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Evaluation of STEAM-Based Educational Material Titled "Touch and Explore Landforms"

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Abstract

The correct use of geographical concepts depends on the correct learning of the meanings of these concepts. In geography teaching, expressing elements such as place, rivers, lakes, mountains with special names; using terms and concepts specific to geography in explaining geographical phenomena and events; and making use of terms and concepts from various branches of science such as geology, biology, hydrology play an important role in the learning process. In this regard, the main objective of the project is to develop a three-dimensional educational material to enable secondary school students to learn about landforms in a more effective and interactive way. This project was designed with the STEAM (Science, Technology, Engineering, Art and Mathematics) approach to enable secondary school students to learn landforms in a more effective and permanent way. Within the scope of the project, an interactive educational material programmed using Arduino Uno and mBlock software was developed. This material, which appeals to students' visual, tactile and auditory senses, supports the concretisation of landforms and offers a more interesting and understandable learning process compared to traditional teaching methods. In the study, the design-development research model was adopted and the effect of the developed material was evaluated with student opinions. The results indicated that students found this material enjoyable, interesting, and conducive to lasting learning. The project provides an innovative model for geography education and contributes to students' conceptual learning about landforms by establishing connections between different disciplines. As a result of the interviews, all students expressed positive opinions about this material and stated that this project was more effective than the classical method and could be used in other courses.

Keywords: Educational material, geography, landforms, STEAM

Introduction

In recent years, the importance of technology integration in education has been increasing; it is stated that addressing the fields of science, technology, engineering, art, and mathematics (STEAM) with an interdisciplinary integrated approach enhances the effectiveness of learning processes (Henriksen, 2017; Perignat and Katz-Buonincontro, 2019). Particularly in subjects such as geography education, which involve a high concentration of conceptual and abstract information, the use of visual, interactive, and concrete materials is seen as an important requirement for students to achieve meaningful learning. Various studies have shown that digital and three-dimensional learning environments support spatial thinking and conceptual understanding skills and increase students' active participation in the learning process (Dede, 2014; Wu et al., 2013). In this regard, it can be said that STEAM based digital teaching materials developed in this direction are an effective tool in concretising geographical concepts and increasing the permanence of learning.

Within the scope of geography education, it is known that students need visual and tactile learning environments to recognise landforms and understand the processes of their formation (Civan, 2017). Although traditional teaching methods support students' understanding of these concepts, the lack of three dimensional visualisation tools can complicate the learning process. Therefore, technological solutions that combine physical and virtual learning environments can support students' in depth learning. In particular, by using a 3D model coded using the Arduino Uno board and mBlock programme, students can receive both visual and tactile feedback, making the learning process more meaningful (Ergün, 2023).

Research aimed at developing students' cognitive processes has determined that STEAM based teaching applications have positive effects on students' attitudes towards the environment, scientific thinking skills, and problem-solving competencies (Perignat and Katz-Buonincontro, 2019; Henriksen, 2017). In this context, it is thought that the three-dimensional model developed within the scope of the project will contribute to making abstract geographical concepts more understandable by supporting students' conceptual learning about landforms. Indeed, previous studies have emphasised that technology supported and three-dimensional learning environments strengthen students' spatial thinking skills and enable them to establish more effective relationships between concepts (Wu et al., 2013). Furthermore, it is anticipated that this project will serve as a unique application example in the context of technology supported geography teaching, thereby establishing a guiding model for similar STEAM-based educational materials to be developed in the future.

In conclusion, this project, which integrates digital and physical learning environments, is expected to fill an important gap in geography education and increase students' conceptual understanding of landforms. Thus, it will provide a concrete example of how STEAM based learning environments can be used more effectively in education.

Challenges Encountered in Learning Landforms

Geography education aims to provide students with spatial awareness, an understanding of environmental processes, and an understanding of human-nature interactions. However, in the process of teaching landforms, students encounter various conceptual, pedagogical, and technological challenges. These challenges stem from gaps in students' prior knowledge, inadequate teaching materials, and difficulties in concretising abstract concepts (Bozyiğit and Kayaardı, 2023).

Conceptual Challenges

As landforms involve abstract concepts encompassing complex geomorphological processes, students struggle to mentally visualise these processes (Akengin and Süer, 2011). For example, topics such as the formation of mountains, erosion, tectonic movements, and volcanic activity create difficulties for students in understanding the relationships between natural events. This situation can lead to deficiencies in students' conceptual development, negatively affecting the learning process. Students' prior knowledge plays a critical role in understanding geographical concepts. However, research has shown that a large proportion of students have deficiencies in basic concepts related to landforms (Civan, 2017). In particular, underdeveloped map reading skills make it difficult to comprehend spatial information such as elevation and slope.

Inadequacy of Teaching Materials

Teaching materials used in geography lessons are of great importance for students to comprehend the subjects. However, traditional textbooks and two-dimensional maps are insufficient in enabling students to understand landforms in three dimensions (Ergün, 2023). Teaching processes that are not supported by maps and digital tools make it difficult for students to grasp surface features. At this point, although the use of three-dimensional materials such as relief maps is recommended, the lack of widespread use of such materials in educational settings is a significant shortcoming (Civan, 2017). The fact that maps do not show landforms accurately and to scale makes it difficult for students to establish a connection between the real world and the map.

Insufficient Use of Technological and Digital Tools

Alongside traditional teaching methods, digital technologies are increasingly being used in geography education today. However, it is observed that technologies such as digital maps, geographic information systems (GIS), and augmented reality are used to a limited extent in Turkish schools (Bozyiğit and Kayaardı, 2023). While digital maps and simulations can help students better understand geographical processes, teachers' lack of knowledge about using these tools limits the effective use of technology in education (Ergün, 2023). The lack of interactive learning tools for students, such as augmented reality or virtual tour applications, negatively affects the process of developing spatial awareness (Baygül and Akış, 2024). Therefore, digital resources need to be integrated more effectively into educational programmes.

Lesson Duration and Curriculum Intensity

Teachers struggle to cover the topic of landforms within limited class hours, making it difficult to explain concepts in detail and implement effective learning processes (Bozyiğit and Kayaardı, 2023). Activities such as experiments, fieldwork, and group discussions are needed for students to understand the formation processes of landforms. However, due to the current curriculum density, sufficient time cannot be allocated for such activities.

Insufficiency of Field Studies

Field studies, one of the fundamental components of geography education, enable students to learn by directly observing landforms. However, for various reasons, field studies are often not carried out. Increasing students' learning experiences through observation in natural environments will contribute to the concretisation of abstract information (Bozyiğit and Kayaardı, 2023).

Geography Education and STEAM

STEM (Science, Technology, Engineering, and Mathematics) education, which aims to develop students' problem-solving, critical thinking, and creativity skills by integrating the disciplines of science, technology, engineering, and mathematics, is becoming increasingly important in today's education systems (Doğan et al., 2022). Unlike traditional teaching methods, STEM has an interdisciplinary structure and supports learning by translating theoretical knowledge into practice (Saralar Aras, 2021). Geography education, as a field that enables students to understand natural and human systems and develops their analytical and spatial thinking skills, is one of the important disciplines that can be integrated with the STEM approach. The application of the STEM approach in social studies and geography lessons helps students better understand landforms, climate events, environmental changes, and human nature interactions (Bulut, 2024).

Supporting Conceptual Learning

One of the most challenging topics for students in geography lessons is the dynamic processes of landforms and natural systems (Bozyiğit and Kayaardı, 2023). STEM education enables students to make abstract geographical concepts concrete, facilitating their understanding through methods such as modelling and simulation (Ergün, 2023). For example, the use of digital maps and three-dimensional modelling techniques enables students to better understand how landforms such as mountains, plateaus and valleys are formed. In addition, the STEM approach supports students' discovery-based learning processes, enabling them to question the mechanisms behind geographical processes (Baygül and Akış, 2024). Thus, students can understand concepts not only through memorisation but also through direct observation and application.

Effective Use of Technology and Digital Tools

STEM education ensures the more effective use of technology in geography teaching. In particular, geographic information systems (GIS), augmented reality applications, and digital maps are among the STEM-based applications in teaching geographic information (Ergün, 2023). Digital tools integrated with STEM education enable students to learn about geographic events interactively. For example, augmented reality applications can be used to simulate how a volcanic eruption occurs or how rivers erode over time. Such applications facilitate the concretisation of abstract information for students, making learning more permanent (Bozyiğit and Kayaardı, 2023).

Developing Critical Thinking and Problem-Solving Skills

STEM education has a teaching approach aimed at developing students' critical thinking and problem solving skills (Doğan et al., 2022). In social studies and geography lessons, STEM based projects can be developed that offer students the opportunity to produce solutions to the environmental and human problems they encounter. For example, topics such as global climate change and sustainable urban planning can be addressed through projects that enable students to perform data driven analysis and develop solution proposals (Bulut, 2024). Through STEM applications, students can acquire the skills to develop science based solutions to local and global geographical problems.

Increasing Student Motivation and Participation

Research shows that STEM based learning processes increase student motivation and reinforce their interest in the subject (Saralar Aras, 2021). When the STEM approach is used in geography lessons, students move away from traditional passive learning methods and become involved in an active learning process. Participating in STEM activities such as conducting research, developing projects, and group work helps students develop their collaborative work and communication skills (Doğan et al., 2022). Furthermore, combining STEM-based applications with problem-based learning methods contributes to the development of students' independent thinking and creative problem solving skills.

Supporting Field Studies and Experiential Learning

Field observations and fieldwork in geography lessons are important components that develop students' spatial thinking skills. STEM education supports the integration of such activities into the curriculum, increasing students' participation in direct observation and data collection processes (Bozyiğit and Kayaardı, 2023). The literature emphasises that field-based learning activities strengthen students' spatial perception, environmental awareness, and scientific inquiry skills (Orion and Hofstein, 1994; Fuller, 2006). For example, students can organise field trips to examine local geographical features, take measurements, and analyse the data they collect using digital maps and geographic information systems. Such technology-supported fieldwork allows students to concretise abstract geographical concepts while also helping them actively participate in scientific research processes (Bednarz et al., 2013). It is noted that these applications increase students' environmental awareness and reinforce their interest in scientific research (Ergün, 2023).

Purpose of the Study

The inability to learn geographical concepts without understanding them and to transform them into lasting knowledge is one of the fundamental problems encountered in geography education. This situation leads to rote learning replacing understanding-based learning in geography teaching and hinders students' processes of questioning or internalising information. Consequently, information learned by rote is forgotten within a short period of time, and lasting learning cannot be achieved. In this regard, the main objective of this project, designed based on the STEAM approach, is to develop a three-dimensional educational material to ensure that middle school students learn landforms more effectively and interactively. Considering the contributions of STEAM education applications to students' problem-solving skills and scientific thinking processes (Bulut, 2024), it is necessary to disseminate such technology-based approaches in education.

This research examines the applicability of a model called “Touch and Discover Landforms,” which enables students to concretise landforms that they cannot physically experience within the holistic structure of the STEAM approach in geography teaching in a virtual environment, to interactively comprehend the formation processes of these structures, and to establish connections with different disciplines. The developed material will be programmed using an Arduino Uno board and mBlock software and coded in a digital environment, supported by feedback mechanisms that appeal to students' visual, tactile, and auditory senses. Thus, within the holistic structure of the STEAM approach, it is expected that students will be able to concretise landforms that they cannot experience in a physical environment in a virtual environment, understand the formation processes of these structures in an interactive way, and make progress in their ability to establish connections between different disciplines .

In this regard, the aim of the research is to develop a STEAM based three dimensional digital learning environment for secondary school students, supported by Arduino Uno and mBlock, containing visual, tactile, and auditory components, and to examine the contribution of this environment to the teaching of geographical concepts through student opinions. This general objective corresponds to the main problem of the study: “How do STEAM based digital learning environments affect the teaching of geographical concepts?” The sub-objectives are presented below in line with this main problem.

Sub-objectives

1.What are the students' views on digital geography learning environments designed with the STEAM approach, which include visual, tactile and auditory elements, and how do these environments contribute to the concretisation of geographical concepts?

2.What are the views of students who have experienced the digital learning environment designed within the scope of this study regarding the differences between the transmission of geographical concepts through STEAM based learning environments and traditional methods?

3.What are the students' views on the use of this material in other subjects?

4.What are the positive feedback from students regarding the designed learning environment?

5.What are the negative feedback from students regarding the designed learning environment?

Significance of the Study

STEM (Science, Technology, Engineering, and Mathematics) and its expanded version, STEAM (Science, Technology, Engineering, Arts, and Mathematics), support interdisciplinary learning and develop students' critical thinking, problem-solving, and creativity skills (Doğan et al., 2022). This approach aims not only to transfer knowledge but also to enable students to construct knowledge and establish meaningful connections between different disciplines. Particularly in disciplines with a high concentration of abstract concepts, such as geography, the STEAM approach offers significant potential for developing students' spatial thinking and analytical skills (Bulut, 2024).

However, as emphasised in the literature, traditional teaching methods do not sufficiently support the three-dimensional perception of landforms, causing students to learn concepts mostly at a superficial level (Civan, 2017). This limitation increases the need for alternative teaching approaches based on learning by doing and experiencing, which encourage students' active participation in the learning process. The use of digital and tactile learning environments is considered an important tool that can contribute to students' more effective and lasting understanding of geographical processes (Ergün, 2023).

Learning environments developed with Arduino Uno and mBlock software will contribute to making geography education more interactive, engaging, and meaningful by enabling the concretisation of landforms (Bozyiğit and Kayaardı, 2023). Such technological applications support students not only in learning geographical information but also in developing their skills in using technology for educational purposes. Furthermore, the integration of electronic systems and digital structures into education offers students engineering and technology based learning opportunities, while the inclusion of artistic and aesthetic elements in the process increases learning motivation and strengthens students' interest in the subject (Baygül and Akış, 2024).

Furthermore, the integration of mathematical and algorithmic modelling with geography education contributes to the development of students' data analysis, measurement, calculation, and problem solving skills. Thus, students have the opportunity to evaluate geographical events and processes within cause and effect relationships rather than merely memorising them. This STEAM based approach not only enhances academic achievement but also contributes to students' acquisition of scientific thinking, creativity, and an interdisciplinary perspective , which are considered 21st century skills. In short, by presenting an innovative model for the use of the STEM/STEAM approach in geography education, the aim is to develop students' scientific thinking, technology use, and ability to approach different disciplines from a holistic perspective.

Original Value of the Research

This study differs from many others in the literature in that it focuses on integrating the STEAM approach with concrete and digital learning materials in the context of geography education. In the literature, STEAM education is mostly addressed within the framework of science, technology and engineering disciplines; in geography teaching, it is generally limited to two-dimensional digital content, map applications or simulations (Yakman and Lee, 2012). However, in this study, a three-dimensional and interactive model supported by Arduino Uno and mBlock software was developed with the aim of enabling students to experience landforms through visual, auditory, and tactile interactions. Including scientific models in lesson plans not only provides students with conceptual knowledge but also offers them the opportunity to see how scientific knowledge is structured and evaluated (Ünal Çoban, 2021). In this respect, the study brings together physical modelling, coding, and geographical concept teaching within a holistic STEAM framework. Furthermore, unlike many STEAM studies in the literature, the effectiveness of the developed material was evaluated based on student opinions, thus revealing in-depth student experiences regarding the learning process. This approach is consistent with studies showing that STEAM-based teaching practices enhance creativity, learning motivation, and interdisciplinary connections (Henriksen et al., 2018). In this context, the research makes a significant contribution to the literature by presenting an applicable, developable, and original STEAM-based teaching model for geography education.

Method

Research Design

This study adopted a design and development research model, with Type 1 development research being the preferred method. McKenney and Reeves (2013) state that the fundamental aim of design and development research is to develop new models and tools that support education. Büyüköztürk et al. (2021) define this research approach as "studies aimed at developing, testing, and evaluating the feasibility of new products, tools, models, and processes." Richey and Klein (2007) divide design and development research into two main categories: Type 1 research focuses on the development of specific products and tools, while Type 2 research focuses on the creation of design and development models. According to Büyüköztürk et al. (2021), the development, implementation, and evaluation of teaching materials, educational software, websites, and learning systems that can be used in teaching processes can be cited as examples of Type 1 research. In line with this, the research conducted involved the design of digital geography learning materials and the testing of the applicability of these materials, therefore employing a Type 1 development research method. Furthermore, TÜBİTAK (2013) defines design and development research as a systematic study that aims to create new materials, products or devices; develop new processes, systems and services; or significantly improve existing ones, using information obtained from current research and applications. In this context, it can be said that this method, which focuses on the design and development of a new model, tool, or product in scientific research, is appropriate for use in research on product development processes (Büyüköztürk et al., 2021).

This study, conducted in line with the design and development research model, was carried out in five stages. The general flow chart of the study is summarised in Figure 1.

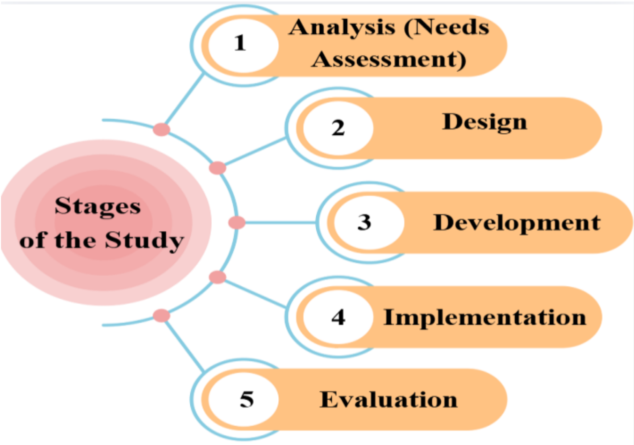

Figure 1
Flow chart showing the stages of the study

Participant Group

The population of this research consists of secondary school students attending state schools in a city in Central Anatolia. The sample of the research consists of 30 sixth-grade students attending state schools in a city in Central Anatolia during the 2024-2025 academic year. In selecting the sample, the convenient sampling method was preferred because it was easy to reach the participants. This method involves the researcher selecting individuals who are easier to access and is commonly used in studies with time, cost, and large population constraints (Etikan et al., 2016). During the participation process in the study, the necessary parental permissions were obtained for the students to participate, and participation was entirely voluntary. An examination of the participant profile revealed that a total of 30 students participated in the study, comprising 15 girls (50%) and 15 boys (50%). However, during the project evaluation process, interviews were conducted with nine sixth-grade students aged 11-13, five girls and four boys, who were studying at the same school.

Phases of the Process

During the analysis phase, classroom discussions were held to identify the possible reasons why students were struggling to achieve lasting learning in the subject of landforms within the social studies curriculum. These discussions revealed that students lacked sufficient knowledge of geographical concepts related to landforms. In order to assess whether similar situations existed in other classes, discussions were held with students and teachers from different classes, and it was concluded that students had difficulty learning geographical concepts related to landforms.

During the design phase, a brainstorming session was held with the pupils on how the topic of landforms could be better learned. The pupils' opinions were then evaluated. It was decided that a three-dimensional model appealing to the pupils' visual, tactile and auditory senses would be prepared in a digital environment, programmed and coded using an Arduino Uno board and mBlock software, with the pupils volunteering to carry out this work. The design of the study was developed with input from education specialists. In this context, the materials needed for the development phase were identified and procured by the students. The materials used in the project are as follows:

a) Materials required for visual design: 2 egg cartons, 4 packs of tissues, 200g plaster, 350g water-based glue, acrylic paint in different colours, 4 brushes
b) Materials required for the Arduino Uno connection: 1 Arduino Uno board, 1 medium-sized breadboard, 5 buttons, 5 10 kΩ resistors, 7 jumper cables.

During the development phase, the students in the project team, under the guidance of their supervising teacher, first defined the following objectives for the project according to the STEAM approach:

- Presenting information about landforms (mountains, plains, plateaus, valleys, volcanoes, rivers, etc.) to students with the support of visual, tactile, and auditory elements (Science).
- The integration of digital systems with electronic structures to provide technology-based applications for teaching students (Technology).
- Creating a digital learning experience using Arduino Uno and mBlock software (Engineering).
- Presenting geographical structures in an aesthetically effective manner based on scientific principles, preparing the material ground and painting it (Art).
- In-depth analysis and modelling of geographical processes through algorithmic approaches and calculations, measurements of the material base, and proportions in the placement process of the prepared shapes (Maths).
- Developing secondary school students' science, technology, engineering, art, and mathematics (STEAM)-based skills.
- Ensuring interdisciplinary integration by emphasising the competencies that each field will provide to students.

Students created a mould by stacking egg cartons to prepare the landforms on the project base. They then carefully glued small pieces of tissue paper, coated with a mixture of plaster, glue and water, onto the mould. This process made the surface more durable and ensured that the shape was more solid and resembled a landform. Thus, they created an aesthetically pleasing and durable model in terms of both texture and appearance. The surface shapes obtained at the end of this process are shown in Figure 1. After the drying process was completed, the painting process was carried out by selecting the appropriate colour tones for the work. The painting process is shown in Image 2. Subsequently, the base of the material was prepared using cardboard and boxes (Images 3 and 4).

Image 1
Unpainted earth surface shapes

Image 2
Painting process of earth shapes

Image 3
Creating a base by cutting cardboard and boxes

Image 4
Process of combining the base and landforms

Image 5
Research process

Subsequently, the students in the project team conducted research using the STEAM approach, digital applications they could use, and the visual and written materials they needed from TÜBİTAK Science and Youth (Image 5), National Geographic, sosyalciyiz.net, and the MEB Social Studies 6th Grade textbook. First, three-dimensional designs were created for the identified landforms. Simultaneously, coding was done via mBlock. The images used in mBlock were prepared with an artificial intelligence tool (Microsoft Bing, Chat GPT Image Generator Pro). The texts in the project were narrated using an artificial intelligence tool (ElevenLabs AI). After these stages were completed, the codes written in mBlock were transferred to Arduino Uno and combined with the three-dimensional designs using cables and sensor buttons.

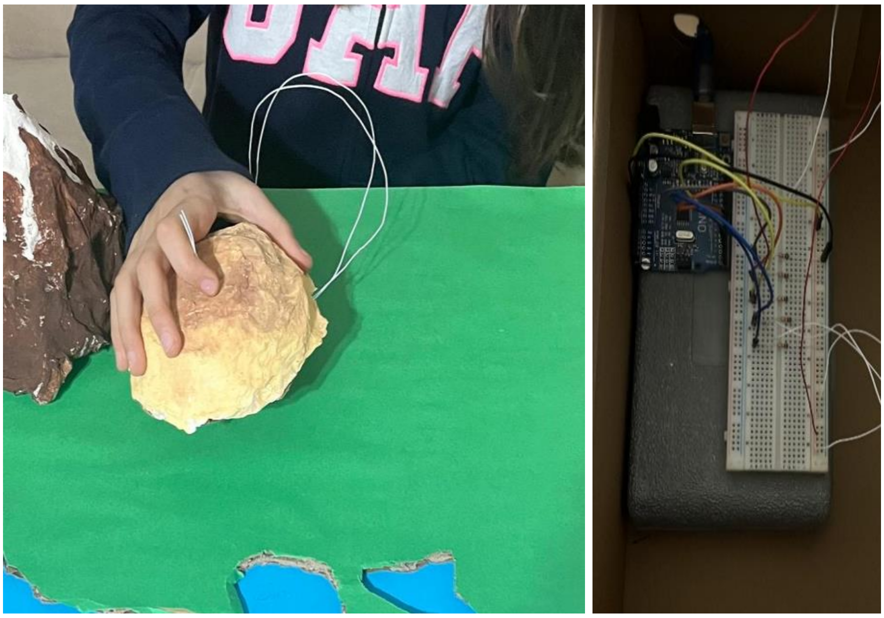

Image 6
Integration process with arduino uno

Feedback was obtained from the IT teacher at our school during the process, and the necessary corrections were made. After the corrections, the presentations prepared on landforms were added to mBlock, along with audio files narrated by artificial intelligence.

During the implementation phase, the prepared design was shared with students in the sixth grade classes at the secondary school where the project was implemented (Image 7). The students experienced the developed design in the classroom environment under the supervision of their subject teachers. Subsequently, a game prepared using the Scratch programme was played to provide a brief evaluation of this activity.

Image 7
Classroom implementation process

At this stage, data was collected using an interview form to reveal the impact of the digital learning environment created with the STEAM approach on students' concretisation of geographical concepts and to reveal their views on a geography learning environment that includes visual, tactile and auditory elements.

In the *evaluation* phase, content analysis was performed on the student opinions collected through the interview form. Thus, opinions regarding the overall impact of the research, the benefits it provided, and the strengths and areas for improvement of the developed three-dimensional design were revealed. This provided a concrete example of how learning environments based on the STEAM approach can be used more effectively in education.

The product developed by the students using mBlock and Arduino Uno based on the STEAM approach is shown in Image 8. The Arduino Uno and cables are placed in the box below.

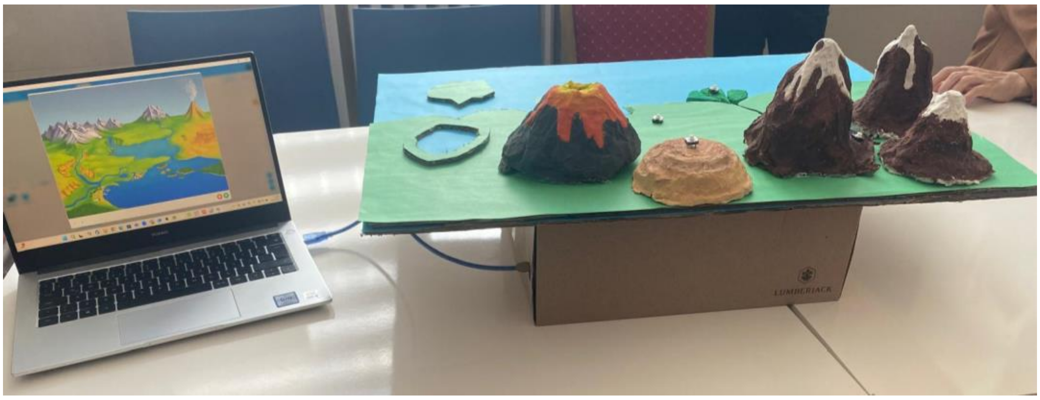

Image 8
Developed educational material

The background for the material prepared by the students can be found in Figure 9. Symbols representing mountains, plains, deltas, plateaus, volcanic mountains, islands, bays, capes, and lakes have been placed on the prepared material. When students wish to learn about a particular landform, they press the button and an informational animation appears on the computer screen. The images in the informational animation were created using Microsoft Bing and Chat GPT-Image Generator Pro at , and the voiceovers were created using the ElevenLabs AI artificial intelligence application.

Image 9
The background of the material prepared by the students

Students wrote codes for all landforms using the mBlock application. This way, when the button on the landform is pressed, the codes for that section are activated.

Data Collection Tools

In order to determine the effect of STEAM based digital learning environments on the teaching of geographical concepts, a semi structured interview form developed by the researchers after the study was used. Semi structured interviews are known to be an effective data collection method that allows participants to express their thoughts in detail (Polat, 2022). The interview form consisted of five open ended questions aimed at understanding the students' experiences and opinions. To increase the validity of the form, the opinions of two academics specialising in education were sought, and the necessary adjustments were made. Prior to conducting the interviews, research permission was obtained from the Provincial Directorate of National Education. Before the interviews, audio recordings were made with the permission of both the participants' parents and the participants themselves.

Data Analysis

The data obtained from the interview form was analysed using descriptive analysis and content analysis. The data was first organised using analytical strategies, then read repeatedly to produce open codes, and the codes were converted into categories and themes. The themes obtained were interpreted in relation to the research questions. In creating the themes, care was taken to ensure that each theme was supported by at least two different data sources.

Validity and Reliability

In qualitative research, it is important to report data in detail and explain how the results were obtained in order to ensure validity (Yıldırım and Şimşek, 2012). In this study, the findings are presented in detail, supported by direct quotations from participant statements. Validity in qualitative research is divided into two types as internal and external. Internal validity refers to the adequacy of the research process in discovering the truth about the research topic, while external validity concerns the generalisability of the research results. Various strategies are applied to ensure internal validity, such as long term observation, peer review, participant confirmation, and detailed description. To increase external validity, it is important to describe the findings in detail and ensure their comparability with different contexts (Creswell, 2017; Glesne, 2015). To contribute to the validity of the research, visuals related to the project design and development stages, research permission, the mBlock file prepared by the students, a sample interview audio file, a digital game prepared by the students using the Scratch programme for evaluation purposes, and the QR code related to this game have been made available for review.

Reliability refers to the reproducibility of research findings. The fact that the same research yields similar results at different times indicates that reliability has been achieved. In this study, the researcher diversification technique will be applied to ensure reliability. One quarter of the randomly selected interview transcripts were analysed by different researchers, and the coding was compared. Reliability was assessed by calculating the consistency ratio according to the formula suggested by Miles and Huberman (1994) (number of agreed codes / total number of codes). As a result of analysing the similarities and differences between the views, the reliability ratio was determined to be 83%.

Research Ethics

This study was conducted in accordance with fundamental ethical principles in educational research. Prior to the implementation process, necessary permissions were obtained from the relevant Provincial Directorate of National Education. Participation in the study was entirely voluntary, and informed consent was obtained from both the students and their parents.

Participants were informed about the purpose of the study, the procedures involved, and the intended use of the data. Confidentiality and anonymity were ensured by excluding any personally identifiable information during data collection, analysis, and reporting. Audio recordings were carried out with the permission of both the participants and their parents and were used solely for research purposes. Throughout the study, all procedures were implemented with sensitivity to students' rights, well-being, and privacy.

Findings

Findings regarding the interviews, categorised according to the questions posed to the students, are presented under subheadings. Nine students participated in the interviews and were coded as S1, S2, S3,…S9.

Opinions Regarding the Prepared Digital Educational Material

The codes for the responses to the questions asked to the students who participated in the interviews, "What did you think of this material prepared on the physical map of Türkiye? Do you think it contributes to the concretisation of geographical concepts?", are presented in Figure 2.

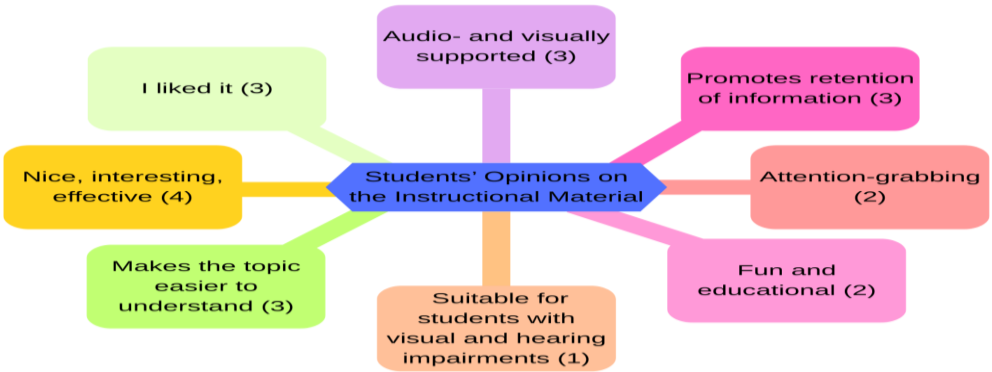

Figure 2

Opinions regarding the prepared digital educational material

Note: Some students provided more than one response.

According to Figure 2, 4 students found the prepared digital educational material beautiful, interesting, and effective, 3 liked it, 3 found it to be supported by audio and visual aids, 3 found it to ensure that the information was retained, 2 found it to be educational while entertaining, 2 found it to be attention-grabbing, 1 stated that it was suitable for the visually and hearing impaired, and 3 stated that it made the subject easier to understand. All students stated that the prepared digital educational material made geographical concepts concrete. Student Ö5 stated, "*I think the colours and sounds make this material interesting*," and student Ö7 stated, "*I think that placing different landforms on a base in this material will attract more attention, and that the visual and auditory nature of the material, with its integration of technology, will make it easier for disabled children to understand the subject*."

Opinions on the Differences Between the Educational Material and the Traditional Method

The codes related to the responses to the question asked to the students interviewed, "How does teaching landforms with this prepared material differ from teaching them with the classical method?", are presented in Figure 3.

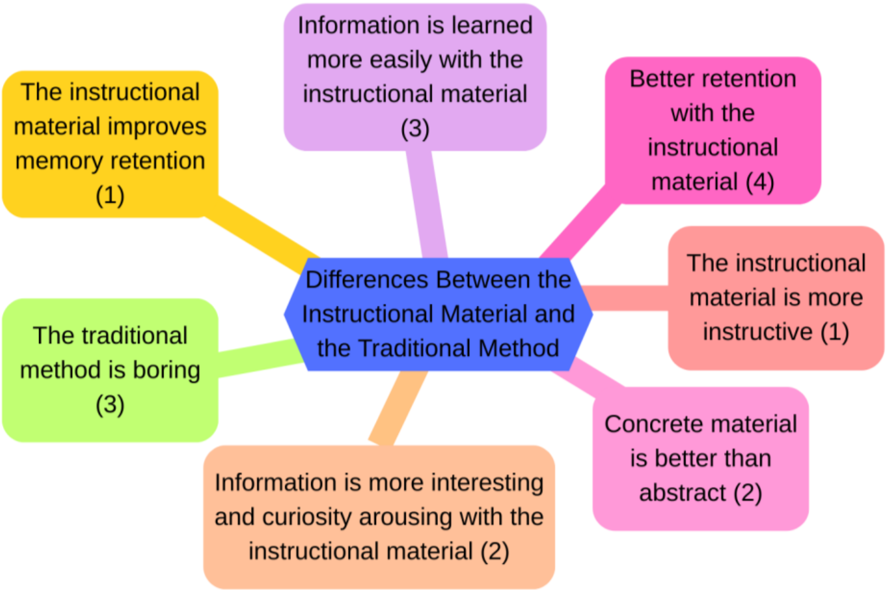

Figure 3
Student opinions on the differences between educational materials and the traditional method
Note: Some students provided more than one response.

According to Figure 3, 3 students stated that the traditional method was boring, 1 stated that the educational material was more instructive, 4 stated that information was more memorable with the educational material, 3 stated that the educational material taught information more easily, and 2 stated that the educational material made information more interesting and aroused curiosity. In addition, 2 students responded that "Concrete material is better than abstract material" and 1 student responded that "Educational material ensures that information is retained in memory." Student Ö9 stated, "*We had difficulty learning without this material, but thanks to this material, we can learn the subject more easily,*" and Ö1 stated, "It *provides a more lasting presentation compared to the traditional method. It is a better teaching method for students because it arouses interest and curiosity in people*."

Opinions on the Use of Educational Materials in Other Subjects

The codes for the responses to the question asked to the interviewed students, "Do you think similar material should be used in other subjects and topics? In which subjects and topics could this be?" are presented in Figure 4.

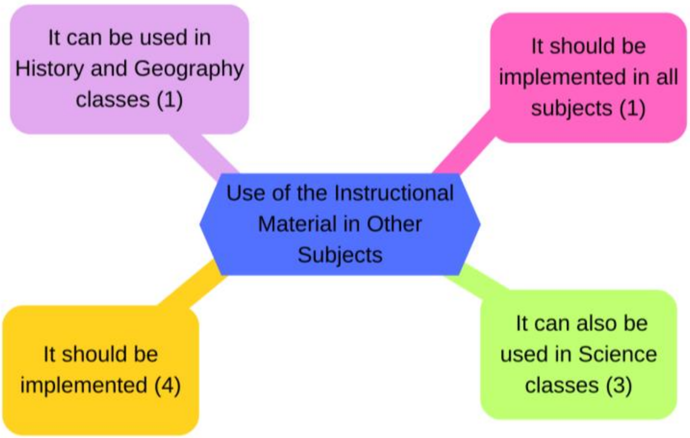

Figure 4
Student opinions on the use of educational materials in other subjects

According to Figure 4, 4 students responded that it should be implemented, 3 responded that it could also be used in science subjects, 1 responded that it could also be used in history subjects, and 1 responded that it should be implemented in all subjects. Student Ö3 responded, "*Yes, I recommend that this material be used in other subjects. For example, I think there could be material related to planets and stars in science lessons. It could also be used in history lessons.*" and Ö8 stated, "*Yes, it could be used in geography lessons as well, not just in social studies.*"

Positive Opinions Regarding Educational Material

The codes for the responses to the question "What aspects of this material do you like?" asked to the students interviewed are presented in Figure 5.

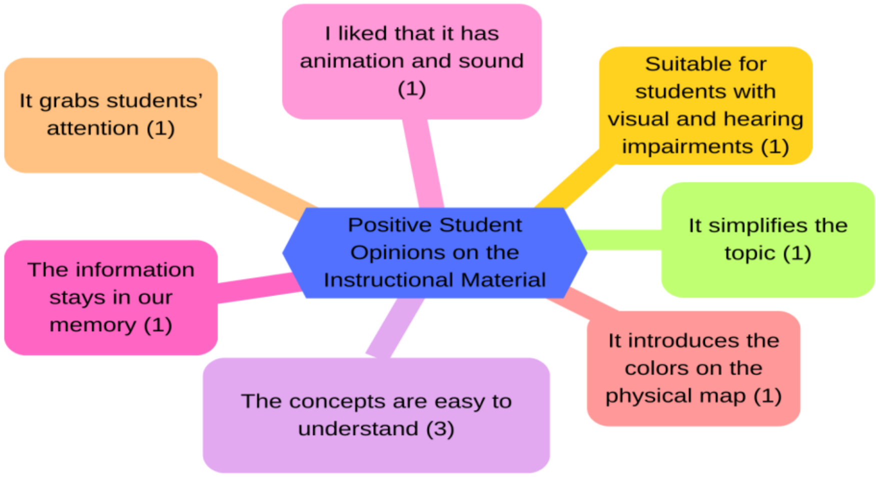

Figure 5
Positive student opinions regarding educational materials

According to Figure 5, one student stated that it is suitable for the visually and hearing impaired, one stated that it simplifies the subject, three stated that the concepts are easy to understand, one stated that the information stays in our memory, one stated that they liked the animation and sound, one stated that it introduces the colours on the physical map, and one stated that it attracts students' attention. Student Ö2 stated, "*I think this material not only makes it easy for people to understand the subject, but also allows hearing-impaired individuals to understand the subject by seeing and visually impaired individuals to understand it by hearing,*" and Ö7 stated, "*I liked* the *animation and sound.*"

Negative Opinions Regarding the Educational Material

The codes for the responses to the question "What aspects of this material did you dislike?" asked to the students interviewed are presented in Figure 6.

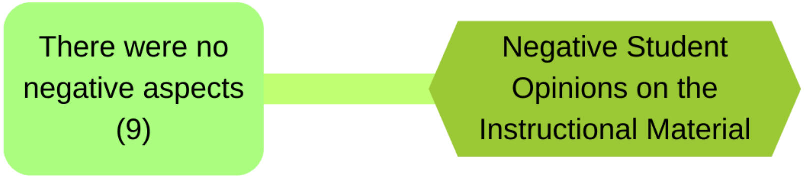

Figure 6
Negative student opinions regarding educational material

According to Figure 6, all students stated that they liked the material very much and did not see any shortcomings. Student Ö3 stated, "*There is no part that I did not like or thought was negative,*" and student Ö2 stated, "I *did not see any negativity*."

Discussion

This study evaluated the contribution of STEAM-based digital learning environments to the teaching of landforms in the context of geography education. The main objective of the study was to enable students to learn geographical concepts more effectively and permanently by developing a three-dimensional model integrated with Arduino Uno and mBlock software. An interactive teaching material on landforms in Turkey was designed in line with the STEAM approach and the design-development method. Including scientific models in lesson programmes not only provides students with discipline-specific conceptual knowledge but also enables them to develop awareness of how scientific knowledge is produced and evaluated (Gilbert and Justi, 2016; Schwarz et al., 2009; Ünal Çoban, 2021). In this project, the model development process was adopted within the scope of geography and social studies education. The literature emphasises that design-based development studies offer an effective and systematic approach to adapting educational technologies to the classroom environment (McKenney and Reeves, 2018). During the preparation of the material, the opinions of education field experts and the consultant teacher were sought, and the functionality and educational quality of the material were improved based on the feedback received. Similar studies also indicate that digital learning materials developed based on expert and user feedback enhance the quality of the learning process (Perignat and Katz-Buonincontro, 2019). Following the completion of the material, the views of secondary school students regarding the developed material were gathered to evaluate the educational value of the application. Findings based on the data obtained were examined in terms of similarities and differences in relation to the relevant literature. The common and different aspects of the findings in the literature are summarised in Table 1.

Table 1

Comparison of findings with the literature: common and distinct aspects

Theme / Finding	Finding in this study (summary)	Common aspects with the literature (example sources)	Differences from the literature	Interpretation / Possible explanation
Interaction and motivation	Students described the material as "fun", "different" and a tool that increases participation in class.	It is emphasised that digital/interactive learning environments support deep learning and student participation (Dede, 2014).	It is emphasised that the effect of technology integration depends on the design of the lesson and how the teacher uses the material; the alignment of material use with instructional objectives is critical (Dede, 2014; Ulusoy and Gülüm, 2009).	In this study, the material's appeal to multiple senses and its integration with classroom practice may have strengthened positive perception.

Table 1
Continued

Conceptual understanding and retention	Students stated that the information “stayed in their memory” and that they understood landforms better.	It is noted that the use of appropriate materials in geography teaching strengthens concept teaching (Akengin and Süer, 2011; Doğanay, 2002).	It has been reported that in some contexts, digital tools can lead to superficial learning and require alignment with conceptual goals (Wu et al., 2013).	The fact that the material is directly related to the target concepts and provides interaction/feedback may have increased the perception of retention.
STEAM approach and skills	The material was designed using the STEAM approach; students found the process engaging.	There is evidence that STEAM applications support holistic learning experiences and thinking skills (Perignat and Katz-Buonincontro, 2019; Yakman and Lee, 2012).	If interdisciplinary integration is weak in STEAM activities, the impact may be limited (Perignat and Katz-Buonincontro, 2019).	Making interdisciplinary connections visible in practice (tasks/questions) increases positive perception.
Transferability to other subjects	Students suggested that the material could also be used in other subjects and topics.	It is stated that technology-supported designs can be adapted to different learning areas (Dede, 2014).	Content-tool mismatch and time/infrastructure issues may be limiting factors in adaptation (Wu et al., 2013).	The teacher's material selection and usage competence are decisive in the adaptation process; it is recommended that the use of materials in different contents be designed in line with instructional objectives (Ulusoy and Gülüm, 2009).
Accessibility and inclusivity	Students have indicated that the material may also be suitable for visually/hearing impaired students.	It is emphasised that accessibility can be supported by different representation formats and designs that appeal to multiple senses (Wu et al., 2013).	Inclusivity may be limited when universal design principles and technical standards are not provided.	This finding points to an “inclusive” perception; however, it should be noted that its verification through accessibility testing is limited in the discussion.
Negative aspects/limitations	Students did not express any significant negative aspects.	Satisfaction may be high with new materials; technical/logistical problems may be reported with long-term use (Wu et al., 2013).	Some studies highlight difficulties with cost, maintenance, classroom management, and time management.	The low number of negative views may be related to the novelty effect and short-term application; this situation can be discussed as a limitation.

Table 1 shows similarities and differences with the literature. Thus, the dimension of the findings based on student statements becomes more visible. In this context, when students were asked how they found this material prepared on the physical map of Türkiye, they stated that it was beautiful, interesting, effective, appealing, supported by audio and visual aids, ensured that the information was retained, taught while entertaining, attention-grabbing, suitable for the visually and hearing impaired, and facilitated understanding of the subject. The research findings show that, as emphasised in studies in the field (Bulut, 2024; Saralar Aras, 2021), such digital learning environments increase students' conceptual understanding, learning motivation, and participation in the learning process. Similarly, İpçioğlu (1999) and Doğanay (2002) stated that computer-assisted instruction would be more successful in history and geography lessons, respectively. This statement supports the students' responses. Other studies on students' levels of understanding landform concepts have also indicated that visual and interactive materials yield more successful results than traditional learning methods (Akengin and Süer, 2011). This statement supports the project results.

When asked about the difference between teaching landforms to students using this prepared material and teaching them using traditional methods, they stated that traditional methods are boring, educational materials are more instructive, information is more memorable with educational materials, educational materials teach information more easily, and educational materials make information more interesting and intriguing. The findings that visual and tactile materials support conceptual learning are consistent with previous studies (Civan, 2017; Ergün, 2023). Çavaş et al. (2013) similarly state that design-based education will make students interested and eager to learn. Furthermore, students stated that "Concrete materials are better than abstract ones" and "Educational materials ensure that information remains in memory." When teaching history and geography topics in social studies, visual materials (photographs, pictures, graphs, cartoons, maps, etc.) are more effective than written materials consisting solely of text, especially when dealing with abstract concepts (Ulusoy and Gülüm, 2009). The necessity of using teaching methods supported by concrete materials to help students better understand concepts related to landforms has also been emphasised in previous studies (Öğün, 2010). Well-designed materials enrich the educational process, facilitate learning by providing concreteness in the perception of information, reduce forgetting, motivate students, focus their attention, stimulate their desire to learn, enable them to achieve gains by doing and experiencing, contribute to the conceptualisation of thought, and naturalise the learning environment (Özyürek, 1983). These statements support students' choice of prepared educational materials over traditional methods.

When asked whether similar materials could be used in other subjects and topics, and if so, in which subjects and topics, students responded that they should be applied, that they could be used in science lessons, that they could be used in history lessons, and that they should be applied in all subjects. In primary education, it is important for students to be active, to learn by doing and experiencing, to establish connections between new knowledge and life, to access knowledge themselves, and to use their own materials in particular to access knowledge, in order for meaningful learning to take place (Ulusoy and Gülüm, 2009). Therefore, it is thought that the material developed can contribute to the learning process when used in other subjects as well. Indeed, the literature emphasises that interdisciplinary and student-centred STEAM applications increase student participation in class, strengthen learning motivation, and enable meaningful connections between different subjects (Perignat and Katz-Buonincontro, 2019; Yakman and Lee, 2012). The findings obtained show that the STEAM approach increases students' interest in learning processes and provides more holistic learning by establishing interdisciplinary connections, as stated by Saralar Aras (2021). Various studies have also shown that the integration of educational technologies into learning environments leads to more active participation and responsibility on the part of students in their learning processes (Henriksen et al., 2018).

When students were asked what they liked about this material, they stated that it was suitable for the visually and hearing impaired, simplified the subject matter, made concepts easy to understand, helped information stick in their memory, featured appealing animations and sound, introduced the colours on the physical map, and captured students' attention. When asked what they disliked about this material, the students stated that there was nothing they disliked about it. These models and mock-ups, used in workshop applications with educational scenarios led by teachers, help students visualise and hear the simultaneous interactions of natural components explained in laboratory, workshop, and classroom environments. They also help the teacher convey the relevant curriculum topic in a much more creative and inspiring way, more comprehensively (Altan et al., 2024a). It is known that students learn more easily through visual representations; even students who learn more easily through verbal means need visual support to learn certain concepts (Ulusoy and Gülüm, 2009). These statements by Altan et al. (2024b) and Ulusoy and Gülüm (2009) support the positive feedback from students regarding the developed educational material.

In light of these results, this educational material, developed with great effort, is considered to be a STEAM based educational technology product that combines science and technology. This material can be described as an original product with the potential to be patented, developed, translated into different languages, and adapted to different subjects and topics. Moreover, the use of this material in social studies and geography lessons, particularly in schools, will contribute to the learning of earth concepts in society from an early age. It is believed that this developed model will be particularly beneficial to students in terms of both practical application and knowledge and skills regarding earth shapes.

Conclusions and Recommendations

The STEAM based digital educational material developed within the scope of this research, which appeals to visual, tactile, and auditory senses, was evaluated based on the experiences of secondary school students in terms of their processes of understanding and concretising geographical concepts. Student opinions focused on the material increasing interest in the lesson, facilitating the understanding of concepts, and supporting more permanent learning. This result indicates that interactive and multi-sensory designs can be a functional alternative in geography teaching.

Within the context of the main problem, it was concluded that STEAM based digital learning environments positively affect the teaching of geographical concepts; in particular, they facilitate learning in content that requires three-dimensional thinking, such as landforms. Students stated that the combined presentation of the material's visual, auditory, and tactile components made the subject more understandable and memorable, and concretised geographical concepts. In this context, it was observed that students generally described the designed learning environment as “beautiful,” “interesting,” and “effective”; they stated that the material allowed them to learn while having fun and focused their attention on the lesson. Furthermore, students emphasised that similar materials could be adapted to other subjects and topics, pointing to the interdisciplinary potential of this approach. It was understood that the prominent positive feedback focused on the themes of visual-auditory support, attractiveness, ease of understanding, and learning retention; in addition, the emphasis on the material's potential usability for individuals with visual and hearing impairments presented a noteworthy opportunity in terms of inclusive education. Finally, the fact that students did not express any significant negativity about the material supports the strengths of the design in terms of student acceptance and usability.

Recommendations

The following recommendations can be made within the scope of the study:

- In subjects with strong spatial content, such as landforms, two dimensional maps and text-based explanations can be systematically supported with three dimensional and interactive materials.
- Implementing the material in small groups or through station work within the classroom can

enhance the learning experience by increasing each student's interaction time.

• Short, practical in-service training sessions can be planned for teachers on integrating the material into lessons and designing STEAM based activities.

• The accessibility dimension can be piloted in inclusive education practices by enhancing settings such as audio instruction variety, tactile guidance, and contrast/readability.

• A similar design approach can be adapted with subject-specific content in social studies, science, and other subjects to create a school level interactive material pool.

In conclusion, this study contributes to the literature by demonstrating the applicability of a multisensory learning environment produced through a design and development approach in the context of geography education and by evaluating it with a focus on student experiences. The developed material, which brings the STEAM approach into the classroom through a concrete product, provides an exemplary framework for application based research. Future research could use mixed designs that collect quantitative and qualitative data together from larger and more diverse class samples; outcomes such as academic achievement, retention, and motivation could be examined comparatively. Furthermore, teacher opinions and classroom observations could be used to evaluate the material's conditions of use, sustainability, and adaptability to different school contexts in greater detail.

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