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The Reflections of the “Stop Climate Change Digital Game” on Primary School Students' Learning about Climate Change

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Reflections of the Stop Climate Change Digital Game on Primary School Students' Learning about Climate Change

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Abstract

Climate change and its effects are impacting our world more and more with each passing day. For this reason, we must ensure that our children, as the society of the future, grow up as individuals with high environmental awareness, being aware of climate change and its effects. The aim of this study is to inform students about the subject of climate change and to educate them as individuals with climate change literacy. In this context, a digital game about climate change and its effects was developed for primary school students. A qualitative research method and techniques were adapted in this research. Interview, observation, and document analysis techniques were used to ensure variety in data acquisition in the research. The study was conducted in the 2022 spring semester during the science courses. It was conducted at an urban primary school in Ankara. 22 fourth grade students were participated as control group and 23 fourth grade students were participated as treatment group in the study. It was determined that the students enjoyed this game, called Stop Climate Change; they had fun and simultaneously learned about concepts related to climate change.

Introduction

There are many problems facing the world today, one of which is climate change. The climate is changing due to the increase in temperatures around the world because of the release of harmful gases such as carbon dioxide and carbon monoxide into the atmosphere and the greenhouse effect, caused by greenhouse gases released into the atmosphere (Boon, 2009). Climatologists agree on the dangers of climate change but opposing views may still be found. Climate change causes many negative effects in the world, including air pollution, desertification, and the melting of glaciers. We are experiencing all of these effects today. The most important factor causing climate change is the effect of humans on the environment. Therefore, people should be made aware of climate change and its consequences. It is a particularly important duty to inform children, who constitute the society of the future, and to ensure that they are educated as environmentally conscious individuals. It is crucial for the future of our world to raise the awareness of students on this issue and have them grow up to be environmentally sensitive.

Theoretical Background

Climate Change in Science Education

One of the biggest challenges facing the world is climate change (UNESCO, 2012). Climate change is by far the most important environmental problem facing society and is therefore an important environmental education topic (Jickling, 2001). "The world urgently needs to address the causes of climate change and prepare for the resulting climatic and environmental consequences (IPCC, 2007). The world also needs to take certain steps against the threat of human-induced climate change (Somerville, 2010). Humans have never experienced such a situation of climate change before. The fact that climate change is a broad topic makes it a difficult topic to teach because it has many different aspects. Educators try to convey knowledge through schools, programs, and informal venues. However, there are many misunderstandings about the causes of climate change. Vitale et al. (2016) explained that climate change is important, but it is a challenging topic. In particular, many young people have trouble understanding climate change (Monroe et al., 2017). Therefore, climate change education must be offered, helping young people adapt to risk, uncertainty, and rapid changes (Stevenson, Nicholls, & Whitehouse, 2017). Teaching about climate change is essential in the education of well-rounded students and for overcoming gaps in learning (Shepardson et al., 2009).

It is difficult to understand exactly why the Earth's climate is changing, and not only because the basic scientific principles are complex (Lombardi et al., 2016). Despite the scientific consensus on climate change and the potential risks, the media often portrays climate science as controversial and debatable (Lambert, Lindgren, & Bleicher, 2012). Understanding the science and nature of climate change is also important for future teachers, as global climate change is a complex subject. A primary school student does not have a sufficient level of cognitive development to face the full complexities of the concept of climate. On the other hand, students experience the basics of this subject in science lessons (Fortner, 2001).

Digital Games in Science Education

In light of technological developments in science education in recent years, we can say that various new applications are used in research. Digital games can make unique and powerful contributions to K-12 science education, but much of their potential is still unrecognized (Kinnebrew et al., 2017). Digital games entail reconstructions of reality created by coding a reading system with the help of a sign system along with sounds. Digital games contain various elements, and they include Atari games, computer games, console games, mobile games, and all their different types (Yengin, 2011). Digital games can also be of many different genres (Parekh et al., 2021). They can be used for entertainment as well as for educational purposes (Chen et al., 2020). The educational version of the game Minecraft is an example of this. Students can learn coding, math, chemistry, and other topics with this game and apply the game in their lessons (Sajben, Klimova, & Lovaszova, 2020). In the digital game presented in this paper, we address climate change and global warming, which we think students should be informed about. Computer games, as a type of digital game, are among the most popular leisure activities of children and adolescents (Hussein et al., 2019). Mobile devices and apps, which include digital games, are also very popular among young children. However, the impact of mobile devices on learning and development has not been sufficiently explored. In comparative research conducted within the scope of science lessons, in which 32 students aged 4-5 years participated, significant differences were identified between two groups in terms of game skills and the understanding of throwing motions (Herodotou, 2018). Considering mobile applications, augmented reality and location-based mobile games have become exciting tools for education (Atwood-Blaine & Huffman, 2017). Many researchers have argued that digital games have the potential to help students learn (Martin, Silander, & Rutter, 2019). Game-based learning environments will have an important future in STEM education (Lester, Spiers, Nietfeld, Minogue, Mott, & Lobene, 2014). Predictably, the harmony between science education and games is considered to be good (Samuelson et al., 2010).

Climate Change and Digital Games in Science Education

Great efforts are being made to position information and communication technologies such as digital games as a central issue in educational policies and guidelines (Fernandes et al., 2018). It is very important to proceed based on the story in digital games and to take the story into account. Even if digital games do not contain a fixed story, it is important to consider the plot flow and moods. For this reason, emphasis was placed on the flow of the story in developing the game presented here, called Stop Climate Change (Kim et al., 2018). Teaching science through the making and designing of games in elementary, middle, and high school is a promising approach according to both educators and curriculum developers (Parekh et al., 2021). Galeote and Hamari (2021) stated that video games have emerged as a popular medium with the potential to be powerful tools for social participation regarding climate change. Games about climate change face a challenge, though, being largely at risk of adopting the same dynamics as "serious games" (Abraham & Jayemme, 2017). Climate change games are often considered serious games. Well-designed digital games will provide opportunities for young people to engage with the problems of climate change, encouraging them to think, feel, and act with a focus on problem-solving (Ouariachi et al., 2018). Reckien and Eisenack (2013) stated that there has been a rapid increase in the number of online games or games with online components regarding climate change, especially after the climate negotiations held in Copenhagen in 2009. Climate change and its effects are important for the future of the world, and children, who are the future, should be aware of climate change and its effects and act for a sustainable world. We must talk to children about Earth's problems. In this process, children may learn about these topics by playing in their early years, as information transferred in a fun way will be more effective for them. Therefore, while informing children about climate change, we can choose applications that are fun and educational for them. Today we can find many different applications with themes of fun learning (Chen & Lo, 2011). One type of these applications is digital gaming, which has become popular in recent years. Thinking deeply about climate change can be difficult, but games are natural tools for climate

change education and participation (Wu & Lee, 2015). Digital games can be used while teaching about global climate change in science education.

Purpose and Importance of the Research

One of the emerging challenges in climate change education is the complexity of the science behind climate change (Svihla & Linn, 2012). Numerous studies show that students' knowledge of climate change science is limited and they have many misconceptions (Pruneau, Moncton, Liboiron, & Vrain, 2001; Tolppanen & Maija Aksela, 2018). Previous studies show that knowledge and attitude towards specific environmental concerns can be developed using instructional strategies appropriate for the learner. At primary level, students need to develop an understanding of the basic concepts underlying weather and climate change (Lambert, Lindgren, & Bleicher, 2012). It is important for students to be active during the teaching of the subject of climate change so that they learn the concepts related to this subject correctly. Porter, Weaver, & Raptis, (2012) stated that active teaching strategies also significantly improved students' understanding of climate change.

It is seen that the use of technological applications in science teaching has increased in recent years. The use of smart boards in classrooms and students' use of devices such as tablets and laptops with technological software in science lessons can be given as examples of this. Säljö (2010) stated that educational technology can enrich the way students learn and interpret learning in formal and informal settings.

Learning about the concepts related to climate change can be challenging for students. Concepts such as global warming, greenhouse gases, and the decrease in the thickness of the ozone layer are taught within the scope of climate change. It is stated in the national Turkish science curriculum that it is aimed to provide students with knowledge and skills related to global climate change and its effects within the framework of seasons and climates. It is expected that they will be able to discuss the causes and possible consequences of global climate change and they will know what measures are being taken by different countries of the world to prevent global climate change (MoNE, 2018). However, it has been determined that technological applications are not used to provide more effective content alongside the textbooks used for the science curriculum. To teach students about climate change more efficiently and effectively, a technological platform called Unity was used to design an educational game. When the literature is examined, it is seen that no scientific study has been carried out at the level of primary school education with the Unity platform regarding the issue of climate change. This reveals the originality of the present research. The aim of this work is to develop a game called Stop Climate Change so that students can gain permanent knowledge about climate change. Observations and interviews were conducted with students to determine their thoughts on the subject of climate change, which was covered during the game. Thus, efforts were made to determine how the developed game contributes to the learning processes of students in the scope of climate change.

Method

A qualitative research method and techniques were adapted in this research. In this context, a case study strategy was benefited. Interview, observation, and document analysis techniques can be used to achieve data variety (triangulation) in case studies. Case study is one of the qualitative strategies widely used in qualitative researches (Yıldırım and Şimşek, 2011). In this study, interview, observation, and document analysis techniques were also used to ensure variety in data acquisition in the research.

Participants

The study was conducted in the 2022 spring semester during the science courses. It was conducted at an urban primary school in Ankara. 22 fourth grade students were participated as control group and 23 fourth grade students were participated as treatment group in the study. In one class, stop climate change digital game was used to teach climate change and its concepts to students, while in one class only the regular curriculum was applied.

In order to determine how the developed game was perceived by students and whether it was productive or not, fourth-grade students were invited to play the game. A total of 45 fourth-grade students studying at a public primary school in Ankara participated in the research. Students were selected based on easy accessibility. In this context, the purposive sampling method was applied in this research. The purposeful sampling technique

involves the deliberate selection of participants due to their qualifications. It is a non-random technique that does not require the application of basic theories or a certain number of participants. The researcher decides what needs to be known and sets out to find people who can and are willing to share that knowledge (Bernard, 2002). Generally, this technique is used in qualitative research to identify and select information-rich cases for the most appropriate use of available resources (Patton, 2002).

Data Collection Tool

Both the treatment group and the control group students were asked to draw about climate change before the subject of climate change was taught. In these drawings, students were asked to prepare drawings showing the factors that cause climate change and the consequences that may occur due to the effects of these factors. The drawings requested before the climate change teaching process were evaluated as a pre-test. The same drawings requested after the climate change issue were evaluated as a post-test. It was expected from students that they were able to reveal some concepts in relation with climate change such as global warming, melting of glaciers, greenhouse gas emissions etc. Beside this, students were observed while courses were being applied for the both groups. In this context, the educational environments were observed about four hours for each group. Some criteria were determined to identify whole science course process such as the students' reactions regarding the content of the game were being tried to be fixed. Their feedbacks to the teachers, learning-teaching environments were observed. No camera was used while observation process. The interviews were also carried out with all students while/after games completed. Their views regarding the game processes were tried to be revealed through interviews. Therefore, an interview was prepared that consisted of one question (What have we learned about climate change?). Based on the question, students' views are given exactly. Including this, to be able to gain much more information regarding students' views on climate change a main question was asked to students and probe questions were prepared, as well. In the results, students are coded as "S" and each student is mentioned by using this code such as S1, S2, S3 etc.

Main question:

Why did you draw on climate change like this? Can you please explain it to me?

Probe questions:

1. I see factory chimneys and exhaust gases on the paper. What is the meaning of this drawing?
2. I see polar bears standing on a small land. What is the meaning of this drawing?
3. I see green there is no land on your drawing. Instead, brown land is drawn for describing the environment. What is the meaning of this drawing?
4. I see the trees have not leaves. What is the meaning of this drawing?
5. I see glaciers and sea ice melting? What is the meaning of this drawing?
6. I see some energy suppliers have been drawn. What is the meaning of this drawing?
7. In your opinion, what would be done to generate energy?
8. I see there are some gases drawn on the paper. What is the meaning of this drawing?

Data Analysis

The data of the study were obtained by using interview, observation and document analysis techniques. To be able to variety of the study, several analysis techniques were used such as interview, observation, and document analysis techniques that are called triangulation (Yıldırım & Şimşek, 2011). Content analysis and descriptive analysis techniques were used to have results of the study. The data acquired from interviews and observations, first sent to field experts. They separated them into concepts. The drawings created by the students were categorized as factors causing climate change and the results of climate change by two educators who are experts in their field, and frequency values were given as percentages. The data obtained were evaluated based on how much change occurred in which category before and after the application as pre-test and post-test.

Validity and Reliability

As in all qualitative research, necessary arrangements were made for the validity of this study, taking into account the concepts of "Internal validity and External validity". In order to ensure validity, it was emphasized

that both validities should be provided. The internal validity of the research was carried out by taking into account the environment in which the data were obtained, making use of the field expert. When the findings are examined carefully, the obtained data are meaningful appears to be a holistic one. Since the purpose of qualitative studies is not to generalize, two expert opinions were taken. As a result of the analysis of the experts, the necessary feedback was received that the sample size was sufficient. This research is not concerned with generalization. Considering the conceptual framework, the generalization effects of the research subject are not felt. In order to generalize, various factors had to be made according to certain criteria. Since such an analysis was not performed in this study, it does not carry any generalization concerns.

In this study, interview, observation and drawings data were examined by two experts. Concepts were created independently by field experts. The data taken by drawings were examined by two experts, characteristics were formed independently from each other. "Compatibility percentage" formula suggested by Miles and Huberman (1994) was benefited from to determine the reliability of the characteristics acquired by the drawings. According to "Compatibility percentage= (Agreement)/ (Agreement + Disagreement) X100", the compatibility percentage in the drawing form for the student was found as 88.38. It is stated that if a compatibility percentage in studies is at .70 and on .70, interview data can be used in a study (Yıldırım, 2008). The observation form was examined by two experts, concepts were formed independently from each other. The same formula was also used to determine reliability of the concepts acquired by the observation form. According to that formula the compatibility percentage in the observation form was found as 91.16.

Ethics

After necessary permission was taken from the school' directorate, the students were informed about the study such as the reason, period of study, content and which apps would be carried out during the study. Students were tried to participate in the study voluntarily. In this context they were given "Volunteer Participation Form".

Stop Climate Change Game

The Houston Center for Advanced Research (2021) found that games about climate change have three main purposes. These are teaching knowledge and familiarizing players with the issue of climate change, making players aware of the challenges associated with global warming, and encouraging players to develop solutions. In this study, an open-source digital game called Stop Climate Change was developed for primary and secondary school students using the Unity platform. With this game, the aim is to inform students about the subject of climate change and educate them as individuals with climate change literacy. During the research process, attention was paid to those three main purposes. The following steps were applied during the game development process:

- Studies on climate change in the field of education were examined.
- The learning outcomes and topics in the science curriculum related to climate change were examined.
- Items related to climate change that would be included in the content of the game were determined by interviewing experts in this field of science.
- Having determined the game content, the game was prepared using Unity.
- The game was designed to be open source for Android and Windows.

Our aim in designing the Stop Climate Change game is to inform children about climate change and increase their awareness. For that purpose, the game essentially answers three questions: What causes climate change? What is happening in the process of climate change? What can we do to avoid global warming? The game also includes a level called "Green World," where a world without climate change is portrayed. Players can learn the answers to the aforementioned questions by choosing a question from the selection screen, entering the relevant level, and playing. In the last part of the game, a world that we can obtain by preventing climate change is described.

Technical Background

The game developed with Unity that is a game engine. The game can be played on Windows, Android, IOS and WebGL platforms. It can be played non-touch devices be available on "<https://anonymous010.itch.io/stop-climate-change>" and touch devices be available on "<https://anonymous010.itch.io/stop-climate-change-touch>".

In non-touch devices: In Windows, player will be used the mouse cursor to press buttons in the game. After placing the mouse cursor on the button that press, it will be pressed the left button by player. For example, when the player opened the game, player moved the mouse cursor over the word "Play" on the screen and left clicked, and then the level selection screen will be appeared. We can move our character to the left by pressing the A key, and to the right by pressing the D key. Also, player can make our character jump with the spacebar.

In touch devices: On mobile devices, it is enough to click the buttons to press them. For example, when the player opens the game and click the "Play" button on the screen that appears, the episode selection screen appears. The use of joysticks will help at this point, as mobile devices do not have a keyboard to move the character. When the joystick is moved to the left, we move the character to the left, and when the joystick is moved to the right, the character moves to the right. right. When we pull the joystick up, the character makes a jumping motion.

Login page would see when you open the game. And the main song would start. On the login page, there are three choices (Play, Settings, Quit). You can start the game with play. You can arrange the volume of song from settings. And you can quit from the game. When "Play" is selected, three different levels and an additional final level are displayed. The questions led to the relevant levels. On this screen, there are visuals that will help in understanding what global warming is, including CO2, Earth and a thermometer, the Sun, and a tree.

The player can go to the desired level of the game by clicking on the relevant question on this screen. The order of the questions and the related levels is chronological. The first question is "Why is climate change happening?" In this level, the player is informed about the causes of climate change. The second question is "What happens in the process of climate change?" In this level, the player is informed about what happens during the process of climate change and the results through visuals and gameplay. The third question is "What can we do to prevent global warming?" In this level, there is information about how we can prevent global warming and the wasting of energy sources with visuals and platform elements. In the Green World level, a green and beautiful world, which we could obtain if we prevent global warming, is depicted for the player. The player does not need to pass a previous level to move on to the next one. As levels are finished, the player is directed back to the level selection screen. It will be more beneficial for the player to proceed in chronological order, but the level selection screen nevertheless allows players to choose levels in any preferred order.

Every episode the game has include scoring system, sign system and restart system. Besides there are game objects which portals, character, and trees. Scoring system keeps score a player when the character collides with tree. Sign system inform the player about climate change. Restart system is a death and start again system. Player can explore these systems and game objects. Stop Climate Change allows that an exploring. There can be seen two figures taken from the inside of the game.

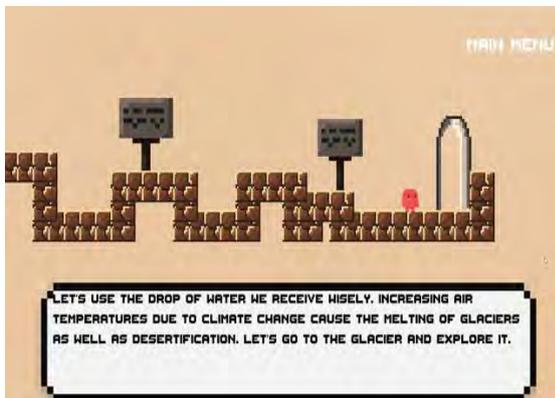


Figure 1. A view of the game relating to glacier

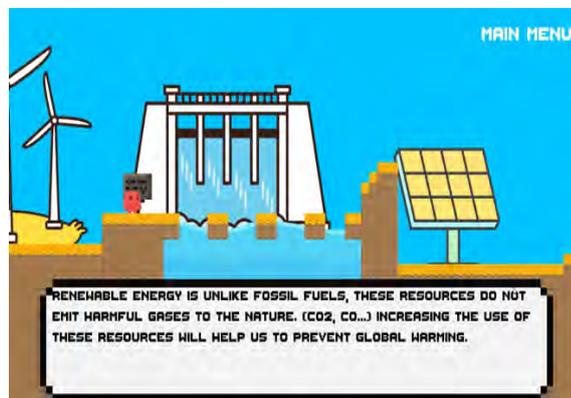


Figure 2. A view of the game relating to energy sources

In figure 1, some reasons of the climate change and the results of those reasons are given. At this stage, students are expected to aware of some indicators of the climate change. In figure 2, the importance of renewable energy and also the advantages of using those resources are being stated. Students are expected to learn renewable energy sources.

In figure 3, it is seen that S3 coded student is playing this digital game. She is playing the game at the phase of renewable energy sources. In figure 4, S7 coded student is playing the game and trying to get marks to pass to another section.



Figure 3. Student 3 is playing the game



Figure 4. Student 7 is playing the game

Results

In this section, data obtained through observations, interviews and drawings, with the students during the gameplay process, are presented. Before beginning the game, the second author of the study asked the students what they knew about climate change. Some of the participating students gave answers. These included “We should not throw garbage on the ground” and “There are gases coming out of the exhaust of cars.” All students were observed to be very excited before the game. In the gameplay process, it was observed that the students read the signs on the screen and read the texts about climate change and its effects with interest. In this process, some students tried to compete with each other and started the game quickly with the desire of beating their friends. After the game was over, all students expressed that they wanted to play it again. Since the class period had ended and there was no time left for continuing the game, the students indicated to the researcher that they would like to play the game at home. They asked questions about the possibility of downloading the game online so that they could play at home. After the game was over, the researcher asked if the students had fun. All of the children stated that they liked the game very much and that they had a lot of fun while playing. The data from the observations made during gameplay confirmed the students’ statements. After the game was over, the researcher asked, “What have we learned about climate change?” The concepts contained in the answers given by the students to this question are provided in Table 1.

Table 1. Concepts from replies to the question of “What have we learned about climate change?”

Concept	f	%
Glacier melting	24	37.50
Effects of harmful gases	18	28.12
Renewable energy sources	8	12.50
Solar energy	6	9.37
Wind energy	12	18.75

When the data in Table 1 are examined, it is seen that the most common concept among the answers offered by the students was the glacier melting (37.5%). Both the presence of these objects in the game and the fact that the glaciers on the Antarctic continent were included in the related section of textbooks in the curriculum about climate change may have been effective in the students providing this particular answer. In addition, the effects of gases such as H₂O and CO₂ on the climate change process were illustrated in the game, and this helped to concretize the students’ knowledge of these gases (28.12%). Answers about renewable energy sources (12.5%) and specifically solar energy (9.37%) and wind energy (18.75%) are important in terms of revealing that students learned concepts for reducing climate change.

The data taken by students’ drawings are given under this section. It was found that some developed concepts are similar for the both group students. Following concepts were created in pre-test by control group students: “Fume, Exhaust, Greenhouse gases, Garbage, Recycling, Acid rain, Oxygen reduction, Temperature rising, Drought, Glacier melting, Pesticide application and Population growth”. Some concepts such as “Fume, Exhaust, Greenhouse gases, Garbage” were created by treatment group students within pre-test. These similar concepts show us both group have similar concepts within the scope of climate change before they exposure to the teaching process. The important point for treatment group students is that they also created different concepts including pre-test results, which are in relation with climate change after digital game-based teaching process ended. Following concepts are given within this result: “Ozone depletion, Sea level rise, Forest fires,

Biodiversity loss, Turmoil and deaths, Food shortage caused by famine, Animal extinction, Resources depletion, shifting seasons and People getting sick". These concepts revealed that treatment group students were able to create almost all necessary concepts in climate change after they finished learning process through Stop Climate Change game. At this time, control group students created their own concepts such as "Recycling, Acid rain, Oxygen reduction, Temperature rising, Drought, Glacier melting, Pesticide application and Population growth". Considering the post-test data obtained from the control group students, it was determined that they did not include concepts such as "shifting seasons temperature rising and drought", which should be considered within the scope of events seen as a result of climate change. The fact that the control group students, who were educated according to the school curriculum, did not include the consequences of climate change in their post-test drawings, reveal that learning is not fully realized. Treatment group students completed their learning process through the digital game called Stop Climate Change. At the end of the learning process, it is seen that the rate of these students to include climate change and related concepts in their drawings has increased. Drawing of student 6 (treatment group) is given as before and after application.

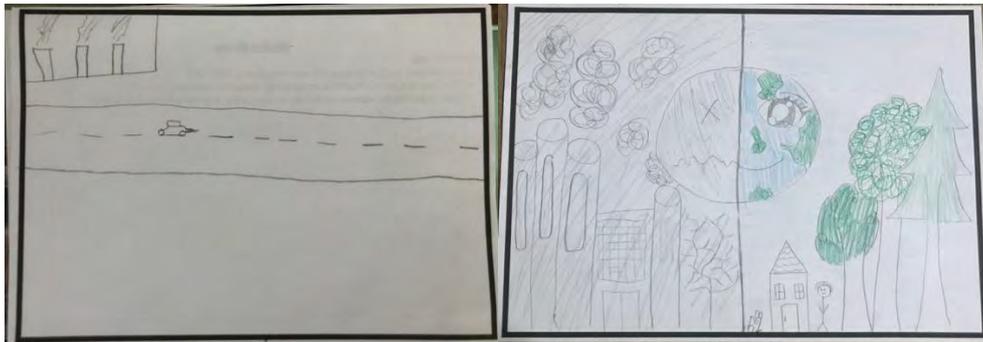


Figure 5. Drawing of student 6 before and after the application

In the figure showing before application gives us some details regarding S6's knowledge about climate change. It is clearly understood that we can only see some factory chimneys and a car being drive on the road. We can think that this student had limited knowledge on climate change because he just mentioned factories. However, in the figure, after application, shows us that this student has learnt necessary knowledge about climate change and its effects, as well. It is because especially the world has been given as livable after application and the world cannot be livable if the climate change fully affects the world. To be able to gain more information about students' knowledge on climate change and its effects a question was asked to another student. Within this context, student 4 (treatment group) views are given below.

Researcher: Why did you draw on climate change like this? Can you please explain it to me?

S4: Before application process, I knew that just factory chimneys and exhaust gases were the only reasons within climate change. After this process, by playing this game, I have realized that there are more than two reasons that cause climate change.

Researcher: Can you please give some specific examples of the situation?

S4: I learnt about greenhouse gases such as CO₂, NO and methane. I have realized that using those gases have negative effects on climate change and global warming. Because, burning coal, oil and gas produces CO₂ and NO. including greenhouse gases, deforestation and increasing livestock farming have negative effects on climate change, as well.

Researcher: I see two different sides are. What is the meaning of this drawing?

S4: I tried to tell the importance of negative effects of the climate change on environment. The drawing which prepared after application process, seen on the left side, I gave some reasons for climate change and at the same time the results of the climate change. On the right side in the same figure, you are able to see that we have green, trees are green with their leaves and the world itself is happy with green and blue.

Researcher: In your opinion, what would be done to generate energy?

S4: To be able to decrease negative effects of climate change, more renewable energy sources might be used. Those resources can be given as Sun, hydroelectric, wind, bioenergy and geothermal energy.

With this interview, we understand that this student has obtained some significant knowledge on climate change and its effects such as global warming, the reasons (burning coal, oil, deforestation and increasing livestock

farming) and also be able to illustrate for climate change. We understand from this that student 4 is able to give deep information on climate change and gained required knowledge after completed this game. Drawing of student 22 (treatment group) is given as before and after application.



Figure 6. Drawing of student 22 before and after the application

In the first figure, on the left side, there can be seen two penguins that they have a very limited ice mass standing on it. There are several waste materials around the ice mass and the only place for standing is just that mass. Here, S22 tried to tell us the reasons of the climate change. S22 actually wanted to highlight the importance of global warming. When we interviewed with S22, he was not able to state some reasons of the climate change and could not define the climate change term. After application process, there is seen two different worlds. On the left side, a world is pictured and it is unhappy, while the latter, on the right side, is happy. When we asked the reason of this situation, S22 stated that because of temperature, happy world's temperature has normal degrees while the other has not. Including this, unhappy world has factory chimneys, exhaust gases and garbage. Meanwhile, happy world has livable land with green trees, clean water and average temperature degrees. When we focus on another figure drawn by a student 8 (control group), we can also see some changes regarding the knowledge about climate change.

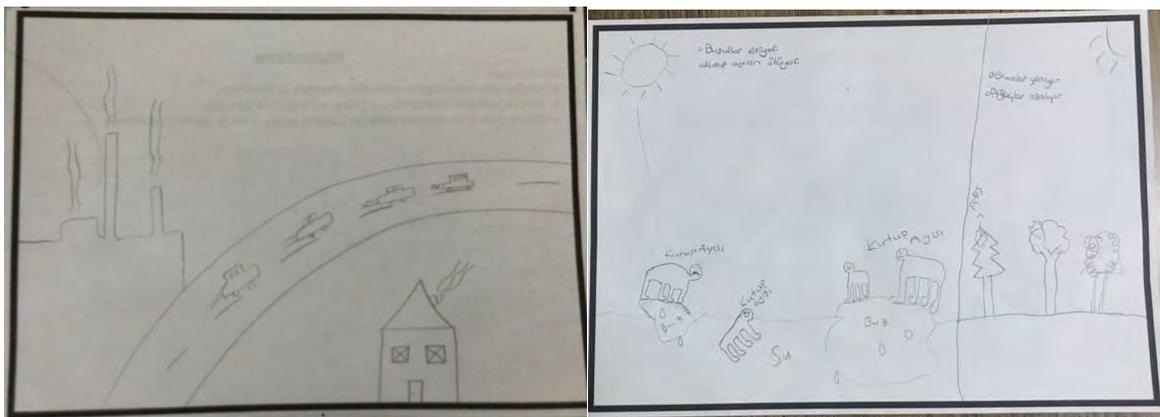


Figure 7. Drawing of student 8 before and after the application

In the figure showing before application gives us some details regarding student 8's pre-knowledge about climate change. It is clearly seen that this student has limited knowledge on climate change because just factory chimneys and exhaust gases have been pictured. However, it is also seen that student S8 has increased her knowledge on climate change and its effects after formal education process. We understand this from her drawing because she mentioned about polar bears. As she stated that ice was being melted and weather temperature increases the number of forest fires originated from climate change. But here, we also know that this knowledge might be gained by science textbook prepared by Ministry of National Education. Because it can be thought that it highlights polar bears when climate change-based subjects are being mentioned. Besides, science teacher gives polar bears as example while teaching climate change and its effects. To be able to gain more information about students' knowledge on climate change and its effects a question was asked to students. In line with this, the view of student 12 (control group) was applied and the answers of S12 is given below.

Researcher: Why did you draw on climate change like this? Can you please explain it to me?

S12: I learnt that climate change has negative effects on environment. For example, some animals will be not able to find any places to live in future.

Researcher: I see polar bears standing on a small land. What is the meaning of this drawing?

S12: I think that polar bears will not have any place to live in future. It is because, as the temperature increases the glaciers will melt.

Researcher: I see green land cannot be seen on your drawing. Could you please explain this?

S12: I believe that the number of forest fires will increase in the near future. Because of this reason we will lose more green land.

Researcher: What are you trying to say? Could you please specify this?

S12: As the number of forest fires increase the number of buildings will also increase. This relation is connected to each other, according to me. This process will lead to loses of living things' habitat.

Researcher: In your opinion, what would be done to generate energy?

S12: According to me, instead of coal, natural gas and any other energy sources, some energy sources could be used. For example, energy and hydroelectric power can be used to obtain energy with no harm effects to environment. By doing this, the temperature rises can decline.

By focusing on both drawings, it can be stated that this student's knowledge on climate change originates from her teacher and science textbooks. This information is also understood from the interview carried out by this student. She has limited knowledge on climate change and were not able give detailed information about climate change and its effects.

Observation data and some students' answers are given below, including interview data and drawings. Within this context, students were observed by the researchers and some observation data are given below. The game comprises four levels, and the S16 was observed. S16 was learning about the toxic gases polluting the air that cause global warming and thus climate change. For this knowledge to be permanent in the student's mind, greenhouse gases such as H₂O and CO₂ are illustrated in the clouds in the background of the game. In another observation, S2 is shown playing the third level of the game. In this level, the student learns about renewable energy sources and how using they will cause greenhouse gas emissions to decrease, slowing the process of climate change. A solar panel is illustrated in this level to help the student realize that solar energy can be used for energy production. In relation to that S9 and S18, both from treatment group, stated their views as given below.

S9: Thanks to this game, I learned that the climate has changed as a result of the gases from factory fumes and car exhaust. While playing the game, I realized that these gases are water vapor and carbon dioxide.

S18: I learned that solar energy and wind energy do not end and they do not harm the environment. Through the game, I learned that the natural gas we use in our house and the gasoline necessary for the operation of the cars cause climate change.

In another observation, S17 was seen to successfully passed the first three levels to reach this final level. Before this final level, S17 would have seen the factors that cause climate change, the negative effects seen in our world because of climate change, and the effects on life. In the final level, students see the hypothetical green world that they will encounter if they respect the environment and do less harm to nature. In this way, it is aimed that they will understand what they should do and not do for a sustainable green world.

S17: I learned about the factors affecting climate change until I reached the last stage of the game. I also realized that it is actually people who cause these factors the most. If we use less products such as coal, natural gas and gasoline, we can prevent climate change.

Situations such as the student being active in the learning process, learning by having fun while playing the game, and being responsible for his or her own learning process are assumed to have positive effects on their permanent knowledge. In line with this, S12 stated his views as given below.

S12: With this game, I learned the concepts about climate change that I did not know. Through the game I played, I learned that events such as temperature increase, melting of glaciers and drought are dependent on climate change. I loved this game. The game was both educational and entertaining.

Discussion

In the research, which was carried out with primary school students, the subject of climate change was tried to be taught with the developed digital game. It is understood that some studies within climate change topic have been conducted. Sjöblom et al. (2022) asked them to express climate changes in their study with primary school students. Some students put forward statements such as “it will be warmer”, something is changing, and we will have global warming.

The students revealed that they could not fully explain the formation processes of climate change because they did not see climate change as a natural phenomenon. Boyes & Stanisstreet (1993) determined that 11-year-old students had enough knowledge about the role of CO₂ in climate change. Lambert, Lindgren & Bleicher (2012) revealed in their research that many students could not explain greenhouse gases and their effects according to the pre-test results. In addition, according to the post-test findings, they determined that many students expressed carbon dioxide as a greenhouse gas. Bodzin et. Al. (2014) conducted a study with eighth-grade students in order to find out the differences between air and climate, the composition of the Earth's atmosphere and greenhouse gases, how greenhouse gases affect climate change, the characteristics of the climate system, paleoclimatology, anthropogenic resource contributions to climate change, and their lack of knowledge about environmental effects. They emphasized. Similar results were obtained in this study as well. Treatment group students expressed the gases emitted from factories and vehicles as greenhouse gases after the related digital game process. By expressing gases such as CO₂ and H₂O, they expressed these gases as greenhouse gases that have harmful effects on the climate. Francis et. al. (1993) stated in their research that reducing the use of vehicles by many students would reduce the greenhouse gas effect. Some of the students participating in this research also stated that the number of vehicles is high and that it has a negative effect on climate change in the long term. Siegner & Stapert (2020) stated that Lowell middle school students are more knowledgeable about climate change than American teenagers or adults. According to the research findings of Li & Liu (2022) on the knowledge and views of university students on climate change, they revealed that the level of knowledge about global warming is surprisingly weak. They concluded that even at the end of the teaching process on climate change, there was little improvement in these students' perceptions of knowledge and action on climate change. It is known that students learn faster and more efficiently at earlier ages. Primary school fourth grade students took part in this study. According to the research findings, it can be said that the students are younger and learn climate change and the concepts it covers faster through the practice in the treatment group.

Tolppanen & Aksela (2018) stated that students' knowledge level about climate change is limited, and they have various misconceptions. Some of these are students' belief that ozone layer depletion and air pollution cause climate change (Andersson, & Wallin, 2000; Pruneau, Moncton, Liboiron, & Vrain, 2001; Baker, Loxton & Sherren, 2013). Within the scope of this research, some students in the control group attributed the depletion of the ozone layer to air pollution. Working with children at the primary level is important because they are less likely to require them to "learn" any harmful environmental behaviour acquired later. It was determined that some students in the treatment group had various misconceptions about climate change before the application. These students stated that the weather changes during the day and the occurrence of fog events is due to climate change. Both the drawing data of the experimental group students and the data obtained from the interviews and observations show that the misconceptions they had about climate change disappeared after the application. In addition, the treatment group students stated the concepts related to the causes and consequences of climate change at a high rate after the digital game. It was determined within the scope of the research that the control group students did not reach the same conclusion after the subject was covered. In line with this result, some studies have evidenced the positive effect of digital games in teaching science for climate change subject. Wu and Lee (2015) stated that games on the subject of climate change are well-suited to address some challenges because they can serve as effective tools for education and engagement. Ouariachi et al. (2019) argued that video games have the potential to educate and engage especially young people in climate change and energy issues by facilitating the improvement of helpful thoughts, feelings, and actions.

Conclusion

The Stop Climate Change digital game was developed by the researchers because it is difficult to teach the subject of climate change, one of the most important events affecting our world, and the relevant scientific concepts at primary and secondary school levels. It was understood from interviews, drawings and observation data that the students who played this game liked it, had fun, and were very active in the learning process. It was concluded that the students playing this game learned scientific concepts about climate change.

Recommendations

In future studies on climate change and its effects, it would be helpful to conduct scientific research with larger student groups to further clarify the effectiveness of this game.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in JESEH journal belongs to the authors.

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