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The Role of AI-Generated Cartoons in Science Education: Enhancing Conceptual Understanding Among Primary School Students

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Abstract

Objectives: This study investigates the impact of AI-generated cartoons on third-grade students' academic performance in science. It aims to determine whether the integration of such digital tools enhances engagement and conceptual understanding compared to traditional teaching methods.

Methods: A quasi-experimental design was employed involving 58 third-grade students from Muscat Governorate, Oman. Participants were divided equally into an experimental group (N=29), which received instruction via AI-generated cartoons, and a control group (N=29), which received traditional instruction. Pre-test and post-test assessments were used to measure learning outcomes.

Results: The experimental group demonstrated a statistically significant improvement in post-test scores compared to the control group. This indicates that AI-generated cartoons effectively enhance students' conceptual understanding and engagement in science education.

Conclusions: The study underscores the potential of AI-generated cartoons as an innovative instructional tool in primary education. These findings support their broader integration across subjects and recommend the inclusion of teacher training programs focused on AI-based educational technologies.

Keywords: AI-generated cartoons; science education; digital learning; primary education; innovative teaching methods

دور الرسوم الكرتونيَّة المُنتَجة بالذكاء الاصطناعي في تعليم العلوم: تعزيز الاستيعاب المفاهيمي لدى طلبة المرحلة الابتدائيَّة

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ملخّص

الأهداف: تهدف هذه الدراسة إلى فحص تأثير الرسوم الكرتونيَّة المنتجة بالذكاء الاصطناعي في الأداء الأكاديمي لطلبة الصف الثالث في مادة العلوم، كما تسعى إلى تحديد ما إذا كان دمج الرسوم الكرتونيَّة التعليميَّة المنتجة بالذكاء الاصطناعي يُعزِّز تفاعل الطلبة ونتائج تعلمهم مقارنة بالطرائق التقليديَّة في التدريس.

المنهجيَّة: استخدمت الدراسة تصميمًا شبه تجريبي شمل 58 طالبًا من الصف الثالث الأساسي في محافظة مسقط بسلطنة عُمان، وقد جرى تقسيم المشاركين إلى مجموعتين: مجموعة تجريبية (N=29) تلقت تعليمها باستخدام الرسوم الكرتونيَّة المنتجة بالذكاء الاصطناعي، ومجموعة ضابطة (N=29) تلقَّت تعليمها باستخدام الطرائق التقليديَّة، وأُجرِيَ اختباران قبليٌّ وبعديٌّ لكلا المجموعتين لقياس الفروق في نتائج التعلم.

النتائج: أظهرت النتائج تحسُّنًا ملحوظًا من الناحية الإحصائيَّة في درجات الاختبار البعدي لدى المجموعة التجريبيَّة مقارنة بالمجموعة الضابطة. يشير ذلك إلى أنَّ الرسوم الكرتونيَّة المنتجة بالذكاء الاصطناعي تسهم بشكل إيجابي في استيعاب الطلبة للمفاهيم العلميَّة؛ مما يجعل عملية التعلُّم أكثر تفاعليَّة وفعاليَّة.

الخلاصة: تسلط الدراسة الضوء على الدور التحولي للرسوم الكرتونيَّة المنتجة بالذكاء الاصطناعي في تعليم العلوم، مؤكدةً إمكاناتها في تعزيز تعلُّم الطلبة وتفاعلهم، كما تؤكد الحاجة إلى تبني أساليب تعليميَّة مبتكرة في التعليم الأساسي. توصي الدراسة بتوسيع استخدام الرسوم الكرتونيَّة المنتجة بالذكاء الاصطناعي في مختلف المواد الدراسيَّة، ودمج برامج تدريبيَّة للمعلِّمين تركِّز على توظيف أدوات الذكاء الاصطناعي في التدريس.

الكلمات الدالَّة: الرسوم الكرتونية المنتجة بالذكاء الاصطناعي، تعليم العلوم، التعلم الرقمي، التعليم الأساسي، طرائق التدريس المبتكرة.

Introduction

In today's rapidly evolving world, where information can be overwhelming, the need for effective educational strategies that enhance knowledge acquisition has become increasingly pressing (Shahar et al., 2024a). Digital images, and cartoons in particular, have emerged as a powerful medium for presenting complex concepts in an accessible way, making it a valuable resource in education. Research has highlighted the effectiveness of visual tools such as cartoons in enhancing students' comprehension, cognitive development, and engagement (Chaniotakis & Papazoglou, 2019; Wang, 2022). As Abdul Rahman (2001) noted, we live in a "Civilization of the Image" (p. 43), where visuals shape how information is received and processed.

This study examines the unique educational advantages of cartoons, which use exaggeration and satire to make abstract ideas concrete and relatable (Gelir & Akran, 2021). Scholars like Al-Mutawalli (2003) and Al-Jiroudi (2017) emphasize that cartoons capture students' attention and facilitate understanding through humor and simplification. Artificial intelligence (AI) enhances this potential by transforming cartoons into highly adaptable and interactive learning tools. AI-generated cartoons can be customized to different learning styles, ensuring that students receive content tailored to their cognitive preferences and academic needs. AI algorithms can analyze student responses and modify content in real time, creating a personalized learning experience that traditional static cartoons cannot achieve. Additionally, AI-driven interactivity allows students to engage dynamically with the content, reinforcing key concepts through adaptive storytelling and contextual learning.

The rationale for this study is rooted in the potential of AI-generated cartoons to create an engaging, low-stress learning environment that boosts motivation and retention (Çelik & Gündoğdu, 2016). By examining the impact of these cartoons on the academic achievement of third-grade science students in Oman, this study aims to provide insights that can enhance curriculum design both locally and internationally. For local curriculum developers, the findings could offer insights on the benefits of integrating AI-powered visual aids into the science curriculum, particularly related to engagement of young students. On an international scale, the study may contribute to broader discussions on AI in education and how AI-driven visuals can transform learning spaces into dynamic, student-centered environments. This research, therefore, aims to address local educational needs while supporting global innovation in educational methodologies, demonstrating how AI-powered learning aids can make education more accessible, adaptive, and enjoyable across diverse contexts.

Problem Statement

Traditional education often prioritizes rigor over engagement, leading to a learning environment that may lack enjoyment and student motivation (Shahat et al., 2025). Research highlights the importance of integrating humor and visually engaging elements into teaching to reduce anxiety, foster a positive atmosphere, and enhance academic performance (Chaniotakis & Papazoglou, 2019; Wang, 2022). While the benefits of cartoons in education are well established (Çelik & Gündoğdu, 2016; Wijethilaka, 2020), there is limited exploration of AI-generated cartoons as a medium for delivering educational messages that enhance student engagement and learning outcomes.

As mentioned, AI has the potential to transform traditional instructional methods by enhancing the communicative power of cartoons, making complex or abstract concepts more accessible and meaningful (Çoban et al, 2025). However, its application in cartoon-based learning remains underexplored due to several barriers, including technical limitations, lack of educator training, and uncertainty regarding its pedagogical effectiveness. This gap in research is particularly evident in science education, where AI-generated visuals could play a crucial role in conveying knowledge in a way that resonates with students (Shahat et al., 2025).

In Oman, studies have shown that cartoons enhance creativity and academic achievement (Al-Urimiya, 2017; Al-Saadiya, 2018), yet research on AI-generated cartoons as an educational message remains scarce. This study seeks to address this limitation by evaluating the effectiveness of AI-designed cartoons in improving academic achievement among third-grade science students. By identifying the challenges and opportunities of AI-generated cartoons in education, this research aims to contribute to both local and international discussions on integrating artificial intelligence into student-centered learning environments.

Theoretical Background

This section provides a comprehensive view of the role of **AI-designed cartoons in education**, synthesizing definitions, characteristics, advantages, and functions of cartoons while introducing their **potential for transformation through AI integration**. What follows is an exploration of how **AI enhances the educational functions of cartoons by improving customization, interactivity, and adaptability**, thereby contributing to student engagement and learning. **By framing AI-powered cartoons within established learning theories, particularly the Cognitive Theory of Multimedia Learning (Mayer, 2005) and Dual-Coding Theory (Paivio, 1986), this study provides a clearer framework for understanding how AI tools engage students.**

Theoretical Foundations of AI-Generated Cartoons in Learning

AI-generated cartoons leverage key **multimedia and cognitive learning theories** that emphasize the role of visual and interactive elements in facilitating learning. Two primary theoretical frameworks support the integration of AI-generated cartoons into education:

1. **Cognitive Theory of Multimedia Learning (CTML) – Mayer (2005):**
    - CTML suggests that learning is **more effective when words and visuals are presented together**, as learners process information through **dual channels—verbal and visual**.
    - AI-generated cartoons align with this theory by offering **dynamic, multimodal content**, combining **narratives, animations, and tailored feedback** to enhance understanding.
    - AI also optimizes the **segmentation principle** (breaking complex concepts into digestible visual components), ensuring that students do not experience cognitive overload.
2. **Dual-Coding Theory – Paivio (1986):**
    - This theory states that information is better retained when it is **processed through both verbal and non-verbal (visual) representations**.
    - AI-generated cartoons **capitalize on this principle** by combining humor, symbolic representation, and animated storytelling to reinforce **memory retention and conceptual understanding**.

By applying these theories, AI-powered cartoons serve as **interactive cognitive tools** rather than mere instructional visuals, promoting deeper learning engagement through personalized adaptation.

How AI Enhances Educational Cartoons

1. **Customization and Personalization:** Traditional cartoons, while effective, are static and generalized. AI-generated cartoons, on the other hand, can adapt content dynamically to students' needs based on learning progress, individual preferences, and areas requiring reinforcement. AI algorithms can analyze student responses and modify visual elements accordingly, ensuring personalized learning experiences that align with cognitive abilities and academic backgrounds. This customization supports Mayer's (2005) individualization principle, ensuring that learners receive instruction at an appropriate cognitive level.
2. **Interactivity and Engagement:** AI-integrated cartoons introduce interactive elements, allowing students to engage with educational content beyond passive viewing. Unlike traditional cartoons, AI-generated versions respond to user input, creating adaptive learning pathways. For instance, AI-driven educational platforms can present interactive cartoon sequences where students make choices, predict outcomes, or manipulate elements to test scientific concepts. This approach aligns with constructivist learning theories, which emphasize active student engagement in knowledge construction.
3. **Adaptive Learning Capabilities:** AI-designed cartoons integrate real-time feedback and adaptive difficulty levels, ensuring that students receive targeted instruction based on their performance. AI tools can assess students' comprehension through quizzes, interactive prompts, and answer validation, adjusting the complexity of the cartoon-based lesson accordingly. This supports Vygotsky's (1978) Zone of Proximal Development (ZPD), where AI serves as a "scaffold" that gradually increases cognitive challenge based on student ability.

Cartoons as an Educational Message, Enhanced by AI

Cartoons possess distinct characteristics that make them well-suited for education. AI-driven advancements enhance these characteristics, making cartoons more effective in delivering complex scientific concepts to young learners:

1. **Exaggeration:** AI enables the dynamic exaggeration of key elements to emphasize crucial scientific ideas, making abstract topics more concrete. For example, AI can modify visuals in real-time to illustrate molecular interactions or energy transformations, reinforcing conceptual understanding.
2. **Simplification:** AI algorithms filter and streamline information to prevent cognitive overload, ensuring that cartoons effectively communicate essential knowledge without unnecessary distractions.
3. **Humor and Emotional Connection:** AI enhances humor through context-sensitive modifications, adapting the tone and expressions of cartoon characters based on student engagement levels, thus increasing relatability and enjoyment.

These features position AI-generated cartoons as a bridge between traditional instructional media and modern, student-centered learning approaches. Unlike static cartoons, which serve as fixed messages, AI-generated cartoons function as dynamic, evolving educational narratives that cater to the diverse and changing needs of learners.

Significance of AI-Driven Cartoons in Education

The integration of AI into cartoon-based education reflects a broader shift toward interactive and adaptive learning methodologies. This study builds upon previous research while expanding the understanding of AI's role in enhancing learning engagement. Key contributions include:

1. **Extending Research on Cartoon-Based Learning:**
    - Prior studies have examined cartoons' impact on creative thinking, academic achievement and student attitudes (Al-'Urimiya, 2017; Bedeir, 2020, Yilmaz, 2020).
    - This study advances the discussion by focusing on AI-driven customization, adaptability, and interactive engagement.
2. **Using Pedagogical Theories to Examine the Use of AI:**
    - This study aligns with multimedia learning theories, constructivist theories, and cognitive load principles, which emphasize interactive, visually enriched, and student-driven learning.
    - AI-powered cartoons embody these principles by allowing students to interact with, manipulate, and influence the learning experience.
3. **Enhancing Science Education:**
    - This study contributes to science education research by demonstrating how AI-generated cartoons facilitate knowledge acquisition, conceptual clarity, and student motivation.
    - AI-driven visuals allow real-time content modification based on student needs, making science concepts more accessible and engaging.

In summary, this theoretical background establishes the foundation for understanding the transformative role of AI-designed cartoons in education. By combining insights from previous research with an exploration of the potential for AI integration, this study contributes a new dimension to the literature, suggesting that AI-powered cartoons could play a pivotal role in modernizing science education and enhancing student learning outcomes across diverse contexts.

Aim and Research Questions

This study aims to investigate the role of AI-designed cartoons as an innovative educational tool for enhancing academic achievement in science among third-grade students in Oman. By exploring visual technology integration into science education, the study seeks to address whether AI-generated cartoons can provide a more engaging and effective learning experience compared to traditional teaching methods. This research aligns with broader educational objectives to make learning more interactive and responsive to the needs of young learners, particularly in foundational science education. The main research question and hypotheses are:

How does using AI-designed cartoons affect the academic achievement of third-grade students studying science in Oman?

H1: There are no statistically significant differences at the 0.05 level between the mean post-test scores of students in the experimental group (who are taught using AI-designed cartoons) and those in the control group (who are taught using traditional methods) in science achievement for third-grade students.

H2: There are no statistically significant differences at the 0.05 level between the mean pre-test and post-test scores of students in the experimental group (who are taught using AI-designed cartoons) on the science achievement test for third-grade students.

Through testing these hypotheses, the study seeks to determine if the use of AI-designed cartoons can serve as an effective teaching strategy, potentially influencing future educational practices and curricular design. By establishing whether this approach yields measurable improvements in students' understanding and retention of scientific concepts, the research aims to contribute valuable insights into the application of AI in early education.

Methodology

Design

A quasi-experimental approach was used, which examines the impact of AI-designed cartoons on third-grade students' academic achievement in the "Exploring Materials" science unit. A pre-test and post-test design was employed with two groups of third-grade students. The study divided participants into an experimental group, which studied the "Exploring Materials" unit using AI-designed cartoons, and a control group, which received instruction through traditional methods. The study was conducted during the second semester of the 2023/2024 academic year, from March 14, 2024, to April 22, 2024.

Sample

The population of this study consists of third-grade students enrolled in basic education schools in the Muscat Governorate, Oman, under the supervision of the Directorate of Education in Wilayat Seeb. From this population, a purposive sample of 58 third-grade students was selected from Al-Nubouga Basic Education School (grades 1–4). The sample was randomly assigned into two groups:

- **Control group (29 students):** received traditional instruction without AI-generated cartoons.
- **Experimental group (29 students):** exposed to AI-generated cartoons integrated into science instruction.

This **random assignment** ensures that any observed differences in academic achievement can be attributed to the intervention rather than pre-existing differences between students. The selection of the sample from a single school was based on accessibility and feasibility while ensuring a representative distribution of students.

Instrument

Teacher's guide

A comprehensive teacher's guide was developed to facilitate the teaching of unit topics using AI-generated cartoons for the experimental group. This guide includes structured lessons and activities aligned with Unit 5 of the third-grade science curriculum for the second semester, specifically the "Exploring Materials" unit. This unit was selected for its manageable scope and suitability for effectively applying the study's methodology. The guide was created through a systematic process to ensure both instructional relevance and pedagogical effectiveness.

To begin, a thorough review of the educational literature and relevant studies was conducted to structure the unit's sub-topics and activities. Research and case studies on the use of cartoons in educational settings were consulted (e.g., Acesta, 2024; Al-Kharsha, 2024; Al-Saadiya, 2018; Al-'Urimiya, 2017; Kocakavak & Erokten, 2021; Mreesat, 2019; Yilmaz, 2020). These studies provided valuable insights into how cartoons can effectively convey complex concepts and engage students within classroom settings.

Next, the content of the "Exploring Materials" unit was reviewed in detail. Topics such as properties, classification, uses, testing of materials, and magnetism were carefully examined using science encyclopedias, online resources, and the student science activity book. This process ensured that the material was scientifically accurate and developmentally

appropriate for third-grade students, aligning with the study's learning objectives.

Finally, AI technology, specifically ChatGPT4, was used to design cartoons illustrating the unit's concepts. Guided by the principles outlined by Kleftodimos (2024) and Liu and Elms (2019), each cartoon was developed with a focus on scientific accuracy, clarity, and simplicity. Key design criteria included a) ensuring that each cartoon accurately represented a specific scientific concept such as the concepts of matter, solids, soft materials, and water-absorbent material, b) emphasized a single scientific idea, and c) avoided unnecessary complexity to prevent distractions. It is believed that this guide can support teachers in effectively using AI-generated cartoons to enhance student comprehension and engagement in science education.

Achievement Test

The achievement test was developed to assess students' academic performance in Unit 5 of the third-grade science curriculum, which was taught in the second semester. This test was administered both before and after the intervention. The pre-test aimed to ensure the equivalency of the study groups in terms of prior knowledge and scientific understanding, and the post-test allowed for a comparison of average scores between groups to determine statistically significant differences in academic achievement.

To design the test, sample assessments, quizzes, and activities related to the unit were collected from the Ministry of Education's Educational Portal test section. These samples were supplemented by reviewing appropriate question formats for third-grade students, as outlined in the assessment framework. Additional questions were adapted from the "Check Your Progress" section at the end of the unit to ensure alignment with curriculum expectations.

The test blueprint was constructed by consulting sources on test specification tables, such as those provided by Abu Allam (1987). The blueprint development included several steps. First, each lesson in the unit ("Properties of Materials," "Classification of Materials," "Uses of Materials," "Testing of Materials," and "Magnetic Materials") was analyzed to allocate a weight based on the number of instructional periods dedicated to each topic. The relative importance of each topic was calculated as a percentage of the total instructional periods for the unit. Next, weights were assigned according to the significance of each topic, followed by determining the number of questions for each cognitive level, including knowledge, understanding, and inquiry-based skills. This approach allowed for a balanced assessment of the unit's content.

Table 1 presents the test specifications, showing topics, cognitive levels, and distribution of questions.

Table 1. Specifications for the Achievement Test

Topics	Number of Periods	Relative Weight	Knowledge & Understanding (70%)	Scientific Inquiry (30%)
Properties of Materials	3	25%	1.22	0.52
Classification of Materials	3	25%	1.22	0.52
Uses of Materials	2	17%	0.83	0.35
Testing of Materials	2	17%	0.83	0.35
Magnetic Materials	2	16%	0.78	0.34
Total	12	100%	Total items=5	Total items=2

The test included two types of questions to assess knowledge and understanding, and scientific inquiry skills: objective questions and short essay. The objective section consisted of three items (multiple-choice and true/false) with a total score of 4 points, while the essay section included four items worth 6 points.

The preliminary version of the test comprised seven questions, divided into sections for knowledge and understanding (7 points) and scientific inquiry skills (3 points). The questions were aligned with Bloom's Taxonomy across four cognitive levels, covering knowledge, understanding, application, and inference. Instructions included guidance on the test's purpose,

allocated time, and recommendations for students to read the questions carefully before answering.

To verify content validity, a panel of nine experienced science teachers from the Muscat Governorate reviewed the initial version of the test. The reviewers were asked to provide feedback on the clarity of instructions, difficulty level, alignment with learning objectives, language accuracy, appropriateness of cognitive levels, and overall presentation. Based on their feedback, revisions were made to improve the quality of the test and ensure it aligned with the educational objectives.

The test's reliability was assessed through a pilot test with a sample of 30 third-grade students. This pilot was conducted to determine test duration, verify instruction clarity, and calculate reliability. The test duration was set at 40 minutes based on the time taken by the first (36 minutes) and last (45 minutes) students to complete it. Cronbach's alpha was calculated using SPSS and resulted in a reliability coefficient of 0.84, indicating a high level of consistency that is acceptable for the main study.

After confirming the validity and reliability, the final version of the test included seven items that were a mix of objective and short essay questions, as outlined in Appendix 1. The test items were aligned with the unit topics and cognitive levels specified in the assessment framework for grades 1–4, as shown in Table 2. This structured test design ensures a comprehensive assessment of students' understanding and inquiry skills within the targeted science unit.

Table 2. Cognitive Levels and Item Numbers in the Achievement Test

Cognitive Level	Relative Weight	Item Numbers
Knowledge & Understanding	70%	1, 2, 3, 4, 5
Scientific Inquiry	30%	6, 7

Procedures and data analysis

The study began with a comprehensive review of previous studies related to the research topic. This review provided a foundation for selecting the "Exploring Materials" unit from the third-grade science textbook, which includes topics and concepts that align well with the study's objectives.

A teacher's guide was developed to facilitate the teaching of this unit, including detailed lesson plans and prepared content. The guide contained instructions, a proposed implementation timeline, AI-designed cartoons, and related assessment activities tailored to the "Exploring Materials" unit topics.

An achievement test was prepared for both pre- and post-testing purposes. This instrument aimed to measure academic performance before and after the intervention. The test were subjected to expert review and assessment to ensure the validity and reliability.

The study sample consisted of 58 third-grade students from two class sections. These students were randomly assigned to an experimental group (29 students) and a control group (29 students). To ensure consistency, the control group teacher was instructed to maintain parity in the number of instructional sessions with the experimental group while using traditional teaching methods. The teacher began each lesson with motivational prompts, using standard instructional strategies and materials to achieve the learning outcomes.

A pilot test was conducted using students not participating in the main study to refine the achievement test. This was followed by a pre-test to verify the equivalency of the control and experimental groups. A t-test for independent samples confirmed group equivalency. As shown in Table 4, there were no statistically significant differences between the means of the control and experimental groups for the pre-test (t-value was -0.390), indicating that the groups were equivalent at the outset.

The experimental intervention was then implemented over four weeks, during which the students participated in 10 science sessions in the second semester of the 2023/2024 academic year. Following the intervention, the post-test was administered to measure academic achievement. The results were scored and recorded, with statistical analyses performed using SPSS software.

Quantitative data from the achievement test were analyzed using appropriate statistical techniques. The findings were then discussed and interpreted. The quantitative data were supported by examples and evidence derived from qualitative data collected through classroom observations by the participating teachers and the lead researcher. This qualitative data provided deeper insights into the study results and directly aided in addressing the research questions. Finally, a set of recommendations and suggestions were formulated based on the study's outcomes, providing guidance for further research and instructional practices.

To address the research questions, the data were analyzed using the Statistical Package for the Social Sciences (SPSS). Several statistical methods were employed to ensure robust results. First, Cronbach's alpha reliability coefficient was calculated to confirm the reliability of the achievement test. Then, means, standard deviations, and an independent samples t-test were used to assess any significant differences in the dependent variable between the control and experimental groups. Additionally, a paired samples t-test was conducted to examine the differences between pre- and post-test scores within the experimental group, providing insights into the effectiveness of the intervention.

Results

The present study aims to investigate the effect of AI-designed cartoons on academic achievement in science among third-grade students in Oman, and to determine if there are significant differences in achievement between the control and experimental groups.

To address the research question - 'What is the effect of using AI-designed cartoons on the academic achievement in science for third-grade students in Oman?' - an independent samples t-test was used to assess the significance of the differences between the post-test scores of the experimental and control groups. Table 3 and Figure 1 present the findings.

Table 3. T-test Results to Determine the Significance of Differences Between the Means of the Experimental and Control Groups in the Post-Test (N=58)

Group	Mean	Standard Deviation	T	p-value	Direction of Difference
Experimental	83.8	1.26	2.29	0.026	Experimental
Control	80.0	1.49			

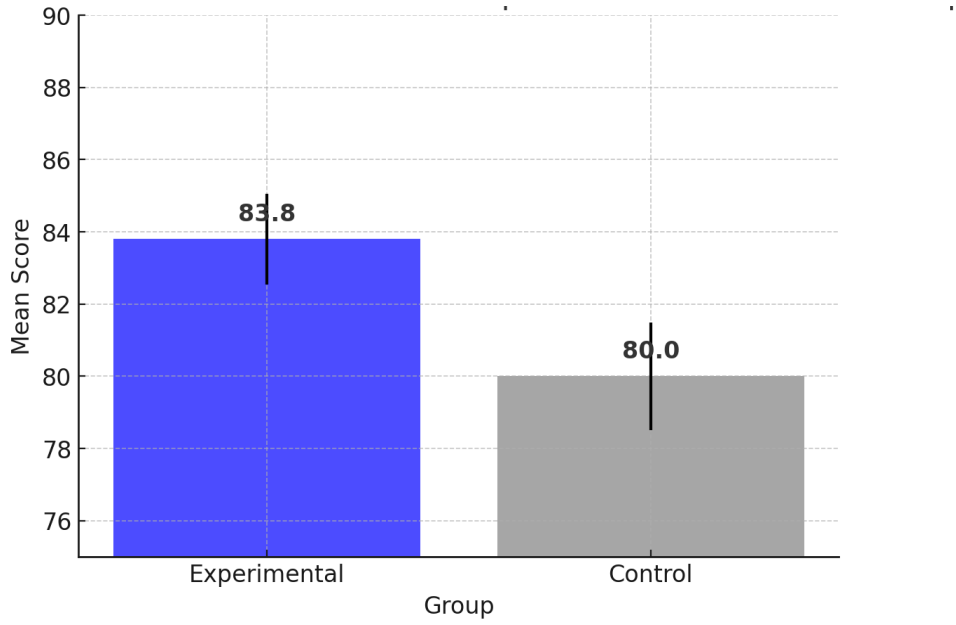


Figure 1. Comparison of Post-Test Mean Scores Between Experimental and Control Groups

Table 5 shows that the mean score of the experimental group in the post-test (83.8) was higher than that of the control group (80.0). This difference is statistically significant at the 0.05 level, favoring the experimental group (see Figure 1). This indicates that students in the experimental group, who studied with AI-designed cartoons, achieved higher scores, thereby rejecting the first hypothesis, which stated that 'there are no statistically significant differences at the 0.05 level between the mean scores of the experimental group students (taught using AI-designed cartoons) and the control group students (taught using traditional methods) in the post-test.'

To further assess the differences between the pre- and post-tests within the experimental group, a paired samples t-test was conducted. Table 4 provides a summary of these results.

Table 4. T-Test Results for Paired Samples to Determine Differences in Student Achievement (N=58)

Measurement	Pre-Test Mean	Pre-Test SD	Post-Test Mean	Post-Test SD	T	p-value	Direction of Difference
Achievement Test	79.7	0.67	83.8	1.43	-3.82	<0.001	Post-Test

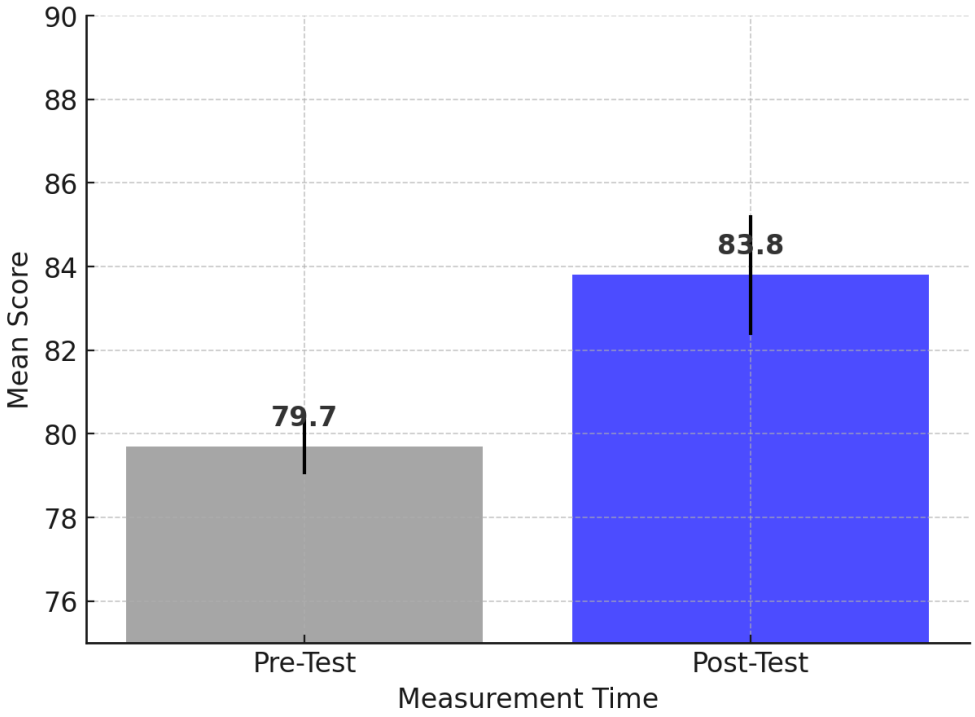


Figure 2. Comparison of Pre-Test and Post-Test Mean Scores in Student Achievement

The results in Table 6 indicate a statistically significant difference between the pre-test and post-test scores of the experimental group, with a clearly higher mean scores in the post-test compared to the pre-test (see Figure 2). This demonstrates the AI-designed cartoon strategy's positive impact on the experimental group's academic achievement. Consequently, the second hypothesis -'there are no statistically significant differences at the 0.05 level between the mean scores of the experimental group in the pre- and post-test' - is also rejected.

Discussion

The findings of this study provide clear evidence regarding the research question: *"How does using AI-designed cartoons affect the academic achievement of third-grade students studying science in Oman?"* By analyzing the data, the study rejects both hypotheses (H1 and H2), demonstrating that AI-designed cartoons significantly enhance academic achievement in science compared to traditional teaching methods.

The results reveal statistically significant differences between the post-test scores of the experimental and control groups, favoring the experimental group. The mean score for the experimental group (83.8) was significantly higher than that of the control group (80.0), with a t-value of 2.29 and a p-value of 0.026. These findings reject H1, which posited no significant differences between the groups. This aligns with research by Yilmaz (2020), who highlighted that concept cartoons improve students' comprehension and retention of scientific concepts by providing a visually engaging and interactive mode of instruction. Similarly, Al-Kharsha (2024) demonstrated that cartoons significantly enhance academic achievement by presenting content in an engaging manner tailored to students' cognitive levels.

The results emphasize how AI-designed cartoons enhance students' understanding of complex scientific ideas by transforming them into visually digestible and relatable elements. This ability to simplify abstract concepts, such as life cycles and ecosystems, allows students to engage more deeply with the material, as Mayer's (2001) multimedia learning theory supports. The visual and interactive elements of AI-designed cartoons enable dual-channel processing of information, making learning more effective. Research by Acesta (2024) also highlights that visual tools like caricatures and cartoons promote meaningful learning by connecting abstract scientific concepts to real-world scenarios.

The paired samples t-test results for the experimental group indicate significant differences between pre-test and post-test scores, with the mean increasing from 79.7 to 83.8 ($t = -3.82$, $p < 0.001$). This rejects H2, which suggested no significant differences between the experimental group's pre- and post-test scores. These findings highlight the effectiveness of AI-designed cartoons in reinforcing learning and improving retention over time. The significant gains in the experimental group align with (Şentürk & ŞİMŞEK, 2022) findings, which demonstrated the value of cartoons in boosting academic performance and understanding in science classes. Likewise (Sıong et al. (2023) reported that using cartoons enhanced both academic achievement, and critical thinking skills (Ritonga et al., 2020), particularly in science education.

The cognitive advantages of AI-designed cartoons are evident in their ability to simplify and clarify abstract scientific concepts. This approach facilitates a deeper understanding of content by breaking it into manageable, visually appealing components. For example, representing complex processes like photosynthesis or ecological interactions in animated form helps students grasp relationships and processes more effectively. These findings echo research by Al-Qurashi (2017), who found that cartoons improved science achievement by presenting challenging topics relatable and engagingly. Similarly, Al-Saadiya (2018) reported that using cartoons in social studies enhanced students' comprehension and ability to retain information, further supporting the cognitive benefits observed in this study.

The interactive nature of AI-designed cartoons also encourages active learning and higher-order thinking skills. Students analyze scenarios, predict outcomes, and interact with the material, fostering critical thinking. This aligns with Kwangmuang et al. (2024) research, which showed that cartoons promote engagement and problem-solving in educational contexts. Moreover, Wijethilaka (2020) emphasized that cartoons in science education foster exploration and active inquiry, helping students build a robust understanding of concepts.

Beyond cognitive benefits, AI-designed cartoons positively influence students' emotional engagement and motivation. The experimental group's improved scores suggest that the dynamic and humorous nature of cartoons fosters intrinsic motivation and reduces anxiety. This supports Chaniotakis & Papazoglou (2019) assertion that humor creates a positive emotional environment, enhancing participation and focus. Similarly, research by Çelik and Gündoğdu (2016) highlights that using humor and concept cartoons reduces anxiety and improves students' attitudes toward learning.

Furthermore, AI-designed cartoons create a supportive atmosphere for young learners who might find traditional science instruction intimidating. By presenting content in a lighthearted and approachable manner, these tools reduce stress, enabling students to concentrate on learning. Çetin (2023) and (Marques et al., 2023) emphasized that visually stimulating and humorous content reduces classroom tension and fosters a more positive attitude toward learning. Wang, (2022) also noted that incorporating cartoons into instruction helps alleviate students' apprehension, allowing them to engage more freely and confidently with challenging material.

The study's findings align with broader educational objectives to integrate technology and make learning more interactive and student-centered (Shahat et al., 2024b). The significant differences in the experimental group's pre- and

post-test scores demonstrate how AI-designed cartoons can serve as a transformative tool in foundational science education. By making scientific concepts engaging and relatable, these tools help bridge the gap between abstract ideas and students' understanding, fostering a lifelong interest in learning. Research by Zivanayi & Nwaigwe (2024) further supports this, noting that the use of cartoons in physics teaching enhanced students' achievement and attitudes toward the subject.

The results of this study conclusively demonstrate the effectiveness of AI-designed cartoons in enhancing the academic achievement of third-grade students in science. By rejecting both hypotheses, the study highlights the cognitive, affective, and motivational benefits of integrating visual technology into education. These findings provide strong evidence for the role of AI-designed cartoons as an innovative and impactful teaching strategy in early education, reinforcing conclusions drawn by Bedeir (2020) and Al-Qurashi (2017) about the educational value of cartoons in improving learning outcomes.

Implications and limitations

This research highlights the transformative potential of integrating AI-based tools into the curriculum by demonstrating the effectiveness of AI-designed cartoons in improving students' academic achievement. This study, therefore, has several key implications for science education and the broader educational landscape, along with practical recommendations for educators on how to effectively integrate AI-designed cartoons into teaching. Additionally, the discussion has been expanded to address challenges related to accessibility and the generalizability of findings to strengthen the study's academic rigor.

Practical Recommendations for Educators

To ensure the effective integration of AI-designed cartoons in education, educators should consider the following actionable strategies. First, teachers should align AI-generated cartoons with specific learning objectives, ensuring that visuals reinforce key concepts in science and other subjects. AI-generated cartoons should be used as both introductory and reinforcement tools, helping students visualize abstract concepts before delving into deeper discussions. Additionally, schools should organize workshops to train teachers in using AI tools effectively, ensuring that they understand how to create and implement AI-generated educational content. Educators need guidance on customizing AI-generated cartoons to suit different learning styles, making lessons more engaging and tailored to individual student needs.

Moreover, AI-generated cartoons should be integrated into interactive learning activities, such as group discussions, quizzes, and storytelling exercises, maximizing engagement and comprehension. Teachers can also encourage students to co-create AI-generated visuals, fostering creativity and deeper engagement in the learning process. Lastly, AI-generated cartoons offer adaptive learning experiences that cater to different student needs. Teachers should leverage this by assigning AI-powered visual content based on student proficiency levels, ensuring equitable learning experiences. Special education instructors can use AI-generated cartoons to support students with learning disabilities, enhancing accessibility and inclusion.

Expanding Accessibility to AI in Resource-Limited Environments

One of the key challenges in implementing AI-generated cartoons in education is the unequal access to AI tools, particularly in resource-limited environments. To address this issue, educational policymakers should advocate for affordable AI-based tools tailored for schools with limited digital infrastructure. Open-source AI platforms and government-supported AI initiatives can help reduce costs, making AI-driven learning more accessible. Additionally, many schools may lack advanced AI infrastructure but have access to smartphones and tablets. AI-generated cartoons can be integrated into mobile-based learning applications, ensuring that students can benefit from AI-powered educational content even in low-tech environments. Furthermore, partnerships between schools, universities, and AI developers can increase access to AI-generated content, particularly in underserved regions. Nonprofit organizations could help develop and distribute AI-powered educational cartoons to schools with limited budgets.

Enhancing the Study's Generalizability

While this study provides promising insights into the effectiveness of AI-designed cartoons, certain limitations affect its generalizability. The study's limited sample size (58 students from a single school) may restrict its applicability to other educational settings. Future research should include a larger and more diverse student population across multiple schools

and grade levels to ensure that findings are more representative of broader student learning experiences. Another limitation is the short duration of the intervention, making it difficult to assess the long-term effects of AI-designed cartoons on academic retention and problem-solving skills. Future research should extend the study duration to determine whether AI-generated cartoons have a lasting impact on conceptual understanding and engagement. Moreover, while this study focused on science education, AI-generated cartoons may also enhance learning in subjects like mathematics, social studies, and language learning. Additional research should explore interdisciplinary applications, investigating how AI-generated cartoons can support diverse learning domains.

Exploring the Future of AI-Designed Cartoons in Education

Beyond addressing current challenges, this study opens new avenues for future research and innovation in AI-powered education. One exciting area for exploration is the integration of AI-generated cartoons with Augmented Reality (AR). Future studies should examine how combining AI-generated cartoons with AR can create immersive learning environments, especially in STEM education. AI-powered AR applications could help students interact with scientific concepts in real time, enhancing engagement and retention. Another area worth exploring is the role of AI-generated cartoons in personalized learning. AI-driven cartoons could be used in personalized learning platforms to adapt content to individual student learning preferences, ensuring more effective engagement. Future research should investigate how AI-generated cartoons can support students with different cognitive abilities and learning speeds, enhancing inclusive education. Lastly, as AI becomes more integrated into classrooms, ethical concerns regarding data privacy and AI-generated content quality must be addressed. Researchers and policymakers should explore guidelines for ethical AI usage in education, ensuring that AI-generated learning materials are accurate, unbiased, and pedagogically sound.

This study offers practical recommendations for educators, strategies for improving accessibility, and insights into the components of AI-designed cartoons. Through these three avenues, this paper provides actionable guidance for integrating AI-driven cartoons into educational practice. Future research should continue exploring ways to expand AI accessibility, enhance its long-term impact on learning, and integrate AI cartoons into more diverse subjects and learning contexts. With the right strategies, AI-powered cartoons can transform education, making learning more engaging, inclusive, and effective for students across all backgrounds and learning abilities.

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