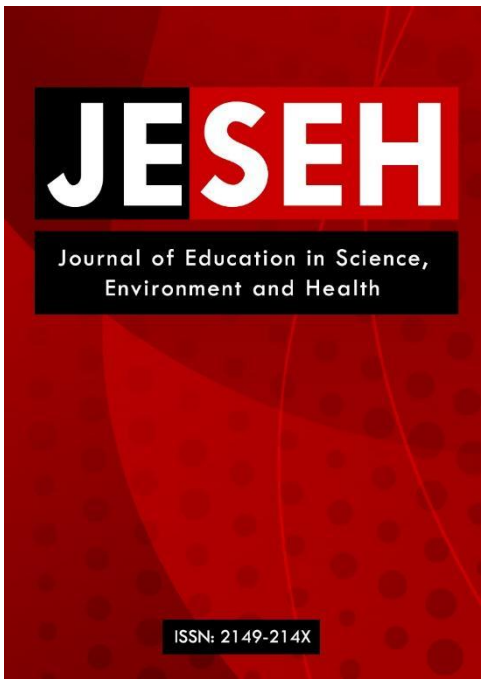

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Introducing Polar Animals with an AI-Based Educational Game: A Study for Middle School Students

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Abstract

The poles are recognized as the northernmost and southernmost points on Earth. These extremes are defined differently in terms of cartography, magnetism, geography, and the polar star. In Turkey, numerous activities have been carried out concerning the polar regions, such as the establishment of a scientific research camp and meteorological station in Antarctica, seabed mapping, and similar initiatives. These activities have continued to expand rapidly. In this context, it is anticipated that the targeted educational content will be more easily accessed through studies conducted not only by public and private research and development institutions but also within the field of education. This study aims to increase middle school students' awareness of 20 animal species living in the polar regions, as part of the "World of Living Things" unit and the "Let's Get to Know Living Things" section of the Science curriculum. The research was designed using a qualitative approach, specifically the phenomenological design, which aims to understand the essence of participants lived experiences with a particular phenomenon. The participants consisted of 105 volunteer 5th-grade students from a public middle school in Ankara. Data were collected through open-ended, self-assessment forms and analyzed using qualitative methods. As part of the study, 20 animals living in the polar regions were identified, and an Artificial Intelligence-Based Educational Game (AIEG) was developed. The game was created using the image recognition feature on the Teachable Machine (URL1) platform and deployed as an online, web-based educational tool. After engaging with the game, students completed a self-assessment form. Additionally, qualitative data were obtained through question–answer interviews with students, and the findings were evaluated using content analysis. The results revealed that students initially had limited knowledge of animals living in the polar regions, but their awareness significantly improved after interacting with the educational game. Based on the findings, it is recommended that educational games be more widely integrated into school settings to support effective and lasting learning. Furthermore, this research is expected to serve as a model for future studies aimed at raising awareness about polar animals and contributing to the protection of species threatened by environmental challenges.

Introduction

The world is divided into various geographical regions, which have often attracted the attention of individuals, institutions, and countries for reasons such as exploration, research, security, and conservation (Çaputçu & Çaputçu, 2021). Moreover, the polar regions' unique ecosystems, extreme climatic conditions, social structures, and challenges posed by harsh living environments have become increasingly prominent in research. The Earth hosts two distinct poles: the North Pole and the South Pole.

The North Pole, situated at the Earth's northernmost axis, is characterized by extensive ice floes. It is located within the Arctic Ocean, which is one of the world's largest oceans and encompasses the entire Arctic region. The Arctic is bordered by eight countries: Denmark, the United States, Norway, Canada, Finland, Russia, Sweden, and Iceland (Tutan & Arpalıer, 2020). The South Pole, located at the Earth's southernmost axis, encompasses a region dominated by landmasses and extensive ice sheets. This region is also referred to as the Antarctic continent, which is one of the seven continents (Çoşkun, 2018). The Antarctic continent is recognized for its highly complex ecosystem (Kırkıncı et al., 2021). In terms of climatic characteristics, the eastern part of Antarctica is colder than the western part due to its higher altitude. It is the coldest continent on Earth and does not host any sovereign states. However, seven countries namely the United Kingdom, France, Argentina, Australia, Chile, New Zealand,

and Norway, have laid territorial claims over parts of Antarctica (Yüksel, 2021). Additionally, as of 2019, 53 countries, including 29 consultative and 24 non-consultative signatories of the Antarctic Treaty, among them Turkey, have been granted permission to conduct scientific research and activities on the continent (Şimşek, 2019). Polar research began globally in 1821. In Turkey, the first institutional initiative in the field of polar sciences was undertaken by Istanbul Technical University (ITU). As a result, the "Istanbul Technical University Polar Research Center Regulation" was published in the Official Gazette on January 17, 2015, and the ITU Polar Research Center was officially established (Istanbul Technical University, 2015).

The increased use of fossil fuels, such as coal, natural gas, and oil, has led to the release of greenhouse gases. These gases trap solar radiation, resulting in a rise in the Earth's temperature, a phenomenon known as global warming. Global warming is one of the most critical environmental challenges affecting the world. The polar regions are among the areas most impacted by this phenomenon. Glaciers at the poles are gradually melting due to rising temperatures, posing a significant threat to their existence. This process has led to the extinction of species that are exclusively adapted to polar habitats. Additionally, the melting glaciers contribute to rising sea levels as the released water flows into the oceans (Akın, 2013). The Arctic region is a significant focus of biodiversity research. Various species, including polar bears, reindeer, polar algae, penguins, seals, polar martens, musk oxen, owls, and Arctic foxes, have adapted to the region's unique environmental conditions, such as landforms and climatic factors (Gözcelioğlu, 2013). Furthermore, the species inhabiting each polar region vary depending on the specific ecological characteristics of that region.

In Türkiye, extensive research is being conducted on the polar regions. In line with Türkiye's commitments under the Antarctic Treaty, the country aims to organize scientific expeditions to the poles, enhance its research activities and presence in the region, raise awareness and provide education on climate change, integrate environmental regulations of the region into national legislation, establish an institutional framework for polar studies, create a management center involving all relevant national stakeholders, and establish and operate a scientific research station in Antarctica.

Extensive research on the polar regions has been conducted both globally and in Türkiye, and such studies continue to be carried out. Education is one of the key areas where these research efforts are focused. Various teaching strategies and methods have been employed to introduce students to the polar regions. Among these, educational games have proven to be one of the most effective approaches for enhancing learning in this field.

Piaget asserts that all cognitive actions are determined by the balance between adaptation and assimilation. In the context of play, however, intelligence is driven by the dominance of assimilation over adaptation. Individuals integrate objects and events into their existing mental structures. Vygotsky, on the other hand, defines play as a continuous social activity, involving more than just an individual child. He argues that even when a child plays alone, the game remains a social element, as its themes and components reflect the cultural aspects of the surrounding social structure. According to Vygotsky, rather than merely reflecting cognitive development, play actively influences and contributes to a child's cognitive growth (Çankaya & Karamete, 2008). Considering the needs of modern learners and the evolving perspective on play, both Piaget and Vygotsky emphasize the importance of incorporating games into education. Educational games, designed for learning purposes, enhance learners' perception, decision-making abilities, and practical thinking skills (Yiğit, 2007).

The content conveyed through educational games holds significant importance in terms of both impact and implementation. In the teaching process, games should be utilized as a means rather than an end. Accordingly, educators must exercise great care in designing and implementing educational games, ensuring that all stages are carried out meticulously. The games developed by educators should be simple and engaging, allowing all students in a class to comprehend and participate actively. Additionally, fostering a competitive environment within the game can help maintain student engagement. Educators should effectively manage the game during its implementation, guide students throughout the process, and organize the play area accordingly (Demirel, 2012). Furthermore, educational games should be designed to align with course objectives and learning outcomes, integrating multiple disciplines, accommodating varying numbers of students, and incorporating diverse teaching methods to enhance their applicability.

A review of the literature on educational games reveals that Kızılçaoğlu and Taş (2007) investigated the use of spheres in geography education at the primary and secondary levels to facilitate students' understanding of the North and South Poles. Their study incorporated various models to enhance learning. The researchers found that students were better able to comprehend the location of the poles and their neighboring regions with modeled spheres (Kızılçaoğlu & Taş, 2007).

In the study titled *Science Journey in Antarctica*, training sessions were conducted for Science and Art Center students, and interviews were held. The findings of the study indicated that students developed awareness about Antarctica and demonstrated increased sensitivity toward the region (Barış, 2020). Göktaş and Göktaş (2022), in their study titled *The Reflection of State Policy on Polar Research in National Education*, presented at the 6th National Polar Sciences Workshop, examined the current Secondary Education Physics and Mathematics curricula and found no learning outcomes related to the poles or polar research. They also observed that mathematics activities and textbooks lacked topics and exercises related to the polar regions. As a recommendation, they proposed incorporating subjects and sub-themes on polar research into 9th and 10th-grade physics textbooks. Additionally, within the scope of the mathematics curriculum, they suggested integrating problem-based scenarios related to the polar regions into both curricula and textbooks, utilizing data from scientific research on the poles for educational activities.

Küçük et al. (2020) conducted a study on the impact of awareness-raising activities related to polar research on students in primary, secondary, and high school education. They stated that the methods employed in the study varied according to age groups and that different levels of sensitivity were observed across each group. Gözcelioğlu (2013), in his study titled Polar Creatures: Lives That Don't Freeze, provided explanations about the harsh living conditions in the polar regions and the adaptations of various species to these extreme environments. Parlak and Vural (2020) reported that they implemented various social activities to share and disseminate the knowledge and experiences gathered about the polar regions with the public. As a result of these initiatives, students' sensitivity and awareness regarding the polar regions increased.

Yirmibeşoğlu et al. (2020), in their study titled *Polar Educators Training*, stated that a secondary school teacher received hands-on training in the polar region and subsequently transferred significant knowledge to their students upon completion of the training. In another study on educational computer games, it was stated that games are used in schools to teach course subjects in three different ways: simulating real-life scenarios in a computer environment, serving as a tool for presenting topics, and motivating students by acting as a source of encouragement for learning (Linderoth et al., 2002).

According to Siang and Rao (2003), computer games are educational materials that provide the shortest learning strategy among all computer programs. Additionally, educational games enable participants to learn directly through play and experience rather than relying on reading help files or following instructions. With advancements in technology, numerous educational games have been developed and implemented, and extensive research has been conducted on these games.

Kaya and Elgün (2015), in their study titled *"The Effect of Science Teaching Supported by Educational Games on the Academic Achievement of Primary School Students,"* examined the impact of educational games on the teaching of the *"Our Planet Earth"* unit in the 4th-grade Science and Technology course. The study was conducted with a total of 61 fourth-grade students attending a primary school in the Bağcılar district of Istanbul. A quasi-experimental design was employed, incorporating pre-test and post-test measurements. The findings of the study indicated that the effective implementation of educational games in the classroom significantly contributes to student achievement.

Canbay (2012) examined the impact of educational games on students' self-regulated learning strategies, motivational beliefs, and academic achievement in mathematics. The study was conducted with 52 seventh-grade students using a pre-test and post-test design. The findings indicated that educational games did not lead to significant differences in knowledge retention, academic achievement, self-regulated learning strategies, or motivational beliefs.

Doğan (2017), in his study titled *The Effect of Teaching the Earthquake Topic in Social Studies through Digital Games on Academic Achievement*, examined the impact of digital game-based learning on student performance. The study was conducted with a total of 108 fifth-grade students from the provinces of Sivas and Tokat. The findings revealed that the academic achievement scores of the experimental group, which was taught using a digital game, were higher than those of the control group, which received instruction through traditional methods.

In the study titled *The Effect of Educational Games on Students' Academic Achievement and Knowledge Retention in the Science and Technology Course*, an experimental design with a pretest-posttest control group was employed. The study sample consisted of 60 eighth-grade students enrolled in a public school, with 30 students in the experimental group and 30 in the control group. The experimental group was taught the *Cell Division and Heredity* unit using educational games, whereas the control group received instruction through traditional methods. A Science and Technology Academic Achievement Test was used as a data collection instrument. The

findings indicated that the use of educational games in teaching significantly enhanced students' academic achievement and contributed to long-term knowledge retention (Alıcı, 2016).

The study titled "The Effect of Educational Games on Social Studies Course Teaching" by Uygun et al. (2018) was conducted with 21 fifth-grade students from a public school. The findings indicated that students' interest, motivation, and enthusiasm for the Social Studies course increased, leading to greater engagement in the lessons. It was noted that traditional evaluation activities conducted at the end of the lesson did not sufficiently support long-term retention. However, when the evaluation was conducted using the educational game method, learning was found to be significantly more permanent.

As evidenced by the studies, educational games have been shown to enhance students' interest, attention, motivation, and enthusiasm across various fields of study. Furthermore, these games contribute to students' academic achievement, foster a positive attitude toward learning, and facilitate the comprehension of complex subjects. Additionally, the findings suggest that educational games play a crucial role in the development of essential skills and values, including responsibility, cooperation, respect, empathy, and self-expression.

Purpose of the Study

The purposes of this study were to explore the learning experiences and perceptions of fifth-grade students regarding a web-based educational game supported by artificial intelligence technology. The game was designed to teach endangered animals living in the polar regions and to raise environmental awareness about the threats to their habitats caused by global climate change. Conducted with 145 volunteer fifth-grade students from a public secondary school in Ankara, the study aims to investigate how such a game can contribute to students' subject-specific knowledge, language use, attention, and motivation within a digital learning environment.

Adopting a qualitative research approach based on a phenomenological design, the study seeks to provide an in-depth understanding of students' individual experiences and feedback regarding the game. The study also aims to identify the strengths and potential areas for improvement in the design and instructional content of the game. The findings of this research are intended to inform educators, curriculum developers, and game designers about the pedagogical potential of AI-supported educational games, particularly in the context of environmental education.

The study is structured into four main sections. The Methodology section explains the research design, participant characteristics, and data collection tools, along with an overview of the AI-supported game development process. The Results section presents the data obtained from students' self-assessment forms. The Discussion section interprets these findings in light of relevant literature, and the Suggestions section offers recommendations for future research and practical implementations.

Method

Research Design

This study is qualitative research based on phenomenological design. Phenomenology focuses on individuals lived experiences and aims to uncover the meanings they assign to a particular phenomenon. According to Creswell (2018, p. 77), the phenomenological design seeks to reveal the common meaning of the lived experiences of several individuals regarding a phenomenon or concept. The main goal in this design is to understand the essence of experiences of individuals who have deeply encountered a specific phenomenon. In this context, after identifying the research area, a review of the literature was conducted on topics such as the Polar Regions, animals inhabiting these regions, and Turkey's polar policies. Although access to relevant sources was limited, it was observed that research in this field has increased in recent years. Noting the absence of an educational game specifically developed for middle school students about animals in the Polar Regions, a need for such a study was identified. Data were collected in line with the principles of qualitative research.

Participants

The study was carried out during the 2022–2023 academic year in the multipurpose hall of a public middle school in Ankara, Türkiye. The participants consisted of 145 volunteer fifth-grade students (82 boys and 63 girls). Before the data collection process, written approval was obtained from the District Directorate of National Education,

and informed consent was received from the students' parents or guardians. All official permissions and documentation are available on file. Ethical standards were strictly followed throughout the research process, and confidentiality was ensured at all stages.

Data Collection Tool

Google Forms was used as an online data collection tool. 145 students were asked about their opinions about the application. However, 40 students either filled out the scale incorrectly or left it incomplete. As a result, the final sample consisted of 105 students who properly completed google form. Each question was designed to gather specific data. The questions were developed and refined following a literature review. In total, six questions were prepared using Google Forms, and data were collected accordingly.

Data Collection

Data on Arctic animals were collected using Google Images because it is a widely used method. Initially, a list of the most well-known polar animals was compiled through a literature review, resulting in the identification of 20 species. The "Download All Images" extension from Google was used to download images of these animals in bulk. Each animal's name was entered into Google Images, and the resulting images were downloaded as compressed files using the extension. These compressed files were then extracted, and irrelevant images were removed.

Additionally, the backgrounds of the images were removed to ensure accurate classification with artificial intelligence. As a result, a dataset comprising 4,592 images of 20 Arctic animal species was created. After constructing the dataset, the Teachable Machine platform (URL-2), which operates using artificial neural networks and is widely used for web-based image classification, was utilized. Classes for the 20 Arctic animals were created on this platform, and the model was trained by adjusting parameters such as epoch count, batch size, and learning rate.

Data Classification

The dataset includes 20 classes of Arctic animals categorized for classification using artificial intelligence technology. The distribution of images for each class is given in Table 1.

Table 1. The distribution of images for each class.

Image	Counts
Alaska Wolf	228
Albatross	213
Antarctic Orca	256
Owl	315
Sea Elephant	419
Sea Rhino	234
Seal	261
Ferret	312
Greenland Whale	364
Thick-Billed Bird	194
Polar Bear	229
Arctic Tern	143
Arctic Hare	171
Arctic Fox	121
Lemming	229
Minke Whale	234
Musk Ox	160
Walrus	197
Penguin	176
Reindeer	136

Data Analysis

This figure illustrates the general design of an artificial intelligence-based classification model. The model was developed using Teachable Machine, an AI-powered web platform where different classification categories were defined. The dataset was structured to include various animal species, with each class represented by a specific number of images. The training process was conducted using 50 training cycles, a batch size of 16, and a learning rate of 0.001.

As shown in the figure, the system was tested in preview mode to evaluate its accuracy. The model successfully classified an input image of an owl with 98% accuracy, demonstrating the effectiveness of the training process. The high classification accuracy indicates that the model was properly trained using optimized hyperparameters, enhancing its ability to recognize and categorize images correctly. This AI-based classification model can be applied in image processing and object recognition tasks, where the diversity and balance of training data play a crucial role in overall model performance. The general design of the system was shown in Figure 1.

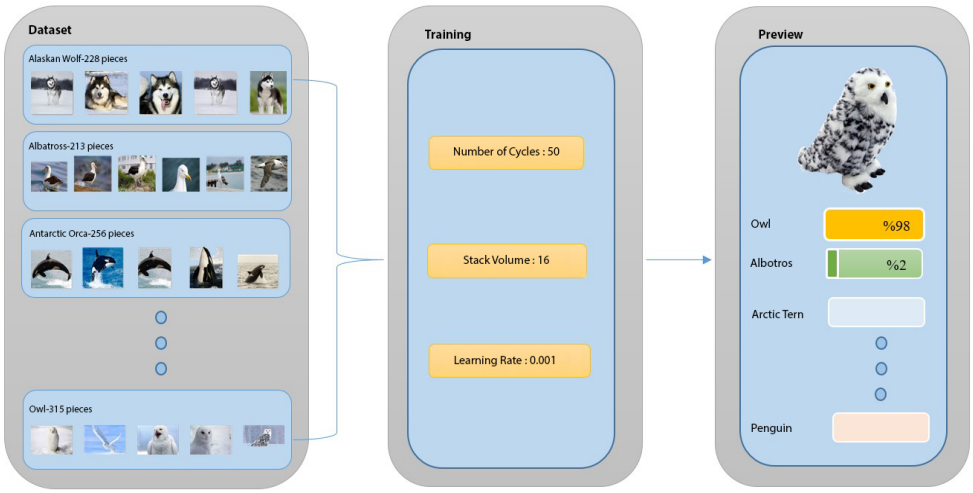

Figure 1. General design of the system

'This figure illustrates both the development process of an artificial intelligence-based classification model and the ratio of training to test data. Initially, data collection was conducted, and the quality of the collected data was validated. Subsequently, 85% of the data (3,903 images) was used to train the AI model (Figure 2). To assess the model's performance, the remaining 15% (689 images) were reserved for testing. After training, the AI model processed input data to generate predictions, and its accuracy was evaluated using the test data. This process represents a systematic model development approach consisting of data collection, training, testing, and validation phases.

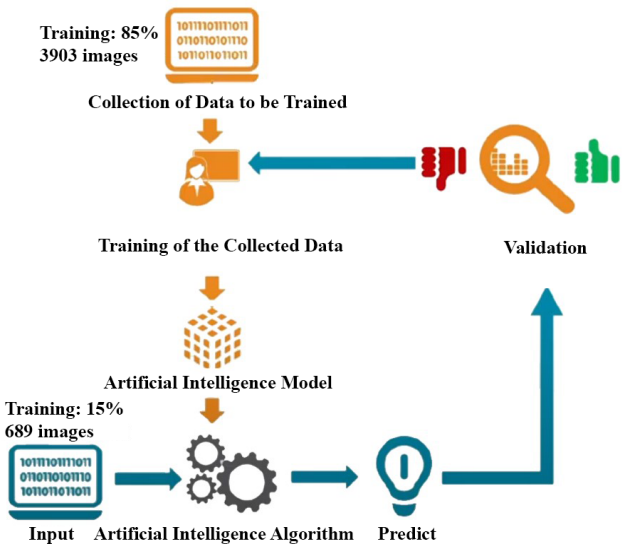

Figure 2. The ratio and modeling of training and test data in the system

Preparation for a Web-Based Educational Game

Figure 3 presents the block-based coding structure of AIBEG, an artificial intelligence-based online educational game designed to enhance students' knowledge of polar animals. The development of the game followed an instructional phase, where informational presentations on the Polar Regions and their wildlife were delivered to four different classes. Student feedback was collected and incorporated into the game design to ensure an engaging and effective learning experience.

The block diagram illustrates the game's logic and interaction flow. The system utilizes Teachable Machine, an AI-powered model, to recognize and classify images of polar animals. The program begins by activating the model and camera input. It then prompts students with a question about a specific polar animal and processes their responses by comparing them with the AI-generated prediction. If the prediction matches the expected answer, the game provides positive reinforcement through visual (costume change) and auditory (sound effects) feedback. If the response is incorrect, the system signals an incorrect answer using different visual and auditory cues. This AI-integrated educational tool enables students to engage in interactive learning, reinforcing their understanding of polar animals through gamification and real-time feedback. The integration of machine learning in educational settings enhances student participation and fosters a deeper understanding of the subject matter.

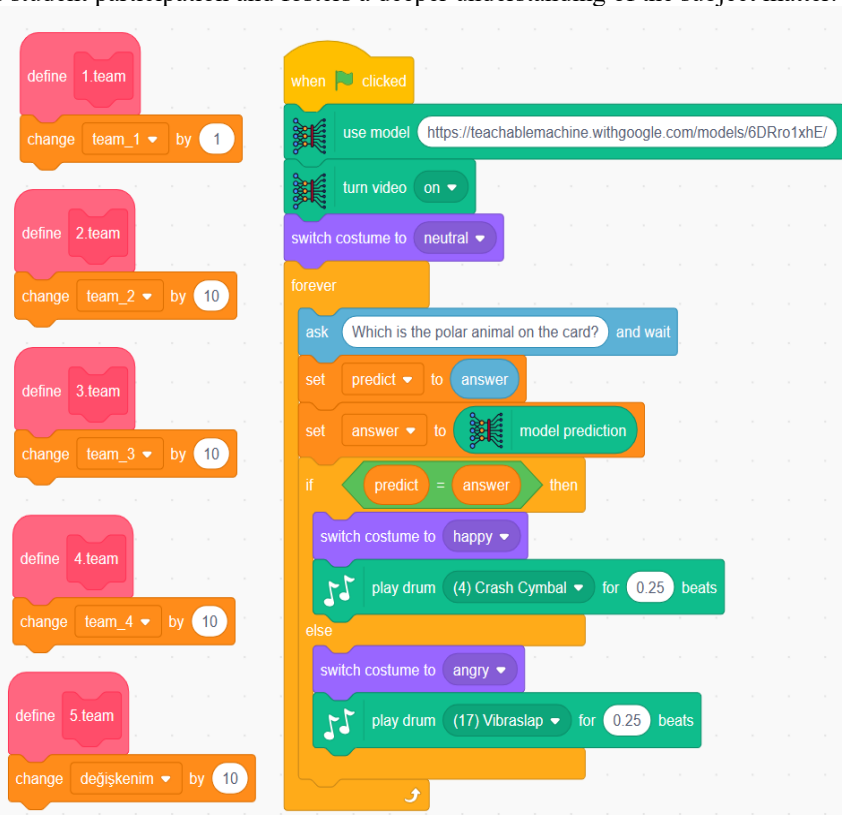

Figure 3. Block coding of an artificial intelligence-based online educational game

The block coding structure of AIBEG consists of 14 sequential tasks, which are as follows:

- **Step 1:** Initiates the program.
- **Step 2:** Enter the URL of the model created using the Teachable Machine platform, enabling the artificial intelligence model to function.
- **Step 3:** Activates the camera connected to the computer.
- **Step 4:** Sets the puppet to a neutral state.
- **Step 5:** Executes the code blocks in a continuous loop.
- **Step 6:** Prompts the student with the question: *"Which polar animal is on the card?"*
- **Step 7:** Creates a variable named *Prediction* and stores the student's response.
- **Step 8:** Transfers the predicted polar animal name from the artificial intelligence model to the response variable.
- **Step 9:** Compares the student's response with the prediction generated by the artificial intelligence model.

- **Step 10:** If the answer is correct, the puppet displays a happy expression.
- **Step 11:** Plays a *Crash Bell* sound effect.
- **Step 12:** If the answer is incorrect, the puppet displays an angry expression.
- **Step 13:** Plays a *Vibraslap* sound effect.
- **Step 14:** Awards 10 points to the team's score for each correct answer.

Implementation of the Educational Game

Figure 4 displays the card images of 20 distinct polar animal species utilized in the AIBEG (Artificial Intelligence-Based Educational Game) system. The dataset was curated to include key representative species inhabiting the Arctic and Antarctic regions, with each animal being assigned a unique identification number ranging from 1 to 20. To optimize image recognition accuracy, the backgrounds of the selected images were removed, ensuring a clear and standardized visual format for the game.

The AIBEG system was designed as an interactive and competitive educational tool to engage students in learning about polar animals through AI-based image recognition. The research activity was conducted in a classroom setting, where students were divided into six groups. Each group received ten polar animal cards, and a designated student was asked to identify and name the animal depicted on their card. The student then presented the card in front of a webcam, allowing the AIBEG system to process the image and determine whether the identification was correct. If the system's recognition matched the student's response, the group was awarded 10 points, fostering a gamified learning environment that encouraged participation and knowledge retention.

The maximum achievable score in AIBEG was 100 points, with the highest-scoring team declared the winner. Analysis of the results demonstrated that top-performing teams exhibited a higher accuracy rate in identifying the polar animals, suggesting that the AI-supported educational approach enhanced student engagement and learning outcomes.

Figure 4. Card images of arctic animals

The working screen of AIBEG was shown in Figure 5. After naming the polar animal depicted on the card, the student verifies their answer by holding the card up to the computer's webcam. AIBEG utilizes an artificial intelligence model running in the background to recognize the Arctic animal. If the answer is correct, 10 points are added to the team's leaderboard. If the answer is incorrect, no points are awarded.

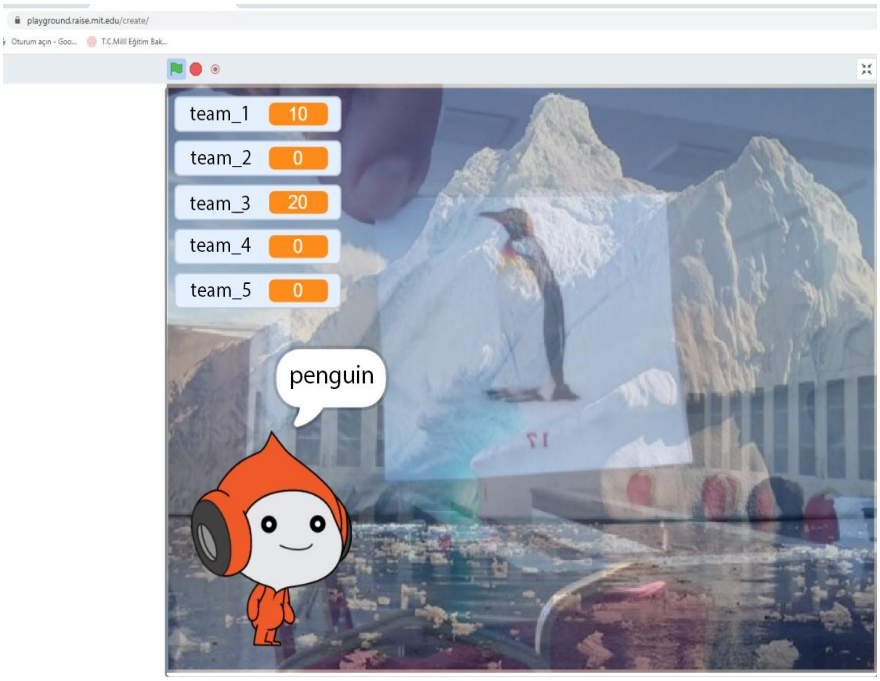

Figure 5. AIBEG working display

Findings

The responses to the Arctic Animals Educational Game Self-Assessment Form were provided below Figure 6.

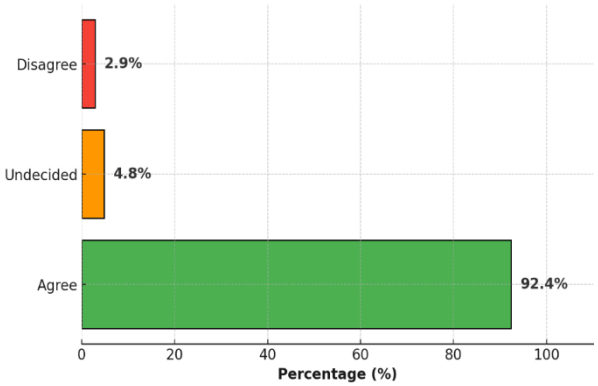

Figure 6. Percentage-based graphical representation of the responses to the third question.

This graph illustrates the responses to the statement: "I learned about new Arctic animals while playing the game." The survey results reveal the following:

- 92.4% (97 students) *agreed* with the statement. This overwhelming majority indicates that the game was highly effective in introducing new Arctic animals to the students. The high engagement level suggests that the game's educational content was well-received and contributed positively to their learning experience.
- 4.8% (5 students) were *undecided*. These students were uncertain about whether they had learned new Arctic animals or not, which might suggest varying levels of prior knowledge or different learning experiences within the game.
- 2.9% (3 students) *disagreed* with the statement, meaning a small fraction of students felt that they did

not learn any new Arctic animals during the game. This could be due to prior familiarity with the topic or a lack of engagement with the game's educational content.

Overall, the results strongly suggest that the game successfully achieved its educational goal of teaching students about Arctic animals. With over 92% of students confirming their learning experience, the game appears to be a highly effective and engaging tool for interactively introducing new information. Based on the results of the activity, it was found that students acquired new information about polar animals. Through content analysis, it was observed that their awareness particularly increased regarding the animals' habitats, feeding habits, and the environmental threats they face.

From a scientific perspective, students demonstrated gains in knowledge related to ecosystems, adaptation mechanisms, and the impacts of global warming on polar regions. The visuals and explanatory content presented during the game contributed to the development of students' skills in identifying and classifying the physical characteristics of animals. Furthermore, students experienced the processes of collecting and classifying scientific data through an artificial intelligence-supported application. This experience also enhanced their understanding of the technological tools used in scientific research. To further analyze the impact of the educational game on the students' semi-structured interviews were conducted with two randomly selected students. The following questions were asked by the students in the interviews:

- What new information did you learn thanks to this game?
- How did the game contribute to the learning process in science class?
- Which parts did you like the most while playing the game and why?
- Do you have any suggestions for improving the game?

Some of the student responses obtained are as follows:

S1: "A fifth-grade male student stated that although he had previously heard of the Arctic fox, he was not aware of its specific behaviors. Through the game, he learned that Arctic foxes change color—appearing white in the winter and brown in the summer. He noted that although this information had been explained during science class, he had not remembered it as well. However, because he learned it through matching animals in the game, he found it easier to retain the information (personal communication, 2022)."

S2"One fifth-grade female student reported that she previously believed penguins only lived in Antarctica, but through playing the game, she learned that there are various species of penguins and that some inhabit warmer regions. She expressed that answering questions and earning points during gameplay made the learning process enjoyable and stated, "I don't remember learning something in science class with so much fun before." She further suggested that the game could be improved by including more animal species and occasionally increasing the difficulty of the questions (personal communication, 2022)."

The data obtained from these interviews shows that the game helps students learn science topics in a fun and permanent way. It was also determined that it increased students' interest in educational games and encouraged their active participation in the learning process.

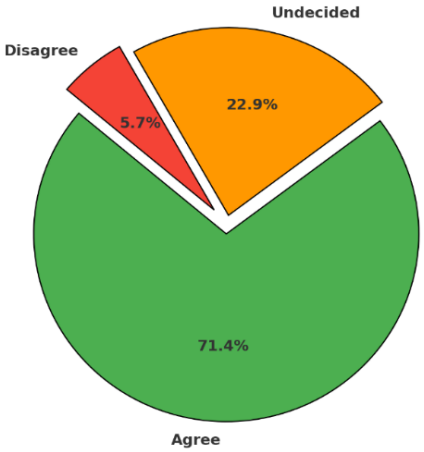

Figure 7. Percentage-based graphical representation of the responses to the fourth question.

Here is a more aesthetically pleasing pie chart with different colors and styles to enhance readability (Figure 7). Below is a detailed explanation of the results:

Detailed Explanation: The survey question asked students whether they were able to match polar animals while playing the game correctly. The results indicate the following:

- 71.4% (75 students) agreed that they were able to correctly match polar animals, suggesting that the game effectively helped them recognize and pair the animals.
- 22.9% (24 students) were undecided, meaning they were unsure of their ability to match the animals.
- 5.7% (6 students) disagreed, indicating that they did not find the game helpful in recognizing and matching polar animals.

These findings highlight that most students (nearly three-quarters) successfully engaged in learning through the game. The high percentage of agreement suggests that the game provided an interactive and effective way to improve students' knowledge of polar animals. However, a small percentage of students either struggled or were uncertain, which could indicate areas where the game might be improved to enhance learning outcomes further. Students stated that they gained knowledge on the following subjects after playing the game:

- Names and characteristics of animals living in polar regions: They had the opportunity to get to know animals they had never heard of before.
- Animal habitats and adaptations: They learned how they adapt to cold weather conditions.
- Biodiversity and environmental awareness: They gained awareness about how polar animals are under threat due to climate change.

Students noted the game supported science learning by:

- Visual and interactive learning: Since they learned by directly seeing and matching animals, their knowledge became more permanent.
- Experiential learning: It was more effective than traditional teaching methods thanks to the learning by doing and living method.
- Increased motivation: Thanks to gamification, students' interest increased, and they stated that they found the lesson more entertaining.

Challenges in Using AI-Based Educational Games

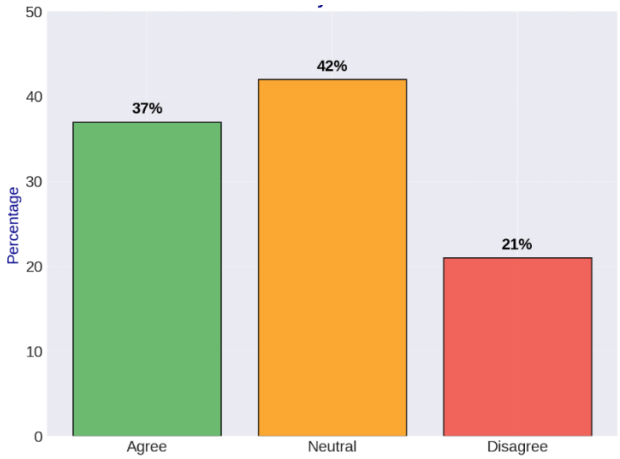

Figure 8. Graphical representation of the responses to the fifth question as a percentage.

The survey asked students whether they found it difficult to play the game. The responses were distributed as follows (Figure 8):

- 41.9% (44 students) disagreed, indicating that they did not experience significant difficulty while playing the game. This suggests that the majority of students were able to engage with the game easily.

- 37.1% (39 students) agreed, meaning they faced some level of difficulty during gameplay. This indicates that a considerable portion of the students encountered challenges while playing.
- 21% (22 students) were undecided, suggesting they were uncertain about whether the game was difficult or not.

In addition to the advantages that AI-supported educational games provide to students, it has been determined that some difficulties are also encountered during the learning process. In line with the feedback from students and the data analyzed, these difficulties are addressed within the framework of the following themes:

The game uses image processing technology to introduce arctic animals. However, some students may have experienced errors due to the AI model not recognizing certain animals correctly or the images being of low quality at times. In particular, the probability of students and the AI model making matching errors increased in species that are similar to each other, such as the arctic fox and the arctic hare.

S1: "I thought I guessed some animals wrong, but it turns out that the AI also sometimes gets them wrong. I got a little confused when I saw the arctic hare instead of the arctic fox."

Although this situation provides a learning opportunity for students to develop their visual discrimination skills. It has led to conceptual confusion, especially for students who have no previous knowledge of these animals. Students encountered some technical limitations during the game process. Among these, camera detection problems, dependency on internet connection, and moments when the AI worked with low accuracy stand out. In particular, incorrect camera angles or variable lighting conditions made it difficult for the AI to make correct identifications.

S2: "Sometimes it was difficult to recognize the animal while holding the camera. When the light was too bright, it was difficult to recognize some animals."

Such technical obstacles show that students need to develop technological literacy in AI-based learning processes.

Enjoy Using Educational Games Based on Artificial Intelligence

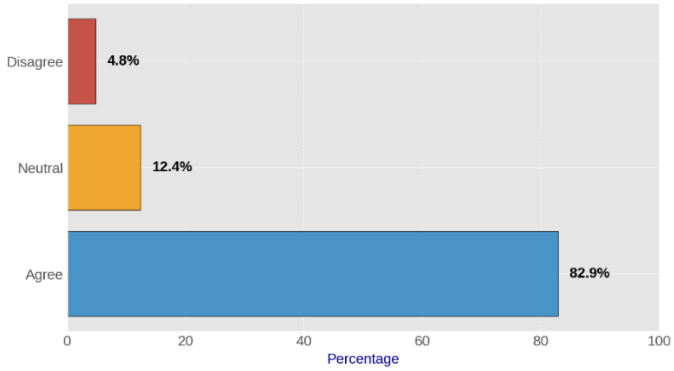

Figure 9. Graphical representation of the responses to the sixth question as a percentage.

The bar chart illustrates the responses to the statement "I had fun playing the game", which was the sixth question in the survey. The responses were collected from a total of 105 students, and their opinions were categorized into three groups: Agree, Neutral, and Disagree (Figure 9).

- 'Significant majority' and '87 out of 105' express the same idea. This indicates that the game was generally well-received and enjoyable for most participants.
- 13 students (12.4%) were neutral, meaning they were unsure or had mixed feelings about their enjoyment of the game.
- A small minority of 5 students (4.8%) disagreed, indicating that they did not find the game enjoyable.

The results suggest that the educational game was effective in engaging students, with a high percentage (over 80%) reporting a positive experience. However, a small portion of students either remained indifferent or did not

enjoy it, which could be due to personal preferences, gameplay mechanics, or other external factors. This feedback can be valuable for further improvements in game design to enhance engagement and ensure that even those who were neutral or disagreed have a more enjoyable experience in the future. Although the game contributes greatly to students in terms of science education, some students stated that they had difficulty in the process of learning information in depth. It was stated that topics such as:

The role of animals in the ecosystem, climate change, and adaptation of animals, and the food chain in the polar region should be included more in the game.

S3: "I got to know the animals, but the game did not explain why there were so few or why they disappeared. I wish these topics had been included more."

In line with this feedback, it was concluded that AI-supported games should include more detailed content suitable for the science curriculum instead of providing only superficial information. Since students were accustomed to traditional learning methods, they experienced some adaptation problems in the transition to the game-based learning model. Students who could not establish a direct connection between the points earned and learning success could not fully understand the educational value of the game.

S4: "It was nice to collect points, but I realized I had memorized some things. I wasn't sure if I had learned them."

This situation shows that gamification mechanisms should not only make knowledge fun but also support deep learning. In AI-supported games, detailed explanations should be added to better explain the differences between similar animal species. To minimize technical glitches, the accuracy of the game's AI model should be increased, and a user-friendly interface should be provided. The game should have a stronger integration with the science curriculum and should not be limited to just introducing animals. To increase students' adaptation to game-based learning, guiding information should be provided in advance.

Discussion

This study explored fifth-grade students lived experiences and perceptions regarding an Artificial Intelligence-Based Educational Game (AIEG) designed to teach polar animals. Conducted within the framework of a qualitative research approach using the phenomenological design, the study aimed to understand the essence of students' experiences while engaging with the game and the meanings they attributed to those experiences.

Findings indicate that the majority of students reported positive emotions and thoughts after engaging in the educational game. Most participants expressed enjoyment, increased interest, and a sense of curiosity toward the topic, suggesting that the game succeeded in creating a meaningful and engaging learning environment. This aligns with prior studies indicating that educational games foster intrinsic motivation, encourage active participation, and make abstract concepts more tangible (Prensky, 2001; Tüzün et al., 2006).

Students commonly described the game as fun, informative, and visually appealing, noting that they were able to better recognize and remember the animals featured in the polar regions. These qualitative responses are in line with literature asserting that game-based learning supports deeper understanding and long-term retention of content (Gee, 2003; Papastergiou, 2009).

A significant theme emerging from students' responses was the clarity of instruction and language used in the game. While most students found the instructions understandable, a few mentioned challenges with some of the language or gameplay steps. These comments highlight the need to ensure age-appropriate linguistic design and potentially support comprehension with visual or auditory aids (Kafai & Burke, 2015). Such enhancements can make the experience more inclusive and accessible.

Another key theme was engagement and sustained attention. Many students emphasized that the game kept them focused and attentive throughout the experience. This is consistent with research suggesting that interactivity and visual stimulation in educational games help sustain learners' focus (Squire, 2003). However, a few students noted difficulty concentrating, which might reflect differing learning styles or external distractions, pointing to the value of designing flexible and adaptive learning tools (Fleming & Mills, 1992).

In terms of cognitive engagement, the students' ability to match animals with their characteristics revealed that many could apply what they had learned meaningfully. Some students, however, reported confusion or

uncertainty, suggesting that further enrichment of content—such as more descriptive information or contextual visuals—could strengthen learning outcomes (Shute & Ke, 2012).

Students' feedback on the difficulty level varied: while some found the game appropriately challenging and enjoyable, others reported it as too easy or too difficult. This variance suggests that future versions of the game might benefit from offering differentiated levels of difficulty or scaffolding options to better support individual learners (Tomlinson, 2014).

Overall, students' reflections emphasized that the educational game helped them engage with the topic emotionally and cognitively, suggesting that such tools have strong potential for enhancing awareness of lesser-known ecosystems like the polar regions. The enjoyable format and accessible interface appeared to support learning while maintaining student motivation (Hamari et al., 2016).

In conclusion, this phenomenological study reveals that digital educational games, —when thoughtfully designed— can enhance students' awareness, promote engagement, and foster meaningful learning experiences. Nevertheless, the study also highlights areas for improvement, such as instructional clarity, content richness, and adaptability to diverse learning preferences. Future research could explore how these games affect long-term understanding and whether similar methods could be used for other science topics, contributing to both curriculum development and ecological awareness.

Conclusion

This study, grounded in a qualitative research approach with a phenomenological design, aimed to explore the experiences and perceptions of 145 fifth-grade students (63 females and 82 males) who interacted with an Artificial Intelligence-Based Educational Game (AIEG) designed to teach about polar animals. All participants voluntarily took part in the study and completed the self-assessment form following their gameplay experience.

The findings demonstrate that the educational game effectively supported student learning and engagement. A majority of students reported acquiring new knowledge about Arctic animals, indicating that the game successfully achieved its instructional purpose. This aligns with the view that digital games can reinforce subject-specific content and support meaningful learning. Students' statements revealed that the game was not only educational but also enjoyable and engaging, fostering curiosity and sustained attention. Many participants noted that they were able to use Turkish correctly and effectively during the game, suggesting that the language and instructions were generally age-appropriate and accessible. However, a small subset of students expressed difficulty understanding certain instructions, pointing to a need for clearer and more simplified language, or the addition of supportive visuals and auditory cues to improve comprehension. While student opinions on the game's difficulty level varied, the majority found the gameplay elements realistic and the instructions understandable. These responses indicate that the game was mostly well-balanced in terms of challenge and usability. Nevertheless, the presence of varied feedback highlights the importance of integrating adaptive difficulty levels or scaffolding strategies to better meet individual learner needs.

In conclusion, this study illustrates that an educational game designed with pedagogical intent and user-centered design principles can enhance learners' understanding of scientific topics such as polar animals, while also promoting engagement and correct language use. Future iterations of such games would benefit from increased clarity of instructional content, enhanced detail in the informational materials, and greater adaptability to accommodate diverse learning preferences. These refinements would further strengthen the educational impact and accessibility of game-based learning environments.

Suggestions

In light of the findings from this phenomenological study exploring fifth-grade students' experiences with an artificial intelligence-based educational game focused on polar animals, several recommendations are presented to enhance the use and development of educational computer games in learning environments:

- Integration into Curriculum: The Ministry of National Education should consider systematically integrating educational computer games into classroom curricula as complementary learning tools. These games can reinforce subject-specific knowledge while increasing student motivation and engagement.

- Teacher Training and Professional Development: Comprehensive professional development programs should be developed to train teachers in the effective pedagogical use of educational games. Educators need guidance not only on technical usage but also on instructional integration and assessment strategies.
- Support for Game Development and Research: There is a noticeable scarcity of domestically developed educational computer games and corresponding academic research in this area. National efforts should support interdisciplinary collaborations between educators, game designers, and researchers to create culturally relevant and pedagogically sound games. Funding mechanisms and research grants can also be expanded to stimulate innovation in this field.
- Raising Polar Awareness: Polar-themed learning content, including digital games, should be expanded within the national education system to raise awareness of polar ecosystems, climate change, and biodiversity. Such content contributes to global environmental consciousness among young learners.
- Experimental and Comparative Studies: Future research should include experimental or mixed-method designs to further investigate the impact of educational computer games on student achievement, motivation, and knowledge retention. Replicating international studies within local contexts can provide valuable comparative insights.
- Digital Learning Infrastructure: To maximize engagement and access, the game can be implemented in a fully equipped computer laboratory with internet access and interconnected devices. Transforming all components of the game—including information cards—into fully digital formats would enable a seamless learning experience while promoting environmentally conscious practices.
- Differentiation and Adaptability: The developed game can be adapted for different educational levels (e.g., middle school, high school) and for use in various professional or public awareness contexts (e.g., museums, environmental education programs). Such scalability ensures the broad utility of the game across learning ecosystems.
- Expanding Turkish-Language Resources: Further academic studies focusing on the Polar Regions should be conducted in the Turkish language to expand the national bibliography and ensure accessibility for Turkish-speaking researchers, educators, and students.

By addressing these recommendations, educational stakeholders can better harness the potential of game-based learning environments to foster meaningful, engaging, and long-lasting learning experiences for diverse learner populations.

Scientific Ethics Declaration

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

Conflict of Interest

* The authors declare that they have no conflicts of interest

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