still influence sea level rise by reducing back stress on neighboring glaciers and increasing glacial melt. Despite all of this, there has not been much research done on how well students comprehend sea level rise (Breslyn et al., 2016).

2.8. Summary of the Literature

Many global challenges, such as GCC, require a multidisciplinary approach, supported by further advances in STEM fields, to adequately address these challenges (Kelley & Knowles, 2016). Besides that, gamification is a technique that could engage individuals and diverse stakeholders in GCC communication that is dynamic, participatory, and meaningful. Some researchers have used various tools to understand effective teaching practices (Monroe et al., 2019), one of which is gamification.

Numerous interesting, interactive, and student-centered instructional techniques were employed in the programs, curricula, and lessons examined in this evaluated paper collection.

Regardless of whether the intervention was described as using an experiential, inquiry-based, or constructivist approach, these instructional techniques have been shown to be successful in science and environmental education (Bybee et al., 2013; Jacobson et al., 2015) and are thus frequently used in climate change education as well (Monroe et al., 2019). Climate change gamified-integrated STEM applications can increase climate change awareness and their urgency for altering the future via today's actions and behavior change. The findings indicate that climate change gamification is a study field that merits further attention from academics, as just a few studies address this critical issue (Rajanen & Rajanen, 2019). Understanding GCC also requires critical thinking (Lombardi et al., 2016). To be successful in critical thinking, students are expected to reflect on the development of knowledge in problem-solving (Lombardi et al., 2016; McNeal et al., 2017).

Gamified-integrated STEM education, which is presented by combining both gamification, whose main purpose is to create behavioral change, and 21st-century skills gained through the integrated STEM approach, is supported by the processes of problem identification, research, solution development, design, testing, and presenting the product about GCC. Thus, students' skills and attitudes about environmental education and GCC issues, which are also included in the curriculum, can be investigated.

3. METHODOLOGY

This chapter gives detailed information about the methodology of the research. The research design, sample, definition of key terms and variables, data collection instruments, materials, procedure, data collection, and data analyses of the study are described below.

3.1. Research Design

The present study is a quasi-experimental study with pre & post-tests (Campbell & Stanley, 1963). The researcher utilizes control and experimental groups in quasi-experimental designs but does not randomly assign individuals to groups (Creswell, 2003). In the current study, participants were already enrolled in specific classrooms at the beginning of the academic year, therefore, there was no group reassignment. Quantitative and qualitative methods were used together in order to add depth to the research and to obtain valid and reliable results (Table 3.1). In this study, two different scales were used as a quantitative data collection tool. One of the scales is the Problem-Solving Skill Perceptions Scale, and the other is the Critical Thinking Disposition Instrument. Semi-structured interviews were used as qualitative data collection tools.

Table 3.1. The research design of the study.

Groups	**Pre-intervention**	**Intervention**	**Post-intervention**
Experimental Group 1	Problem-solving Skill Perceptions Scale Critical Thinking Disposition Instrument	Integrated STEM instructional design	Problem-solving Skill Perceptions Scale Critical Thinking Disposition Instrument Interviews

Table 3.1. The research design of the study (cont.).

Experimental Group 2	Problem-solving Skill Perceptions Scale Critical Thinking Disposition Instrument	Gamified-Integrated STEM instructional design	Problem-solving Skill Perceptions Scale Critical Thinking Disposition Instrument Interviews
Control Group	Problem-solving Skill Perceptions Scale Critical Thinking Disposition Instrument	Traditional lesson	Problem-solving Skill Perceptions Scale Critical Thinking Disposition Instrument

3.2. Sample of the Study

The first phase of data collection, pilot study - 1, was conducted to develop the structure of the instructional designs. In the second phase, the data obtained from pilot study-2 was used to evaluate time and applications to the instructional designs. The main sample was used to investigate the research questions. Pilot study-1 was conducted at the course center, pilot study-2 was conducted in a private school in İstanbul/Turkey, and lastly, the main study was carried out in a public school in Kırklareli/Turkey. In the next sections, the sample for pilot study-1, pilot study-2, and the main study was described, and detailed information about the study context was explained.

3.2.1. Sample for the Pilot Study-1

In June 2022, pilot study-1 was carried out with four students who voluntarily participated in the acceleration period of a course center in a small district of Kırklareli province. Three female and one male student participated in the pilot study - 1. They were in the 8th grade and were 13 years old. None of them indicated they had taken a course in STEM or gamification before.

3.2.2. Sample for the Pilot Study-2

In September 2022, pilot study-2 was conducted with 79 students in a private school in Istanbul. The gender distribution of the students participating in the research was 39 female and 40 male. They were all 13 years old. In the pilot study, four different classes were included, and the number of students in each class was approximately 20. While 54 of the students indicated they had previously taken STEM instruction, 25 of them indicated that they had not taken STEM instruction before. In addition, 53 students stated that they had not received gamification instruction before, while 26 students reported that they had received it before.

3.2.3. Sample for the Main Study

The main study was conducted with 8th-grade middle school students. Participants of this study were determined by purposeful sampling. The research progressed in the first term of the 2022-2023 academic year, equivalent to the Seasons and Climate unit. The study was carried out in a public middle school in Kırklareli/Turkey, with three different classes in the school. Each class consisted of 23 students and a total of 69 students formed the sample group of the research. One of the classes was randomly assigned as a control group, and the other two were determined as experimental groups. Traditionally prepared instructional design was applied to the control group, integrated STEM education instructional design was applied to experimental group 1, and gamified-integrated STEM instructional design was applied to experimental group 2. In short, there were three different groups in the research, namely the control group, experimental group 1, and experimental group 2.

The number of students in each class and each group was adequate for conducting a quasi-experimental research design. Additionally, the number of students in each group was considered sufficient for the quantitative data analysis. The gender distribution of the students consisted of 37 female and 32 male. The age group distribution of these students consisted of 4 students at the age of 12, 53 students at the age of 13, and 12 students at the age of 14. Only 2 students reported that they had received STEM instruction before, and 67 students indicated that they had not received STEM education. Likewise, only 9 students indicated that they had received gamification education before, and 60 indicated they had not received gamification education.

3.3. Definitions of Key Terms, Concepts, and Variables

This section is divided into two sections. The first section explains the conceptual definitions, while the second section explains the operational definitions of the study's terms and variables.

3.3.1. Conceptual Definitions

Explanations of the concepts in this study are given below:

- Problem-solving: Problem-solving is a process that starts from the moment when students face the problem and covers solving problems related to experience, perception, and understanding of a particular phenomenon (Walsh et al., 2007), and extends to the time when the problem is solved (Polya, 1981).

- Problem-solving skill perception: It is the mind's understanding of the cognitive process of the various ways students use to solve problems related to experience, perception and understanding of a particular phenomenon (Walsh et al., 2007).

- Critical thinking: It is an attribute or habit of mind that is integrated into one's beliefs or actions (Profetto-McGrath et al., 2003) to effectively solve problems and make decisions as a product of thinking (Facione & Facione, 2007).

- Critical thinking disposition: Critical thinking disposition is a cognitive characteristic or habit that is incorporated into one's beliefs or behaviors in order to successfully solve issues and make judgments as a result of thinking (Fitriani et al., 2018).

- Integrated STEM Education: It is a seamless amalgamation that integrates science, technology, engineering, and mathematics disciplines (Nadelson & Seifert, 2017) into real-world and purposeful learning experiences for students and removes traditional barriers (Vasquez et al., 2013).

- Gamification: "Gamification refers to a process of enhancing a service with affordances for gameful experiences in order to support user's overall value creation" (Huotari & Hamari, 2012, p. 19).

- Climate change: "Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer" (IPCC, 2014, WG II, p. 6).

3.3.2. Operational Definitions

The operational definitions of the concepts to be examined in this study are as follows:

- Problem-solving Skill Perceptions: The summated score of responses to the Problem-solving Skill Perceptions Scale, based on a five-point Likert scale, from 1 = strongly disagree to 5 = strongly agree.
- Critical Thinking Dispositions: The summated score of responses to the Critical Thinking Disposition Instrument, based on a five-point Likert scale, from 1 = strongly disagree to 5 = strongly agree.

3.4. Data Collection Instruments

In this section, the demographic form, quantitative tools which are problem-solving skills perception scale and critical thinking disposition instrument and qualitative tool which is interviews used as data collection tools are explained.

3.4.1. Demographic Form

The demographic form was developed to collect information about the participants (See Appendix B). Questions pertaining to the participants' name, gender, age, grade and whether they had previously received STEM education and gamification education.

3.4.2. Quantitative Data Collection Tools

There are two qualitative data collection tools. The first one is "Problem-solving skill perceptions scale" and the second one "Critical thinking disposition instrument" are described below.

3.4.2.1. Problem-solving skill perceptions scale. Ekici and Balım (2013) developed the Problem-solving Skill Perceptions Scale (See Appendix C). The scale has a two-factor structure consisting of 22 items, including 15 positive and 7 negative items in a 5-point Likert type. The first factor was named "Students' perception of problem-solving skills," and the second factor was named "Students' perception of willingness and determination towards problem-solving". The reliability coefficient was calculated as 0.88. The participants rated each item on a five-point Likert scale, ranging from 5 = Strongly Agree to 1 = Strongly Disagree. A possible minimum score is 22, and the possible maximum score is 110 for the scale.

3.4.2.2. Critical Thinking Dispositions Instrument. Irani and his colleagues (2007) developed the University of Florida Engagement, Maturity, and Innovativeness (UF/EMI) Critical Thinking Disposition Scale. This scale was adapted to Turkish and implemented to students by Kılıç and Şen (2014) (See Appendix D). There were 25 item with three factors in the Critical Thinking Disposition Scale. The Cronbach Alpha internal consistency coefficient was calculated as 0.91 for the whole scale; 0.88 for the engagement sub-dimension; 0.70 for the cognitive maturity sub-dimension; 0.73 for the innovativeness sub-dimension. The participants rated each item on a five-point Likert scale, ranging from 5 = Strongly Agree to 1 = Strongly Disagree. A possible minimum score is 25, and the possible maximum score is 125 for the scale.

3.4.3. Qualitative Data Collection Tools

Interview questions were developed to gain insight into the students' experiences during the intervention (Appendix E). In reviewing the literature while developing these questions, it was noted that Haynes and Bailey (2003) emphasized the importance of asking the right questions to activate students' critical thinking skills. Other researchers (Brown & Kelley, 1986; Hemming, 2000) have emphasized the importance of supporting an educational environment in which students can demonstrate and practice their critical thinking skills. It was noted that Snyder & Snyder (2008) also created sample questions for problem-solving and critical thinking skills. In accordance with the information and sample questions obtained after the literature review, expert opinion was obtained, and interview questions were created. There were 12 questions for experimental group 1 (integrated STEM group), and 15 questions for experimental group 2 (gamified-integrated STEM group) to have a deeper understanding of the students' learning experiences in the experimental groups.

3.5. Interventions (Instructional Designs)

In this section, interventions (instructional designs) applied to 8th grade students are presented. Integrated STEM instructional design, integrated STEM stages, gamified-integrated STEM instructional design, and course design prepared with traditional methods are included in detail.

3.5.1. Integrated STEM Instructional Design

The instructional design was prepared in a STEM lesson plan format on the topic of the melting of glaciers (See Appendix G). This instructional design was based on STEM learning outcomes (Table 3.2), and it was approved by subject matter experts in the STEM field.

Table 3.2. Integrated STEM instructional design stages.

Integrated STEM-Stages	**Time (min)**	**Content**
Authentic Problems of Knowledge Society (APoKS) and Constraints	40	Introduction of the problem and conducting research to define the problem.
Fact Finding	40	Finding facts about the distinction between weather and climate. Interpreting factors affecting climate and determining who is affected by climate changes.
Ideation	40	Making observations about melting ice and brainstorming about its impacts and about what we can do to prevent the melting of glaciers and protect coastal cities.
Product Development	80	Sharing some of the precautions Transforming ideas into products
Testing	20	Testing and trying created products and developed ideas.
Dissemination and Reflection	20	Presentation, feedback, and evaluation

In the "Authentic Problems of Knowledge Society & Constraints, and Fact-Findings" stages (Table 3.2), students were confronted with the problem and conducted research about it and its causes. The lesson started with a story about the flooded city of Pavlopetri. Students individually searched for a flooded city like Pavlopetri in the world and questioned its reasons. Followingly, in the “Fact Findings” stage (Table 3.2), the differences between seasons and climate were questioned, and the greenhouse effect and climate change were mentioned. At the end of the fact findings, research questions were given as homework, considering that they would both generate ideas and conduct research based on what they had learned. In the “Ideation, Product development, Dissemination and Reflection" stages (Table 3.2), students made observations, solved problems, and also developed a product that aimed to provide a solution to the problem. The ideation stage consisted of the observation task. The teacher asked the students whether land ice or sea ice raises the water level, and the students made observations. Considering the melting process of the ice, students made measurements and created graphs. After the ideation stage, students tried to find possible solutions to the flooding. To guide students, sample suggestions for possible solutions to the melting of the glaciers were shared with the students. In this stage, students were expected to create a solution-oriented product and present this product to their peers. When the presentations were completed, a discussion environment was created.

3.5.2. Gamified-Integrated STEM Instructional Design

The instructional design was prepared in a gamified-integrated STEM lesson plan format on the topic of the melting of glaciers. This instructional design was based on integrated STEM learning outcomes (Table 3.3), and it was approved by both gamification and STEM subject matter experts. The game elements used in the gamified-integrated STEM instructional design were time, rewards, points, badges, leaderboards, materials, stories, goals, and rules. Badges included: "Decoders, Explorer, Meteorologist, Climatologist, Benevolent Koala, Scientist, Engineer" (See Appendix F).

Table 3.3. Gamified-integrated STEM instructional design stages.

Gamified STEM-Stages	**Time (min)**	**Content**
Authentic Problems of Knowledge Society (APoKS) and Constraints	40	Introduction of the problem and conducting research to define the problem. Storytelling, Password Badge, Explorer Badge, Bonus Kahoot, Bonus points for questions.

Table 3.3. Gamified-integrated STEM instructional design stages (cont.).

Fact Finding	40	Finding facts about the distinction between weather and climate. Climatologist Badge, Meteorologist Badge, Helping Koala Badge, Research questions-points, Bonus Wheel.
Ideation	40	Making observations about melting ice and brainstorming about its impacts and about what we can do to prevent the melting of glaciers and protect coastal cities.
Product Development	80	Sharing some of the precautions being implemented. Scientist Badge, Engineering Badge, Points.
Testing	20	Testing and trying created products and developed ideas.
Dissemination and Reflection	20	Presentation, feedback, and evaluation Best's List/Leaderboard and Awards

In the "The Player's Journey, Authentic Problems of Knowledge Society & Constraints, and Fact-Findings" stages, students were introduced to the problem and conducted research about it and its causes. The lesson started with a story, and students were expected to decode a password using the Pigpen Cipher alphabet. Then, there was a story about the flooded city of Pavlopetri. Students individually searched for a flooded city like Pavlopetri in the world and questioned its reasons. Afterward, students whose player types had been determined were divided into groups for group work. At the end of the tasks, students were rewarded according to the difficulty/ease of the task. These rewards included points, badges, or status. Followingly, in the “Fact Findings” stage, the differences between seasons and climate were questioned, and the greenhouse effect and climate change were mentioned. At the end of the fact findings stage, research questions were given as homework, considering that they would both generate ideas and conduct research based on what they had learned. In the “Ideation, Product Development, Dissemination and Reflection" stages, students made observations, solved problems, and also developed a product that aimed to provide a solution to the problem. The ideation stage consisted of the observation task. The teacher asked students whether land ice or sea ice raises the water level, and students made observations. Considering the melting process of the ice, students made measurements and created graphs. After the ideation stage, students tried to find possible solutions to the flooding. To guide students, sample suggestions for possible solutions to the melting of the glaciers were shared with the students. In this stage, students were expected to create a solution-oriented product and presented this product to their peers. When the presentations were completed, a discussion environment was created, the leaderboard was shown to the students, and the statuses they achieved were shared in line with the awards and points they earned.

3.5.3. Traditional Instruction

This course design had been prepared on the melting of glaciers. The course design, which was applied with traditional methods, was given in accordance with the objectives in the MEB curriculum (See Appendix H). The lesson began with a story about the flooded city of Pavlopetri. "What could be the reasons for an area to be flooded?" was asked. Afterward, information was given on areas that have been flooded and/or are in danger of being flooded. Then, the differences between seasons and climate were questioned, greenhouse effect and climate change were mentioned. Information was given about meteorologists and climatologists. The teacher asked the students whether it is land ice or sea ice that raises the water level, and the reasons for their thinking this way were discussed with the students. The teacher explained that the rise in sea level is land ice, with necessary explanations and lectures. Students tried to find possible solutions for flooding. In order to guide the students, possible solutions for the melting of glaciers were shared with the students. After receiving the creative answers from the students, these suggestions were shared with the rest of the class.

3.5.4. Comparison of the Instructional Designs

Table 3.4 presents the comparison of the instructional designs. Integrated STEM and gamified-integrated STEM compromises the experimental, and the traditional design reveals the control group's instructional designs.

Table 3.4. Comparison of the instructional designs.

Stages	Integrated STEM	Gamified-Integrated STEM*	Traditional**
APoKS and Constraints	• APoKS presentation: Daily life problem with more than one solution, pertaining to 21st century life and including product-process association. • Supporting with interesting questions • Supporting with stories, images, and videos	• APoKS presentation: Storytelling • Decryption / PASSWORD BADGE • Supporting with intriguing questions • EXPLORER BADGE • Supporting with stories, images, and videos • Bonus-Kahoot (+/- points) • Bonus-Question/Answer (+ points)	• Engaging and intriguing introduction • Informing about the problem • Open-ended questions • Supporting with stories, images, and videos

Table 3.4. Comparison of the instructional designs (cont.).

Fact Finding	• The research and discussion questions prepared are open-ended, related to APoKS and intriguing for students to create their own questions. • Activities for the knowledge notebook: the activities prepared are inspiring and motivating to work independently.	• The research and discussion questions prepared are open-ended, related to APoKS and intriguing for students to create their own questions. • CLIMATOLOGIST BADGE / METEOROLOGIST BADGE / HELPING KOALA BADGE • Activities for the knowledge notebook: the activities prepared are motivating and motivating to work independently. • Points, Research Questions-points, Interaction with the bonus wheel (+/- points/badges/pass)	• Lecturing • Question answer • Discussion environment • Supporting with videos

Table 3.4. Comparison of the instructional designs (cont.).

Ideation	• The process of developing and selecting an idea that is democratic and in which each student can freely express their opinion. • An activity for students to develop ideas in a systematic way. • Sharing ideas created in different groups with the whole class	• The process of developing and selecting an idea that is democratic and in which each student can freely express their opinion. • An activity for students to develop ideas in a systematic way. • Sharing ideas created in different groups with the whole class • SCIENTIST BADGE, Points	• Narration of the observation activity (no application) •Inference-discussion environment from the results • Developing solution proposals & brainstorming
Product Development	• Utilizing technology • Product design associated with theoretical knowledge explanation and knowledge / idea development phases that overlap with the determined objectives.	• Utilizing technology • Product design associated with theoretical knowledge explanation and knowledge / idea development phases that overlap with the determined objectives. • ENGINEER BADGE, Points	• Sharing some of the precautions being implemented

Table 3.4. Comparison of the instructional designs (cont.).

Testing	• Testing and further development of the product, returning to all stages • Calculating predictions	• Testing and further development of the product, returning to all stages • Calculating predictions	• Discussion for shared solutions
Dissemination and Reflection	• Level-determining assessment both MEB objectives about climate tests-climate questions • A sharing activity that will allow students to evaluate their own products and the products of their friends.	• Level-determining assessment both MEB objectives about climate tests-climate questions • A sharing activity that will allow students to evaluate their own products and the products of their friends. • BEST'S list-Leaderboard • Awards	• MEB objectives tests-climate questions measurement and evaluation
*: Gamified-Integrated STEM instructional design included all integrated STEM education contents. Game elements, which are among the gamification elements used in addition to the integrated STEM steps, were specified in the plan. **: Integrated STEM content and gamification elements are not directly involved in traditional course design. This plan was in line with the MEB objectives; was implemented by traditional methods in line with other plans.			

3.6. Procedure

Following the literature review based on the concept of gamification, the gamified-integrated STEM topic was selected, and the research questions were established. Gamified-integrated STEM course contents (See Appendix F), integrated STEM course contents (See Appendix G), and traditional lesson plan (See Appendix H), which were differentiated versions of the same content on global climate change comprehensively, were developed. The demographic information form was constructed after reviewing the literature. Expert judgments were obtained to confirm the face and content validity of the instruments.

Prior to the data collection for both the pilot and the main study, the necessary permissions for conducting research were obtained from the Ethical Committee of Boğaziçi University and the Ministry of Education. The participants were asked to sign the informed consent form (See Appendix A).

3.6.1. The Procedure of the Pilot Study-1

The pilot study - 1 was conducted with a group of 4 students. The main purpose of this pilot study was to test the applicability of the gamified-integrated STEM lesson design, the effects of game elements, and time management. Time was controlled during the implementation phase of the lesson design. After the implementation, the students were interviewed, and their opinions and suggestions for the pilot study were noted in line with their responses.

Students stated that they learned new vocabulary and concepts and associated the purpose of this lesson mainly with global climate change, melting glaciers, and protecting coastal cities. Students said that they found the Kahoot activity interesting, but they thought that the answers to some of the questions in Kahoot were difficult. Students added that the most interesting activity was the observation and its result and that they also found the information about the causes and consequences of climate change useful. Students emphasized that finding solutions was very useful for developing and expanding their imagination and that they did not find anything boring and/or unnecessary.

Students stated that group work was very important at the product stage. Students also indicated that game elements such as badges, points, leaderboards, etc., which they encountered in other games they played, increased competition, made them more ambitious, and made them realize that conditions could change at any time because there were also negative points and bonuses. Students emphasized that they liked the badges more than the points. In addition, they stated that they would like to have such activities in social studies and mathematics lessons because it would increase their interest. One of the students said, *"In games, we keep even unnecessary information in our minds; if the lessons are taught in this way, we will learn the whole lesson much more easily and never forget it"*.

The students stated that they enjoyed the lesson. One of the students stated, *"It did not feel like it was a lecture; it felt like we were doing fun games and activities"*. Students indicated that under normal conditions, they would not be able to endure even 40 minutes of lectures, but in today's lesson they did not even want to look at the clock.

The gamified-integrated STEM instructional design was revised in the light of these feedbacks. Entertainment elements have been increased and bonus points have been added. Kahoot questions have been updated and some questions have been made easier. Since the observation was found to be remarkable, it was concluded that it should be emphasized during the implementation.

3.6.2. The Procedure of the Pilot Study-2

After pilot study - 1, the course designs to be implemented were finalized. In line with the permissions obtained, the pilot study - 2 was conducted with the 8^{th} grade students in a private school in Istanbul. For the pilot study - 2, the classes were divided into control group, experimental group 1, and experimental group 2. Before the implementations, the instruments which are the "Problem-solving Skill Perceptions

Scale", and the "Critical Thinking Disposition Instrument" were given to all groups as a pre-test. The average time spent by the students at this stage was 15 minutes. The implementation of the instructional designs took 4 lessons and at the end of these lessons, the pilot study was terminated because the school's academic program was too intensive. For this reason, the product creation and presentation phases and the post-test could not be applied. Nevertheless, it was an important pilot study in terms of forming an idea about which stages 4 lessons would be enough. At the same time, the science teacher was present in the lessons along with the researcher. In this way, additional data was obtained from this study through teacher observation.

The teacher's comment is summarized below:

> *"In the class where the gamified-integrated STEM instructional design was implemented, students were very active in the lesson. I observed that students who had low interest in the lesson, who was distracted and had difficulty following the lesson, participated enthusiastically in the lesson. I thought that the exam group students would not be affected by elements such as badges, points, and leaderboards. Almost all of the students in the class said that the lesson was very enjoyable and only 2 students said that they were bored. One of them is a student who prefers to remain passive in normal classes and does not like to stand out in the classroom. The other student stated that he was bored because he could not use his phone; it was not related to the content of the lesson. In addition, earning and losing points increased participation. Although they did not understand the purpose of points and badges at the beginning, they tried to make up for the points they lost or to earn the most badges in the process. Some students did not want to participate in group work and wanted to work individually. It was concluded that it was more difficult to observe their individual achievements when they were in groups, but it was more meaningful in terms of creating an understanding of cooperation. Similarly, students in the class where the integrated STEM lesson plan was implemented were very active in the lesson. It was observed that all students followed the lesson with interest and actively participated. I think the fact that they encountered a different teacher than their own teacher also had an effect. In this group, there were no factors that increased motivation because game elements were not used, but the students enjoyed the entire lesson. The observation study was the most remarkable part. In the traditional lecture class, students were passive listeners. They participated by answering questions. However, they did not express that the lesson was fun and different compared to the other groups. They did not have the opportunity to experience the sea ice-land ice observation. Their problem-solving and critical thinking skills were limited to what they thought and knew. While the traditional group learned from the video, the gamified STEM and integrated STEM groups observed the answers, they thought and found in the videos."*

In the light of these feedbacks, the instructional designs have been revised again. Group work was explained in more detail and tasks were allocated. The experimental groups who did group work in the videos were shown the videos again after the study. In this way, the memorability of the videos was increased. A Benevolent Koala badge was added to increase awareness of cooperation. It was realized that the traditional group, which did not make observations, could not fully understand the most crucial part of the plan because they could not see it. Therefore, the lecture part of the lesson for them was updated and supported with related visuals.

3.6.3. The Procedure of the Main Study

According to the outcomes of pilot study - 1 and pilot study - 2, changes were made to the lesson designs. More game elements were added to the gamified-integrated STEM instructional design, the time required for each section was estimated precisely, and precautions were taken against possible problems such as time, technology, and lack of materials.

The main study was implemented in the first semester of the 2022-2023 academic year in the light of the first unit of the science course which is called Seasons and Climate. One of the classes was designated as the control group and the others as the experimental groups. Before the implementations, firstly consent forms and then instruments which are the “Problem-Solving Skill Perceptions Scale” and the “Critical Thinking Disposition Instrument” were given to all groups as a pre-test.

The course duration required for each of the instructional designs was determined as at least 6 class hours. The lessons were planned to be taught as block lessons and therefore the implementation was planned to be spread over three weeks. The classes where the implementations were conducted were selected by the principal, so they were not randomly selected. The researcher implemented the plans prepared with traditional methods to the control group, the integrated STEM instructional design for experimental group 1 and gamified-integrated STEM instructional design for experimental group 2. After the implementation of the instructional designs, the instruments which are the "Problem Solving Skill Perceptions Scale" and the "Critical Thinking Disposition Scale” were applied to the students as a post-test.

At the end of the applications, individual interviews were conducted with 6 students from each experimental group. The participants to be interviewed were selected among those with low, medium, and high problem-solving skill perception and critical thinking disposition scores from each group. A total of 12 students were interviewed from these groups. The researcher made statements during data collection to give a brief explanation of the research and to clarify the confidentiality of the information. Following the data collection, the data was transferred to the cloud environment on the computer, and the names of the students were coded.

3.7. Data Collection

In this section, validity & reliability analyses of the scales and interviews are explained below.

3.7.1. Validity & Reliability Analysis of the Scales

Descriptive statistics related to the participants' problem-solving skill perceptions and critical thinking disposition levels were calculated. The pre-test results showed that the participants' mean scores for the problem-solving skill perceptions were M = 78.7 (SD = 11.1.), and the critical thinking disposition levels measure were M = 91.5 (SD = 13.4). The post-test results showed that the participants' scores for the problem-solving skill perceptions were M = 81.4 (SD = 13.6.), and for the critical thinking disposition levels measure were M = 93.9 (SD = 14.5). As a result, there is an increase in mean scores for both scales applied.

For the Problem-Solving Skill Perceptions Scale, the reliability coefficient was calculated as 0.88. When this study is examined, the reliability coefficient was calculated as 0.80 for the pre-test and 0.91 for the post-test. Accordingly, for the Critical Thinking Disposition Instrument, the Cronbach Alpha internal consistency coefficient was calculated as 0.9. When examining this study, the reliability coefficient was calculated as 0.88 for pre-test and 0.92 for post-test (Table 3.5).

Table 3.5. Descriptive statistics regarding the variables of the study.

N_{Total}=69	Mean	SD	Range	Skewness	Kurtosis	Cronbach's alpha
Problem Solving/Pre-test	78.71	11.8	2.45	-.044	.036	.80
Problem Solving/Post-test	81.38	13.64	3.14	-.521	.971	.91
Critical Thinking/Pre-test	91.49	13.39	3.16	-.505	1.771	.88
Critical Thinking/Post-test	93.90	14.50	3.36	-.496	1.969	.92
The possible score range is 22-110 for the problem-solving skill perceptions scale, and 25-125 for the critical thinking disposition instrument.						

3.7.2. Interviews

Immediately after the post-test, the scores of the experimental groups were evaluated. After this evaluation, the high, middle, and low scoring students were selected from each experimental group. Among these students, two students from each score level and substitute students were selected. Individual interviews were conducted with selected students to better understand what they thought about the instructional design and to get their views on global climate change. The interviews lasted approximately 15 minutes for each student. These interviews were audio-recorded and then transcribed for the analysis of the written data.

Interviews were used because sometimes students have difficulty expressing themselves and writing down their thoughts and these interviews were useful in understanding their thought process. Another reason for conducting interviews was to confirm their answers on the tests (Rowley, 2012). The main aim was to clarify any ambiguities in their answers. Examples of interview questions are "Can you explain the solution you proposed as a group?" "If you had to propose a solution on your own, would you want to follow the same path?" "Did these lessons we did about climate change affect your knowledge about climate change? Can you explain?". These questions aimed to elicit their problem-solving perceptions, critical thinking dispositions, and their views on climate change.

3.8. Data Analysis

In this section, the analyses of quantitative and qualitative data are evaluated separately. Quantitative data were analyzed through SPSS using paired samples t-test and one-way ANOVA. For qualitative data, content analysis was used.

3.8.1. Analysis of Quantitative Data

Both Problem-Solving Skills Perception Scale and Critical Thinking Disposition Instrument are 5-Point Likert Scale. For all scales, data was coded like 1: Definitely Disagree 2: Disagree 3: I am not sure 4: Agree 5: Definitely Agree. Reverse items were taken into account accordingly.

Table 3.6 shows the data analysis for each research question. The first research question was analyzed by using paired samples t-test. Paired samples t-test was used to compare the means of two variables for a single group. There are two assumptions that need to be considered when using paired samples t-test. The first one is that the levels of the independent variable are matched similarly since it is dichotomous. The second one is that the dependent variable has a normal distribution (Morgan et al., 2019). All the assumptions were checked and since the assumptions were met, this test was used in the study.

The second research question was analyzed by using ANOVA. A one-way ANOVA test was used to compare means across three or more independent groups, in this case, the control group, experimental group 1, and experimental group 2. There are three assumptions that need to be considered when using a one-way ANOVA test. The first one is that observations need to be independent, so one person's score should not give any idea of how the other individuals would score. The second one is that variances on the dependent variable needs to be equal across groups and the last one is the normal distribution (Morgan et al., 2019). All the assumptions were checked and since the assumptions were met, this test was used in the study.

Table 3.6. Data analysis.

Research Questions	**Data Analysis**
1) Are there any statistically significant differences in 8^{th} graders' problem-solving skill perceptions and critical thinking dispositions that resulted from interventions?	Paired samples t-test
2) Are there any statistically significant differences in 8^{th} graders' problem-solving skill perceptions and critical thinking dispositions between control and experimental groups?	One-way ANOVA
3) How do students express their problem-solving skill perceptions and critical thinking dispositions in their products after the interventions?	Content analysis
4) What are the students' views on learning about global climate change through gamified-integrated STEM or integrated STEM lessons?	Content analysis

3.8.2. Analysis of the Qualitative Data

The third and fourth research questions were analyzed by using content analysis. Content analysis is a qualitative research tool or technique widely used to analyze content and its features. It is an approach used to quantify qualitative information by sorting data and comparing different pieces of information to summarize it into useful information. First, the interviews were transcribed and then coded by three different researchers.

4. RESULTS

In this chapter, the results of the study are presented in four main sections according to the research questions. First, whether there was a difference in the problem-solving skill perceptions and critical thinking dispositions of 8th grade students as a result of the interventions is presented with statistics. Secondly, whether there was a difference between the experimental groups and the control group is presented. Finally, content analysis was conducted for the third and fourth research questions. Each result is also presented in the tables below.

4.1. Research Question 1: Are there any statistically significant differences in 8th grade students' problem-solving skill perceptions and critical thinking dispositions that resulted from interventions?

In this section, quantitative data were analyzed. For both scales, paired sample t-test was applied first for the integrated STEM group and then for the gamified STEM group. Assumptions were checked for the paired samples t-test. According to the paired samples t-test, the following assumptions were found to be appropriate to apply this test.

- The dependent variable was continuous.
- The observations were independent of one another.
- The dependent variable was approximately normally distributed.

4.1.1. Differences in 8th grade students' problem-solving skill perceptions resulting from interventions

Table 4.1 below presents the descriptives for pre and post-test results for problem-solving skill perceptions of students in the integrated STEM, gamified-integrated STEM, and control groups. According to the results, there was an increase in the mean scores of post-tests for the integrated STEM and gamified-integrated STEM groups, while there was a slight decrease in the mean scores of post-tests for the control group (Table 4.1).

Table 4.1. Descriptives for problem-solving skill perceptions.

Groups		Mean	SD	SE
Integrated STEM (N=23)	Pre-Test	80.65	11.53	2.40
	Post-Test	81.56	13.47	2.81
Gamified-Integrated STEM (N=23)	Pre-Test	78.52	11.64	2.43
	Post-Test	87.09	14.87	3.10
Control Group (N=23)	Pre-Test	76.96	10.52	2.19
	Post-Test	75.48	10.11	2.11

In order to check if the increase in the mean scores of the post-test is significant, a paired sample t-test was conducted for integrated STEM pre and post-test results and for gamified-integrated STEM pre and post-test results separately. As presented in Table 4.2, there was no statistically significant difference between pre and post-tests scores in the integrated STEM group. For the gamified-integrated STEM group, there was an average of 8.57 difference between the problem-solving scores. Since the p value corresponding to this value is 0.01 ($p<0.05$), it can be stated that gamified-integrated STEM instructional design was effective in problem-solving and there was a significant difference between before and after applying gamified-integrated STEM instructional design (Table 4.2).

Table 4.2. Paired samples t-test results for problem-solving skill perceptions.

	Pre-test		**Post-test**		**Sig. (2-tailed)**		
Variables	*M*	*SD*	*M*	*SD*	*t*	*P*	*r*
Integrated STEM	80.65	11.53	81.56	13.47	.40	.69	.62
Gamified-Integrated STEM	78.52	11.64	87.09	14.87	2.64	.01	.33

4.1.2. Differences in 8th grade students' critical thinking dispositions resulting from interventions

Table 4.3 below presents the descriptives for pre and post-test results for critical thinking disposition levels of students in the integrated STEM, gamified-integrated STEM, and control groups. According to Table 8, there was an increase in the mean scores of post-tests for the integrated STEM and gamified-integrated STEM groups, while a decrease was observed in the control group.

Table 4.3. Descriptives for critical thinking disposition levels.

		Mean	**SD**	**SE**
Integrated STEM (N=23)	Pre-Test	94.78	12.37	2.58
	Post-Test	94.22	16.76	3.50
Gamified-Integrated STEM (N=23)	Pre-Test	92.43	15.51	3.24
	Post-Test	101.35	11.40	2.38
Control Group (N=23)	Pre-Test	87.26	11.37	2.37
	Post-Test	86.13	10.85	2.26

In order to check if the increase in the mean scores of the post-test is significant, a paired sample t-test was again conducted for integrated STEM pre and post-test results and for gamified-integrated STEM pre and post-test results separately. As presented in Table 4.4, there was no statistically significant difference between pre and post-tests scores in the integrated STEM group. For the gamified-integrated STEM group, there was an average of 8.92 difference between the critical thinking scores. Since the p value corresponding to this value is 0.00 ($p<0.05$), it can be stated that gamified-integrated STEM was effective in critical thinking and there was a significant difference between before and after applying gamified-integrated STEM instructional design (Table 4.4).

Table 4.4. Paired samples t-test results for critical thinking dispositions.

	Pre-test		**Post-test**		**Sig. (2-tailed)**		
Variables	*M*	*SD*	*M*	*SD*	*t*	*p*	*r*
Integrated STEM	94.78	12.37	94.22	16.76	.15	.88	.30
Gamified-Integrated STEM	92.43	15.51	101.35	11.40	2.95	.00	.45

4.2. Research Question 2: Are there any statistically significant differences in 8th grade students' problem-solving skill perceptions and critical thinking dispositions between control and experimental groups?

In order to check if there is a difference between groups, one-way ANOVA test was conducted. Table 4.5 below presents the one-way ANOVA results for each group. Assumptions were checked for the one-way ANOVA. According to the one-way ANOVA, the following assumptions were found to be appropriate to apply this test.

- Variances on the dependent variable were equal across groups.
- The observations were independent of one another.
- The dependent variable was approximately normally distributed.

Table 4.5. Descriptives for pre-test.

	Groups	**N**	**Mean**	**Std. Deviation**	**Std. Error**	**Lower Bound**
Problem Solving Skill Perceptions	Gamified-Integrated STEM	23	78.52	11.64	2.43	73.49
	Integrated STEM	23	80.65	11.53	2.40	75.67
	Control	23	76.96	10.52	2.19	72.41
	Total	69	78.71	11.18	1.35	76.02
Critical Thinking Dispositions	Gamified-Integrated STEM	23	92.43	15.51	3.23	85.73
	Integrated STEM	23	94.78	12.37	2.58	89.43
	Control	23	87.26	11.37	2.37	82.34
	Total	69	91.49	13.39	1.61	88.28

Table 4.5 showed the descriptives for pre-test results. According to one-way ANOVA results, there was no statistically significant difference between pre-test scores of groups for both problem-solving skill perceptions (p=.80) and critical thinking

dispositions (p=.88). Table 4.6 showed the descriptives for post-test results. In terms of post-test scores, there was a statistically significant difference in terms of both problem-solving skill perceptions (p=.01) and critical thinking dispositions (p=.00).

Table 4.6. Descriptives for post-test.

	Groups	N	Mean	Std. Deviation	Std. Error	Lower Bound
Problem Solving Skill Perceptions	Gamified-Integrated STEM	23	87.09	14.87	3.10	80.66
	Integrated STEM	23	81.57	13.47	2.81	75.74
	Control	23	75.48	10.11	2.11	71.11
	Total	69	81.38	13.64	1.64	78.10
Critical Thinking Dispositions	Gamified-Integrated STEM	23	101.35	11.40	2.38	96.42
	Integrated STEM	23	94.22	16.76	3.49	86.97
	Control	23	86.13	10.85	2.26	81.44
	Total	69	93.90	14.50	1.75	90.42

When mean scores were analyzed, it was seen that there was an increase in the pre & post-test results of both problem solving skill perception and critical thinking disposition scales. Since there was also a statistically significant difference between the groups in terms of problem-solving skill perceptions and critical thinking dispositions, post-hoc test was applied to understand which groups this difference was between.

Table 4.7. Post Hoc for post-test.

Dependent Variable	Groups	Between Groups	Mean Difference	Std. Error	Sig.
Problem Solving Skill Perceptions	Gamified-Integrated STEM	Integrated STEM	5.52	3.82	.33
		Control	11.61	3.82	.01
	Integrated STEM	Gamified-Integrated STEM	-5.52	3.82	.33
		Control	6.09	3.82	.26
	Control	Gamified-Integrated STEM	-11.61	3.82	.01
		Integrated STEM	-6.09	3.82	.26
Critical Thinking Disposition	Gamified-Integrated STEM	Integrated STEM	7.13	3.91	.17
		Control	15.22	3.91	.00
	Integrated STEM	Gamified-Integrated STEM	-7.13	3.91	.17
		Control	8.09	3.91	.11
	Control	Gamified-Integrated STEM	-15.22	3.91	.00
		Integrated STEM	-8.09	3.91	.11

When the p-values between the groups were examined, it was found that there was a statistically significant difference for problem-solving skill perceptions between the gamified-integrated STEM and control groups (p=.01). It was also found that there was a statistically significant difference for critical thinking disposition between the gamified-integrated STEM and control groups (p=.00). On the other hand, there was no statistically significant difference between the gamified-integrated STEM and integrated STEM groups for problem-solving skill perceptions (p=.33) and critical thinking dispositions (p=.17) and also between the control and integrated STEM groups for problem-solving skill perceptions (p=.26) and critical thinking dispositions (p=.11). In general, it can be said that gamified-integrated STEM is more effective than other methods in terms of both problem-solving skill perceptions and critical thinking dispositions and there is a significant difference before and after the implementation of gamified-integrated STEM instructional design.

4.3. Research Question 3: How do students express their problem-solving skill perceptions and critical thinking dispositions in their products after the interventions?

To answer the third research question, the responses were analyzed under two headings: problem-solving skill perception and critical thinking disposition. For each heading, integrated STEM and gamified-integrated STEM groups were evaluated.

The students to be interviewed were determined according to their scores obtained from the two scales. The score range in the Problem-Solving Perceptions Scale was 22-110. In the Critical Thinking Disposition Levels Instrument, the score range was 25-125. In these value ranges, the scores obtained by the students from the two scales were evaluated. High, medium, and low score categories were determined. According to the categories, 6 students in each score group were identified. The value ranges of these students are shown in Table 4.8. The identified students were coded as S1-S2-S3-S4-S4-S5-S6 in the integrated STEM group and G1-G2-G3-G4-G4-G5-G6 in the gamified STEM group.

Table 4.8. Categorization of students according to their scores.

Experimental groups	**High Scores**		**Medium Scores**		**Low Scores**	
Integrated STEM	S1: 117	S2: 113	S3: 95	S4: 95	S5: 80	S6: 73
Gamified-integrated STEM	G1: 123	G2: 114	G3: 96	G4: 95	G5: 83	G6: 70
*Ranges for High Score: 125-105, Medium Score: 104-85, Low Score: 84-65						

According to the analyses, it was observed that the students' answers did not differ according to their scores. For this reason, the scores of the students were not included in the tables separately. Instead, the answers given by the students were presented in general.

4.3.1. Students' expressions of their problem-solving skill perceptions after the interventions

In this section, the problem-solving skill perceptions of interviewed students selected from the integrated STEM group and interviewed students selected from the gamified-integrated STEM group were evaluated with content analyses.

4.3.1.1. Students' expressions of their problem-solving skill perceptions in the integrated STEM group. According to the analysis of the third research question, firstly, the problem-solving skill perceptions of the students in the integrated STEM group were examined, and categories were first determined according to the dimensions in the Problem-Solving Skill Perceptions Scale. These dimensions were determined as "Students' perception of problem-solving skills" and "Students' perception of willingness and determination towards problem-solving" categories. Then, different subcategories emerged for each category (Table 4.9).

Table 4.9 Problem-solving skill perceptions - integrated STEM group.

Categories	**Subcategories**	**Example Student Answer**
Students' perception of problem-solving skills	Understanding of the problem	S2: "We examined flooded cities. We learned the difference between land ice and sea ice. We did research. Based on these, I realized that we would save the flooded cities."
	Problem-solving process	S1: “We searched and found the cities that were under water and why they were flooded. After that, you opened videos from an application. We thought about what we can do to prevent climate change. Then we did group work. We came up with good things for a while. We shared what we did with our friends and you. We also had an exam.”
Students' perception of willingness and determination towards problem-solving		S5: “We were able to get help from each other because we did it as a group. If I did it alone, I would have to think more. Still, I would try to achieve the best result as much as I could. My idea was actually similar. However, they chose someone else because they thought it was better. I also shared what we learnt with my sister and her class.”

In the first category, there were two subcategories which were “understanding of the problem” and “problem-solving process”. In the first subcategory, the interviewed students stated that the problem was clear and understandable in the integrated STEM lessons and that they were aware of the issue from the very beginning of the lessons. S2 and S5 stated that they thought that we would find solutions to global climate change directly. However, in general, students at all levels (low, medium, and high score levels) defined the general problem correctly because they stated different perspectives and were able to predict what to do in the process.

The answers given in the second subcategory were related to the students' evaluation of the lessons in all stages. All interviewed students were asked to explain the lesson from the beginning to the end as much as they remembered. Thus, it was aimed to make them aware of the problem-solving process. At this point, the responses of the high and mid-level students mainly covered the entire lessons, while the responses of the low-level students described the lessons in general terms. High and mid-level students (S1, S2, S3, and S4) mentioned the videos a lot. While only S2 recalled the review on NASA's page, S2 and S4 recalled the use of the notebooks distributed. Another noteworthy point is that only two students (S4 and S6) indicated that there was an exam during the lesson. Although this exam did not aim to measure their level of knowledge or achievements, it was important for the students as it covers the MoNE acquisitions related to the subject.

In the second category, all interviewed students stated that they created a discourse environment to find ideas. In the idea stage, students said that they tried to choose the best idea or the most feasible idea. Since some students were in the same group at the product creation stage, their explanations were similar about their products. S4, unlike the other students, stated that it was necessary to find a three-dimensional idea and realized that the materials were for this purpose. S3 stated:

> *"At the beginning, everyone gave their opinion one by one. X's project was very good, and we started making it. We thought it would be difficult because it was in 3D. First, we started with cardboard. Here we made the land, grass, and sea. It took a while to assemble the cardboard, and cutting the sticks was extremely difficult. When we finished them, it was very nice looking. We went to the stationery store and bought extra materials. We first thought of a ship to prevent the excess water in the sea from damaging the land, but since we could not make a ship, we turned it into something like a box. In our project, the box was measuring the excess water in the sea and pulling it to itself and purifying it with the help of its hose and turning it into drinking water."*

In terms of finding a solution to the problem, in addition, some students (S5 and S6) could not offer any ideas other than taking personal measures. When the products of the students were analyzed (See APPENDIX I), it was seen that the first two groups prepared their works in a similar way. The general aim of both of them was to turn salty water into fresh water and make it drinkable. The third group, unlike other groups, focused on the greenhouse effect and tried to reduce the consequences of the greenhouse effect. The last group, with a different perspective, created their projects on a system that can keep the cities that are in danger of being flooded above water or protect them like an aquarium. Looking at the products, it can be said that the students understood the problem correctly, were creative in finding ideas and tried to develop feasible solutions.

As a result, in the lessons taught with integrated STEM, interviewed students defined the problem and transferred the problem-solving steps in detail. Students stated that they improved their perceptions of problem-solving skills in this way. On the other hand, students indicated that they created an effective discourse environment in the process of finding a solution to the problem. However, as seen from their answers, they mostly tried to choose the better one among the ideas instead of consensus in the solution proposal they found for the problem. In this regard, students used the discussion environment for different purposes. Students' willingness to share the new information they learned with others showed that they have a perception of willingness and determination to solve this problem.

4.3.1.2. Students' expressions of problem-solving skill perceptions in the gamified-integrated STEM group. According to the analysis of the third research question, the problem-solving skill perceptions of the gamified-integrated STEM group were also examined, and categories were first determined according to the dimensions in the Problem-Solving Skill Perceptions scale. These dimensions were determined as "Students' perception of problem-solving skills" and "Students' perception of willingness and determination towards problem-solving" categories. Then, different subcategories emerged for each category (Table 4.10).

Table 4.10. Problem-solving skill perceptions – gamified-integrated STEM group.

Categories	**Subcategories**	**Example Student Answer**
Students' perception of problem-solving skills	Understanding of the problem	G4: "We examined flooded cities. We learned the difference between land ice and sea ice. We did research. Based on these, I realized that we would save the flooded cities."
	Problem-solving process	G1: "We searched and found the cities that were under water and why they were flooded. After that, you opened videos from an application. We thought about what we can do to prevent climate change. Then we did group work. We came up with good things for a while. We shared what we did with our friends and you. We also had an exam."

Table 4.10. Problem-solving skill perceptions – gamified-integrated STEM group (cont.).

Students' perception of willingness and determination towards problem-solving		G3: "We were able to get help from each other because we did it as a group. If I did it alone, I would have to think more. Still, I would try to achieve the best result as much as I could. My idea was actually similar. However, they chose someone else because they thought it was better. I also shared what we learnt with my sister and her class."

Like the students in the integrated STEM group, the interviewed students stated that the problem was clear and understandable and that they were aware of the issue from the very beginning of the lessons. Most students (G1, G2, G3, G4, and G6) expressed the problem first as global climate change and then the melting of glaciers. However, the students who considered the melting of glaciers as the main problem generally defined the problem correctly.

The answers given in the second subcategory were about students' evaluation of the lessons with all stages, but here, the answers of the gamified-integrated STEM group and the integrated STEM group differed. It was seen that game elements such as decryption stand out in the responses of students with high and medium scores. Games, especially Kahoot, were mentioned by students at all score levels. One student (G4) even defined Kahoot as a competition. According to the inferences made during the observations in the classroom, it was concluded that students saw Kahoot as a means of competition and strived to defeat each other. Only G1 mentioned Pavlopetri. However, most of the interviewed students mentioned learning about flooded and threatened cities, not only Pavlopetri. All interviewed students emphasized earning badges and points. G2 and G3 added that there was an exam, but other students stated that they forgot about the exam.

In the second category, high-scoring students mentioned discourse environment, group work, and all of them mentioned the division of labor. What is noteworthy in these codes is that students stated that they combined their ideas differently from other students.

While choosing the best idea was seen in the integrated STEM group, in the gamified STEM group, there was an effort to reach a better idea by combining ideas that came from group members. In addition, G2 mentioned that they helped other groups. It was concluded that students experienced cooperation and sharing in gamified STEM lessons.

When the students' products were analyzed (See APPENDIX J), it is seen that the products of all groups differ. While the first group aimed to turn water into ice, the second group aimed to build a dam and obtain energy. In fact, since these two groups aimed to turn water into ice, it can be said that they were similar projects. The third group, unlike all other groups, carried out an awareness raising activity. For this purpose, they tried to raise awareness of people with the banner they prepared. The fourth group aimed to protect the glaciers by reflecting the sun rays back. The students indicated about their problem-solving process that they understood the problem correctly, were creative in finding ideas, provided innovations with different studies, and tried to develop feasible solutions.

As a result, it was seen that in the lessons taught with gamified-integrated STEM, students stated that they did group work in defining the problem and finding solutions to the problem, and that their skills such as cooperation, sharing and project-making developed thanks to these group works. It can be said that interviewed students had a perception towards problem-solving skills and their willingness and determination towards problem-solving. On the other hand, another important indication was that after the games students initially defined as competition, feelings of sharing and acting together emerged.

4.3.2. Students' expressions of their critical thinking dispositions after the interventions

In this section, the critical thinking dispositions of interviewed students selected from the integrated STEM group and interviewed students selected from the gamified-integrated STEM group were evaluated by content analyses.

4.3.2.1. Students' expressions of their critical thinking dispositions in the integrated STEM group. According to the analysis of the third research question, the critical thinking disposition levels of the integrated STEM group were examined, and categories were determined according to the dimensions in the Critical Thinking Disposition Scale. These dimensions were determined as "Engagement", "Maturity", and "Innovativeness" categories. Then, different subcategories emerged for each category (Table 4.11).

The engagement dimension is explained as the realization of the reasoning process through effective communication skills by creating opportunities to use their abilities to reason, solve problems and make judgments (Kılıç & Şen, 2014). For this reason, group work constitutes a subcategory of engagement category. The maturity dimension is explained as the ability to evaluate experiences, recognize prejudices, and make objective assessments to develop different perspectives (Kılıç & Şen, 2014). The categorization of activities as interesting, useful, boring, and difficult constituted the subcategories of maturity category. Lastly, the innovativeness dimension is explained as being innovative, being open to new ideas, having a high sense of curiosity and research skills, and tending to find the right thing by questioning (Kılıç & Şen, 2014). The subcategories of these categories include some additions in the gamified STEM group. These are given as game elements in the engagement category, and gamification in the innovativeness category (Table 4.11).

Table 4.11. Critical thinking disposition - integrated STEM group.

Categories	**Subcategories**	**Example Answer**
Engagement	Group work	S4: "We tried to find the best idea, first we thought of it ourselves and then we told it to each other. Some of them insisted on their own ideas, some of them had little participation and could not come up with any ideas."
Maturity	Activities which are interesting	S5: "I learned about how glaciers raise sea level, what are global climate change and the gases that cause this change. It was interesting for me."

Table 4.11. Critical thinking disposition - integrated STEM group (cont.).

	Activities which are useful	S5: "I learned a lot of new and useful things about the climate, and I realized that creative thinking could lead to solutions in faster and simpler ways."
	Activities which are boring	S3: "In the first lessons, we had done seasons and climate, causes and consequences of global climate change as a subject repetition. They were things I knew; I was bored."
	Activities which are hard	S6: "I had a hard time coming up with creative ideas, I always came up with simple examples."
Innovativeness		S2: "We did the glacier activity; we put the ice on the dough and put it in the water, we had never done that before, and it was the first time we had done what we did as a project. It was different to come up with activities and ideas and to try so hard to find a solution."

In the first category, group work was identified as a subcategory. S1, S2, S3, and S5 found group work effective, and these students stated that their own ideas were applied in this study. While S4 and S6 stated that group work was more difficult because they could not apply their own idea, and they stated that they had a hard time engaging in the activities. With this result, it can be concluded that students have problems with their perspectives on ideas other than their own. This situation was interpreted by the students as behavior contrary to critical thinking.

In the second category, the activities were subcategorized as interesting, useful, boring, and difficult. Interviewed students with high scores (S1 and S2) found learning about flooded and threatened cities interesting. Students with medium and low scores (S3, S4, S5, and S6) stated that they found it interesting to observe the melting of glaciers and the effects of melting glaciers. S3 stated that s/he did not encounter anything interesting. S2, one of the high-scoring students, stated that it was useful to think of solutions and precautions against the problem of sea level rise. Only S1 mentioned that repeating the topic was boring, while none of the other students mentioned anything boring. Finally, S1, S3, and S4 pointed out the difficulty of creative thinking. It is interesting to note that students with high and medium scores in creativity mentioned that they had difficulty, while students with low scores mentioned that they did not have difficulty.

In the third category, one of the students with a high score (S2) was “thinking about solutions to global climate change”. This data is important in terms of students’ thinking that they do not do thinking exercises as well as critical thinking in other courses. For half of the students (S2, S4, and S5), experimentation is an aspect that distinguishes them from other courses. It is noteworthy that even in the science course, students were told not to conduct experiments. The point that attracted the attention of the students expressed as S1 and S5 was making projects. When the answers were analyzed, it was seen that all of the interviewed students found the content of this course more detailed.

As a result, when the answers of the students were divided into engagement, maturity and innovativeness in the lessons taught with integrated STEM, students stated that they developed skills such as cooperation because they stated that even if their own ideas were not implemented, they helped each other in creating a product. In terms of maturity, the students emphasized that they developed critical perspectives about the course. In line with the answers given by interviewed students, they stated that they contributed to the identification of interesting, useful, boring, and difficult areas related to the lesson. In terms of innovativeness, students made comparisons with other courses and reported the aspects of this course that contributed to and affected the development of these skills. It is noteworthy that students stated that they did not work on skills and did not do thinking activities like this one in other lessons.

4.3.2.2. Students’ expressions of their critical thinking dispositions in the gamified-integrated STEM group. According to the analysis of the third research question, the critical thinking disposition levels of the gamified-integrated STEM group were examined, and categories were determined according to the dimensions in the Critical Thinking Disposition Scale. These dimensions were determined as “Engagement”, “Maturity”, and “Innovativeness” categories. Then, different subcategories emerged for each category (Table 4.12).

Table 4.12. Critical thinking disposition - gamified STEM group.

Categories	Subcategories	Example Answer
Engagement	Group work	G6: "At first, I thought to do a dam, but then I realized that everyone thinks differently. Then, I told my friend how we could do something. We all thought together. Anyway, if I did it alone, I would probably do it very difficult, we did it all together. I think if I was alone, I would do very little, I couldn't think comprehensively."
	Game elements	G4: "It was fun, it was exciting, and it was nice to compete with my friends. Everyone had an effort, and this was very good, and I liked it. My friends come up with a lot of ideas, they help me a lot, but I do not have much confidence in myself, I mean, I did not believe I could do it, but with the help of my friends and because of the exciting environment we were in, I did it easily, it was a lot of fun."
Maturity	Activities which are interesting	G6: "This study made me want to do more research on such topics. I will also research historical places more."
	Activities which are useful	G3: "I learned what global climate change is, how climates are changing, and how we can prevent it. I had never taken volume into account in the experiment, and this new information helped me in the pressure unit. I learned a lot about science."
	Activities which are boring	G1: "There was nothing boring, the lessons were very full."
	Activities which are hard	G4: "It was difficult to visualize the model we made about global warming, but it was fun."
	Similarities with other games	G2: "There are many instructive things in computer games like these. For example, there is house building in a game, there is a timer on the side. After you build a house there, a flood comes there, and it shows how durable that house is. -Minecraft"
Innovativeness	Gamification	G2: "In other lessons, they usually teach us by writing or in other ways. In this lesson, we did more role-playing, we did experiments we had never done before, and the games were very fun. There was a pleasant environment for group work. It was not like a lecture at all."

Table 4.12. Critical thinking disposition - gamified STEM group (cont.).

	Adaptation to other courses	G4: “I think it's definitely mathematics. A difficult subject like mathematics becomes fun, not boring like a lecture. Maybe then I can do better.”

In the first category, there were two subcategories which are “group work” and “game elements”. For the first subcategory, the results were similar to the integrated STEM group. Students who found group work effective (G1, G2, and G4) generally stated that their ideas were implemented, or similar ideas were implemented. However, G5, one of the students with low level scores, stated that simpler ideas can be done alone, but comprehensive projects can be developed through group work and therefore group work was effective. G3, one of the students who scored at the medium level, was part of the group that did poster work. This student stated that their product was insufficient and stated that *"All the other groups made three-dimensional works, only our group made a poster. If I was by myself, I would not want to make a poster. I do not think it was good enough."*

G6, one of the students with low scores, stated that he saw the group work as a challenge and added that *“I would have liked to follow other paths. For example, building a dam would have been more useful. When the sea rises, I could divert the water there, and it would be easier to build.”* Although the students' expressions about group work differed, all interviewed students stated that they achieved better results when they combined their ideas and that they produced better projects because they did it as a group.

In the second subcategory, the impact of game elements on students' engagement was examined. The interviewed students stated that elements such as time, leaderboards, and badges increased their willingness to participate in the lesson. G2 said *that "Actually, I was more interested. I got more attached to the lesson and the subject and focused on what we were doing at that moment. I fought well with my friends."* Interviewed students mostly expressed opinions about the feeling of competition, and by competing, their interest in the lesson increased, they became excited, and they tried harder because they wanted to succeed. G4 stated that *"Competition, in my opinion, allows two people to push* *their limits and bring out their best selves. That's why I think it affected me positively. Other factors also affected me positively. The competitive environment is always important."* However, G6 stated that it was not the rewards or the competitive game elements, but the elements within the activities, such as decryption, that affected him more. G6 indicated that:

> *"I liked the activities and the cooperation more than the points because we do it all together and it gives me a lot of happiness to do something with people we love. The points or ranking is not very important to me. After all, we are all doing something together. It was fun to do that activity rather than earning a badge."*

When the answers given by the students were evaluated, it was seen that they generally made positive sentences about the game elements. In addition to the idea that they competed with each other, they also mentioned the happiness of being with their friends. As a result, students thought that both game elements and group work were successful. The preference for badges instead of points was one of the similar ideas among the interviewed students. In addition, all interviewed students stated that they had fun and were happy. They stated that their motivation towards the lesson increased. During in-class observations, it was observed that one student in the class did not want to participate in the lesson, and his excitement increased after the second lesson. It is also important to conclude that despite the negative statements about losing points or failing when using the bonus wheel, all students were willing to try their luck.

In the second category, the activities were subcategorized as interesting, useful, boring, and difficult. All students except G4 stated that they found the difference between sea ice and land ice interesting and that the result of the study was different from their predictions. G4, unlike the other students, stated that he found the game elements interesting. It is important for the study to create a situation in which students can think about and generate ideas. It is seen that one student from each group level found the information that the melting of glaciers raises the sea level useful. Again, it is seen that G4 found it useful to increase his interest in the subject, and similarly, G5, one of the students with low level scores, stated that his exam success increased thanks to this lesson. He stated that:

> *"I can say that it improved my knowledge. At first, I had trouble with climate, I could not understand the climate topic properly, but thanks to this course, I think I will get high grades in such exams. It was good for me to learn with games."*

It is important that all interviewed students stated that they were never bored during the lessons. G3 stated that the exam was difficult, while G5 said that doing a project was difficult. On the other hand, the other students did not mention anything they found difficult.

In the other subcategory, students were asked to compare the game elements they encountered in this lesson with other games. Interviewed students stated that elements such as rewards, fulfilling tasks, racing against time, competition, and decryption were frequently encountered in other games. G1 stated that *"We used to play a game with an older brother, and he would tell us to research important places, for example Chernobyl. He would give us chocolate etc. as a reward. Password decryption or something like that happens in research knowledge games."* Also, the student G5 who told what was done in the game in case of flooding by telling the Minecraft game stated that games and these lessons are very related. On the other hand, some of the students (G3 and G4) stated that they did not play many games, or they preferred different games such as dressing up dolls, and therefore did not specify similarities. G3 said that *"I do not play games"* and G4 stated that *"Not in my games. I used to play games like dress up dolls."*

In the third category, there were two subcategories which were gamification and adaptation to other courses. In the gamification subcategory, interviewed students with high and medium scores emphasized entertainment. Compared to other lessons, G4 clearly stated that a stress-free environment was provided and an environment where ideas could be expressed openly was created. It is interesting to note that the majority of the students saw the badges and reward system as different from other lessons, but none of the interviewed students mentioned the points specifically. The interviewed students with low scores also evaluated the lesson only with the experiments performed.

In the adaptation to other courses category, students criticized in which other courses the gamified-integrated STEM method could be meaningful. G1, G2, G3, and G6 stated that they would like to see mathematics lessons taught in this way because they found mathematics lessons difficult and boring. G4 indicated that the most appropriate course to include games would be science, while another student said that English would be the most appropriate subject. The student, who thinks that it is necessary to be in English, has stated that thanks to this course, the memorability has increased and stated that she thinks it will be effective in overcoming difficulties such as memorizing words in English. Therefore, it can be said that gamified-integrated STEM lessons were expressed by interviewed students as fun, easier and more memorable.

As a result, when the opinions of the students in the gamified-integrated STEM group were divided into participation, maturity, and innovation, it was seen that the critical thinking perceptions of the interviewed students about participation were similar to those in the integrated STEM group, but the interviewed students in this group were influenced by each other's ideas and participated in the idea generation stage by bringing together ideas that would benefit from a critical perspective. In line with the answers given by each of the interviewed student, they contributed to the identification of interesting, useful, boring, and difficult areas related to the course. Unlike the other group, the students in this group also mentioned game elements and said that gamification also had an impact on critical thinking. Students made comparisons with other courses and talked about the aspects of this course that contribute to skill development. Since the students were facing a new educational perspective, the entertainment elements and the reward system were described as different for them. At the same time, interviewed students stated that they were encouraged to think more effectively and develop a critical perspective thanks to the relaxed environment created by the feedback system.

4.4. Research Question 4: What are the students’ views on learning about global climate change through integrated STEM and gamified-integrated STEM lessons?

To answer the fourth research question, students' views on global climate change were obtained. Integrated STEM and gamified-integrated STEM groups were explained separately.

4.4.1. Students' views on learning about global climate change through integrated STEM lessons

According to the analysis of the fourth research question, students' views on learning about global climate change through integrated STEM were examined, and categories were determined according to interview questions. Categories were named as "Knowledge about global climate change", "Impact of the course on taking action", and "Hope for actions for global climate change". Then, different subcategories emerged for each category (Table 4.13).

Table 4.13. Students' views on global climate change in the integrated STEM group.

Categories	**Example Answer**
Knowledge about global climate change	S4: "I learned what climate change causes, what it harms, and how we can turn negative effects into positive effects."
Impact of the course on taking action	S3: "It affected me because I knew most of the things were wrong. In this activity, I thought that the glaciers on the land did not actually affect the water level, but I learned that they did. The other thing that affected me was the greenhouse effect; I also could not write the definition of climate change exactly. These lessons were very good even though we had learned them before."
Hope for actions for global climate change	S5: "My hope has increased. Actually, I was hopeless because normally winters are not this dry. It snows when it shouldn't, or the temperature rises too much. So, surprisingly, the climate is constantly changing. I think it would continue to change if measures were taken."

In the first category, S1, S2, S3, S4, and S5 stated that they learned valuable information about the causes and effects of global climate change and realized that they should be sensitive about the environment. The high-scored students stated that integrated STEM lessons included skill-building activities and information outside the curriculum. Also, high-scored students were mainly interested in sea levels. S1 stated that *"I learned a lot of new things about the climate, and I realized that creative thinking could lead to solutions in faster and simpler ways."*. S2 also stated that *"I learned about how glaciers raise sea level, what are global climate change and the gases that cause this change."*

In the second category, when the students' responses were analyzed, it was seen that there were common responses, such as the land ice-sea ice observation and the inclusion of information outside the curriculum among. One of the group observation made by the students is given in Figure 4.1 below. It was observed that the land ice raised the water level more than the sea ice.

Figure 4.1. Yellow Dough: Land Ice & White Dough: Sea Ice.

Students generally stated that these courses contained more detailed information, but that they reinforced them better in terms of subjects. High and medium scored students (S1, S2, S3, and S4) reported that they had learned a lot of detailed information in these lessons, that they liked this way of learning, and that they would also like to transfer on this knowledge and methods to other lessons. S3 stated that *"I did not have such in-depth knowledge before, but now I feel like I have a PhD on global climate change."* As a result, the activities and information learned in integrated STEM courses were explained by students as different and useful.

In the third category, it is seen that there was no commonality among the responses of students who scored at different levels in terms of hope for global climate change. It is noteworthy that among the students scoring at all score levels, there were students who indicated that they are hopeful (S1, S2, S4, and S6) as well as students who indicated they do not have hope about the future (S3 and S5). For example, S3 stated that: *"People do* *not care about global climate change. I have hope, but I do not really have hope because I think nothing will change."*

As a result, interviewed students stated that the lessons taught with integrated STEM increased their interest in and knowledge about global climate change. When the answers given by the interviewed students were analyzed, it is understood that some students answered the questions by looking at the issue of global climate change from a broad perspective, while some students drew attention to the topics covered in the course and the tools used in the lessons.

4.4.2. Students' views on learning about global climate change through gamified-integrated STEM lessons

According to the analysis of the fourth research question, students' views on learning about global climate change through gamified-integrated STEM were examined, and categories were determined according to interview questions. Categories were named as "Knowledge about global climate change", "Impact of the course on taking action", and "Hope for actions for global climate change". Then, different subcategories emerged for each category (Table 4.14).

Table 4.14. Students' views on global climate change in the gamified-integrated STEM group.

Categories	**Subcategories**	**Example Answer**
Knowledge about global climate change	Learning outcomes of Instructional Design	G3: "I learned what global climate change is, how climates are changing, and how we can prevent it. I had never taken volume into account in the experiment, and this new information helped me in the pressure unit. I learned a lot about science."
Impact of the course on taking action	Views about the course	G2: "This course contributed a lot to me. I remembered all the subjects I had forgotten. I also had fun with the games. Thanks to the game, lessons stayed in my mind more, now I will not forget global climate change."

Table 4.14. Students' views on global climate change in the gamified-integrated STEM group (cont.).

Hope for actions for global climate change	Hope for actions	G3: "I have hope. After all, if I did not come up with ideas and make products, I would say "I cannot do it, let someone else do it", but I can do it if I try, so effort is needed. I am more hopeful now."

When the responses in the first category are examined, it is seen that the causes and effects of global climate change and sea levels rise was the common response in the responses of the student. In the integrated STEM instructional design, 6 out of 23 students gave the correct answer "Land Ice" to the question "Predict the observation result". On the other hand, this number was 10 out of 23 students in the gamified STEM instructional design. Most of the students answered, "Sea Ice" and stated that they were surprised by the difference in the observation result. One of the group observation made by the students is given in Figure 4.2 below. It was observed that the land ice raised the water level more than the sea ice. In addition, the student G6 said in the interview that "This study made me want to do more research on such topics. I will also research historical flooded places more." It is important for the study to create a situation in which students can think about and generate ideas.

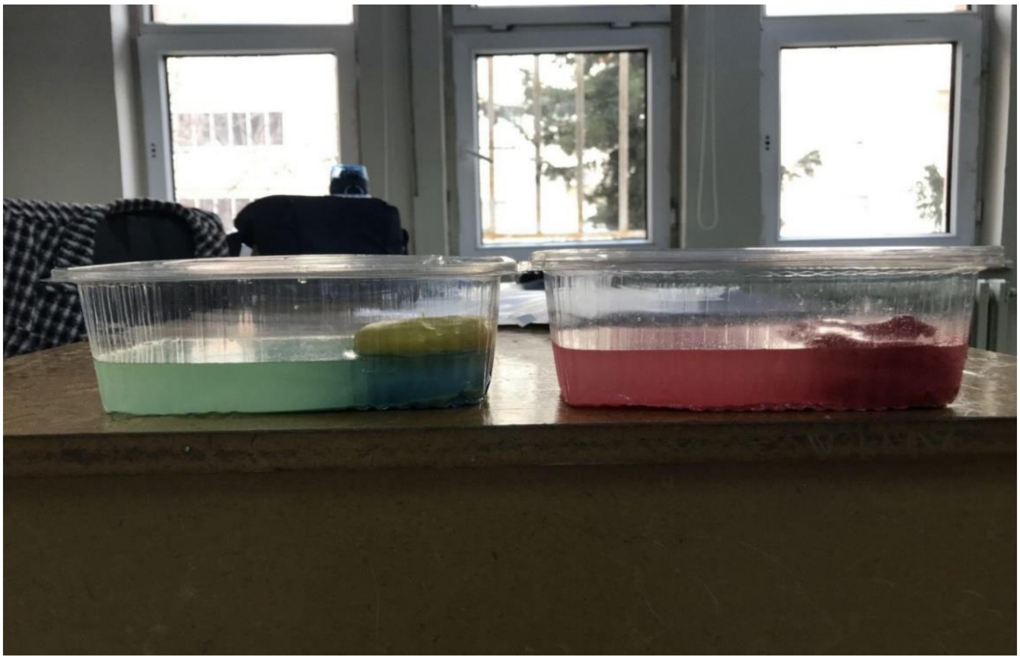

Figure 4.2. Blue-Yellow Dough: Sea Ice & Red Dough: Land Ice.

In the second category, the interviewed students stated that the lessons were very effective and that they both had fun and reinforced their knowledge thanks to the game elements. They stated that this lesson improved their perspectives, and they were able to have a better idea about the subject. In the last part of the lesson, the students realized that there was a question related to this topic in a book they were solving (ATA-Ben Korkmam 8. sınıf Fen Bilgisi). G5 stated that his exam success increased thanks to this lesson and added that:

> *"I can say that it improved my knowledge. At first, I had trouble with climate, I could not understand the climate topic properly, but thanks to this course, I think I will get high grades in such exams. It was good for me to learn with games.".*

Although the question in that book was not directly related to global climate change, G5 stated that they were able to make better connections between the topics, especially thanks to the activities they did in the lesson.

For the third category, students coded G2 and G3 stated that their hopefulness changed thanks to this course. G3 stated that *"I have hope. After all, if I did not come up with ideas and make products, I would say "I cannot do it, let someone else do it", but I can do it if I try, so effort is needed. I am more hopeful now."* Except for the student coded G4, it is seen that other students are hopeful for the future about global climate change in general. However, G4 stated that *"In terms of hope change, what we are learning now is just words, if there are people who can mobilize them, I am really hopeful, but if it is just words, I am not hopeful."*

As a result, students stated that they gained various and detailed information about global climate change in the lessons taught with gamified STEM. Gamified STEM lessons are seen by students as motivating them to take action on global climate change and useful for the future. Students stated that their state of hope changed with these lessons.

4.5. Summary of the Results

- There is no statistically significant difference between pre and post-test scores in terms of problem-solving scores in integrated STEM group.

- There is a statistically significant difference between pre and post-test scores in terms of problem-solving scores in gamified-integrated STEM group ($p=.01$).

- There is no statistically significant difference between pre and post-test scores in terms of critical thinking scores in integrated STEM group.

- There is a statistically significant difference between pre and post-test scores in terms of critical thinking scores in gamified-integrated STEM group ($p=.00$).

- There is no statistically significant difference between the integrated STEM group and gamified-integrated STEM group in terms of both problem-solving skill perceptions ($p=.33$) and critical thinking disposition ($p=.17$).

- There is no statistically significant difference between the integrated STEM group and the control group in terms of both problem-solving skill perceptions ($p=.26$) and critical thinking disposition ($p=.11$).

- There is a statistically significant difference between the gamified-integrated STEM group and the control group in terms of both problem-solving skill perceptions ($p=.01$) and critical thinking disposition ($p=.00$).

- In the integrated STEM instructional design, interviewed students stated that the problem was understandable from the beginning of the lesson and problem-solving process was clear for them. Students were willing to solve the global climate change problem, and they wanted to choose the best idea in the group work.

- In the gamified-integrated STEM instructional design, interviewed students stated that the problem was understandable from the beginning of the lesson and problem-solving process was clear for them. While explaining the steps of problem-solving, students mentioned game elements as well as problem-solving process. Students were willingness to solve global climate change problem, and they wanted to develop each other's ideas and try to reach the best, so the division of labor came to the fore.

- In the integrated STEM instructional design, interviewed students mentioned that thinking critically is new for them. How glaciers raise sea levels were interesting and useful for students. There are those who think that group work is effective and those who think that it is difficult. They explained this situation as those who could apply their own ideas and those who could not.

- In the gamified-integrated STEM instructional design, the interviewed students emphasized that it was an environment where they felt comfortable in critical thinking and could share their ideas freely. They stated that game elements were applied differently from other lessons. Students stated that group work was generally effective in product creation. Students indicated that badges attracted more attention than points and all students reported that they had a lot of fun in the lessons. When they compared this lesson with games, they found similar elements. It was generally emphasized that mathematics is suitable for gamification because it can be easier to learn.

- When the students' views on global climate change are analyzed, it is seen that interviewed students indicated they gained awareness in the integrated STEM instructional design, although they had different interpretations.

- When the students' views on global climate change are analyzed, it is seen that interviewed students stated that they gained awareness in the gamified-integrated STEM instructional design, also they have learned more about global climate change. Game elements and gamification attracted their attention. In addition, they have hope for actions for global climate change.

5. DISCUSSION

In this section, first the study was summarized. Then, the results were discussed based on the findings of the study. Finally, implications and limitations were shared for the benefit of other researchers.

5.1. Summary of the Study

This study was conducted in a quasi-experimental design with 69 8^{th} grade students in a public school in Turkey. The aim of this study is to investigate gamified-integrated STEM-based instruction about global climate change causes a significant change on 8^{th}-grade students' problem-solving skill perceptions and critical thinking disposition levels. Also, in this study, it is aimed to explore students' views about problem-solving skill perceptions and critical thinking disposition levels, and their views about global climate change after interventions. In this study, students' opinions were also analyzed in this direction. Three instruments were used to collect data. These are Problem-solving Skill Perceptions Scale, Critical Thinking Disposition Instrument, and interviews.

In order to test the implementation of the instructional designs and the scales, pilot study-1 was conducted with four students and pilot study-2 with 79 students in the fall semester of 2022, and the main study was conducted with 69 participants in the fall semester of 2022. Paired samples t-test, one-way ANOVA, and content analysis were conducted to answer the research questions.

The findings of the study revealed that the gamified-integrated STEM instructional design was more effective than the instructional designs applied to other groups. Statistically significant differences were found in the results of the gamified-integrated STEM group in terms of both problem-solving skill perception and critical thinking disposition. When the groups were compared, no significant difference was found between the gamified-integrated STEM and integrated STEM groups and between the integrated STEM and control groups, while statistically significant differences were found between the control group and the gamified-integrated STEM group. In addition, these findings were supported when the interviews with the students were evaluated. Although the answers given in the integrated STEM group and the answers given in the gamified-integrated STEM group were similar, the positive effect on the problem solving and critical thinking skills of the students in the gamified-integrated STEM group was observed. Another finding was that game elements and gamification contributed positively to the lesson. Although the students were not very hopeful about global climate change, the feeling of accomplishing something affected them positively, and it was observed that their interest in the subject and their desire to take action increased.

5.2. Discussion of the Results

In this section, the existing literature and the findings of the study were discussed. There are four subtitles in this section. Two of these titles discuss the results of the quantitative data and the other two discuss the results of the qualitative data.

5.2.1. Differences in eighth-grade students' problem-solving skill perceptions and critical thinking disposition levels that resulted from interventions

The first research question of the study was “Are there any statistically significant differences in eighth graders’ problem-solving skill perceptions and critical thinking disposition levels that resulted from interventions?”

According to the findings of the study, a statistically significant difference was found between the pre-test and post-test scores of students' perceptions of problem-solving skills for the lessons conducted with gamified-integrated STEM activities. Accordingly, it was showed that gamified-integrated STEM instructional design positively affected and improved students' perceptions of problem-solving skills. In the study conducted by Doğusoy and İnal (2006), it was found that game-based education improved students' problem-solving skills. Also, Erol & Çırak (2022) indicated that game design activities increased individuals’ problem-solving skills. Likewise, Poonsawad et al. (2022) emphasized that elements that are used in gamification, such as storytelling, can significantly improve students' problem-solving skills. In order to encourage students' problem-solving skills, Hou (2023) stated that using gamification activities is an effective method for students. Additionally, Wang et al. (2022) found that digital games are an effective pedagogical method in STEM education. These results in the literature supports the findings of this study.

According to the findings obtained after the intervention, no significant difference was found between the pre-test and post-test scores of the students' problem-solving skills perceptions for the courses conducted with integrated STEM activities. Similarly, in the study conducted by Elliot et al. (2001) with university students, it was concluded that STEM education had no effect on students' problem-solving skills. Also, Sarıcan and Akgündüz (2018) found that integrated STEM education did not significantly increase problem-solving skills and academic achievement. On the other hand, there are studies in the literature in which students' problem-solving skills increased with STEM education (Dewetres & Power, 2006; Mater et al., 2022; Pekbay, 2017; Shanta & Wells, 2022).

According to the findings obtained after the intervention, a statistically significant difference was found between the critical thinking pre-test and post-test scores of the students for the lessons carried out with gamified-integrated STEM activities. This finding shows that gamified-integrated STEM applications positively affected students' critical thinking dispositions. Asigigan and Samur (2021) supported the results obtained in the study by stating that students' critical thinking dispositions developed positively in the lessons carried out with the gamified STEM approach. Mao et al. (2022) found that critical thinking disposition was higher than critical thinking in similar studies. Like problem-solving skills, Mater et al. (2022) found that game elements increase critical thinking. Also, Dictus and Tiemann (2021) indicated that gamification promoted critical thinking.

In the integrated STEM group, no significant difference was found between the critical thinking pre-test and post-test scores. On the other hand, Duran and Şendağ (2012), in their study with high school students, stated that STEM experiences had a significant effect on the development of students' critical thinking. Like problem-solving skills, Mater et al. (2022) found that integrated STEM education improves thinking critically and solving complex problems. Moreover, Shanta & Wells (2022) argued that critical thinking is necessary for developing problem-solving skills, and therefore integrated STEM also increases critical thinking. Considering the literature, it can be said that the findings on integrated STEM group and critical thinking disposition levels were not compatible with the existing literature.

5.2.2. Differences in eighth graders' problem-solving skill perceptions and critical thinking disposition levels between control and experimental groups

The second research question of the study was "Are there any statistically significant differences in eighth graders' problem-solving skill perceptions and critical thinking disposition levels between control and experimental groups?"

According to the findings of the study, in terms of problem-solving skill perceptions, no statistically significant difference was found between experimental groups (p=0.33). Also, there was no statistically significant difference in terms of critical thinking dispositions (p=. 17). In addition, there was no statistically significant difference between the scores of the integrated STEM group and the control group for both problem-solving skill perceptions (p=.26) and critical thinking dispositions (p=.11). On the contrary, there was a statistically significant difference between the scores of the gamified-integrated STEM group and the control group for both problem solving skill perceptions (p=.01) and critical thinking dispositions (p=.00). It can be said that gamified-integrated STEM education is more effective than integrated STEM and traditional methods. In addition, it is noteworthy that the scores of the control group were low when all scores are considered. This finding shows that the lessons carried out with the experimental groups positively improved students' perceptions of problem-solving skills and critical thinking disposition levels.

In the literature, there are studies showing that integrated STEM education increases problem-solving skills (Ceylan, 2014; Mater et al., 2022). There are also findings on critical thinking in the literature (Gencer & Doğan, 2020; Hacioglu & Gulhan, 2021; Onsee & Nuangchalerm, 2019; Rogovaya, 2019; Siregar et al., 2019; Waddell, 2019). For example, Capraro and Slough (2013) stated that STEM project-based learning improves students' critical thinking skills. The findings obtained in studies examining the effect of traditional courses on students' critical thinking levels are similar to the results of this study. For example, Gandi et al. (2021) examined the differences between the experimental group and the control group in integrated STEM courses and found that there was a difference in critical thinking skills between the experimental group and the control group.

Similarly, in this study, the total scores of the experimental groups were higher than the control group. This shows that the implementation of the gamified-integrated STEM course affects students' critical thinking skills. Bourke (2021) found that gamification has an important role in developing students' higher-order thinking skills. It is thought that opportunities such as making decisions, making choices, and taking risks to reach the goal in a free environment offered by gamification positively affect this skill. In another study, it was observed that students' skills improved in gamification activities involving problem-solving scenarios that require critical thinking (McDonald, 2017). In contrast to these studies, another study found that there was no statistical difference between the gamification and control groups in terms of critical thinking skills (Jodoi et al., 2021). The common point of all these studies is that gamification should be further investigated.

5.2.3. Students' expressions of their perceptions of problem-solving skills and critical thinking dispositions after the interventions

The third research question of the study was "How do students express their problem-solving skill perceptions and critical thinking dispositions after the interventions?"

In line with the findings obtained from the analysis of the student interviews conducted within the context of the research, at the end of the study, it was found that the activities carried out within the scope of gamified-integrated STEM affected the students positively and students indicated that they learned and enjoyed together.

In order to determine the students' perceptions of problem-solving skills and critical thinking disposition levels, the students were asked questions about the lesson plans and the process. The integrated STEM group stated that the problem was clear and understandable regarding the process, and the students with high scores defined the steps followed on the way from the problem to the solution with more appropriate expressions. Students in this group interpreted the problem from different perspectives and defined the problem correctly in general. In addition, the integrated STEM group developed a project by choosing the best one among the ideas that emerged within the group at the point of finding a solution to the problem.

The gamified-integrated STEM group also stated that the problem was clear and understandable from the beginning of the application. While defining the steps followed on the way from the problem to the solution with appropriate expressions, unlike the integrated STEM group, they also mentioned the game elements and the effects created by these elements. The students who defined the problem correctly did not want to choose the best idea to find a solution but synthesized the different ideas mentioned in the group and produced a better/greater idea. Both groups indicated that they have high perceptions of problem-solving skills. Asigigan and Samur (2021) found similar to this study that students' problem-solving skills improved based on interviews with students and observation notes in her lessons conducted with gamified STEM activities. Hebebci and Usta (2018) shared the finding that game elements increase active participation and interest in their study. At the same time, they also mentioned the negative aspects of gamification, such as increasing the sense of competition. Contrary to Hebebci and Usta's study findings (2018), competition elements were found in integrated STEM lessons, especially in the product development phase in this study. Students insisted on their own ideas, and if they were not accepted, they felt they were not following an effective path. In the gamified-integrated STEM group, on the contrary, students stated that they chose to combine different ideas and cooperate by revealing their skills, such as problem-solving and critical thinking.

When the students' perceptions of critical thinking tendencies are examined, it is seen that there is a difference between the integrated STEM group and the gamified-integrated STEM group. While the students in the integrated STEM group stated that critical thinking was new for them and that they had difficulties, the students in the gamified-integrated STEM group showed a positive attitude towards different thoughts within the group and shared their thoughts openly in the process of producing solutions to the problem posed. At the same time, it is seen that the gamified-integrated STEM group agreed that group work and different ideas had a greater impact on the product development phase. The integrated STEM group, on the other hand, kept the group and the ideas developed in the background at this point and emphasized their own opinions. In previous studies, differences were found in the design process between analyses and interviews. Based on this, it is said that creativity and brainstorming-based elements are used more in gamified lessons (Morschheuser et al., 2017). The findings support the results of this study. In the gamified STEM group, students' more effective use of critical thinking skills to create a better idea and the creative solutions they found in problem-solving processes can be given as examples. In other studies which are supporting the findings, it was found that gamification increased peer learning, increased students' interest in science subjects by making the course subjects fun, and that students turned elements such as competition into positive emotions such as excitement and not giving up. (Hursen & Bas, 2019; Kılıçel & Kılıç, 2021)

Both groups found the activities interesting and useful. In addition, the students in the gamified-integrated STEM group stated that the game elements were different from other lessons, that gamification increased their interest and motivation, that these lessons had common points with other games they played, and that, in general, it would be effective to progress mathematics lessons with this method because mathematics is more difficult than other lessons. Bolat et al. (2017) found that the lessons taught with gamification facilitated the learning process. Similarly, in this study, it was found that the students thought that the lessons taught with gamification were more memorable and entertaining, but they also thought that more difficult lessons, such as mathematics could facilitate the learning process. Based on these, it can be stated that students' perceptions of critical thinking tendencies are more developed for the gamified-integrated STEM group.

5.2.4. Students’ views on learning about global climate change through gamified-integrated STEM or integrated STEM lessons

The last research question of the study was “What are the students' views on learning about global climate change through gamified-integrated STEM or integrated STEM lessons?”

In order to determine students' views on global climate change, various questions were asked to the integrated STEM and gamified-integrated STEM groups. Students in the integrated STEM group stated that they learned useful information about the causes and effects of global climate change during the application. While the students explained global climate change in different dimensions, it is seen that what they were told generally remained in their minds. Students in this group generally mentioned individual measures to take action against climate change. When asked about their hopes for the future of the world in the face of the effects of global climate change, it is understood that there is no commonality in the students' thoughts. In general, it can be said that students are not fully hopeful.

The gamified-integrated STEM group gave a common answer about the effects of global climate change as the sea level rise. Apart from this, they emphasized that they learned many new and technical information about global climate change. The students who stated that the games positively affected their knowledge also agreed that gamification was useful. When students were asked about their suggestions for solutions to global climate change, no common answer could be obtained, but they said that they should do more research on this issue as well as taking individual measures as an integrated STEM group. It is understood that students' hope for the future of the world changed positively with the lessons. It is seen that the gamified-integrated STEM lessons motivated students to take action for global climate change and increased their hope.

When the literature is examined, positive findings of researchers such as Hestness et al. (2016) and Svihla and Linn (2012) on climate change gamification are found. It is emphasized that systems such as global climate change, which are complex to teach and learn, can be easily learned through gamification, that better planning should be made to understand the lessons better, and that it will provide permanent learning if integrated into daily life problems. In a similar study, Rousell and Cutter-Mackenzie-Knowles (2019) drew attention to the importance of developing and influencing students in every aspect of teaching global climate change. Özdem et al. (2014), who conducted studies on the desire to take action towards global climate change, which is another finding of the research, it is seen that students mostly define global climate change as a result of the modern world, explain its causes and consequences correctly, but say that there is nothing they can do about it. This result is similar to the findings of the integrated STEM group students. In contrast to this study, Kolenaty et al. (2022) stated that students' desire to take action is in line with the plans made and that the studies supported climate action. These findings are similar to the findings of the gamified-integrated STEM group in the study. Finally, there are studies in which the hope that global climate change can be improved is questioned (Karsgaard & Davidson, 2023; Marks et al., 2023; Ojala, 2012). In these studies, it is stated that the new studies help to improve the belief in global climate change and that students' hopefulness improves and they become more motivated with the change in climate teaching.

5.3. Implications of the Study

This study has important implications for science teachers, STEM educators, gamification educators, climate change educators, and researchers. This study shows statistically significant differences between gamified integrated STEM education, integrated STEM education and traditional lessons. Problem solving skill perceptions and critical thinking disposition levels improved in the groups where gamified integrated STEM activities were implemented compared to the other groups. In addition, supporting the data of the quantitative study with qualitative data increases the reliability of the research.

As revealed in the current study and supported by the literature, the lessons taught with gamified-integrated STEM instructional design in global climate change education produced more positive results compared to other lessons. This result does not mean that integrated STEM is unsuccessful. On the contrary, it shows that its impact increases when game elements are added using the same framework. In addition, only climate was addressed in this study. In this respect, since it is not known what the results will be about other topics, future researchers are recommended to address topics other than climate.

In the existing literature, studies were generally conducted with younger age groups. Since this study was conducted with 13-year-old students, the findings obtained contribute to the literature. In addition, since students in this age group are preparing for a national exam, academic performance is very important for them. While this situation was expected to cause difficulty, on the contrary, it was observed that students' motivation increased, but the assessment test did not cause a change in their achievement. In this respect, it should be taken into consideration that gamified-integrated STEM lessons are successful in lessons that are more difficult or complex to learn. In parallel, the significant difference between gamified-integrated STEM lessons and students' perceptions of problem solving skills and critical thinking disposition levels may support teachers' implementation of gamified-integrated STEM lessons in teaching these skills. Since it is seen that students try to establish connections in different fields with these skills they develop, it is seen that it is successful in terms of skills training and gamified-integrated STEM needs to be further researched.

5.4. Limitations & Suggestions

In this section, the limitations of the study were presented, and some possible suggestions were revealed.

The first limitation was that the study group was students. Due to the fact that 8th grade students are included in an intense exam schedule, it was hard to find a suitable time in the weekly schedule; however, during the implementation, weekly schedules were made suitable with the help of the principals. Although it was thought that it will be difficult to do activities for the exam group students, positive feedback was received from the students, as the topics are both compatible with the curriculum and enable them to better understand not only one topic but also other topics by improving their ability to make inferences. Future researchers are recommended to conduct a study with 5th, 6th, and 7th grade students at the middle school level to improve this study. In this way, more effective studies can be conducted as the course schedules of students in these grade levels are more appropriate. The best time to work with 8^{th} grade students was observed to be the beginning of the semester. Therefore, it is recommended that future research be conducted during this period.

The second limitation was time. It is difficult to see big changes in terms of problem-solving skills perception and critical thinking disposition with a few weeks of lessons. However, this study is a suggestion to the researchers in the literature that a deeper research should be conducted in this field. Instructional designs can be increased, and more skill-based applications can be made. The scales can be repeated after a certain period of time.

The third limitation was that the materials provided to students during product creation did not include technological tools. Students tried to create their products with limited material. The positive feedback about this situation was that it allowed creativity to develop in their ideas. It is recommended to support product development with different materials and to leave it up to students to choose which method they want to use to create and present their products.

The fourth limitation was that students in classrooms with integrated STEM and traditional instructional designs were not able to take advantage of game mechanics such as badges, points, or leaderboards. This situation caused some students to be upset. After that, when the applications were completed, some additional badges were shared with them so that these students would remember these lessons happily. It is recommended that the plans applied to the experimental groups be applied to the other groups at the end of the implementation or that the plans be shared with the teachers so that these students can also benefit from the activities.

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APPENDIX A: CONSENT FORM

KATILIMCI ONAM FORMU

Araştırmanın adı: Oyunlaştırılmış STEM veya STEM: Ortaokul 8. Sınıf Öğrencilerinin Küresel İklim Değişikliği Konusunda Eleştirel Düşünme Eğilim Düzeylerini ve Problem Çözme Becerisi Algılarını Keşfetmek

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E-posta adresi: ilkem.ozdinc@boun.edu.tr

Sevgili Öğrencimiz ve Değerli Veli,

Bu araştırma, Boğaziçi Üniversitesi Matematik ve Fen Bilimleri Eğitimi Bölümü yüksek lisans öğrencisi İlkem Özdinç tarafından, "Oyunlaştırılmış STEM veya STEM: Ortaokul 8. Sınıf Öğrencilerinin Küresel İklim Değişikliği Konusunda Eleştirel Düşünme Eğilim Düzeylerini ve Problem Çözme Becerisi Algılarını Keşfetmek" adı altında, Gaye Defne Ceyhan Maclellan danışmanlığında yürütülmektedir. Bu araştırmanın amacı, küresel iklim değişikliği ile ilgili oyunlaştırılmış STEM etkinlikleri aracılığıyla 8. sınıf öğrencilerinin eleştirel düşünme eğilimlerini ve problem çözme becerileri incelemektir. Kararınızdan önce araştırma hakkında sizi bilgilendirmek istiyoruz. Bu bilgileri okuduktan sonra araştırmaya katılmak isterseniz lütfen onam formunda bulunan "EVET" ibaresini onaylayınız.

Bu araştırmaya katılmayı kabul ettiğiniz takdirde ilk olarak demografik bilgi formunu doldurmanız beklenecektir. Bu sayede araştırmadaki değişkenler belirlenecektir. Demografik form isim-soy isim, cinsiyet, yaş, şube, daha önce STEM Eğitimi ve Oyunlaştırma Eğitimi alma durumundan oluşmaktadır. Demografik bilgilerinizi doldurmanız yaklaşık 2 dakika sürecektir. İkinci olarak, Eleştirel Düşünme Eğilimi Ölçeği ve Problem Çözme Becerisine İlişkin Algı Ölçeği 'ne yönlendirileceksiniz. Toplam 47 sorudan oluşan bu anketleri doldurmanız en çok 15 dakikanızı alacaktır.

Ölçeklerin ardından uygulanacak olan ders içeriği toplamda 4-6 ders saati olmak üzere 2 haftayı kapsamaktadır. Ders planları bittiğinde ölçekler tekrarlanacaktır.

Bu araştırma bilimsel bir amaçla yapılmaktadır ve katılımcı bilgilerinin gizliliği esas tutulmaktadır. Bu araştırmaya katılmak tamamen isteğe bağlıdır. Katıldığınız takdirde çalışmanın herhangi bir aşamasında herhangi bir sebep göstermeden onayınızı çekmek hakkına da sahipsiniz. Eğer araştırmanın amacıyla ilgili verilen bilgiler dışında daha fazla bilgiye ihtiyaç duyarsanız ilkem.ozdinc@boun.edu.tr ve gaye.ceyhan@boun.edu.tr adreslerine ulaşabilirsiniz.

Araştırmaya getireceğiniz katkı için teşekkür eder, saygılarımızı sunarız.

APPENDIX B: DEMOGRAPHIC INFORMATION

Demografik Bilgi Formu

1. Adınız Soyadınız:
2. Cinsiyetiniz:
3. Yaşınız:
4. Şubeniz:
5. Daha önce STEM Eğitimi aldınz mı? Evet ☐ Hayır ☐
6. Daha önce Oyunlaştırma Eğitimi aldınız mı? Evet ☐ Hayır ☐

APPENDIX C: PROBLEM-SOLVING SKILL PERCEPTIONS SCALE

No	**Problem Çözme Becerisine İlişkin Algı Ölçeği** **YÖNERGE:** Aşağıdaki maddeler problem çözme becerisine ilişkin algıları belirlemeye yönelik bilgiler içermektedir. Lütfen aşağıdaki her bir maddede, sizin için en uygun olan seçeneği işaretleyiniz.	Kesinlikle katılmıyorum	Katılmıyorum	Kararsızım	Katılıyorum	Kesinlikle katılıyorum
1	Bir sorunla karşılaştığımda sorunu her yönüyle incelemeye çalışırım.					
2	Bir sorunu anlamakta sıkıntı yaşarsam sorunla ilgili araştırma yaparım.					
3	Bir sorunu çözüme ulaştırmak için araştırma yaparım.					
4	Sorunları çözmek için çeşitli denemeler yaparım.					
5	Bir sorunu çözdükten sonra elde etmiş olduğum sonuçları dikkatlice değerlendiririm.					
6	Sorunları çözmek için önceki bilgilerimi hatırlamaya çalışırım.					
7	Sorunlarla karşılaştığımda soruna neden olan şeyi araştırırım.					
8	Bir sorunu çözerken, soruna ilişkin düşündüğüm farklı çözüm yollarını karşılaştırırım.					
9	Bir sorunu çözmek için çevremdeki kişilerin fikirlerini alırım.					
10	Bir sorunla karşılaştığımda ilk önce sorunu açıklarım.					
11	Sorunları çözmek için gözlem yaparım.					
12	Bir sorunun çözümüyle ilgili karar verirken her çözüm yolunun sonuçlarını düşünürüm.					
13	Sorunu çözmeden önce uygulamak istediğim çözüm yolu üzerine düşünürüm.					
14	Bir sorunu çözmek için benzer sorunların çözümlerinden yararlanırım.					
15	Gerektiğinde bir sorunu çözebilmek için farklı çözüm yollarını birlikte kullanırım.					
16	İlk denememde sorunu çözmede başarısız olursam sorunu çözmekten vazgeçerim.					
17	Karşılaştığım sorunların zor olması benim o sorunu çözme isteğimi azaltır.					
18	Bir sorunla karşılaştığımda sorunu çözmeyi mümkün olduğu kadar ertelerim.					
19	Zor sorunları çözmektense kolay sorunları çözmeyi daha çok isterim.					
20	Sorunları çözmek yerine sorunlardan kaçınmayı tercih ederim.					
21	Zor bir sorunla karşılaştığımda onu çözebileceğimden şüphe duyarım.					
22	Karşılaştığım sorunları çözmek için uğraşmam.					

PERMISSION

Didem İnel <dideminel@gmail.com>
Alıcı: ben

3 Şub 2022 Per 11:21

Merhaba İlkem hocam,

Ölçeği çalışmalarınızda kullanmanızdan dolayı mutluluk duyarım. Ölçeğin uygulama için son halini ekte gönderiyorum. Ölçek iki alt boyuttan oluşuyor. Ölçeğin birinci boyutundaki 15 madde (makalede yazılı maddeler) olumlu algı maddeleri; ikinci alt boyutundaki maddeler ise isteklilik ve kararlılığa ilişkin olumsuz algı maddeleri (7 madde makalede yazılı). Ölçeği çalışmalarınızda kullanabilirsiniz. İyi çalışmalar diliyorum.

ilkem özdinç <ilkemozdinc@gmail.com>, 2 Şub 2022 Çar, 17:01 tarihinde şunu yazdı:

•••

--
Doç. Dr. Didem İNEL-EKİCİ
Uşak Üniversitesi, Matematik ve Fen Bilimleri Eğitimi Bölümü
Fen Bilgisi Eğitimi Anabilim Dalı
E-mail: dideminel@gmail.com
Cep Tel: 0506 2355193
İş Tel: 0 276 221 21 30 Dahili 2126

APPENDIX D: CRITICAL THINKING DISPOSITION INSTRUMENT

No	**Eleştirel Düşünme Eğilim Ölçeği** **YÖNERGE:** Aşağıdaki maddeler eleştirel düşünme eğilimini belirlemeye yönelik bilgiler içermektedir. Lütfen aşağıdaki her bir maddede, sizin için en uygun olan seçeneği işaretleyiniz.	Kesinlikle katılmıyorum	Katılmıyorum	Kararsızım	Katılıyorum	Kesinlikle katılıyorum
1	Benimle aynı fikirde olmasalar bile, başkalarının fikirlerini dikkatlice dinlerim.					
2	Problemleri çözmek için fırsatlar ararım.					
3	Pek çok konuya ilgi duyarım.					
4	Pek çok konu hakkında bilgi edinmekten hoşlanırım.					
5	Çok çeşitli konuları birbiriyle ilişkilendirebilirim.					
6	Bir öğrenme ortamındayken pek çok soru sorarım.					
7	Zor sorulara cevap aramaktan hoşlanırım.					
8	İyi bir problem çözücüyüm.					
9	Sorunları çözerken, mantıklı bir sonuca ulaşabileceğimden eminim.					
10	Bir konu hakkında iyi bilgilendirilmiş olmak önemlidir.					
11	Problem çözmeyi severim.					
12	Önyargılarımın kararlarımı etkilemesine izin vermeden, gerçekleri göz önünde bulundurmaya çalışırım.					
13	Çeşitli sorunları çözmek için sahip olduğum bilgileri kullanabilirim.					
14	Okulda olmadığım zamanlarda bile öğrenmekten hoşlanırım.					
15	Fikirlerime katılmayan insanlarla da iyi geçinebilirim.					
16	Anlatmak istediğimi açık ve net bir şekilde ortaya koyabilirim.					
17	Bir çözümü açıklamaya çalışırken doğru sorular sorarım.					
18	Sorunları açık ve net bir şekilde ortaya koyarım.					
19	Önyargılarımın düşüncelerimi etkiliyor olabileceğini göz önünde bulundururum.					
20	Doğruya ulaşmak bana rahatsızlık verse bile, bunun için çabalarım.					
21	Bir konuda doğruyu elde edene kadar, o konu üzerinde çalışmaya devam ederim.					
22	Problemin doğru yanıtını bulmak için bildiğim yolların dışına çıkarım.					
23	Problemlere birden fazla çözüm yolu bulmaya çalışırım.					
24	Bir karara varırken pek çok soru sorarım.					
25	Çoğu problemin birden çok çözüm yolu olduğuna inanırım.					

PERMISSION

Ahmet İlhan Şen <ahmetilhansen@gmail.com> 10 Mar 2022 Per 10:14

Alıcı: ben

Sayın İlkem Özdinç,

Bahsi geçen ölçeğimizi referans göstermek suretiyle kullanabilirsiniz. İyi çalışmalar dilerim.

ilkem özdinç <ilkemozdinc@gmail.com>, 10 Mar 2022 Per, 00:33 tarihinde şunu yazdı:

...

--

Prof. Dr. Ahmet İlhan Şen

Hacettepe University
Faculty of Education
Department of Mathematics and Science Education
Division of Physics Education

06800 Beytepe-Ankara / Turkey

Tel: (0312) 2978618- (0312) 7805618
Fax: (0312) 299 2083 / 2978600

APPENDIX E: INTERVIEW QUESTIONS FOR EXPERIMENTAL GROUPS

Interview Questions for Experimental Group 1 (Gamified-Integrated STEM):

1) Uyguladığımız iklim değişikliği konulu derslerde ne öğrendin?
2) Diğer fen derslerinde yapılan çalışmalardan farklı neler vardı?
   *Bu derslerde ilginç, yararlı, sıkıcı/gereksiz, zor bulduğun bir şeyler var mıydı? Varsa nedir?
3) Pek çok uygulama yaptık. Yaptığımız uygulamalardan aklında kalanları açıklar mısın?
4) Bu derslerin başında sunulan problemi hatırlıyor musun? Sence bu problem açık ve anlaşılır mıydı?
5) Grupça ürettiğiniz çözüm önerisini açıklar mısın?
   * Bu çözüme ulaşırken yaptığınız fikir paylaşımlarını ve varsa iş bölümünü anlatır mısın?
   *Grup olarak sunduğunuz fikrin kıyı kentlerini koruyacak çözüm olduğuna inanıyor musun? Neden?
6) Tek başına çözüm önerisi sunman gerekseydi yine aynı yolu izlemek ister miydin?
7) Süre, rozetler, rekabet, lider tablosu gibi uygulamalar seni nasıl etkiledi?
8) Daha önce oynadığın oyunlarla bu derslerin bir benzerliği var mıydı?
9) Başka hangi derslerin bu şekilde oyunlaştırma ile işlenmesini isterdin?
10) Son olarak iklim değişikliği ile ilgili yaptığımız bu dersler iklim değişikliği konusundaki bilgini etkiledi mi? Açıklar mısın?
11) Harekete geçme isteğini ve davranışlarını etkiledi mi? Açıklar mısın?
12) Umut durumunda bir değişikliğe yol açtı mı? Açıklar mısın?

Interview Questions for Experimental Group 2 (Integrated STEM):

1) Uyguladığımız iklim değişikliği konulu derslerde ne öğrendin?
2) Diğer fen derslerinde yapılan çalışmalardan farklı neler vardı?
   *Bu derslerde ilginç, yararlı, sıkıcı/gereksiz, zor bulduğun bir şeyler var mıydı? Varsa nedir?
3) Pek çok uygulama yaptık. Yaptığımız uygulamalardan aklında kalanları açıklar mısın?
4) Bu derslerin başında sunulan problemi hatırlıyor musun? Sence bu problem açık ve anlaşılır mıydı?
5) Grupça ürettiğiniz çözüm önerisini açıklar mısın?
   * Bu çözüme ulaşırken yaptığınız fikir paylaşımlarını ve varsa iş bölümünü anlatır mısın?
   *Grup olarak sunduğunuz fikrin kıyı kentlerini koruyacak çözüm olduğuna inanıyor musun? Neden?
6) Tek başına çözüm önerisi sunman gerekseydi yine aynı yolu izlemek ister miydin?
7) Başka hangi derslerin bu şekilde problem çözüp ürünler oluşturarak işlenmesini isterdin?
8) Son olarak iklim değişikliği ile ilgili yaptığımız bu dersler iklim değişikliği konusundaki bilgini etkiledi mi? Açıklar mısın?
9) Harekete geçme isteğini ve davranışlarını etkiledi mi? Açıklar mısın?
10) Umut durumunda bir değişikliğe yol açtı mı? Açıklar mısın?

APPENDIX F: GAMIFIED-INTEGRATED STEM INSTRUCTIONAL DESING

Gamified-Integrated STEM Lesson Plan

Date: 00.00.0000 **Subject:** Seasons and Climate **Topic:** Global Climate Change

Grade: 8th-grade **Duration:** 6x40 min. **Teacher:** İlkem Özdinç

1. Target Outcomes:

1.1.Cognitive process Outcomes:

Outcomes related to the main discipline:

SCIENCE

F.5.6.2.1. Students will be able to express the importance of the interaction between humans and the environment.

F.5.6.2.3. Students will be able to make inferences about the environmental problems that may occur in the future because of human activities.

F.7.5.1.3. Students will be able to associate the reason why objects appear black, white, and colored as a result of observations with the reflection and absorption of light.

F.8.1.2.1. Students will be able to explain the difference between climate and weather events.

F.8.6.3.3. Students will be able to discuss the causes and possible consequences of global climate change.

Outcomes of other STEM disciplines:

ENGINEERING

A3: In the project work, the students will be able to assume themself as team members in different roles and successfully complete the work required by that role.

A5: The students will be able to express and discuss their ideas and findings clearly and consistently with the professional target audience using visual, written, and verbal communication methods.

B2: The students will be able to describe the rapid change that innovations bring over time for a particular consumer product.

B6: The students will be able to predict the performance, reliability, and failures of alternative solutions.

B7: The students will be able to realize the importance of precision in measuring and reading measurements in engineering studies.

TECHNOLOGY

E1: When solving algorithmic problems, the students will be able to use simple steps in designing solutions (e.g., problem description and exploration, review of case studies, design, implementation, testing, and evaluation)

E5: Students will be able to use visual representations of problem statements, structures, and data (e.g., graphs, tables, network development charts, concept maps, and flowcharts)

1.2. Social Product Outcomes:

Students will be able to realize the importance of working in a team.

Students will be able to create a product based on creativity.

Students will be able to present the designed product to their classmates clearly and understandably.

Students will be able to welcome compliments, setbacks, and criticism.

Students will be able to use their past experiences to predict future developments.

Students will be able to use problem-solving skills to guide others towards a goal and allow the right people to do the right tasks.

Using visual, written, and verbaï communication methods, students will be able to express and discuss their ideas and findings to their teammates and friends in other teams clearly and consistently.

2. Materials Used:

- Computers/tablets
- Phones
- Two identical transparent storage boxes
- Clay or play dough (enough to cover at least a quarter of the storage box)
- Ice cubes (at least two plates)
- Water
- Ruler
- Marking pen (blackboard pen, etc.)

- Worksheets
- Presentation tools (it can be cardboard, or it can be online tools)

NOTE: Apart from the list, suitable materials that come to mind can also be used. The number of materials may vary depending on the situation.

- Badges (should be planned enough for each student)
- Leaderboard
- Paper
- Pen/pencil
- Stickers for title winners for the end

3. Resources:

PLAYER TYPES:

https://www.gamified.uk/UserTypeTest/user-type-test.php?q=l&lang=tr

ABOUT PAVLOPETRI:

https://www.advenport.com/makale/su-altinda-kalmis-en-bilindik-5-sehir

https://www.youtube.com/watch?v=9xviWyZUzPM

https://collectingplacesblog.wordpress.com/2015/01/21/the-underwater-city-of-pavlopetri/

NATIONAL GEOGRAPHIC ARTICLE:

https://www.nationalgeographic.com/magazine/article/rising-seas-ice-melt-new-shoreline-maps

NASA TIME MACHINE:

https://climate.nasa.gov/interactives/climate-time-machine/

EDPUZZLE VIDEOS:

https://edpuzzle.com/media/606cba4296851742431a17a4

https://edpuzzle.com/media/606cbcc15682fc4242f79eb3

https://edpuzzle.com/media/606cbebc27966742bdef4c9f

SEA ICE OR LAND ICE:

https://www.jpl.nasa.gov/edu/teach/activity/whats-causing-sea-level-rise-land-ice-vs-sea-ice/

SUGGESTIONS:

https://tr.euronews.com/2020/06/21/italya-da-kuresel-s-nmaya-kars-buzullar-korumak-icin-brandal-cozum
https://www.youtube.com/watch?v=BYnjhISGbKY
https://www.log.com.tr/bilim-insanlarindan-buzullarin-erimesine-karsi-ilginc-oneri/#:~:text=Bu%20durumun%20ya%C5%9Fanmamas%C4%B1%20i%C3%A7in%20bilim,erimeyi%20telafi%20edeceklerini%20tahmin%20ediyorlar.

4. Authentic Problems of Knowledge Society (APoKS):

4.1. Authentic Problems of Knowledge Society:

One of the consequences of global climate change is the melting of glaciers. When the land glaciers melt, it causes the seawater level to rise, and in this case, the coastal cities are especially endangered. This danger is too great to be underestimated. Some coastal cities are in danger of extinction, while others are in danger of leaving the land and becoming an island. In addition, some cities fight the danger of drought with adverse effects. In order to prevent this problem, measures such as stretching the foothills of the Alps in Italy or producing artificial snow from the melting waters in Antarctica have been developed. What would you do to protect coastal cities?

4.2. Constraints:

- You should choose a specific place in the world except for Turkey.
- You should determine the reasons why this place is in danger.
- If there are previous studies, you should specify them.
- It would help if you did a study suitable for the solution you have found.
- If you are going to create products, you should use easily accessible products.
- If you are going to work on a poster, you should do work that includes all the details.

4.3. Occupation, Duty, and Responsibilities:

- Explorer: The explorer's job is to browse the internet, searching for flooded or submerged cities.
- Diver: The diver's job is to investigate how the water level in the seas is rising.
- Meteorologist: The task of the meteorologist is to make predictions by looking at the weather.

- Climatologist: The task of the climatologist is to watch the videos carefully and give correct answers in order to understand the difference between climate and weather events and to relate to global climate change.
- Scientist: The scientist evaluates previous ideas and presents new and creative solutions.
- Engineer: The engineer's goal is to design ideas and turn them into reality.

4.4. Player Types:

Occupations are meaningful because they specify the roles that students will take in the group. Student types differ in gamification. Accordingly, whether the students are in the right groups should be checked. It is important for gamification that the power distribution of the students is equal.

Bartle's Player Types:

- Socializers are motivated by Relatedness. They want to interact with others and create social connections.
- Free Spirits are motivated by Autonomy and Self-expression. They want to create and explore.
- Achievers are motivated by Mastery. They are looking to learn new things and improve themselves. They want challenges to be overcome.
- Philanthropists are motivated by Purpose and Meaning. This group is altruistic, wanting to give to other people and enrich the lives of others in some way with no expectation of reward.
- Players are motivated by Rewards. They will do what is needed of them to collect rewards from a system. They are in it for themselves.
- Disruptors are motivated by Change. In general, they want to disrupt your system, either directly or through other users, to force positive or negative change.

5. Lesson Content:

5.1. Storytelling, Players' Journey

The story begins with the password sheet that welcomes the students. In the message given to them, it is mentioned that they will embark on a journey. In order to embark on this journey, the first thing to do is to find out where to go. Students are given a password created with the Pigpen Cipher. (2 min.) Students who solve this password enter the journey by entering the code PAVLOPETRI through the Genially application. It is stated that PAVLO will accompany them on this journey. Together with PAVLO, they go to Pavlopetri.

** You've earned the DECODER badge! This badge is your entry ticket. You are with us now. I'm PAVLO. I will accompany you on this journey.

5.2. APoKS and Constraints

The lesson starts with the Pavlopetri Treasure. The aim is to make an interesting introduction to the subject.

Pavlopetri Treasure - Greece

"Have you ever heard of a flooded city before?"

Today we are going to talk about one of the oldest underwater cities in the world: Pavlopetri.

Pavlopetri, which was submerged in 100 B.C., is thought to have stood for 2000 years before that.

Pavlopetri, which became even more popular with a documentary made by the BBC specifically for the city, was a coastal city five thousand years ago. However, as the waters rose over the centuries, the most famous port city of the period was also flooded.

Research shows that Pavlopetri is the most planned and developed city of the Bronze Age, with its two-story houses, wide streets, and extremely well-designed water channels."

After this introduction, it is aimed to get to know the city by watching a video (https://www.youtube.com/watch?v=9xviWyZUzPM). It is emphasized that the water level in the seas has increased with the Pavlopetri story.

Individual Task: "What could be the reasons for an area to be flooded?" Find an area that is flooded (except Pavlopetri) and gather information on why this area is in this condition. At the end of this task, you will earn 1 BADGE! (5 min.)

**You've earned the EXPLORER badge! Thanks to the explorer badge, you have the right to see the underwater countries and cities!

Examples from different countries, especially coastal cities, are given. The additional risks of melting glaciers (flooding, becoming an island, destruction of agricultural land, or drought) are mentioned.

According to a study in National geographic:

Coastal cities are expected to be inundated.

Important agricultural areas will also disappear due to drought or other different climatic events.

The Netherlands is one of the countries that will be flooded before the next thousand years.

Other cities that will be inundated after the Netherlands will be cities such as New York, Miami, Havana, and Cancun.

Other threatened cities

*London

*Marseille

*Venice

*Copenhagen

* In South America, with the rise of ocean levels, the Amazon basin, which forms almost half of the continent, will merge with the Atlantic Ocean, and cities such as Asuncion (Paraguay), Buenos Aires (Argentina), Montevideo (Uruguay) will be flooded.

*Bangladesh

* Kolkata and Bombay

* Beijing and Shanghai

* Cambodia (an island cut off from Asia)

* In Africa, which is estimated to be less affected by the rise in water level compared to other continents, the effect of a 12-degree temperature increase will be seen. And it is considered inevitable that a large part of Africa will become uninhabitable with this. Finally, a demonstration is made from Nasa's simulation to form ideas about what it would be like when coastal cities were covered in water. Then, a discourse environment is created by asking, **"Why are these waters rising?".**

Bonus: Why are the waters rising? Recheck the link and think about your answer! Be fast! Let's check our knowledge, earn points :)

Example bonus answers: melting glaciers, melting snow, Global warming…

**BONUS REWARD: You've earned 5 points!

5.3. Fact-Finding

What are the differences between weather and climate?

How is the weather today?

These questions provide a link to the topic.

They will earn the METEOROLOGIST BADGE.

Then, children are divided into groups. (Groups are determined according to the number of students.) Next, three videos which are transformed into Edpuzzle videos (https://edpuzzle.com/media/606cba4296851742431a17a4, https://edpuzzle.com/media/606cbcc15682fc4242f79eb3, https://edpuzzle.com/media/606cbebc27966742bdef4c9f) are played. (Edpuzzle is a program used to get feedback from students by adding instant questions to videos.) Their answers to the questions in the videos are evaluated. After videos, groups are combined, and a discourse environment is created.

**You've earned the CLIMATOLOGIST badge! Check out the scoreboard!

Your group earned 20 points thanks to these two badges!

***You've earned the BENEVOLENT KOALA badge!

After this stage, students are given a list of research questions and a list of materials for the next lesson. They are asked to research the questions on this list until the next lesson and watch the videos again. They are also expected to prepare the materials list until the next lesson.

Research Questions:

1) What are the differences between "Weather" and "Climate"?

2) What is "Climate Change"?

3) What are the causes of climate change?

4) What are the effects of climate change?

5) What is the greenhouse effect? (You should associate it with the light unit.)

*** You've earned +10 points.

5.4. Ideation

Students reflect on whether sea ice or land ice causes the water level to rise. Students establish a relationship with the greenhouse effect and the unit of light.

Students make an observation about sea ice and land ice for water level and arrive at a conclusion. At the end of the observations, students are expected to create a product.

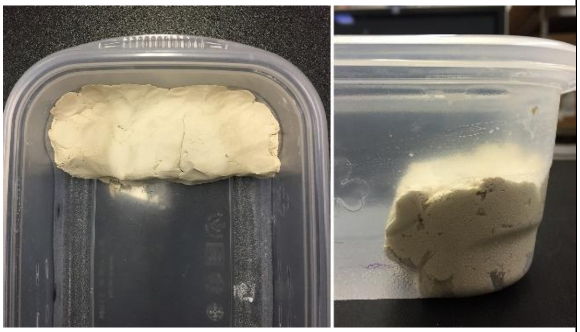
SEA ICE OR LAND ICE?

MATERIALS

- Two identical transparent storage boxes
- Clay or play dough (enough to cover at least a quarter of the storage box)
- Ice cubes (at least 2 plates)
- Water
- Ruler
- Marking pen (blackboard pen, etc.)

DIRECTIONS:

1) Create a smooth, flat surface that represents the land rising from the ocean by placing an equal amount of clay or play dough on one side of each storage container. Be careful not to play too much or create holes in your hands.



2) Place as many ice cubes as possible on a flat clay surface in a container. This represents land ice.

3) In the other container, place the same number of ice cubes on the floor of the bowl, next to the clay. This represents sea ice.

4) Fill water in the first container up to the point where the dough starts. Take care not to touch the ice molds and not exceed the size of the dough.
5) In the other container, put water until the ice floats. Be careful not to exceed the dough.
6) Using a ruler, make a note of the first water levels, mark the first level with a pencil.
7) Take measurements at regular intervals and record your measurement results. (Every 2 minutes)
8) When all the ice has melted, prepare a line graph based on the measurement results.

**You've earned the SCIENTIST badge! This badge is so special! It earned you exactly 25 POINTS! ALSO, You've earned material responsibility!

5.5. Product Development

Students are asked to choose a coastal city in Turkey or the world. Here, an idea is taken on what can be done to prevent the melting of glaciers and/or to protect these cities. Then, examples from Italy and Antarctica are given.

As a solution in Italy, it is covered with special white tarps to protect the snow on the foothills of the Alpine mountains from sunlight.

To protect Antarctica, some scientists have proposed to withdraw water from the ocean, transport it through pipelines to the melting part of the glaciers, turn the water into artificial snow, and then pull the snow to Antarctica by vehicles.

5.6. Disseminate and Reflect

Students present their products with other students. Students give feedback and reflections about the whole process.

**You are a great team! You've earned the ENGINEER badge! This badge is a huge reward. 40 POINTS ARE YOURS! ALSO, You can take your product home today!

5.7. Rewards:

Points: Bonus - 10 points	Badges: Decoder Badge
Edpuzzle - 20 points	Explorer Badge
Observation activity - 30 points	Meteorologist Badge
Product - 40 points	Benevolent Koala Badge
	Climatologist Badge
	Scientist Badge
	Engineer Badge

The MOST:

- 100 Points and 5 Badges: Become a Global Hero. His/her name and title will be displayed on the school's most visible board.
- 99-50 Points and at least 3 badges: He/she will become a Class Hero. His/her name and title will be displayed on the class board.
- 49-0 Points: He/she will be the Hero of the Course. His name and title will be displayed on the board throughout the entire lesson.

PRESENTATION LINKS:

https://view.genial.ly/618ab54990bb540dcc785138/presentation-kuresel-kahramanlar

APPENDIX G: INTEGRATED STEM INSTRUCTIONAL DESING

Integrated STEM Lesson Plan

Date: 00.00.0000 **Subject:** Seasons and Climate **Topic:** Global Climate Change
Grade: 8th-grade **Duration:** 6x40 min. **Teacher:** İlkem Özdinç

1. Target Outcomes:

1.1.Cognitive process Outcomes:

Outcomes related to the main discipline:

SCIENCE

F.5.6.2.1. Students will be able to express the importance of the interaction between humans and the environment.

F.5.6.2.3. Students will be able to make inferences about the environmental problems that may occur in the future because of human activities.

F.7.5.1.3. Students will be able to associate the reason why objects appear black, white, and colored as a result of observations with the reflection and absorption of light.

F.8.1.2.1. Students will be able to explain the difference between climate and weather events.

F.8.6.3.3. Students will be able to discuss the causes and possible consequences of global climate change.

Outcomes of other STEM disciplines:

ENGINEERING

A3: In the project work, the students will be able to assume themself as team members in different roles and successfully complete the work required by that role.

A5: The students will be able to express and discuss their ideas and findings clearly and consistently with the professional target audience using visual, written, and verbal communication methods.

B2: The students will be able to describe the rapid change that innovations bring over time for a particular consumer product.

B6: The students will be able to predict the performance, reliability, and failures of alternative solutions.

B7: The students will be able to realize the importance of precision in measuring and reading measurements in engineering studies.

TECHNOLOGY

E1: When solving algorithmic problems, the students will be able to use simple steps in designing solutions (e.g., problem description and exploration, review of case studies, design, implementation, testing, and evaluation)

E5: Students will be able to use visual representations of problem statements, structures, and data (e.g., graphs, tables, network development charts, concept maps, and flowcharts)

1.2. Social Product Outcomes:

Students will be able to realize the importance of working in a team.

Students will be able to create a product based on creativity.

Students will be able to present the designed product to their classmates clearly and understandably.

Students will be able to welcome compliments, setbacks, and criticism.

Students will be able to use their past experiences to predict future developments.

Students will be able to use problem-solving skills to guide others towards a goal and allow the right people to do the right tasks.

Using visual, written, and verbaï communication methods, students will be able to express and discuss their ideas and findings to their teammates and friends in other teams clearly and consistently.

2. Materials Used:

- Computers/tablets
- Phones
- Two identical transparent storage boxes
- Clay or play dough (enough to cover at least a quarter of the storage box)
- Ice cubes (at least two plates)
- Water
- Ruler
- Marking pen (blackboard pen, etc.)
- Worksheets
- Presentation tools (it can be cardboard, or it can be online tools)

NOTE: Apart from the list, suitable materials that come to mind can also be used. The number of materials may vary depending on the situation.

3. Resources:

ABOUT PAVLOPETRI:

https://www.advenport.com/makale/su-altinda-kalmis-en-bilindik-5-sehir

https://www.youtube.com/watch?v=9xviWyZUzPM

https://collectingplacesblog.wordpress.com/2015/01/21/the-underwater-city-of-pavlopetri/

NATIONAL GEOGRAPHIC ARTICLE:

https://www.nationalgeographic.com/magazine/article/rising-seas-ice-melt-new-shoreline-maps

NASA TIME MACHINE:

https://climate.nasa.gov/interactives/climate-time-machine/

EDPUZZLE VIDEOS:

https://edpuzzle.com/media/606cba4296851742431a17a4

https://edpuzzle.com/media/606cbcc15682fc4242f79eb3

https://edpuzzle.com/media/606cbebc27966742bdef4c9f

SEA ICE OR LAND ICE:

https://www.jpl.nasa.gov/edu/teach/activity/whats-causing-sea-level-rise-land-ice-vs-sea-ice/

SUGGESTIONS:

https://tr.euronews.com/2020/06/21/italya-da-kuresel-s-nmaya-kars-buzullar-korumak-icin-brandal-cozum

https://www.youtube.com/watch?v=BYnjhISGbKY

https://www.log.com.tr/bilim-insanlarindan-buzullarin-erimesine-karsi-ilginc-oneri/#:~:text=Bu%20durumun%20ya%C5%9Fanmamas%C4%B1%20i%C3%A7in%20bilim,erimeyi%20telafi%20edeceklerini%20tahmin%20ediyorlar.

4. Authentic Problems of Knowledge Society (APoKS):

4.1. Authentic Problems of Knowledge Society:

One of the consequences of global climate change is the melting of glaciers. When the land glaciers melt, it causes the seawater level to rise, and in this case, the coastal cities are especially endangered. This danger is too great to be underestimated. Some coastal cities are in danger of extinction, while others are in danger of leaving the land and becoming an island. In addition, some cities fight the danger of drought with adverse effects. In order to prevent this problem, measures such as stretching the foothills of the Alps in Italy or producing artificial snow from the melting waters in Antarctica have been developed. What would you do to protect coastal cities?

4.2. Constraints:

- You should choose a specific place in the world except for Turkey.
- You should determine the reasons why this place is in danger.
- If there are previous studies, you should specify them.
- It would help if you did a study suitable for the solution you have found.
- If you are going to create products, you should use easily accessible products.
- If you are going to work on a poster, you should do work that includes all the details.

4.3. Occupation, Duty, and Responsibilities:

- Explorer: The explorer's job is to browse the internet, searching for flooded or submerged cities.
- Diver: The diver's job is to investigate how the water level in the seas is rising.
- Meteorologist: The task of the meteorologist is to make predictions by looking at the weather.
- Climatologist: The task of the climatologist is to watch the videos carefully and give correct answers in order to understand the difference between climate and weather events and to relate to global climate change.
- Scientist: The scientist evaluates previous ideas and presents new and creative solutions.
- Engineer: The engineer's goal is to design ideas and turn them into reality.

5. Lesson Content:

5.1. APoKS and Constraints

The lesson starts with the Pavlopetri Treasure. The aim is to make an interesting introduction to the subject.

Pavlopetri Treasure - Greece

“Have you ever heard of a flooded city before?”

Today we are going to talk about one of the oldest underwater cities in the world: Pavlopetri.

Pavlopetri, which was submerged in 100 B.C., is thought to have stood for 2000 years before that.

Pavlopetri, which became even more popular with a documentary made by the BBC specifically for the city, was a coastal city five thousand years ago. However, as the waters rose over the centuries, the most famous port city of the period was also flooded. Research shows that Pavlopetri is the most planned and developed city of the Bronze Age, with its two-story houses, wide streets, and extremely well-designed water channels."

After this introduction, it is aimed to get to know the city by watching a video (https://www.youtube.com/watch?v=9xviWyZUzPM). It is emphasized that the water level in the seas has increased with the Pavlopetri story.

Individual Task: "What could be the reasons for an area to be flooded?" Find an area that is flooded (except Pavlopetri) and gather information on why this area is in this condition.

Examples from different countries, especially coastal cities, are given. The additional risks of melting glaciers (flooding, becoming an island, destruction of agricultural land, or drought) are mentioned.

According to a study in National geographic:

Coastal cities are expected to be inundated.

Important agricultural areas will also disappear due to drought or other different climatic events.

The Netherlands is one of the countries that will be flooded before the next thousand years.

Other cities that will be inundated after the Netherlands will be cities such as New York, Miami, Havana, and Cancun.

Other threatened cities

*London

*Marseille

*Venice

*Copenhagen

* In South America, with the rise of ocean levels, the Amazon basin, which forms almost half of the continent, will merge with the Atlantic Ocean, and cities such as Asuncion (Paraguay), Buenos Aires (Argentina), Montevideo (Uruguay) will be flooded.

*Bangladesh

* Kolkata and Bombay

* Beijing and Shanghai

* Cambodia (an island cut off from Asia)

* In Africa, which is estimated to be less affected by the rise in water level compared to other continents, the effect of a 12-degree temperature increase will be seen. And it is considered inevitable that a large part of Africa will become uninhabitable with this.

Finally, a demonstration is made from Nasa's simulation to form ideas about what it would be like when coastal cities were covered in water. Then, a discourse environment is created by asking, **"Why are these waters rising?".**

5.2. Fact-Finding

We said climate and changes in climates too many times. So, do you know what CLIMATE is?

How is the weather today?

What are the differences between weather and climate?

These questions provide a link to the topic.

Then, children are divided into groups. (Groups are determined according to the number of students.) Next, 3 videos which are transformed into Edpuzzle videos (https://edpuzzle.com/media/606cba4296851742431a17a4, https://edpuzzle.com/media/606cbcc15682fc4242f79eb3, https://edpuzzle.com/media/606cbebc27966742bdef4c9f) are played. (Edpuzzle is a program used to get feedback from students by adding instant questions to videos.) Their answers to the questions in the videos are evaluated. After videos, groups are combined, and a discourse environment is created.

After this stage, students are given a list of research questions and a list of materials for the next lesson. They are asked to research the questions on this list until the next lesson and watch the videos again. They are also expected to prepare the list of materials until the next lesson.

Research Questions:

1) What are the differences between "Weather" and "Climate"?

2) What is "Climate Change"?

3) What are the causes of climate change?

4) What are the effects of climate change?

5) What is the greenhouse effect? (You should associate it with the light unit.)

5.3. Ideation

Students reflect on the question of whether sea ice or land ice causes the water level to rise. Students establish a relationship with the greenhouse effect and the unit of light. Students make an observation about sea ice and land ice for water level and arrive at a conclusion. At the end of the observations, students are expected to create a product.

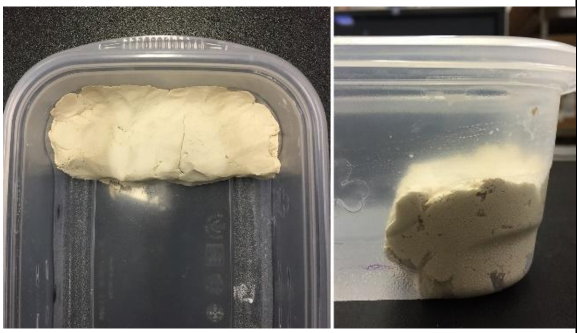
SEA ICE OR LAND ICE?

MATERIALS

- Two identical transparent storage boxes
- Clay or play dough (enough to cover at least a quarter of the storage box)
- Ice cubes (at least 2 plates)
- Water
- Ruler
- Marking pen (blackboard pen, etc.)

DIRECTIONS:

1) Create a smooth, flat surface that represents the land rising from the ocean by placing an equal amount of clay or play dough on one side of each storage container. Be careful not to play too much or create holes in your hands.



2) Place as many ice cubes as possible on a flat clay surface in a container. This represents land ice.
3) In the other container, place the same number of ice cubes on the floor of the bowl, next to the clay. This represents sea ice.

4) Fill water in the first container up to the point where the dough starts. Take care not to touch the ice molds and not exceed the size of the dough.
5) In the other container, put water until the ice floats. Be careful not to exceed the dough.
6) Using a ruler, make a note of the first water levels, mark the first level with a pencil.
7) Take measurements at regular intervals and record your measurement results. (Every 2 minutes)
8) When all the ice has melted, prepare a line graph based on the measurement results.

5.4. Product Development

Students are asked to choose a coastal city in Turkey or the world. Here, an idea is taken on what can be done to prevent the melting of glaciers and/or to protect these cities. Then, examples from Italy and Antarctica are given.

As a solution in Italy, it is covered with special white tarps to protect the snow on the foothills of the Alpine mountains from sunlight.

To protect Antarctica, some scientists have proposed to withdraw water from the ocean, transport it through pipelines to the melting part of the glaciers, turn the water into artificial snow, and then pull the snow to Antarctica by vehicles.

5.5. Disseminate and Reflect

Students present their products with other students. Students give feedback and reflections about the whole process.

PRESENTATION LINKS:

https://view.genial.ly/623a41fd6b15ba001b76c50e/presentation-stem-kuresel-kahramanlar

APPENDIX H: TRADITIONAL LESSON

Traditional Lesson Plan

Date: 00.00.0000 **Subject:** Seasons and Climate **Topic:** Global Climate Change

Grade: 8th-grade **Duration:** 4x40 min. **Teacher:** İlkem Özdinç

1. Target Outcomes:

1.1.Cognitive process Outcomes:

Outcomes related to the main discipline:

SCIENCE

F.5.6.2.1. Students will be able to express the importance of the interaction between humans and the environment.

F.5.6.2.3. Students will be able to make inferences about the environmental problems that may occur in the future because of human activities.

F.7.5.1.3. Students will be able to associate the reason why objects appear black, white, and colored as a result of observations with the reflection and absorption of light.

F.8.1.2.1. Students will be able to explain the difference between climate and weather events.

F.8.6.3.3. Students will be able to discuss the causes and possible consequences of global climate change.

2. Materials Used:

- Computers/tablets
- Phones
- Marking pen (blackboard pen, etc.)
- Pen/pencil
- Notebook

3. Resources:

NATIONAL GEOGRAPHIC ARTICLE:

https://www.nationalgeographic.com/magazine/article/rising-seas-ice-melt-new-shoreline-maps

SEA ICE OR LAND ICE:

https://www.jpl.nasa.gov/edu/teach/activity/whats-causing-sea-level-rise-land-ice-vs-sea-ice/

SUGGESTIONS:

https://tr.euronews.com/2020/06/21/italya-da-kuresel-s-nmaya-kars-buzullar-korumak-icin-brandal-cozum

https://www.youtube.com/watch?v=BYnjhISGbKY

https://www.log.com.tr/bilim-insanlarindan-buzullarin-erimesine-karsi-ilginc-oneri/#:~:text=Bu%20durumun%20ya%C5%9Fanmamas%C4%B1%20i%C3%A7in%20bilim,erimeyi%20telafi%20edeceklerini%20tahmin%20ediyorlar.

4. Lesson Content:

The lesson starts with a question: **“Have you ever heard of a flooded city before?”**

After that, the teacher gives information about Pavlopetri.

Today we are going to talk about one of the oldest underwater cities in the world: Pavlopetri.

Pavlopetri, which was submerged in 100 B.C., is thought to have stood for 2000 years before that.

Pavlopetri, which became even more popular with a documentary made by the BBC specifically for the city, was a coastal city five thousand years ago. However, as the waters rose over the centuries, the most famous port city of the period was also flooded. Research shows that Pavlopetri is the most planned and developed city of the Bronze Age, with its two-story houses, wide streets, and extremely well-designed water channels.”

It is emphasized that the water level in the seas has increased with the Pavlopetri story. "What could be the reasons for an area to be flooded?" are asked.

Examples from different countries, especially coastal cities, are given. The additional risks of melting glaciers (flooding, becoming an island, destruction of agricultural land, or drought) are mentioned.
According to a study in National geographic:
Coastal cities are expected to be inundated.
Important agricultural areas will also disappear due to drought or other different climatic events.
The Netherlands is one of the countries that will be flooded before the next thousand years.
Other cities that will be inundated after the Netherlands will be cities such as New York, Miami, Havana, and Cancun.
Other threatened cities
*London
*Marseille
*Venice
*Copenhagen
* In South America, with the rise of ocean levels, the Amazon basin, which forms almost half of the continent, will merge with the Atlantic Ocean, and cities such as Asuncion (Paraguay), Buenos Aires (Argentina), Montevideo (Uruguay) will be flooded.
*Bangladesh
* Kolkata and Bombay
* Beijing and Shanghai
* Cambodia (an island cut off from Asia)
* In Africa, which is estimated to be less affected by the rise in water level compared to other continents, the effect of a 12-degree temperature increase will be seen. And it is considered inevitable that a large part of Africa will become uninhabitable with this.
Then, a discourse environment is created by asking, **"Why are these waters rising?".**
How is the weather today?
What are the differences between weather and climate?

These questions provide a link to the topic. After getting the answers from the students, the teacher explains the difference between the seasons and the climate with a table which represent comparisons. After this stage, students are given a list of research questions. What are the causes of climate change? What are the effects of climate change? What is the greenhouse effect? A discourse environment is created. After discussing the answers, the teacher will ask the students whether it is land ice or sea ice that raises the water level, and the reasons for their thinking this way will be discussed with the students. The teacher will explain that the rise in sea level is the land ice, with necessary explanations and lectures. Students will try to find possible solutions for flooding. In order to guide the students, possible solutions for the melting of glaciers will be shared with the students. As a solution in Italy, it is covered with special white tarps to protect the snow on the foothills of the Alpine mountains from sunlight. To protect Antarctica, some scientists have proposed to withdraw water from the ocean, transport it through pipelines to the melting part of the glaciers, turn the water into artificial snow, and then pull the snow to Antarctica by vehicles. After receiving the creative answers from the students, these suggestions will be shared with the rest of the class.
PRESENTATION LINKS: https://view.genial.ly/6229c1d2165a5b0018f1cf82/presentation-kuresel-kahramanlar-kontrol

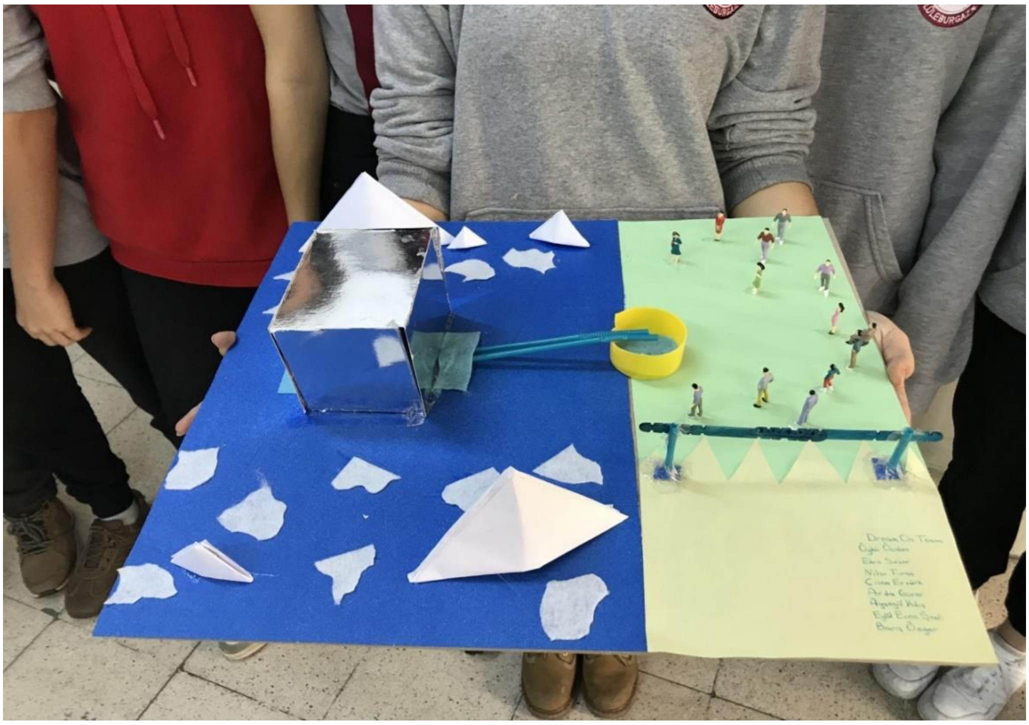
APPENDIX I: STUDENTS' PRODUCTS IN THE INTEGRATED STEM GROUP

1) Visual Representation of First Integrated STEM Group Students' Product

The students explained the project as follows:

"We did this project because glaciers are melting. Glaciers are melting, we cannot stop it, there is nothing we can do about it. So, we built a system that takes sea water, salty water, and distributes it to all countries, including the country where it was built. We also make sales with this method. In other words, we actually turn salt water into fresh water and make it usable."

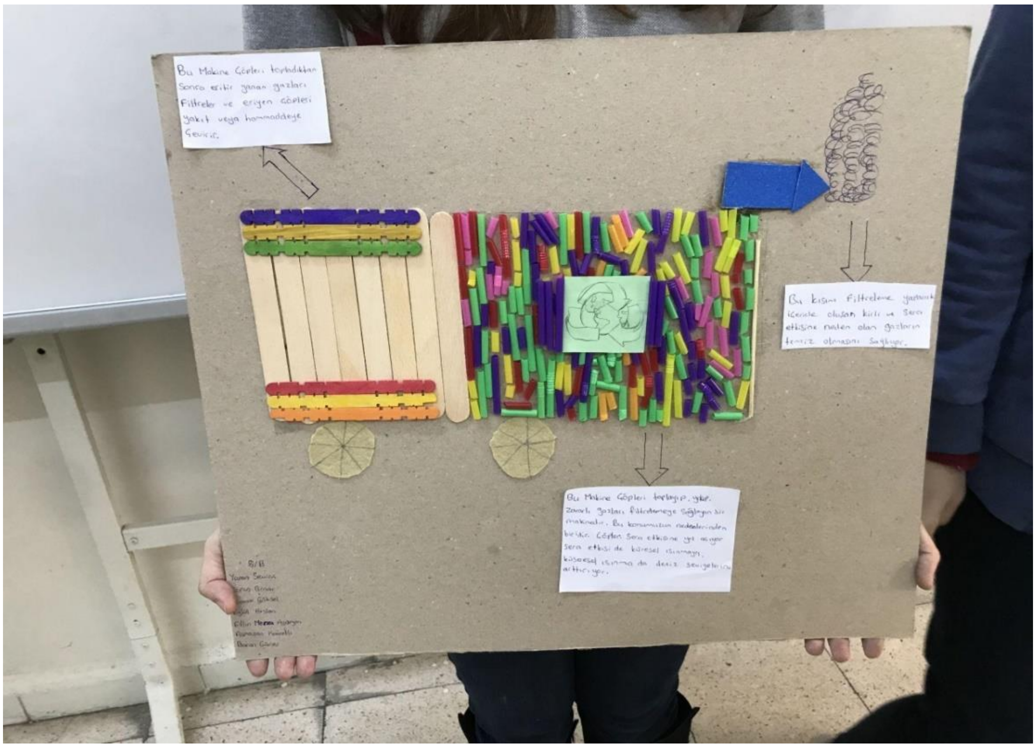
2) Visual Representation of Second Integrated STEM Group Students' Product



The students explained the project as follows:

"Our product is designed to collect, purify, and deliver excess water to drought-stricken countries in order to equalize the water level that increases with the melting of glaciers and to prevent the continents from being flooded. The product takes the melting glaciers with hoses, collects them, purifies them, and sends them as water to drought-stricken countries like Africa."

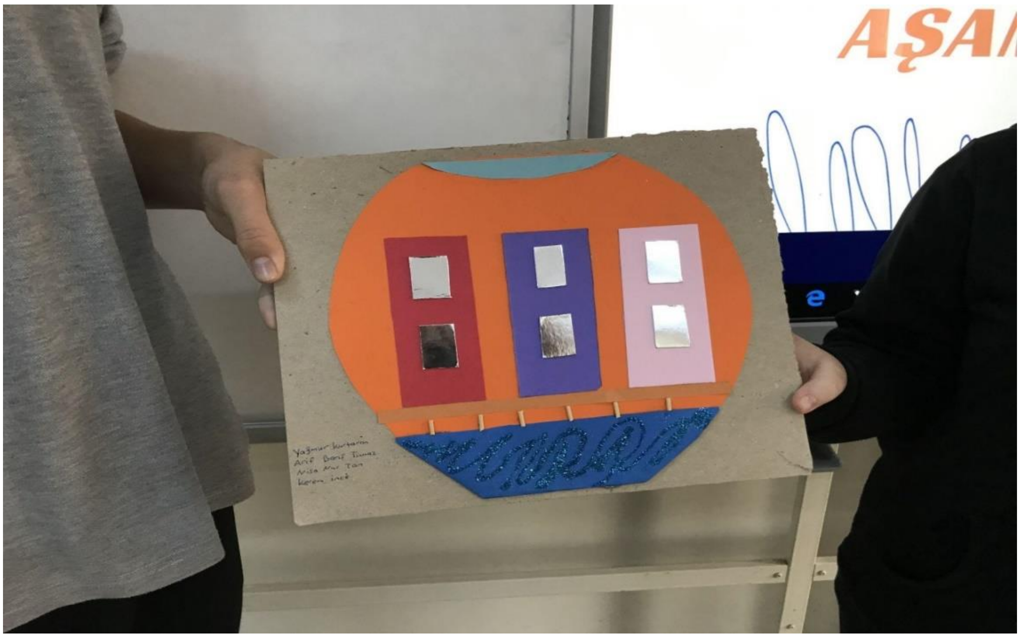
3) Visual Representation of Third Integrated STEM Group Students' Product



The students explained the project as follows:

"Our world is being destroyed by garbage day by day. Garbage causes the greenhouse effect, fires, and many other things. We are losing our seas because of this garbage. On top of that, our animals are dying. Because of the greenhouse effect, gasses from forest fires have a greenhouse effect. That's why our glaciers are starting to melt. As our glaciers melt, sea levels rise, and countries start to break up and get submerged. So, we built a garbage collector that collects garbage, filters greenhouse gasses and turns them into fuel. This will not only make our world more beautiful and greener, but also prevent countries from being flooded and prevent glaciers from melting."

4) Visual Representation of Forth Integrated STEM Group Students' Product

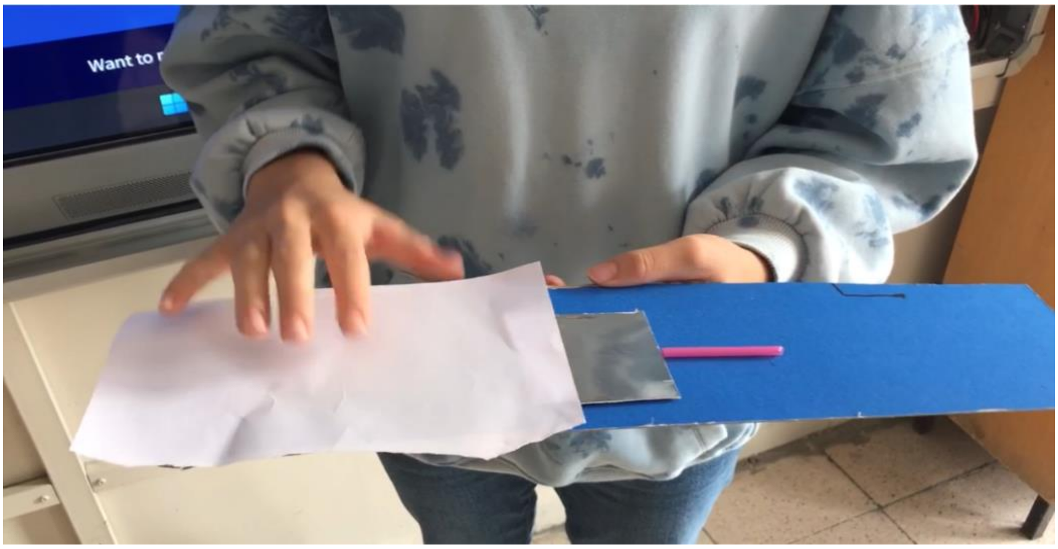


The students explained the project as follows:

"Recently, we have found a method for our cities that are in danger of being under water. When they are under water, they still need to be a living space for people. For this, we will make our cities stand on the upper side of the water, attached to the ground. First of all, we prepare a ground, and we need a big, thick, and strong chain at the bottom of the ground to the deepest part of the water so that it can hold all the buildings above the water. But this chain must be a chain that will never shake so that the buildings will not collapse. In this way, it is ensured to be strong against earthquakes. People's living spaces are not endangered again so that everyone can continue to live. We likened the shape to an aquarium. Actually, our first idea was to build a city in water in an aquarium. We combined both of these ideas. It can also be a city in a box, where water cannot get inside. That's why we thought of such a shape as an aquarium."

APPENDIX J: STUDENTS' PRODUCTS IN THE GAMIFIED-INTEGRATED STEM GROUP

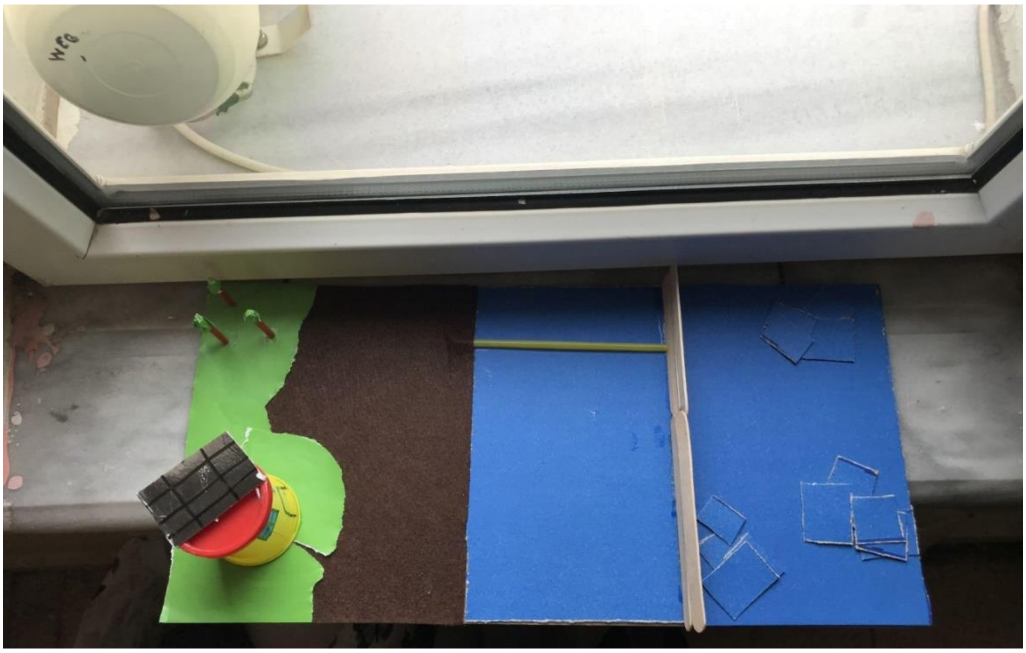
1) Visual Representation of First Gamified-Integrated STEM Group Students' Product



The students explained the project as follows:

"We turn the water of melting glaciers back into snow with the machine. So, we recycle it. Then we leave it on the glaciers and let it become ice."

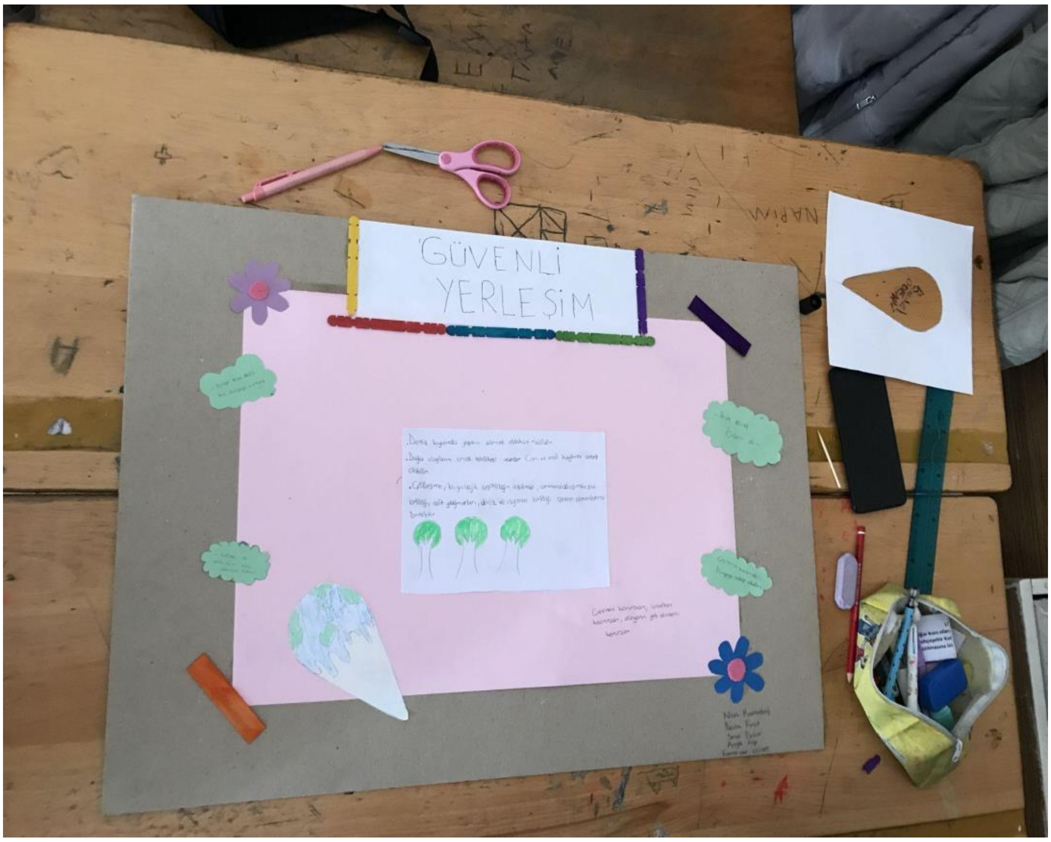
2) Visual Representation of Second Gamified-Integrated STEM Group Students' Product



The students explained the project as follows:

"Melting glaciers are causing the seas to rise. Therefore, coastal cities are in danger of being flooded. So, we built a dam here. Thanks to the dam, no one is flooded, and the dams produce water and energy. Thanks to this energy, the water is refrozen and transferred to the poles."

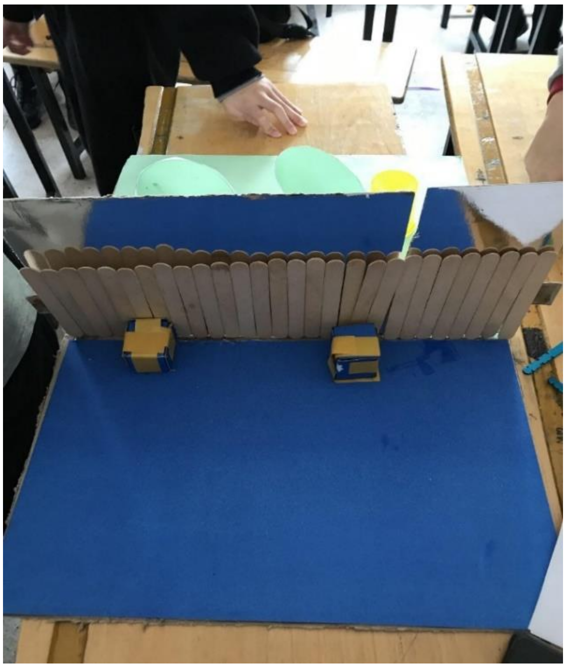
3) Visual Representation of Third Gamified-Integrated STEM Group Students' Product



The students explained the project as follows:

"Living by the sea is risky. There is a danger of many natural phenomena. When the sea level rises with the melting of glaciers, these cities are in danger of being flooded. They can cause loss of life and property. Desertification, reduction of biodiversity, deforestation, water pollution, acid rain, sea and ocean pollution are examples of other environmental problems. We wanted to raise people's awareness by preparing a banner that indicates these problems."

4) Visual Representation of Forth Gamified-Integrated STEM Group Students' Product



The students explained the project as follows:

"Since ancient times, large organizations have built their structures on the water's edge. This is a challenge in the future due to the impact of global climate change. In our project, the sun's rays are shining on the mirrored part. So, we reflect the sun's rays back to the sun in the opposite direction. In other words, while the city benefits from sunlight, sunlight does not go to the glaciers. Both the city and the glaciers are protected."