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Transforming Primary Science Education: Unlocking the Power of Generative AI to Enhance Pupils' Grasp of Scientific Concepts

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Abstract. Artificial intelligence (AI) has significantly impacted the integration of technology into education and thus into teaching methods. This research explored the role of generative AI in enhancing the understanding of scientific concepts among primary school pupils. Qualitative research methodology was employed through semi-structured interviews with 43 primary science teachers from Saudi Arabia who regularly use AI applications in teaching, and data were analyzed using grounded theory. The findings indicated that generative AI supports pupils' personalized learning by contributing to the development of creativity, critical thinking, problem-solving, activity-based constructive learning, and thus the understanding of scientific concepts. The findings also indicated that generative AI encourages the adoption of more pupil-centered and inquiry-based teaching approaches. Based on the findings of the study, the researchers underlined that there should be an increased emphasis on the use of AI in education through specialized training for teachers on implementation frameworks and AI integration into lessons. The findings emphasized the need for improved collaboration among teachers within and between schools. A professional

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exchange network could enable teachers to present experiences and adopt new instructional approaches to improve the learning experience of pupils. The authors recommend future research that includes pupils' perspectives and investigates the long-term effects of integrating AI into the teaching process.

Keywords: AI; science learning; scientific concepts; learning environments

1. Introduction

Scientific concepts and skills have to be learned in a certain way to promote pupils' scientific reasoning because these concepts help them make sense of the world (Cooper, 2023; Khasawneh et al., 2022; Lameras & Arnab, 2021). During the primary school stage, mastering these concepts not only requires the pupil to master the basic concepts, but also involves actively constructing an understanding of the surrounding environment, which has a huge impact on how the pupil thinks and reasons (Al-Halalat et al., 2024; Du & Wong, 2019; Fraihat et al., 2022). Learning scientific concepts at this level makes it possible for learners to generate hypotheses regarding events and phenomena occurring within their environment (Al-Barakat & Alali, 2024; Cooper & Tang, 2024; Întorsureanu et al., 2025). For instance, when pupils learn about the water cycle or planets moving around the sun, they do not simply store this information away but start integrating their knowledge with the real world (Hawamdeh et al., 2025; Irshid et al., 2023; Kang & Keinonen, 2017; Zghoul & Bataineh, 2024).

Scientific concepts and skills are essential in developing pupils' scientific thinking, as these concepts help pupils understand and interpret the world around them (Khasawneh et al., 2022; Lameras & Arnab, 2021). In primary education, attainment of these concepts is not simply about memorizing core concepts, it involves the development of mental and cognitive models that dictate the ways learners think and reason about the world (Du & Wong, 2019; Fraihat et al., 2022). For example, while learning the water cycle or the movements of planets around the sun, learners do not just keep this information in their minds but connect it actively to some phenomena, such as rainfall or changes in seasons (Irshid et al., 2023; Kang & Keinonen, 2017).

Scientific concepts include basic concepts like energy, force, and ecosystems, whereas scientific thinking entails using such concepts to reason out the causative factors, logical explanations, and predictions (Al-Barakat & Bataineh, 2011). Dissecting such concepts is important at the primary level of education, because knowledge acquisition and critical thinking development are simultaneous. For instance, pupils may explain the local environmental change using their knowledge of weather patterns and pollution and suggest possible causative factors and solutions (Bataineh & Al-Ghareeb, 2025; Întorsureanu et al., 2025; Lameras & Arnab, 2021).

Learning scientific thinking aids the development of critical and analytical reasoning skills through inquiring, analyzing, and formulating conclusions based upon proof (Costa & Broietti, 2021; Khasawneh et al., 2023). For instance, when

pupils study global warming, it is not enough for them to just know what it is, they should be able to reason about its effects, causes, and how its negative effects can be reduced (Du & Wong, 2019; Nguyen et al., 2023). This type of learning helps develop and promote a thinking culture which, in turn, aids pupils in coping with future needs and challenges (AlAli et al., 2024; Akgun & Greenhow, 2022; Labadze et al., 2023).

Achieving mastery of scientific concepts helps to improve pupils' systematic thinking, which, in turn, allows them to better organize and analyze information, and draw relationships between various areas of knowledge (Clark, 2023; Mishra et al., 2023). For example, geography pupils can study the interplay between climate, weather, or changes on the Earth's surface and the environmental forces underlying them. Such learning helps to acquire the skills that enable pupils to go beyond a single discipline and use knowledge from multiple fields to address problems and challenges (Mork et al., 2022).

Given the challenging nature of teaching these scientific skills in a classroom setting, technology-enhanced learning has been the area that researchers work on the most. One of the solutions is generative artificial intelligence (AI), which, for the purpose of this discussion, refers to AI systems designed to produce new content like text, images, and simulations based on a user's input. Unlike the traditional educational technologies that offer pre-prepared content, generative AI affords learners the ability to interact, customize, and create in real time during the learning process (Al-Hassan et al., 2012; Herdliska & Zhai, 2023; Xie, 2023). For instance, AI educational instruments can actively guide learners through the water cycle simulation so that they can understand the abstract concept better.

Recent studies indicated that incorporating generative AI tools into the curriculum has been particularly beneficial in aiding pupils in grasping complex concepts in primary science learning (Lee et al., 2021; McDonald et al., 2025; Ramnarain et al., 2024). Advanced technologies, such as ChatGPT, have been found effective in correcting learners' misconceptions, providing individualized instruction, and promoting pupil engagement (Marengo et al., 2025; Nguyen & Truong, 2025). In chat-based feedback sessions, pupils generate dialogues designed to help understand concepts on abstract and difficult science topics, making science learning both highly beneficial and engaging.

Enhancing inquiry-based learning that fosters critical thinking and meaningful classroom dialogues is one of the numerous powers of generative AI. AI tools aid pupils' constructivist learning by responding to their questions in real time and tailoring the responses to meet their learning needs. Such a model is especially important in primary education, where pupils are building foundational knowledge in science, since it helps pupils actively engage with the content and explore scientific concepts deeply and creatively instead of passively absorbing information (Alali & Al-Barakat, 2024b; Al-Hassan et al., 2025; Baidoo-Anu & Ansah, 2023; Barnes & Tour, 2025).

Generative AI tools aid in creating comprehensive and interactive learning experiences and exposing pupils to new ways of visual representation; for

example, they can simulate natural phenomena that are difficult to implement in a traditional classroom, so enhancing understanding of topics in biology, physics, and other fields of science (Alali & Al-Barakat, 2023a; Baidoo-Anu & Ansah, 2023; Barnes & Tour, 2025). Generative AI not only assists in explaining scientific models but also personalizes learning experiences, making learning interesting and simple (Ramnarain et al., 2024).

Generative AI tools also assist pupils in developing their reasoning and critical thinking skills while analyzing scientific knowledge, and in exploring how different phenomena are related to each other; thus pupils are able to learn concepts at different levels and greatly enhance their understanding of details. For instance, pupils can study natural phenomena like the motion of air masses and their effects on the ecosystems in both in-depth and broad perspectives (Al-Barakat et al., 2023; AlAli & Al-Barakat, 2023b; Bataineh & Mayyas, 2017).

However, the full potential of generative AI resources is determined by the quality of the prompts crafted by the users. The context of the AI answers is determined by the way the queries are introduced by the teachers or pupils (Al-Barakat et al., 2022; Getachew, 2024). The ability of generative AI to provide real-time feedback within a context is useful, but within complex scientific discussions, the context is often lost. With all these limitations, research has shown that AI can effectively deal with pupils' misconceptions in physics and thermodynamics, which require pupils' understanding without unambiguous statements (Kieser & Wulff, 2024).

In conclusion, generative AI has the ability to enhance primary science education, as it helps overcome learning obstacles while enhancing engagement and transforming the classroom into an inquiry-centered environment. This new approach has the potential to transform the future of science education and elevate the quality of knowledge provided so that pupils are appropriately equipped with basic scientific reasoning and skills (Ahmad et al., 2021; Alasadi & Baiz, 2023; Baidoo-Anu & Ansah, 2023; Barnes & Tour, 2025).

Earlier research examined how AI significantly helps enhance science learning throughout different educational levels via automated feedback and individualized instructional materials designed for each learner. According to Xia (2023), AI supports the learning process through constructive feedback, which aids in sustained attention and motivation, thus enhancing knowledge retention. Lee et al. (2021) studied the role of AI in game-based applications and reported that AI actively supports participatory and collaborative learning among peers. Herdliska & Zhai (2023) emphasized the value of AI in education by explaining AI's ability to analyze vast datasets and identify patterns, which greatly enriches the learning experience. These results illustrate how AI serves not only as an enabler to aid learning, but also as a transformative force for developing teaching strategies and methods.

Both teaching and learning science can potentially benefit from the inclusion of AI in educational systems. In this regard, El Fathi et al. (2025), who studied the application of ChatGPT as a complementary instructional tool to teach thermodynamics to first-year engineering students in a CILP (Constructivist,

Inquiry-Based Learning) framework, reported that using ChatGPT helped students to correct some scientific misconceptions. Similarly, Erduran & Levrini (2024) who discussed the role of AI in scientific practices, such as forming hypotheses, experiment planning, and data collection processes, encouraged integrating AI in educational curricula and teacher training courses in order to be relevant to modern scientific developments. Further, Ramnarain et al. (2024) investigated the use of AI in teaching science through inquiry methods by teacher candidates and reported that their prior knowledge of AI and its perceived usefulness shaped their attitudes towards employing AI in instruction.

Earlier research pointed out some limitations in using generative AI. While these studies reported the positive impact of using AI in education, they also emphasized the need for further examination. For example, while ChatGPT did poorly with the actual problem-solving chemistry exam questions, as Clark (2023) notes, it was very good at concept identification. Cooper (2023) also pointed out that ChatGPT's responses varied between being consistent with professional standards in some contexts and being vague in others. Regardless, one of the best things about generative AI is its ability to tailor teaching instructions to the unique levels of pupils, enhancing their understanding of difficult concepts in science. Moreover, Ahmad et al. (2021), Alasadi & Baiz (2023), and Baidoo-Anu & Ansah (2023) reported that the immediate feedback provided by AI helps pupils identify errors and rectify them quickly. Supporters of AI claim that technology can provide different formats of content, like animations and other interactive presentations, which makes learning more interesting, especially for children.

In the context of teaching, generative AI provides the teachers with analytical tools for better tracking the advancement of pupils, as it can observe how learners engage with various scientific materials and assist teachers with methods for enhancing science teaching to achieve better results. Moreover, integrating generative AI into the educational framework can enhance pupils' technical skill sets in Saudi Arabia, as the country undergoes digital transformation, and qualifies them to deal with challenges in an innovative and technology-reliant world (Al-Barakat & Al-Hassan et al., 2025; Baidoo-Anu & Ansah, 2023; Barnes & Tour, 2025).

International bodies like UNESCO and the Organization for Economic Cooperation and Development (OECD) have increasingly urged discipline in applying generative AI tools for educational purposes so that its advantages can be optimally harnessed (AlAli et al., 2024; Al-Barakat & AlAli et al., 2025; Olivetti et al., 2020; Sabzalieva & Valentini, 2023). Accordingly, in Saudi Arabia it is necessary to study the impact of generative AI tools on primary school pupils' comprehension of scientific concepts. Considering the available resources and opportunities provided by generative AI, its use in education has not been extensively investigated in relation to overriding gaps in understanding scientific concepts, especially among primary school pupils, knowing that these gaps are crucial to designing educational resources that promote effective learning and innovative teaching methods to actively engage learners with science learning.

2. Research Statement

Despite the trend towards integrating technology into education and the evidence of the effectiveness of AI in enhancing educational processes and improving learners' performance, implementation of generative AI to foster primary school pupils' comprehension of scientific concepts is still a work in progress, and there is still a shortage of research focusing on the ability of generative AI to aid learners in primary education to learn complex scientific concepts.

In Saudi Arabia, there is a paradigm transformation in the education sector along, with Vision 2030, which focuses on the integration of technology in education. Despite the tendency to modernizing approaches in teaching, primary science education is still at a low level. Many learners are simply unable to cope with basic scientific concepts, and conventional teaching approaches do very little to promote active engagement with scientific content. Such issues necessitate the immediate attention of innovative approaches that improve teaching and learning of scientific concepts in primary education.

This research contributes to the growing body of knowledge on the integration of AI in primary education and offers valuable insights for educators and policymakers on advancing science education through emerging technologies. Therefore, this research seeks to assess how generative AI impacts fostering scientific understanding among primary school learners in Saudi Arabia through one main guiding question: *How can generative AI effectively contribute to improving pupils' understanding of scientific concepts in primary education?*

3. Methodology

3.1 Research Design and Sample

Qualitative design was used to analyze the possibilities of generative AI to enhance the understanding of scientific concepts by primary pupils in Saudi Arabia using semi-structured interviews with a broad range of primary school science educators to explore, in depth, their experiences, problems, and views concerning the use of AI tools in teaching.

The sample was made up of 43 primary school science teachers in the Al-Ahsa governorate in Saudi Arabia who were economically and socially homogeneous. Using simple random sampling, every 10th teacher on the list was selected until the desired participant number was achieved. This approach was adopted to improve the possibility that the sample was representative of the research population. Teachers with three to five years of experience made up thirty percent of the group at thirteen teachers, while fifteen teachers, accounting for thirty-five percent of the group, had six to fifteen years of experience. Another fifteen teachers with over fifteen years of experience made up a further thirty-five percent.

3.2 Research Instrument

The data was collected using a semi-structured interview, as the authors reviewed literature pertaining to AI and education and developed an interview guide that included questions relevant to the topic. The interview guide consisted of the following questions:

1. How can generative AI be utilized to deepen a learner's understanding of scientific concepts?
2. What benefits can generative AI bring to teaching and learning science?
3. What is the potential level of AI applications in enhancing teaching and learning of scientific concepts at the primary education level?

The questions were reviewed by a group of specialists in AI and education in order to evaluate their accuracy and appropriateness for the research. Several teachers were also involved in a pilot test of the questions to assess whether the questions were straightforward and directed to elicit the intended responses.

3.3 Data Collection Procedures

The face-to-face interviews took 40 to 55 minutes for each session and were conducted in places selected by the participants in order to make them feel comfortable and to enable effective dialogue. The participants were informed about the significance and objectives of the research and their informed consent to record the interviews was obtained. The data collection took place between September and December 2024. No seasonal or contextual factors are believed to have influenced the results, as the interviews were conducted during stable periods.

The interviews were recorded using high-quality digital recorders to ensure accurate transcription; they were transcribed verbatim, and the transcripts were sent back to the participants for verification. This process helped ensure the reliability of the data. Ethical considerations, data confidentiality and participant privacy were ensured. Informed consent was obtained from each participant before the interview, and institutional approval was also obtained from the relevant authority in Al-Ahsa.

3.4 Data Analysis

Data were analyzed using grounded theory, which involves analyzing the data itself to extract themes and key ideas. The following steps were followed:

1. **Initial Reading**: The texts were read multiple times to extract key ideas related to the use of AI in science teaching.
2. **Inductive Analysis**: Themes were extracted from participants' responses without guiding the analysis with any specific theory.
3. **Coding**: The responses were divided into smaller segments, and each segment was assigned a code representing the main idea.
4. **Developing Categories and Themes**: Similar ideas were grouped into broader categories.
5. **Descriptive Summary**: A narrative summary was written, presenting the key findings supported by direct quotes from participants.

For the grounded theory analysis, **open coding** was applied to identify initial concepts from the raw data, such as assigning codes to ideas expressed in the responses. During **axial coding,** relationships between these codes were identified

and organized into major and sub-categories. In **selective coding**, the core category was identified, integrating all the main themes from the data.

3.5 Ensuring Accuracy and Reliability

To confirm the accuracy of the analysis, additional analysts were involved in reviewing the initial analysis. The agreement rate between analysts was 97%, reflecting high accuracy in data interpretation. Any disagreements in interpretation were resolved through group discussions, which strengthened the credibility of the analysis.

Furthermore, the interview transcripts were sent to participants for verification to ensure the accuracy of the representation of their views. This process helped ensure the trustworthiness of the research and increased confidence in the results.

4. Research Results

The following themes emerged from the data analysis:

First Theme - Personalized and Motivating Education (Meeting Each Child's Needs)

The majority of the participants (95.34%) reported that the use of artificial intelligence in science learning environments helped them to personalize education effectively in a way that met every child's needs, thus making education more relevant to individual differences. This was affirmed by the respondents who commented:

> *"I'm able to customize education to fit every child's needs because of how AI works… um, in a lesson on the circulatory system, kids who learned quickly interacted with complex simulations while other pupils, who needed more time, were given simpler interactive experiences."*
>
> *"With the help of artificial intelligence, I was able to customize the rhythm of learning for each child… in a lesson of atoms, the pupils were able to interact to a simulation where they built atoms, and this helped them easily understand how electrons are placed in different levels of energy."*
>
> *"During the weather and climate lesson, I used an AI tool that helped demonstrate how changes in climate affect the environment. This technology helped pupils engage with various environments and comprehend environmental issues, thus broadening the understanding of scientific issues."*

The preceding quotes point out the role of artificial intelligence in customizing education for every child, improving their engagement, and deepening understanding of scientific concepts. Besides, AI helps teachers to design varied educational tasks that serve individual differences. Such exercises not only assist pupils' understanding of scientific materials but also help to improve the performance of each child, which aids in a profound understanding of scientific phenomena.

Second Theme: Interactive Simulation: Live Scientific Experiments

Most respondents (88.37%) claimed pupils' learning of scientific concepts depended on the use of AI-supported interactive simulations which, in turn, positively impacted pupils' educational experiences and made scientific concepts

more understandable. This was evident in the statements of research participants who pointed out:

> *"In teaching chemistry, I used interactive simulation which made it possible for pupils to add different chemicals and observe how these chemicals mix with one another. The pupils learned how to handle chemicals safely and interacted with the simulation as if they were in a real laboratory."*
>
> *"During the lesson on motion in physics, the pupils took part in an interactive simulation which allowed them to change the speed and angle of inclination and observe the changes in the position of different objects. This type of interaction raised the pupil's ability to understand motion equations by experiencing them themselves."*
>
> *"When teaching about eruptions of volcanoes, there was an AI simulation where pupils were able to construct the volcanoes and then see how the volume of pressure and temperature changed the effects of the eruption. This activity was very engaging and enriched the pupils' comprehension of how these natural phenomena take place."*

The quotes above highlight the role of simulations in aiding pupils to comprehend science through practical and real-life-based activities. Pupils can conduct chemical reactions or observe physical movements happening in a simulated environment, enabling them to grasp these concepts in a more interactive way. The interaction goes beyond formal presentation of information as there is effortless involvement and ongoing activity that enrich understanding and participation in the scientific fields.

Third Theme: Enhancing Scientific Curiosity

Many participants agreed that AI helps to enhance pupils' scientific curiosity through providing scientific inquiry-based opportunities. In this context, the participants highlighted:

> *"While using AI, I noticed that pupils were able to engage with the content in an effortless way... during a lesson on the water cycle, for instance, pupils were able to pose the question of how water evaporates and condenses to the AI... My pupils kept questioning and interacting with the generative AI."*
>
> *"... AI did assist in igniting the scientific curiosity of learners... One pupil asked a question as to why planets moved at different speeds in their orbits, and the child was able to use the AI tool to find answers and even change factors like gravity and distance to see how they impact planetary motion."*
>
> *"During the lessons on cells, pupils were able to work with an animated model of a cell and query what each part of the cell did. They did it, and it was so easy, I think they had a much better understanding of what was going on.*

Based on the above quotes, AI-generated content enabled the pupils to ask questions, find answers, and add to their curiosity about science. This indicates that AI gives pupils practical experience that nurtures asking and exploration.

Answering questions through generative AI makes pupils more interested in scientific issues, and that interest encourages them to participate more. This not only helps pupils learn to explore concepts but also to engage actively with information through structured reasoning and with elements of critical thinking.

Fourth Theme: Stimulating Creativity and Problem-Solving

The majority of respondents agreed that generative AI drives pupils to approach scientific problems creatively. The participants remarked:

> *"While teaching a lesson on energy, I had pupils use AI paradigms to design experiments that examine the effects of heat and pressure on different materials. One child had this brilliant new idea of testing how force impacts heavy objects; she made the experiment more valuable."*

> *"In teaching a lesson dealing with inheritance, I had the pupils use AI to help design experiments aimed at solving some tough genetic puzzles. One child came up with the brilliant idea of testing how recessive genes in viviparous organisms can be modeled by simulating the birth of offspring. That kind of creative thought delighted me."*

The above quotes demonstrate that AI encourages pupils to use imagination and creative thinking and find solutions to problems in science, which helps pupils interact with and solve scientific problems more efficiently and innovatively.

Fifth Theme: Collaborative and Shared Learning

Many participants (90.69%) believed that AI supports collaboration among pupils by enabling them to communicate, brainstorm, and solve problems collectively. They stated that:

> *"The pupils were split into groups to analyze seismic activity data with an AI integrated program. Each group had to come together to solve some challenging scientific queries, and this made them work together."*

> *"During the astronomy lesson, the pupils worked in groups using AI to track the movement of the planets through the solar system. They interacted with and helped each other to solve the challenges; thus, their combined spirit in the class was fostered."*

> *"In my class, we formed teams of pupils to evaluate the effects of climate change, using AI. The pupils communicated and utilized many different materials, which enabled them to view the issue from several angles."*

The above quotes provide evidence that AI fosters the right culture of collaboration among pupils, where they not only work together but also improve their collaborative problem-solving skills. Using AI technology, pupils can collaborate in collecting and analyzing information as well as performing intricate scientific experiments. This collaboration results in the sharing of ideas and information so that pupils have a better understanding of scientific concepts from different point of views. Collaboration improves the spirit of teamwork and gives pupils the chance to learn more about communication and cooperation.

Sixth Theme: Simplifying Complex Concepts: Deep Understanding through Interaction

Most participants declared that AI helps to simplify intricate scientific concepts, making them easier for pupils to grasp. The participants' responses included:

> *"Teaching kids gravity using AI had a meaningful impact on their learning. With the simulation, pupils were able to witness how gravity acted on various objects in different settings, which was extremely difficult for them at the start, but was rather straightforward by the end of the exercise."*
>
> *"During a chemistry lesson about acid reactions, I demonstrated with a simulation showing how temperature influences the speed of the reaction. Certainly, pupils that had a hard time understanding the chemical reactions were able to see the result for themselves, making it easier for them to understand the relationship between different variables."*
>
> *"During one of the lessons on cells, the pupils were able to work with a model of a living cell and interacted with the cell by asking questions about parts of the cell and what these parts do. This feature enabled them to interactively analyze concepts, which was profoundly challenging for them in the past."*

It can be concluded that AI makes learning complex scientific ideas easy for pupils. The quotes indicate that AI helps break down complicated scientific concepts by offering pupils hands-on learning opportunities. The quotes further indicate that younger learners are able to appreciate the effects of different variables on essential scientific activities such as gravity or chemical reactions with the use of interactive simulations, which in turn, help to break down these complex concepts. With the aid of AI tools, pupils are able to integrate and analyze the relationships among variables in a more sophisticated manner, thus improving the seamless blend of theories and real-life experiences.

Seventh Theme: Providing Additional Educational Resources (Expanding Knowledge Horizons)

Most of the coded interview responses (81.39%) noted that AI provides additional learning resources that enable pupils to gain further understanding of scientific concepts and knowledge. The participants pointed out:

> *"Using AI, pupils can get educational videos and interactive materials that explain the scientific concepts at their levels. In a lesson about space, pupils were able to use a program that enabled them to view galaxies and planets on interactive maps, which helped them learn how the solar system works."*
>
> *"Well, I remember when I taught pupils the lesson about plants, I used an AI program which gave pupils extra pieces of information concerning different types of plants and their environments. They were able to watch realistic video clips of how plants grow under different conditions, and this enhanced their understanding."*
>
> *"I was able to give pupils different tools in learning using AI, for instance, educational games that show how animals beget and how earthquakes*

happen, these activities motivated the pupils to do further independent work."

These quotations highlight the role AI plays in providing additional educational resources to assist in broadening pupils' knowledge. The pupils are provided with additional helpful technologies, such as animated videos and other educational materials that reinforce learning of scientific principles, and which help them to study scientific issues more deeply. These pupil-directed learning resources assist pupils to learn in ways that enhance their understanding while also nurturing self-directed learning capabilities.

5. Discussion

The findings demonstrate that pupils gain a better understanding of scientific concepts with the help of generative AI. Engagement in the lessons is remarkable, as the pupils have the opportunity to work interactively with AI tools which provide the opportunity to learn at their own pace. Broad access to information that AI provides significantly ensures that pupils can learn more according to their unique learning attributes, which leads to more effective learning. With regard to education, learners encounter real-world challenges that compel resolution and require integrating one or more fields of knowledge. This context makes the whole knowledge acquisition process holistic and deepens pupils' motivation to explore dynamic scientific phenomena. In general, making AI accessible in learning environments helps improve the engagement levels of pupils and facilitates an effective learning process.

The research outcomes match the fundamental principles of constructivist learning theory as described by Clark (2023), Erduran & Levrini (2024), and Herdliska & Zhai (2023), as they reported that knowledge development occurs through active engagement with the learning environment rather than receiving information from external sources. Cooper & Tang (2024), and Lameras & Arnab (2021) reported that pupils develop their understanding through resource interaction and personal experience application during the learning process. Generative AI acts as an effective educational tool that enables pupils to construct knowledge by interacting with their learning environment through experiences that connect scientific concepts to their real life.

In addition, generative AI tools improve learning through tailoring engagement and content to each pupil's learning preference. This personalization ensures effective learning by addressing knowledge gaps in a more individualized way. Moreover, by employing AI in simulations, pupils can interact with the software and apply the scientific concepts they learn in class to address real-life problems, which deepens their understanding of concepts that are, otherwise, difficult to comprehend. Such interactions are in line with constructivist theory, which asserts that learners need an engaging, active environment to internalize and explore different knowledge and gain theoretical insight (Ahmad et al., 2021; Alasadi & Baiz, 2023; Baidoo-Anu & Ansah, 2023; Barnes & Tour, 2025; Bataineh et al., 2007; Li et al., 2021).

There are other educational benefits of AI, which support the literature on the application of AI in aiding mental self-regulation and self-controlled learning processes. AlAli & Al-Barakat (2024c) have emphasized AI's role in assisting learners with comprehending difficult topics. The findings highlight the role of generative AI as a lever for learning engagement, especially at advanced levels, since it not only facilitates learning but also nurtures intrinsic motivation, scientific interest, and socialized learning among pupils.

Using generative AI made pupils more likely to independently ask novel questions and think critically about the questions posed. These actions support the principles of constructivist learning which emphasize that learning happens when people explore and reflect on something (Bataineh et al., 2019; Khasawneh et al., 2022). Generative AI was also reported to enable learners to have better control over their metacognition and self-directed learning strategies, which emphasizes the argument by Fraihat et al. (2002) about the learner's control over his learning activities. This control over metacognition and learning strategies underlines that learning with the support of generative AI is not and should not be limited to the superficial level of information collection or passive information retrieval (Ahmad et al., 2021; Alasadi & Baiz, 2023; Jia et al., 2023).

AI can encourage collaboration among learners within specific scientific educational contexts as AI tools provide a platform for pupils to work in groups to address given scientific problems, enhancing their understanding of scientific principles as well as developing teamwork and communication skills. This is in line with a number of researchers (Bataineh et al., 2025; Kim et al., 2025; Rowland, 2023; Salvagno et al., 2023; Singh et al., 2023; Spector & Ma, 2019) who reported that education is more than understanding something; it is about coming together, sharing, and solving issues in groups.

The research highlights AI's extensive diverse educational materials, including interactive videos, simulations, and educational software that help pupils approach scientific concepts from multiple angles (Irshid et al., 2023). Such resources help learners understand the same concepts in different ways and promote self-paced learning and proactive knowledge creation beyond the set syllabus. This widens the argument for AI as an all-encompassing educational resource that, when intelligently employed, arouses pupils' interest in science and learning beyond the classroom (Alasadi & Baiz, 2023; Baidoo-Anu & Ansah, 2023; Barnes & Tour, 2025; Kim et al., 2025).

6. Conclusions, Implications, Recommendations and Limitations

The primary focus of the research is to demonstrate the possibility of transforming learning spaces into interactive ones with AI and so stimulating critical thinking. In education, especially in the teaching of science, the integration of AI systems has been neglected; therefore, the learning environment needs to be designed to incorporate AI comprehensively to arouse learners' interest and promote higher-order thinking, as well as enhance learners' grasp of scientific concepts.

First, it is imperative to raise the competency level of teachers on how to use AI tools in inquiry-based pedagogical approaches to ensure that targeted value is

realized, which, in turn, will guarantee fairness in the distribution of knowledge and address the needs of the pupils in a particular class. Learners with knowledge gaps tend to benefit from these tools because of the tailored approach AI can provide in teaching the concepts, thus leading to a greater grasp of the scientific concepts.

However, the implementation of AI in education comes with hurdles, including a lack of access to technology, resistance to change, and the need for extensive training. Further studies should look into ways these obstacles affect the implementation of AI, especially on pupils' higher-order thinking skills and critical and creative thinking skills.

The findings called for a change in the definition of the teacher's role as an instructor in an AI-integrated classroom. Teachers should not just present pre-packaged content but should encourage active collaboration with AI to foster inquiry and critical thinking and help pupils build those skills. This change requires investment in deeper professional development so that teachers can meaningfully integrate AI into their practice.

The research underlined that there should be an increased emphasis on the use of AI in education through specialized training for teachers on implementing frameworks and integrating AI into lessons. It also underlined the need for improved collaboration among teachers within and between schools. A professional exchange network could enable teachers to present experiences and adopt new instructional approaches, which would improve the learning experience of pupils.

However, the research was limited to a single national context and relied on data from a single source (semi-structured interviews). Further, the use of semi-structured interviews conducted with a small group from one area in Saudi Arabia serves as another constraining factor. Follow-up studies would need to increase the sample to include participants from other areas in order to provide a more holistic perspective of the incorporation of AI into education.

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