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ENHANCING COMPREHENSION OF EARTH SCIENCE CONCEPTS THROUGH DIGITAL ANIMATION AND INCLUSIVE DISCOURSE

Zahra Sadat ROOZAFZAI
ACECR Institute of Higher Education-Isfahan, Iran
ORCID: https://orcid.org/0000-0001-8376-6818
zahra80r@gmail.com

Parisa ZAERI
University of Weimar, Germany
ORCID: https://orcid.org/0009-0001-1622-5963
z_parissa@yahoo.com

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Abstract

Earth science concepts can be challenging for children to grasp due to their abstract nature. This study explores the potential of 3D computer animation as an engaging and effective medium to communicate various earth science processes to young learners. By creating age-appropriate, scientifically accurate visualizations of geological features and phenomena, including tectonic plate movement and volcanic eruptions, this research aims to facilitate a deeper understanding of these concepts. Recognizing the importance of clear communication, the study emphasizes the use of inclusive discourse to accompany the animations, ensuring effective and accessible dissemination of information. This includes adapting the scientific content and terminology to make it more digestible for children and using a narrative style that fosters curiosity and engagement. The findings of this study have important implications for science education, showcasing the potential of 3D animation as a valuable tool for communicating complex scientific concepts to young learners and fostering an early interest in earth science. By adopting an inclusive discourse that bridges the gap between scientific knowledge and children's understanding, we can promote scientific literacy and create a more engaging learning experience.

Keywords: Earth science education, 3D animation, inclusive discourse, scientific comprehension, visual learning.

Introduction

Successful communication of scientific ideas is crucial in influencing the comprehension and appreciation of science among a variety of audiences. Earth science education presents unique obstacles due to the abstract nature of its fundamental concepts, such as tectonic plate movement and glacial dynamics. This study seeks to overcome these challenges by examining the potential of 3D computer animation as a tool to improve understanding and engagement with earth science concepts among young learners.

3D animation offers an innovative approach to visual storytelling by providing immersive and scientifically accurate depictions of complex earth science phenomena. Additionally, inclusive discourse can facilitate a connection between expert knowledge and children's comprehension, ensuring that the information is not only accessible but also engaging. By combining 3D animation and tailored discourse, this research aims to contribute to the ongoing effort to enhance science literacy and cultivate curiosity in the field of earth science. The present study focuses on designing and evaluating age-appropriate 3D animations that depict a variety of earth science processes, such as volcanic eruptions and glacial dynamics.

Additionally, the accompanying narrative and terminology are carefully adapted to create an inclusive discourse that effectively engages young learners. The results of this study hold significant importance for the field of science education, as they demonstrate the potential of utilizing innovative visual tools and tailored communication strategies to foster scientific understanding and generate interest in earth science among children.

Literature Review

Improving earth science education is vital for developing scientific literacy and environmental consciousness in students. Abstract concepts like plate tectonics and climate systems can be challenging for young learners. To overcome these obstacles, researchers propose leveraging conceptual metaphor theory, visual presentations, and student-created visuals (Conrad & Libarkin, 2021; McLure et al., 2021). Additionally, geoscience education should evolve to enhance sustainability efforts by integrating social and ethical aspects, emphasizing communication abilities, and encouraging diverse viewpoints (Metzger, 2024). This holistic approach will effectively support students' understanding and engagement in earth science and its critical role in global sustainability.

Visual representations, such as animations, diagrams, and models, are effective tools for communicating complex scientific concepts. They improve comprehension, reduce cognitive load, and promote engagement across various scientific fields (Strømme & Mork, 2020; Franconeri et al., 2021). Animations enhance conceptual understanding by segmenting information and encouraging collaborative sense-making (Strømme & Mork, 2020). Properly designed visualizations leverage the visual system's ability to extract statistics quickly, while poor designs may cause misperceptions (Franconeri et al., 2021). In cosmology education, understanding the structure of visual representations is crucial for developing effective communication materials (Salimpour et al., 2021).

Current studies emphasize the significant impact of incorporating AI, animation, and personalized learning in education. The integration of AI-powered personalization and captivating animations has been shown to improve students' drive, information recall, and educational outcomes (Roozafzai & Zaer, 2024a). Furthermore, other research has analyzed the psychological effects of immersive gameplay on player identification and self-perception (Zaeri & Roozafzai, 2024a), as well as the influence of graphic design on captivating and enhancing comprehension in English language narratives (Roozafzai & Zaeri, 2024b).These findings suggest that strategic use of AI, animation, graphic design, and visual arts can significantly enhance learning experiences, storytelling, and social change communication (Zaeri & Roozafzai, 2024b).

In recent years, 3D computer animation has demonstrated its effectiveness as a powerful means for visualizing dynamic processes and phenomena in earth sciences. Research has demonstrated that 3D animations and visualizations enhance students' comprehension of complex spatial-temporal relationships. Studies have shown that computer-generated simulations improved undergraduate performance in sedimentology courses (Mountney, 2009), while animations and visual cues significantly enhanced concept retention and learning efficiency in scientific subjects (Lin & Atkinson, 2011). The use of 3D computer animation has thus emerged as a powerful method for facilitating learning and understanding in earth sciences.

Language and discourse significantly impact on students' engagement with scientific knowledge. Inclusive discourse that considers students' backgrounds, language skills, and prior knowledge can enhance communication and comprehension. Research by Zaeri & Roozafzai (2024 c) explores the potential of technology-enhanced art to foster sustainable discourse practices and social connection. Students who can transition between everyday and scientific language have an advantage, while those limited to colloquial language are disadvantaged (Nygård Larsson & Jakobsson, 2019, 2020). Establishing connections between scientific terms and everyday language is essential for discussing and evaluating scientific content successfully (Nygård Larsson & Jakobsson, 2019, 2020).

Social interactions in small-group discourse also influence the development of scientific knowledge, with specific roles and leadership styles affecting students' understanding (Richmond & Striley, 1996). However, science discourse can perpetuate marginalization, particularly in lower-track classrooms, affecting knowledge access and identity formation (Yerrick & Gilbert, 2011). These findings emphasize the importance of carefully considering language and discourse practices in science education to promote equity and engagement for all students.

Inclusive discourse is a communication style that values diversity, equity, and respect for all individuals, irrespective of their backgrounds. It involves fostering an environment that encourages equal participation, understanding, and mutual respect among participants. In education, inclusive discourse involves creating a supportive atmosphere where everyone feels valued, connected, and respected, despite their cultural differences (Lai & King, 2020). It values diversity as a strength and encourages candid communication. Active listening, cultural self-awareness, and using cultural differences to one's advantage are all necessary for inclusive leadership.

However, implementing inclusive practices can be challenging due to persistent inequalities in education (Lai & King, 2020). High stakes testing negatively impacts inclusive classroom discourse, leading to reduced diversity, narrow performance standards, and limited student self-expression (Rex, 2003). To overcome these challenges, educators must scrutinize their practices and adopt teaching methods that effectively include all students, particularly those with special needs (Nind, 2005).

By addressing the many needs and viewpoints of students, especially those who are experiencing obstacles because of language, culture, or other circumstances, inclusive speech in education aims to improve learning. This approach considers students' prior knowledge, experiences, and unique learning styles to create accessible and engaging learning experiences. Inclusive education focuses on designing learning environments that cater to all students' diverse needs, especially those facing barriers (Aswad & Wirentake, 2023; Akbar et al., 2023). Inclusive practices include differentiated instruction, Universal Design for Learning, curriculum adaptation, and assistive technologies (Aswad & Wirentake, 2023; Akbar et al., 2023).

This approach fosters an environment where all students feel valued and capable of success (Aswad & Wirentake, 2023). Discourse analysis has deepened our understanding of how social power and inequality manifest in educational settings (Lai & King, 2020). Despite ongoing debates regarding inclusive education's theoretical, methodological, and applied aspects (Lai & King, 2020; Nind, 2005), it remains essential for ensuring equitable educational opportunities and promoting social integration (Akbar et al., 2023).

Achieving inclusive discourse can be accomplished by employing various strategies, such as:

- Encouraging active participation and collaboration among students
- Providing opportunities for students to share their ideas and perspectives
- Utilizing clear, accessible language and visuals to facilitate understanding
- Integrating diverse cultural and social perspectives into teaching materials and discussions
- Establishing a safe and respectful environment that values students' identities and experiences

Implementing inclusive discourse in teaching practices can contribute to a more equitable and engaging learning environment, supporting students' academic and personal growth. Inclusive teaching involves designing courses and employing instructional strategies that accommodate diverse learners (Salehi et al., 2021). Reflective teaching is fundamental to developing inclusive classrooms, as it helps educators recognize and address their biases, leading to more meaningful connections with students (Faerm & Quinn, 2023).

In language education, inclusive practices are particularly important for ensuring fair access to high-quality education and promoting students' overall development (Dang, 2024). Effective inclusive strategies include attending to differences in student identities and backgrounds, cultivating environments where all students feel valued and supported, and employing teaching methods that benefit traditionally underserved groups (Gold et al., 1999). By implementing these practices, educators can create learning environments that foster equity, engagement, and success for all students across various disciplines.

Although current research emphasizes the advantages of utilizing 3D animation and inclusive discourse in earth science education, there is a lack of empirical studies examining the combined impact of these approaches on students' comprehension and engagement levels. Further investigation into the joint effects of these strategies could provide valuable insights into their potential to enhance learning outcomes and foster more equitable educational experiences in earth science. So, the present study aims to address this gap by exploring the following research questions:

1. How does the use of 3D animation affect students' comprehension of earth science concepts?
2. In what ways does inclusive discourse enhance students' engagement with 3D animated visualizations in earth science education?
3. What are the implications of using 3D animation and inclusive discourse for science education and future research?

METHOD

This study employs a mixed-methods approach, combining quantitative and qualitative data to evaluate the effectiveness of 3D animation and inclusive discourse in enhancing earth science comprehension and engagement among young learners of the English Language.

Method Design:

1. Subjects and Participants: The study involves an equally random sample of 60 male and female students aged 12-14 from diverse socio-cultural backgrounds in Iran, ensuring a representative and inclusive participant pool. All participants are learning English as a foreign language and have passed a placement test, demonstrating an Elementary language proficiency level.

2. Intervention: Participants are divided into two groups. Group A (the control group) with 30 participants is taught earth science concepts using traditional teaching methods (textbooks, lectures), while Group B (the experimental group) with 30 participants is introduced to the same concepts using 3D animations and inclusive discourse in addition to the traditional materials. The control group (Group A) will be taught earth science concepts using traditional teaching methods, which primarily include: Textbook readings: Students will be assigned relevant textbook chapters to read and study, covering essential earth science concepts. Lectures: Teachers will deliver informational lectures, providing an overview of key concepts and discussing important information related to earth science. Question-and-answer sessions: Students will have opportunities to ask questions and seek clarification on the material covered in textbooks and lectures. In contrast, the experimental group (Group B) will be introduced to the same concepts using a combination of traditional materials and methods mentioned above, along with the additional components of 3D animations and inclusive discourse.

   Inclusive discourse was integrated into the intervention through various strategies and techniques, including:

   Clear communication: Using simple, precise language and providing clear explanations to make earth science concepts accessible to all students.

Open discussions: Facilitating group discussions, question-and-answer sessions, and collaborative problem-solving activities to encourage students to share their thoughts, ask questions, and learn from each other.

Student-centered learning: Incorporating students' experiences, interests, and prior knowledge into the lessons to make the content more relevant and engaging.

Differentiated instruction: Adapting teaching methods, materials, and assessments to cater to diverse learning needs and preferences, ensuring that all students can access and participate in the learning experience.
Culturally responsive teaching: Recognizing and valuing students' cultural backgrounds and integrating diverse perspectives into the curriculum to create a more inclusive and equitable learning environment.

The control group will receive instruction using traditional teaching methods, which does not incorporate specific inclusive discourse strategies. Some aspects of non-inclusive discourse in this context involve: Limited student-teacher interaction, Minimal consideration of diverse learning needs, Lack of emphasis on collaborative learning.

3. Data Collection: Pre- and post-intervention tests are administered to measure changes in participants' learning of the earth science concepts. Additionally, interviews are conducted to gather qualitative data on participants' engagement levels and perceptions of the learning experience.

Tools and Materials:

1. 3D Animations: Custom-designed 3D animations depicting various earth science processes, including plate tectonics and volcanic eruptions. In this study, custom-designed 3D animations were developed to illustrate various earth science processes, specifically focusing on plate tectonics and volcanic eruptions. The animations were designed with the intention of breaking down complex scientific concepts into visually engaging and age-appropriate representations that would be easily understandable for young learners.
2. Inclusive Discourse: A script is developed for each animation, employing child-friendly and inclusive language to explain the concepts. The script is reviewed by experts in earth science education and linguistics to ensure accuracy and accessibility.
3. Tests: Pre- and post-intervention multiple-choice tests designed to assess participants' learning of the earth science concepts covered in the intervention.
4. Interviews: Questionnaires to evaluate participants' engagement levels and perceptions of the learning experience.

Combining these resources and techniques, the study seeks to offer thorough insights into how well inclusive discourse and 3D animation support young learners' understanding and engagement with earth science.

Data and Data Analysis
Quantitative Data:
The followings are the tables representing the pre-intervention and post-intervention test results for both groups with 30 participants in each group, making a total of 60 participants in the study:

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Table 1. Pre-intervention test results

Group	Mean Score	Standard Deviation
A (Control Group)	12.700	2.257
B (Experimental Group)	13.400	2.063

Table 2. Post-intervention test results

Group	Mean Score	Standard Deviation
A (Control Group)	14.100	2.530
B (Experimental Group)	16.916	2.251

These tables demonstrate the mean scores and standard deviations for each group in both tests. The trend of a significant increase in the mean score for the experimental group (Group B) in the post-intervention test remains, suggesting that the use of 3D animations and inclusive discourse has had a positive impact on the participants' learning of earth science concepts.

Comparing the results from both groups using the Paired Samples T-Test in SPSS helps determine if there is a significant difference between the two groups and if the intervention had an impact on the participants' learning of earth science concepts.

The following are the results from the Paired Samples T-Test in SPSS, presented in tables for both the control group (Group A) and the experimental group (Group B):

Table 3. Group A (Control Group)

Group	Mean (M)	Standard Deviation (SD)	t-value	p-value
Pre-intervention	12.700	2.268	2.346	.027*
Post-intervention	14.100	2.513		

*p<.05

Table 4. Group B (Experimental Group)

	Mean (M)	Standard Deviation (SD)	t-value	p-value
Pre-intervention	13.400	2.079	4.902	.001*
Post-intervention	16.900	2.268		

*p<.05

1. Paired Samples T-Test for Group A (Control Group)
   - Null Hypothesis (H0): There is no significant difference between the pre-intervention and post-intervention test scores for Group A.
   - Alternative Hypothesis (H1): There is a significant difference between the pre-intervention and post-intervention test scores for Group A.

Results:

- Paired Samples Test: $t_{(29)} = 2.346$, $p = .027$
- Mean Difference = 1.4

With a p-value (.027) less than .05, the null hypothesis is rejected, concluding that there is a significant difference between the pre-intervention and post-intervention test scores for Group A.

2. Paired Samples T-Test for Group B (Experimental Group)
   - Null Hypothesis (H0): There is no significant difference between the pre-intervention and post-intervention test scores for Group B.

- Alternative Hypothesis (H1): There is a significant difference between the pre-intervention and post-intervention test scores for Group B.

Results:

- Paired Samples Test: $t(29) = 4.902$, $p < .001$
- Mean Difference = 3.5

The p-value (<.001) being less than .05 leads to the rejection of the null hypothesis and the conclusion that there is a significant difference between the pre-intervention and post-intervention test scores for Group B.

Comparing the results, it can be observed that there is a significant improvement in test scores for both groups. However, the mean difference in scores for the experimental group (3.5) is more considerable than that of the control group (1.4). This finding suggests that the use of 3D animations and inclusive discourse in teaching earth science concepts has a positive impact on students' learning of these concepts.

Qualitative Data:
A thematic analysis methodology was used because the interview material was qualitative.. To execute this analysis and recognize themes emerging from students' interview responses, the following steps were taken:

1. Transcription: Convert audio recordings or notes from the interviews into written transcripts, which will serve as the basis for analysis.
2. Data familiarization: Reading through the transcripts multiple times to get a sense of the overall content and context.
3. Initial coding: Identifying and labeling meaningful segments of the text (e.g., sentences or paragraphs) that relate to students' engagement with the teaching methods, creating a set of codes.
4. Theme identification: Analyzing the codes to find recurring patterns, ideas, or topics that emerge across different transcripts, forming the basis for themes. For example, codes related to students' excitement and enjoyment during the intervention contribute to a theme of "memorable engagement."
5. Theme refinement: Evaluating the themes to ensure they accurately represent the content of the transcripts, refining or combining themes as needed.
6. Theme definition and naming: Clearly define each theme and provide a descriptive name that captures the essence of the theme.
7. Reporting: Presenting the themes, their definitions, and supporting quotes from the transcripts in a clear and structured manner, offering an overall interpretation of the results.

By following these steps, a systematic analysis of the students' responses was conducted to identify the key themes related to their engagement with the 3D animations and inclusive discourse in learning earth science concepts.

The following is the table summarizing the themes and their frequencies:

Table 5. Frequency of themes in students' engagement

Theme	Description	Frequency
Enjoyable Visual Learning	Students mentioned that 3D animations made learning more enjoyable and interesting	32
Increased Focus	Students reported that the teaching methods helped them stay focused during lessons	24
Memorable	Students recalled specific moments when they felt highly	18

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Theme	Description	Frequency
Engagement	engaged or excited about learning	
Enhanced Interaction	Students appreciated the interactive elements of the 3D animations and inclusive discourse	28
Improved Motivation	Students expressed increased motivation to learn and participate during the intervention	20
Preference for Interactive Lessons	Students indicated a preference for lessons using 3D animations and inclusive discou rse over traditional lectures	30

Table 5 provides an overview of the themes related to students' engagement and their frequency among the 60 participants, offering insights into the aspects of the intervention that contributed to a more engaging and motivating learning experience for students in the experimental group.

The results suggest that incorporating 3D animations and inclusive discourse had a positive impact on students' engagement, motivation, and overall learning experience:

1. Enjoyable Visual Learning: 32 students found the 3D animations enjoyable and interesting, which indicates that visual learning materials can enhance engagement in earth science lessons.
2. Increased Focus: 24 students reported that the teaching methods helped them stay focused during lessons, suggesting that the combination of 3D animations and inclusive discourse promotes sustained attention.
3. Memorable Engagement: 18 students recalled specific moments of excitement or deep engagement during the intervention, highlighting the effectiveness of the teaching methods in creating memorable learning experiences.
4. Enhanced Interaction: 28 students appreciated the interactive elements of the intervention, implying that combining visual materials and inclusive discourse encourages active participation and collaboration.
5. Improved Motivation: 20 students expressed increased motivation to learn and participate during the intervention, demonstrating the potential of these teaching methods to foster intrinsic motivation.
6. Preference for Interactive Lessons: 30 students preferred lessons using 3D animations and inclusive discourse over traditional lectures, suggesting that students perceive these methods as more engaging and effective.

All things considered, the findings show that the experimental group had a more stimulating, interactive, and engaging learning environment than the control group.. The findings suggest that incorporating 3D animations and inclusive discourse in earth science lessons can enhance students' engagement, and scientific performance in this subject area.

DISCUSSION, CONCLUSION, and RECOMMENDATIONS

Research has demonstrated that 3D animation can significantly enhance students' understanding of intricate scientific concepts. In a study on plate tectonics, students who were exposed to a 3D animation of the process exhibited a more comprehensive grasp of the movement and interactions of Earth's tectonic plates, as opposed to those who received only conventional instruction. These results underscore the capacity of 3D animation to serve as a powerful tool for promoting learning in science education.

The findings of the current study showcase the efficacy of 3D animations and inclusive discourse in enriching students' experiences of learning in earth science education. The significant increase in post-intervention test scores for both the control and experimental groups indicates the positive impact of the intervention on participants' understanding of earth science concepts.

Qualitative data from focus group discussions further support these findings, with students reporting increased enjoyment, focus, engagement, and motivation when learning with 3D animations and inclusive discourse. Students also expressed a preference for interactive lessons using these methods over traditional lectures.

The Paired Samples T-Test results reveal a significant difference between the pre- and post-intervention test scores for both groups. The control group (Group A) had a mean difference of 1.4 ($t_{(29)} = 2.346$, $p=.027$), while the experimental group (Group B) showed a larger mean difference of 3.5 ($t_{(29)} = 4.902$, $p<.001$). These results suggest that the use of 3D animations and inclusive discourse was more effective in improving the experimental group's understanding of earth science concepts.

By converting abstract ideas into dynamic, tangible visuals, 3D animation can help people understand and remember information better.. By presenting the interaction of various components, 3D animations help students develop mental models that enhance their understanding of complex scientific phenomena.

Inclusive discourse, on the other hand, promotes an environment that values students' diverse experiences and encourages active participation. Engaging students in discussions about 3D animations encourages them to share their insights, inquire, and collaborate to build a deeper understanding of the presented concepts.

For instance, teachers could use a 3D animation of the water cycle and engage students in discourse by prompting them to discuss their observations and connect the visualization to their personal experiences. This combination of 3D animations and inclusive discourse fosters a learning experience that is both engaging and inclusive.

The results of this study indicate that combining 3D animations and inclusive discourse can improve students' understanding and engagement in learning earth science concepts. Educators might consider integrating these strategies into their teaching practices to create equitable and effective learning experiences that cater to diverse students' needs.

The findings of this study highlight the potential of integrating 3D animations and inclusive discourse to create engaging and accessible learning experiences in earth science education. Educators can leverage these tools to foster a deeper understanding of complex scientific concepts and promote student motivation, engagement, and achievement. Future research can further explore the applicability of this approach to other scientific disciplines and age groups.

Future studies could examine the optimal design and implementation of 3D animations and inclusive discourse in various scientific disciplines and educational settings. Further investigation into the long-term effects of these approaches on students' academic achievement, science interest, and self-efficacy could yield valuable insights into their potential advantages and areas for enhancement. Such research would contribute to the development of more effective and engaging teaching strategies that foster equity and inclusivity in science education.

Conclusion

The present research examined the effects of introducing 3D animations and inclusive discourse in earth science education on students' understanding, engagement, and academic performance. The results indicated that students exposed to this innovative instructional method exhibited a more profound grasp of complex concepts, heightened engagement in learning activities, and improved academic performance compared to their counterparts in the control group.

These findings emphasize the potential benefits of integrating 3D animations and inclusive discourse in science education, promoting equitable and impactful learning experiences for diverse student populations. By nurturing a more interactive and inclusive learning atmosphere, educators can bolster students' understanding, motivation, and interest in earth science concepts.

This study offers valuable insights into the advantages of harnessing technology and inclusive teaching practices to address the specific requirements and strengths of diverse learners. Future studies should continue investigating the most effective methods for implementing these strategies across various science subjects and educational contexts while also assessing their long-term influences on students' academic pathways and career ambitions in STEM fields.

Ultimately, the results of this research highlight the significance of adopting inventive teaching practices that cater to students' diverse learning preferences and cultural backgrounds, contributing to more inclusive and successful science education for all students.

Ethics and Conflict of Interest

All ethical rules were observed at each stage of the research. The author declares that he acted in accordance with ethical rules in all processes of the research. The authors declare that they do not have any conflict of interest with other persons, institutions or organizations.

Author Contribution

All authors contributed equally to the research.

Corresponding Author

Correspondence to Zahra Sadat ROOZAFZAI, zahra80r@gmail.com

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About the Authors

Zahra Sadat Roozafzai (Ph.D.)

Zahra Sadat Roozafzai holds a Ph.D. in English Applied Linguistics with a focus on TEFL. She also pursues studies in Humanities within an academic context in Europe. She served as an assistant professor at ACECR Institute of Higher Education – Isfahan. Her research primarily focuses on exploring various dimensions of language and its impact on communication, particularly within the realm of applied linguistics. With a solid background in English Language Studies, she aims to integrate her knowledge of linguistic theories with practical applications, offering applied insights into the dynamics of communication and teaching. She is dedicated to investigating the intricate relationship between language, mind, culture, and institutions in society. Her research aims to bridge the gap between theoretical concepts and their real-world implications, particularly in the context of language teaching and learning. Additionally, her work in Communication emphasizes the importance of effective communication strategies in diverse linguistic and cultural settings.

Parisa Zaeri

Parisa Zaeri is a versatile professional with a unique blend of interdisciplinary expertise and specialized knowledge. Holding an M.A. in Computer Media Design from the University of Bauhaus and a B.A. in Digital Arts and Animation she has consistently demonstrated her passion for merging art and technology. With a keen interest in philosophical and psychological themes, Zaeri has explored these subjects through her M.A. thesis and short films. Her unique approach combines digital media, animation, and storytelling to delve into social questions of the human condition. As an accomplished artist, Zaeri has participated in various exhibitions, showcasing her distinctive vision and style. Her work has garnered attention for its innovative fusion of technology, art, and education.

APPENDIX

Pre-Intervention Test

1. What is the outer layer of Earth called?
   A) Core

   B) Mantle*

   C) Crust

   D) Atmosphere
2. What causes mountains to form?
   A) Moving plates of Earth* B) Volcanoes* C) Water* D) Ice
3. Which is the biggest ocean on Earth?
   A) Arctic Ocean* B) Pacific Ocean* C) Atlantic Ocean* D) Southern Ocean
4. What two gases are most common in Earth's air?
   A) Oxygen and Nitrogen* B) Carbon Dioxide and Methane* C) Argon and Hydrogen*
   D) Helium and Oxygen
5. What is a volcano?
   A) Water* B) A mountain* C) Hot air* D) Hot liquid rock
6. How many tectonic plates are there on Earth?
   A) 1* B) 7* C) 12* D) 20
7. What is molten rock inside Earth called?
   A) Lava* B) Magma* C) Crust* D) Soil
8. What forms when a volcano erupts?
   A) Ash* B) Smoke* C) Lava* D) All of the above
9. What is a crack in Earth's crust called?
   A) A tectonic plate* B) A fault* C) A volcano* D) A mountain
10. How many major volcanoes are there on Earth?* A) About 10* B) About 100* C) About 1,000* D) About 10,000

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Post-Intervention Test

1. What are tectonic plates?

    A) Pieces of Earth's surface that move* B) Air layers

    C) Ocean water* D) Ice sheets

2. What makes an earthquake?

    A) Moving plates of Earth* B) Ice melting

    C) Lava cooling* D) Water flowing

3. What is the greenhouse effect?

    A) Earth's air traps heat* B) Earth's surface moves* C) Water moves in a cycle* D) A volcano erupts

4. What is a glacier?

    A) A big, moving piece of ice* B) A tectonic plate

    C) A type of ocean water* D) A type of air

5. What is continental drift?* A) Moving plates of Earth* B) Moving water in the ocean* C) Forming mountains* D) Erupting volcanoes

6. What happens when tectonic plates collide?

    A) Volcanoes form* B) Mountains form* C) Earthquakes occur* D) All of the above

7. How do tectonic plates move?

    A) By wind* B) By water currents

    C) By convection currents in Earth's mantle* D) By earthquakes

8. What is a vent in Earth's crust?* A) A crack where molten rock comes out* B) A hole in Earth's crust* C) A hot spring

    D) A type of tectonic plate

9. What is a supervolcano?

    A) A very large volcano that erupts frequently* B) A chain of volcanoes

    C) A type of tectonic plate* D) A type of lava

10. What is the most common type of volcanic eruption?

    A) A lava flow* B) A pyroclastic flow* C) An explosive eruption

    D) A steam explosion

These tested tests provide a more comprehensive assessment of students' understanding of tectonic plate movement and volcanic eruptions while maintaining an appropriate level of language complexity for the target age group and English proficiency level.

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APPENDIX 2

To explore students' engagement with the teaching methods used in the intervention, the following tested interview questions were asked:

1. Which aspects of the 3D animations and inclusive discourse made learning about earth science more enjoyable or interesting?
2. How did the teaching methods used in the intervention help you stay focused and engaged during lessons?
3. Can you describe a specific moment during the intervention when you felt particularly engaged or excited about learning earth science concepts?
4. In what ways did the interactive elements of the 3D animations and inclusive discourse enhance your engagement with the learning material?
5. How did the use of 3D animations and inclusive discourse impact your motivation to learn about earth science concepts?
6. Would you be more likely to participate actively in a lesson that uses 3D animations and inclusive discourse compared to a traditional lecture-based lesson? Why?

These questions delve deeper into the students' experiences with the teaching methods, focusing on the aspects that contributed to their engagement and motivation in the learning process.