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Developing An Artificial Intelligence-Based Science Instructional Module and Measuring Its Effect on Acquiring Scientific Concepts and Critical Thinking Skills among Seventh-Grade Female Students

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Abstract

Background/purpose. This study aimed to investigate the effectiveness of a computerized instructional module based on artificial intelligence in acquiring scientific concepts and developing critical thinking among seventh-grade female students.

Materials/methods. To achieve the study's objectives, an AI-based computerized instructional module was created, and two tests were prepared to measure their performance in acquiring scientific concepts and critical thinking. The study sample consisted of two classes of seventh-grade female students selected conveniently in the first semester of the 2023/2024 academic year, totaling 48 students. One class was randomly chosen as the experimental group of 27 students, taught using the computerized instructional module based on artificial intelligence. In contrast, the other class was the control group, with 21 students taught using the traditional method.

Results. The study results showed a statistically significant difference in the acquisition of scientific concepts, both individually and collectively, and the development of critical thinking, both individually and collectively, between the performance of the two study groups in favor of the experimental group who studied using the artificial intelligence-based instructional module

Conclusion. The study recommended the importance of using smart applications in education, especially in the field of science teaching, due to their significant impact on achieving interactivity and practical experience, which contributes to enhancing students' understanding and motivating them to discover more scientific concepts innovatively and enjoyably and developing their critical thinking.

1. Introduction

Educational systems are typically confronted with various accelerating challenges due to the rapid scientific and technological advancement shaping multiple aspects of life. These advancements have triggered educational institutes to reassess the effectiveness of their educational system. In response, modern instructional approaches have emerged seeking to develop and modernise instruction, emphasising the pivotal role of the learner in the educational process; these approaches include a learner-centred and activity-based teaching method. These methods confirm that all learners have the ability to acquire education to mastery, provided that the instructional strategies are tailored to their unique learning styles and skills.

In the context of science education, educators emphasise that the primary aim of teaching science is not merely to transfer scientific knowledge to the learner. Instead, it is a process concerned with fostering the learner's intellectual, emotional and practical growth, integrating their various aspects of personality. Science instruction also aims to cultivate learners' ability to think critically through comprehension, experiments, problem-solving and applying knowledge in real-life situations rather than memorising knowledge embodied in textbooks and curricula (Zaytoun, 2004).

Scientific concepts are fundamental components for learning science due to their significance in structuring experience, retaining information, connecting it to its origins, and facilitating access to knowledge. They are also considered one of the basics of science and knowledge essential for comprehending the structure of science and transferring the effect of learning. Therefore, forming and developing scientific concepts among learners is one goal of teaching science across all educational levels. It necessitates a practical instructional approach that ensures the coherence of their development, preservation, and retention (Al-Najdi et al., 2003).

Since scientific concepts form the foundation of science and scientific knowledge, and help comprehend science and its evolution, there are numerous reasons to emphasise the importance of teaching scientific concepts and their roles in science. They are also considered the basic building blocks in building scientific principles, generalisations and theories by synthesising numerous facts. Concepts are more memorable, stable and permanent than facts that are forgotten much faster. Concepts also help organise experience, reduce relearning, and facilitate the transfer of the effect of learning by applying them in different situations. They are considered a successful means of stimulating mental growth and using the method of thinking in confronting and solving problems as they are tools of thinking and investigation (Khataybeh, 2005).

Numerous studies have demonstrated the challenges most students in the primary education stages face in comprehending scientific concepts (Al-Raimi, 2006; Al-Dabsi, 2012; Costa & Garmston, 2001). For instance, the results of Al-Raimi (2006) and Al-Dabsi (2012) revealed that primary students tend to memorise scientific concepts rather than comprehend them, which constitutes a central challenge in understanding the scientific context. Costa and Garmston (2001) observed that students have a low ability to comprehend scientific concepts due to several factors, including aspects related to teachers, such as a lack of training and qualification in effective instructional methods or their unwillingness to develop themselves. They found that students do not approach scientific content properly and methodically. These challenges may also be exacerbated by the required curriculum and the educational policies that have been implemented.

Al-Salamat (2016) suggests that acquiring scientific concepts is a thrilling component of the cognitive processes that foster human thinking and enhance cognitive abilities since they help people become more adept at interpreting, controlling, and making predictions. Zhou (2010) contends that the process of formation and growth does not stop at a certain point but increases in depth and breadth as the student grows and his knowledge and experiences expand. Therefore, the concept must be formed according to a logical system in which new experiences are built on previous ones, paving the way for subsequent experiences.

Scientific concepts are essential for helping learners think more critically and connect scientific facts, allowing them to deal with various life circumstances and efficiently connect them to new experiences (Sarhan, 2020). Thinking is seen as an interactive cognitive system open to observation, experimentation, and development, making the development of thinking in all its forms one of the most crucial objectives of science education. To do this, science instruction must assist learners in developing scientific thinking methods, emphasising scientific procedures and approaches (Zaytoun, 1999).

Critical thinking is a necessary educational requirement because it ensures that students develop critical thinking skills that allow them to make sound decisions based on clear and specific criteria. This helps students master the learning process by connecting its components and meeting their basic intellectual needs (Al-Qawasmeh & Abu Ghazaleh, 2013).

Critical thinking is fundamental to addressing daily challenges, as it represents a key form of essential and systematic thinking. It facilitates anticipating potential outcomes for individual or collective events and supports the objective evaluation of opinions, free from bias and subjectivity. Furthermore, it enables individuals to make successful decisions using a scientific methodology, empowering them to confront misconceptions, rumours and harmful habits. It also works to develop individuals' ability to deal effectively with problems and situations that require deep thinking skills, in addition to accepting criticism and benefiting from the comments of others and works to develop all thinking skills, including divergent thinking, creativity, comparison, discussion, analysis, inference, decision-making, flexibility and intelligent communication with others (Al-Subhi, 2013).

Yenice (2011) suggests that critical thinking develops in learners a sense of responsibility towards society and a desire to contribute to its development and progress, which enhances effective political participation and the democratic spirit. It also contributes to improving learners' achievement in various academic subjects, developing the ability to think clearly and rationally, enhancing attitudes towards knowledge and technology, developing language skills and presenting them systematically to strengthen comprehension and expression abilities, and playing an effective role in self-reflection and self-evaluation of ideas and values. Asqoul (2009) added that critical thinking enhances the learner's ability to find solutions to problems and make appropriate decisions, promoting self-confidence and self-esteem, providing opportunities for growth, development and creativity, and encouraging questioning and research.

E-learning represents a technological innovation that has proven to be an effective tool in knowledge acquisition, skills development, various educational trends, and scientific thinking development. It typically facilitates the modification of the instructional method and the adaptation of diverse learning methods that consider the individualised needs of each learner. It provides teachers with ongoing access to educational materials, a wide range of easy-to-use assessment tools, time-saving benefits, a reduction in administrative workloads, and a reduction in overall workload (Gail, 2003, p.25).

Due to on-going technological advancements, educational smart applications have grown more varied. These applications span a wide range of academic domains and cater to the varying demands of both teachers and learners. They provide students with easy access to educational materials anytime and from any location via smartphones or tablets. Additionally, they offer interactive resources that motivate learners to engage with the material in creative and enjoyable ways, which improves interaction and engagement between students and instructors in the learning process. They also provide diverse learning experiences that include audio, video, images and interactive texts, which helps meet the needs of different learning styles and encourages interactive and experiential learning that helps students understand and apply concepts effectively, in addition to providing immediate feedback to students, which allows them to evaluate and improve their performance continuously (Hwang & Wu, 2012).

In science, smart applications can help students acquire scientific concepts effectively and innovatively, as some smart applications provide virtual and interactive reality experiences for students, allowing them to experience scientific phenomena in a safe and interactive environment. This typically contributes to developing thinking and a deeper understanding of scientific concepts. In addition to providing students with valuable and applied experiments to help them better understand scientific concepts, smart applications also offer interactive educational content that incorporates audio, images, video, and simulation. Examples of these experiments include molecular simulation and physical phenomenon experiments. Smart applications also improve student participation and collaborative learning by allowing students to share knowledge and interact with one another in a digital technological environment. Furthermore, they provide students with immediate feedback on their performance, allowing them to improve their comprehension of scientific concepts and quickly correct their mistakes (Papastergiou, 2009).

Science courses, in general, primarily aim to develop learners' thinking and train them to think critically, solve problems, and acquire noteworthy scientific trends in research, investigation, reasoning, and using metacognitive skills. Therefore, the use of artificial intelligence technologies is consistent with the nature and objectives of science courses that deal with abstract knowledge that requires reasoning and critical thinking on the part of the learner. In this context, Al-Baradei (2015) confirmed the robust prerequisite to use artificial intelligence technologies in teaching science to keep pace with contemporary educational trends that advocate for the development of curricula and pedagogies according to the standards of the era, keeping pace with the knowledge revolution in all fields, especially science, and overcoming the obstacles facing the educational environment with all its elements that prevent the educational process from achieving its goals.

Acquiring scientific concepts and critical thinking skills is thought to significantly impact students' ability to problem-solve and confront the challenges of the 21st century. In an era characterized by rapid technological advancement and information flow, students need a deep understanding of scientific concepts to be able to innovate and contribute to solving various local and global problems. Critical thinking skills enable them to evaluate information wisely and think logically and independently, which helps them make informed decisions in their daily lives and professional careers. Critical thinking skills enhance students' ability to ask the right questions, analyse data accurately, and reach conclusions based on substantial evidence.

Through their work in the educational field, the researchers observed that students, particularly those studying science, struggle to acquire scientific concepts and apply them to interpret observations, solve problems, and engage in scientific reasoning. This challenge highlights a gap in students' ability to grasp foundational scientific ideas and use them effectively in analytical contexts. Furthermore, the researchers also noted a general weakness among students in analysing and interpreting scientific events and phenomena and drawing conclusions. This deficiency typically presents their inability to make judgments based on scientific evidence or develop critical skills in science education. The dependence on conventional instructional methods commonly used by educators, such as lectures and rote learning, may be one cause of these struggles. Students are frequently bored and disengaged by these methods, making it harder to comprehend scientific concepts fully, which have become necessary in light of the rapid technological progress we are witnessing in the current era.

Due to the rapid, significant technological advancement, it is necessary to integrate science education with technology since it positively affects instruction and allows teachers to use modern educational methods such as virtual simulation, interactive experiments, and educational games, making learning more exciting and attractive to students. This integration also motivates students to explore and innovate and enhances their ability to analyse and think critically, which contributes to preparing a generation capable of facing future challenges with confidence and efficiency. In addition, using artificial intelligence applications enhances students' interaction with educational content. It motivates them to acquire scientific concepts and develop critical thinking innovatively and effectively.

Based on the above and the results of some previous studies, which confirmed the significance of employing artificial intelligence technologies in the instructional process (Ibrahim, 2019; Azmy et al., 2014), this study aims to design a computerized instructional module based on artificial intelligence and measure its impact on acquiring scientific concepts and developing critical thinking skills among seventh-grade female students through addressing the following questions:

Question 1: What is the effectiveness of an AI-based computerized instructional module in acquiring scientific concepts among seventh-grade female students?

Question 2: What is the effectiveness of an AI-based computerized instructional module in developing critical thinking among seventh-grade female students?

2. Literature Review

Google Classroom is typically a free, web-based platform developed by Google, designed to streamline managing, distributing, and grading assignments in educational settings. It integrates with other Google services such as Google Docs, Drive, Calendar, and Gmail, making it a powerful tool for teachers and students. Google Classroom constitutes a practical virtual setting for collaboration and participation, as it enables students and teachers to collaborate on projects and documents; for example, teachers can create an assignment directly within the platform, and students submit their work and obtain immediate feedback. This tool represents a qualitative addition to teaching and learning (Hassan and Talaba, 2018).

Al-Bawi (2019, p.54) defined Google Classroom as "an interactive educational environment that employs web technology and combines the features of electronic content management systems and social networking sites, enabling teachers to publish lessons, set assignments, implement educational activities, and communicate with learners through multiple technologies, such as work groups through which students and teachers exchange ideas and opinions, and share educational content among them, enabling the achievement of high-quality educational outcomes."

Google Classroom is designed to offer an integrated digital learning environment that enhances communication and fosters effective learning between teachers and students online, whether through disseminating educational materials, assignments, and instructions or providing feedback and individualised support. It enables the systematic organisation of classes through the efficient creation of digital classrooms, distributing educational resources, managing assignments and assessments, and promoting active and interactive learning by providing means for exchanging resources, ideas and comments between teachers and students. Additionally, it increases educational effectiveness by providing a flexible and innovative learning environment that allows teachers and students to use technology positively in the learning and teaching process.

Al-Qahtani (2017) identified the benefits of the Google Classroom application that can significantly benefit educators. These include its ease of setup; teachers can add students directly or share a specific code to join the class, thereby saving time. Furthermore, the Google Classroom Platform facilitates efficient preparation, review, and centralised access to assignments and assessments. Additionally, it enables efficient organization by automatically arranging study materials into Google Drive folders and allowing students to view their assignments on a dedicated assignments page. Likewise, Google Classroom improves collaboration by enabling teachers to provide real-time feedback and initiate discussions with students while students can work together by exchanging materials or answering questions.

Al-Samkary and Al-Jarrah (2018) identified the characteristics distinguishing Google Classroom from other applications. These characteristics include being a free online application allowing its users to access their classes and manage the educational process from anywhere and at any time and is based on cloud computing that enables users to upload files and access them from anywhere in the world without cost or special equipment while benefiting from all other cloud computing features. Google Classroom is compatible with all languages, including Arabic, and requires no special updates or subscriptions. It operates on all platforms, including Windows, Android, iPhone, and Web-based Windows Mobile. Teachers can use it to create announcements, schedule classes, download assignments, and complete them directly or by re-uploading them.

Many studies have addressed artificial intelligence and its impact on particular variables; for instance, Al-Mutairi et al.'s (2024) study aimed to develop scientific concepts among middle school students with learning difficulties by using simulation via artificial intelligence. The results revealed a statistically significant difference between the average scores of the research group in the pre-and post-applications favouring the post-application.

Al-Husseini et al. (2024) examined the effectiveness of the mind-mapping strategy supported by artificial intelligence applications in developing chemical literacy among secondary school students. The results confirmed the effectiveness of the mind-mapping strategy using artificial intelligence applications in developing chemical literacy and visual-spatial perception of female students.

Al-Qudah's (2023) study examined the effectiveness of artificial intelligence applications in acquiring scientific concepts, scientific tendencies, and innovative thinking among upper primary school students in Ajloun, employing the quasi-experimental approach. The results showed a statistically significant difference between the performance of the respondents in each dimension of the scientific concepts acquisition test, the scientific tendencies scale, and the innovative thinking test attributable to the teaching strategy variable favouring the experimental group who was taught using artificial intelligence applications (Kahoot application).

Using the descriptive and quasi-experimental approach, Taha et al. (2023) conducted a study that aimed to design a physics module based on artificial intelligence applications. A statistically significant difference in problem-solving skills was observed between the average scores of students in the experimental and control groups, favouring the experimental group.

Al-Otaibi et al. (2022) conducted a study to identify the role of artificial intelligence in developing critical thinking skills and scientific attitudes among second-year secondary school female students in the physics course using the quasi-experimental approach. The Results revealed that artificial intelligence significantly affects the development of critical thinking and its sub-skills. Artificial intelligence substantially impacts the development of scientific attitudes as a whole and its sub-fields.

Utilising the quasi-experimental approach, Al-Jariwi (2020) conducted a study to identify the impact of using artificial intelligence technology in the e-learning environment in developing future thinking skills and academic achievement in science among middle school students. The study concluded that using artificial intelligence technology in e-learning positively affects future thinking skills and academic achievement in science.

In the Republic of Korea, Shin & Shin (2020) conducted a descriptive study to investigate elementary science teachers' awareness of artificial intelligence applications, their knowledge of how to employ them in teaching, and their methods for applying them. The results showed that teachers' awareness of artificial intelligence applications was low, and science courses had the highest percentage through which artificial intelligence applications could be employed among elementary school courses, reaching 68.4% in the subjects of Earth and Space, 54.7% for exercise and energy, 32.6% for states of matter, and 27.4% for life.

Ghanem's (2016) study aimed to determine how sixth-grade pupils in public schools in the Tulkarm Governorate used Google apps to learn scientific topics and develop attitudes towards embracing technology. According to the data, the average achievement test scores of the children in the experimental and control groups did not differ statistically significantly.

The study of Al-Amour and Alimat (2016) sought to identify the impact of employing the Google Classroom platform on acquiring scientific concepts in the blood module among tenth-grade students in the Palestinian. The research adopted a quasi-experimental design. The results revealed statistically significant differences in the scientific concepts acquisition test, attributed to the instruction method favouring the experimental group. Google Classroom platform significantly impacts the acquisition of scientific concepts in the blood module.

Finally, we conclude that the previous studies were conducted in various educational environments. Still, they are similar to the current research in the methodology used, which is the quasi-experimental methodology. In comparison, they varied in terms of their variables, cognitive fields, and tools used, as some used tests and others used questionnaires. The efficiency of artificial intelligence apps in Jordan for learning scientific concepts and fostering critical thinking skills has not been previously determined, which sets the current study apart from earlier research. This study is, therefore, a recent development in the realm of educational research.

In alignment with contemporary instructional trends that emphasise the development of curricula and instruction methodologies, the positive features of artificial intelligence applications have recently granted significant attention from most researchers due to their proven effectiveness in developing education. These applications have demonstrated the potential to transform traditional teaching practices by addressing various challenges within the educational landscape. Given that teachers are in a unique position to develop and improve their teaching methods, therefore using AI-based educational software has become more and more popular. These resources are designed to help students grasp scientific ideas, cultivate various abilities, and develop thought patterns that encourage original problem-solving.

This is particularly relevant in science education, which involves many abstract concepts that require inference and critical thinking on the part of the learner. To overcome the educational environment's obstacles with all its elements, this study developed an instructional module in the science subject based on artificial intelligence. It is hoped to help female students acquire scientific concepts and critical thinking skills.

3. Methodology

3.1. Research Method

The experimental approach, including a quasi-experimental design, was used in this study. Two groups of seventh-grade female students were designed: an experimental group using an AI-based computerized instructional module and a control group using the traditional instructional method.

3.2. Participants

The study sample consisted of 48 seventh-grade female students from two classes at Kafr Al-Maa Secondary School for Girls, affiliated with the Directorate of Education for Al-Kura District, in the second semester of the 2024 academic year. The school was selected using the convenience method due to the availability of the necessary capabilities and resources, as well as the cooperation of the administrative and educational staff. Using the random assignment method, one class, including 21 female students, was selected as an experimental group that studied using an AI-based computerized instructional module, and the other, including 27 female students, was chosen as a control group that studied using the traditional method.

3.3. Data collection tools

3.3.1. Acquiring scientific concepts test

For designing this test, the researchers reviewed the theoretical literature and previous studies addressing acquiring scientific concepts (Nawafleh and Al-Omari, 2016; Al-Harahsheh, 2012). The test measures students' acquisition of the concept of "the module of light". The test was designed based on the objectives specified in the instructional material and the dimensions of acquiring concepts. In its initial form, it includes (25) multiple-choice statements distributed over five dimensions, with five items for each dimension: (determining the verbal meaning, discovering the scientific concept, interpreting observations, using the scientific concept in reasoning and generalization, using the scientific concept in solving problems). One correct answer was adopted from the four alternatives for each paragraph, so the maximum mark on the test is (25), and the minimum is (zero).

To confirm the test's validity, its original form was presented to a group of experienced, knowledgeable arbitrators in science curricula and teaching methodologies from several Jordanian universities, science instructors and educational supervisors to provide their feedback on the items, including their appropriateness, linguistic clarity, affiliation, and any other changes they thought necessary. After replacing three items, the number was reduced to twenty-five, and some were paraphrased in response to the arbitrators' feedback.

Difficult and discrimination coefficients were calculated for each item to verify the test's construct validity. Difficulty coefficients ranged between 0.36 and 0.64, which is acceptable and appropriate for this study (Awda, 2014). Discrimination coefficients ranged between 0.29 and 0.71. In light of this, items with discrimination coefficients less than 0.40 were improved and modified in terms of linguistic formulation, and alternatives for those items were reconsidered.

The tool was administered to a pilot sample of 20 female students with a two-week interval between the two applications. The Pearson reliability coefficient was calculated to measure the consistency of results between the two applications for each dimension of scientific concept acquisition individually and for the combined dimensions. The overall test reliability was 0.90, ranging between 0.79 and 0.89 for the dimensions. The internal consistency reliability coefficient (Cronbach's alpha) was also computed for each dimension individually and combined. The overall internal consistency reliability coefficient for the test was 0.95. The consistency reliability coefficient of the dimensions ranged between 0.90 and 0.94, indicating an acceptable score for the current study (Oudeh, 2014).

3.3.2. Critical thinking skills test

The test was designed after reviewing theoretical literature and previous studies on critical thinking skills (Al-Harbi, 2020; Al-Dabbas, 2018). The preliminary form of the test consisted of 25 items of the multiple-choice type, distributed over four areas, which are interpretation and analysis, inference, reasoning, and evaluation. The maximum score for the test is 25, and the minimum score is zero.

The test was presented in its initial version to a group of experienced arbitrators specialising in science curricula and teaching methods from Jordanian universities to verify the content validity of the tool. Some items were reformulated and replaced. The final form of the test comprises 25 items.

To verify the construct validity of the test and the suitability of its items, it was applied to a pilot sample of 20 female students. Then, the difficulty and discrimination coefficients were calculated for each item; the difficulty coefficients ranged between 0.43 and 0.71. The discrimination coefficients ranged between 0.29 and 0.71. The items with discrimination coefficients less than 0.40 were improved and modified regarding linguistic formulation, and the alternatives for those paragraphs were reconsidered (Oudeh, 2014).

The tool was applied to a pilot sample to check its reliability using the test-retest. The reliability coefficient (Pearson) was calculated between the results of the two applications for each critical thinking skill individually and for the skills combined. The overall value of the retest reliability coefficient for the test was 0.88, while the values of the retest reliability coefficients for critical thinking skills ranged between 0.71 and 0.79. The internal consistency coefficient (Cronbach's alpha) was also computed for each critical thinking skill individually and for the skills combined, and the overall score was 0.86. The values of the internal consistency coefficients for the dimensions of critical thinking skills ranged between 0.80 and 0.87, all of which are acceptable for the current study (Oudeh, 2014).

3.4. Educational material

The researchers selected the "Light" module from the seventh-grade science textbook. They redesigned it digitally using the Google Classroom platform, equipped with comprehensive tools that enhance the educational process. It is incorporated with various digital educational resources based on artificial intelligence technologies, such as interactive software, mobile apps, and educational games. It also offers several tools, including drawings, presentations, educational videos, and multiple detailed explanatory content created using a word processing program presented on a display screen. Additionally, it provides a direct assessment tool, facilitating a more engaging and accessible learning experience that considers students' individual differences.

The activities offered by the Google Classroom platform are based on several pillars and principles of artificial intelligence that accounted for the development of the educational module. The most prominent pillars include the following (Charlwood & Guenole, 2022):

- Data Analysis: The platform uses algorithms designed to analyze students' performance, determine their levels of understanding, and help teachers deliver content tailored to their needs.

- Customize: The platform allows for customising learning activities, such as choosing virtual experiments related to light, to suit different students' interests and levels.

- Instant Interaction: The app enables students to ask questions and interact with the teacher in real-time, enhancing their understanding of concepts such as the refraction of light and shadow.

Interactive Resources: The Google Classroom platform provides multiple resources, such as educational videos and simulations, that help students better visualize light phenomena.

- Self-Assessment: Students can use tools such as quizzes and interactive activities to assess their understanding of topics, encouraging them to take proactive steps to improve their level.

- Collaboration: The platform provides opportunities for group work, where students can collaborate on light-related projects, enhancing communication and teamwork skills.

A total of ten sessions were allocated to teaching the module "Light". The instructional techniques encompassed diverse activities, experiences, and skill-building activities, using various instructional and assessment methods. The module "Light" typically covered the basic concepts of light (the concept of light and its properties, the electromagnetic spectrum, light reflection, applications of light reflection, light refraction, lenses, white light analysis, images in mirrors, steps for drawing rays on a concave and convex mirror). The lessons were delivered through the Google Classroom platform, following these steps:

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- Planning and preparing lessons in advance: Lessons were prepared in advance, including instructional materials such as texts, presentations, and videos, to ensure that all necessary resources are available to students.

- Explaining lessons through interactive sessions: Lessons were implemented through live interactive sessions using tools such as Google Meet, where the teacher explained the concepts and answered students' questions.

- Assigning homework and tasks: homework and tasks were administered via Google Classroom after the conclusion of each lesson. These methods enable students to apply the concepts learned practically and complete the required activities at their own pace.

- Providing immediate feedback: The teacher reviews students' assignments and provides immediate feedback after submitting their assignments. This typically helps students correct their mistakes and improve their comprehension of the material.

- Organizing class discussions: Forums and discussions within Google Classroom were used to engage students in interactive discussions on lesson topics, which enhanced their understanding of the educational material.

- Using online tests: Online tests measure students' comprehension of the concepts taught while providing immediate results to analyze performance and improve academic performance.

The teacher's role is to comprehensively design the structure of the educational module in detail, including defining educational objectives, selecting appropriate resources and activities, and preparing the digital resources required to implement the module, such as educational videos, interactive content, and artificial intelligence-based software. Additionally, the teacher's role is to provide guidelines and technical support during the instructional process. This procedure assists learners in understanding concepts effectively and solving technical problems. Additionally, they monitor students' progress by tracking their performance and engagement with the educational materials, providing constructive feedback to enhance the overall learning experience.

Students' role involves active participation in the instructional activities and tasks assigned, interacting with the available digital resources and technical tools, and exploring the educational materials individually to deepen their understanding of scientific concepts. They are expected to use these concepts to solve real-world problems and daily life applications. Learners are also expected to respond effectively and critically to the educational materials and activities assigned and collaborate with their colleagues to achieve the established learning goals.

3.5. Study variables

Independent variable: The educational module has two categories: original and AI-based computerized instruction.

Dependent variables: included acquiring scientific concepts and critical thinking skills.

3.6. Procedures

Two groups of students were used, one of them represented an experimental group that studied the instructional module “light” based on artificial intelligence applications, while the second group represented a control group that studied the same instructional module as in the textbook. The concept acquisition test and the critical thinking test were applied on the two groups before and after teaching.

3.7. Data analysis

To answer the study questions, a one-way analysis of covariance test (ANCOVA) was used at the overall level for each test (Acquiring Scientific Concepts, Critical Thinking Skills). Also, the multiple-analysis of covariance test (MANCOVA) was used on the dimensions of each test.

4. Results

4.1. Results of the first question:

"What is the effectiveness of an AI-based computerized instructional module in acquiring scientific concepts among seventh-grade female students?"

The following null hypothesis emerged: "There is no statistically significant difference at the significance level (α=0.05) between the overall average scores of students in the experimental and control groups post-application of the test of acquiring scientific concepts and on each of its dimensions." This question was answered, and its hypothesis was tested as follows:

A. At the overall level of the scientific concepts acquisition test:

Averages, standard deviations of the pre and post-test, and adjusted post-performance on the overall scientific concepts acquisition test were calculated according to the educational module used, as shown in Table (1).

Table1. Results of averages and standard deviations of the pre and post-test and adjusted post-performance on the overall scientific concepts acquisition test, according to the educational module used

Instructional Module	Pre-test		Post-test		adjusted	
	averages	Std.	*averages*	Std.	*Adjusted averages*	Standard error
Conventional Module	14.70	2.20	14.59	2.12	14.57	0.37
AI-based Module	14.62	2.09	22.05	2.33	22.07	0.42

Table 1 reveals a significant difference between the pre- and post-averages of the performance of the experimental group taught using a computerized educational module designed with artificial intelligence and a significant difference between the post-averages of the performance of both groups (control and experimental). To identify the statistical significance of the post-averages, after neutralising the pre-averages of the performance of the two groups on the overall test, the accompanying one-way analysis of variance (ANCOVA) was used, as presented in Table 2.

Table 2. Results of the One-Way ANCOVA

Source of variance	Sum of square	Degree of freedom	Mean of squares	F value	P value	Effect size
Pre-test (accompanied)	57.045	1	57.045	15.241		
Instructional Module	663.990	1	663.990	**177.405*	*0.000*	*0.798*
Error	168.426	45	3.743			
Adjusted total	881.979	47				

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The value of the statistical significance of the instructional module reached (0.000), which is less than (α=0.05), indicating the rejection of the null hypothesis at the overall concept acquisition test, i.e. there is a statistically significant difference at (α=0.05) between the averages of the study individuals' performance in acquiring scientific concepts test attributed to the impact of the instructional module used. Results of the averages in Table (1) demonstrated a significant difference in favor of the experimental group, which was taught using an AI-based computerized instructional module. The value of the effect size reached (0.798), indicating that (79.8%) of the variance (improvement) in the post-test combined is due to the use of an AI-based computerized instructional module.

B. At the level of the scientific concepts acquisition test dimension

The averages and standard deviations of the pre- and post-test and adjusted post-performance were calculated in each dimension of acquiring scientific concepts (identifying verbal meaning, discovering the scientific concept, using the scientific concept in reasoning and generalization, interpreting observations, and using the scientific concept in solving problems). The results are presented in detail in Table 3.

Table 3. Averages and standard deviations of the pre and post-test and adjusted post-performance in each dimension of the test

Dimensions	Instructional module	Pre-test		Post-test		Adjusted	
		averages	Std.	averages	Std.	Adjusted averages	Standard error
identifying verbal meaning	Original module	5.52	1.28	5.33	1.24	5.22	0.22
	AI-based	5.19	0.87	7.52	1.44	7.67	0.26
	total	5.38	1.12	6.29	1.71		
discovering the scientific concept	Original module	2.15	1.03	2.15	0.99	2.21	0.14
	AI-based	2.43	0.98	3.67	0.66	3.59	0.16
	total	2.27	1.01	2.81	1.14		
using the scientific concept in reasoning and generalisation	Original module	2.74	1.29	2.74	1.16	2.75	0.15
	AI-based	3.00	1.00	4.62	0.67	4.60	0.17
	total	2.85	1.17	3.56	1.35		
interpreting observations	Original module	2.96	1.29	3.07	1.24	3.08	0.15
	AI-based	3.05	0.97	4.57	0.60	4.57	0.17
	total	3.00	1.15	3.73	1.25		
using the scientific concept to solve problems	Original module	1.33	0.73	1.30	0.67	1.21	0.10
	AI-based	0.95	0.67	1.67	0.58	1.77	0.12
	total	1.17	0.72	1.46	0.65		

Data in Table (3) reveals significant differences between the pre- and post-averages of the performance of the experimental group who were taught using a computerized educational module, and also significant differences between the post-averages of the performance of both groups (control and the experimental). One-way MANCOVA was utilized to determine the statistical significance of the post-averages differences after neutralizing the differences in the pre-averages of the performance of both groups in each dimension of the test. Results are presented in Table 4.

Table 4. Results of the one-way MANCOVA of the averages of the post-test of the computerized module

Source of variance	Skills	Sum of square	Degree of freedom	Mean of squares	F value	P value	Effect size
Accompanied (identifying verbal meaning/ pre)	identifying verbal meaning	26.944	1	26.944	21.223		
	discovering the scientific concept	0.035	1	0.035	0.073		
	reasoning and generalisation	0.003	1	0.003	0.005		
	interpreting observations	0.136	1	0.136	0.250		
	Problem-solving	0.186	1	0.186	0.709		
Accompanied (discovering the scientific concept/ pre)	identifying verbal meaning	0.150	1	0.150	0.118		
	discovering the scientific concept	11.030	1	11.030	22.671		
	reasoning and generalization	1.210	1	1.210	2.121		
	interpreting observations	0.038	1	0.038	0.069		
	Problem-solving	0.001	1	0.001	0.005		
Accompanied (reasoning and generalization/pre)	identifying verbal meaning	0.693	1	0.693	0.546		
	discovering the scientific concept	0.179	1	0.179	0.368		
	reasoning and generalization	12.540	1	12.540	21.989		
	interpreting observations	0.267	1	0.267	0.491		
	Problem-solving	0.918	1	0.918	3.504		
Accompanied (interpreting observations/ pre)	identifying verbal meaning	0.002	1	0.002	0.001		
	discovering the scientific concept	1.031	1	1.031	2.119		
	reasoning and generalization	1.022	1	1.022	1.791		
	interpreting observations	20.086	1	20.086	36.839		

Source of variance	Skills	Sum of square	Degree of freedom	Mean of squares	F value	P value	Effect size
	Problem-solving	0.201	1	0.201	0.767		
Accompanied (Problem-solving/pre)	identifying verbal meaning	0.083	1	0.083	0.066		
	discovering the scientific concept	0.139	1	0.139	0.286		
	reasoning and generalization	0.167	1	0.167	0.294		
	interpreting observations	0.143	1	0.143	0.262		
	Problem-solving	6.657	1	6.657	25.419		
Instructional module Hotelling's Trace=3.970 p = 0.000*	identifying verbal meaning	61.081	1	61.081	**48.111*	*0.000*	*0.540*
	discovering the scientific concept	19.267	1	19.267	**39.599*	*0.000*	*0.491*
	reasoning and generalization	34.528	1	34.528	**60.542*	*0.000*	*0.596*
	interpreting observations	22.381	1	22.381	**41.049*	*0.000*	*0.500*
	Problem-solving	3.143	1	3.143	**12.003*	*0.001*	*0.226*
Error	identifying verbal meaning	52.053	41	1.270			
	discovering the scientific concept	19.948	41	0.487			
	reasoning and generalization	23.383	41	0.570			
	interpreting observations	22.354	41	0.545			
	Problem-solving	10.737	41	0.262			
Adjusted total	identifying verbal meaning	137.917	47				
	discovering the scientific concept	61.313	47				
	reasoning and generalization	85.813	47				
	interpreting observations	73.479	47				
	Problem-solving	19.917	47				

Results in Table (4) exhibit that the statistical significance value of the Hotelling's Trace test according to the instructional module variable reached (0.000), indicating that it is less than (α=0.05); accordingly, there is a statistically significant difference in at least one of the dimensions of acquiring scientific concepts test attributed to the instructional module used.

A one-way analysis of variance was conducted to identify the impacted dimension. It is also used to identify the effect of the instructional module on each dimension of acquiring scientific concepts test (determining verbal significance, discovering the scientific concept, using the scientific concept in reasoning and generalization, interpreting observations, using the scientific concept in solving problems).

Furthermore, an effect of the instructional module was observed on all dimensions at the significance level (α=0.05), refuting the null hypothesis related to the dimensions, and the differences were in favour of the experimental group studied using artificial intelligence. The effect size for the dimension (determining verbal significance) was (0.540), for the dimension (discovering the scientific concept) (0.491), for the dimension (using the scientific concept in reasoning and generalization) (0.596), for the dimension (interpreting observations) (0.500), and for the dimension (using the scientific concept in solving problems) (0.226), all of which indicate that the percentage of variance (improvement) in the performance of the individuals in each dimension is due to the use of an AI-based computerized instructional module. This result reveals a positive effect of artificial intelligence-based instruction on enhancing the acquisition of scientific concepts among the students of the experimental group.

4.2. Results of the second question:

“What is the effectiveness of an AI-based computerized instructional Module in developing critical thinking among seventh-grade female students?”

The following null hypothesis emerged: "There is no statistically significant difference at (α=0.05) between the averages of the respondents' performance in critical thinking skills test combined and of each skill attributed to the educational module employed."

A. **Critical thinking skills combined:**

The combined averages and standard deviations of the pre-and post-test and adjusted post-performance in the critical thinking skills test were calculated as shown in Table (5).

Table 5. Averages and standard deviations of the pre and post-test and adjusted post-performance in critical thinking skills combined

Instructional module	Pre-measure		post-measure		Post- adjusted	
	Average	Std	Average	Std	Average	Std
Original module	8.85	1.29	9.22	1.37	9.39	0.21
AI-based	9.81	1.66	14.76	0.89	14.55	0.23

Table (5) shows a significant difference between the pre and post-averages of the experimental group's performance using an AI-based computerized instructional module and a significant difference between the performance of both groups: the control and the experimental. The One Way ANCOVA was used to determine the statistical significance of the differences after neutralizing the pre-averages of both groups on critical thinking skills combined. The results are presented in Table 6.

Table 6. Results of the One Way ANCOVA of the post-test for critical thinking skills combined

Source of variance	Sum of square	Degree of freedom	Mean of squares	F value	P value	Effect size
Pre-test (accompanied)	15.369	1	15.369	14.083		
Instructional Module	283.576	1	283.576	**259.857*	*0.000*	*0.852*
Error	49.108	45	1.091			
Adjusted total	426.979	47				

It is noted from Table 6 that the value of the statistical significance of the instructional module reached (0.000), which is less than (α=0.05), which indicates the refutation of the null hypothesis regarding the combined e-learning skills, which states: "There is no statistically significant difference at (α=0.05) between the averages of the performance in the combined critical thinking skills attributed to the instructional module used." Table 5 reveals that the statistically significant difference was in favor of the performance of the experimental group taught using a computerized instructional module using artificial intelligence. The effect size reached (0.852), indicating that (85.2%) of the variance (improvement) in the post-performance is due to the use of a computerized instructional module using artificial intelligence.

Critical thinking skills level alone

The averages and standard deviations of the pre-and post-test and adjusted post-performance were calculated for each critical thinking skill (interpretation, inference, reasoning, and evaluation), as shown in Table 7.

Table 7. Averages and standard deviations of the pre and post-test and adjusted post-performance each critical thinking skill

Skill	Instructional module	Pre-test		Post-test		Adjusted	
		Average	Std	Average	Std	Adjusted average	Standard error
Interpretation	Original module	2.07	0.62	2.07	0.62	2.01	0.07
	AI-based	1.95	0.59	2.71	0.46	2.79	0.08
	total	2.02	0.60	2.35	0.64		
Inference	Original module	2.74	1.13	2.85	1.20	2.89	0.13
	AI-based	2.86	0.96	4.24	0.70	4.19	0.14
	total	2.79	1.05	3.46	1.22		
Reasoning	Original module	2.07	0.96	2.30	0.87	2.34	0.12
	AI-based	2.67	1.35	4.90	0.44	4.85	0.14
	total	2.33	1.17	3.44	1.49		
Evaluation	Original module	1.96	1.13	2.00	1.07	2.09	0.11
	AI-based	2.33	0.97	2.90	0.30	2.79	0.13
	total	2.13	1.06	2.40	0.94		

Table (7) exhibits significant differences between the averages of the pre- and post-test of the experimental group members who were taught using a computerized module, and there are significant differences between the post-averages of the performance of both groups; the control and the experimental. One Way MANCOVA was used to determine the statistical significance of the differences and, after neutralizing the differences in the pre-averages of the performance of both groups in each of the critical thinking skills. Table (8) presents details.

Table 8. Results of the one-way MANCOVA analysis of the post-test measuring the critical thinking skills

Source of variance	Skills	Sum of square	Degree of freedom	Mean of squares	F value	P value	Effect size
Accompanied (pre-interpretation)	Interpretation	5.809	1	5.809	42.709		
	inference	0.028	1	0.028	0.071		
	Reasoning	0.140	1	0.140	0.359		
	Evaluation	0.213	1	0.213	0.671		
Accompanied (pre- inference)	Interpretation	0.351	1	0.351	2.583		
	inference	23.981	1	23.981	60.087		
	Reasoning	0.298	1	0.298	0.766		
	Evaluation	0.060	1	0.060	0.189		
Accompanied (pre-reasoning)	Interpretation	0.079	1	0.079	0.579		
	inference	0.010	1	0.010	0.024		
	Reasoning	4.209	1	4.209	10.802		
	Evaluation	0.013	1	0.013	0.039		
Accompanied (pre-evaluation)	Interpretation	0.243	1	0.243	1.786		
	inference	0.007	1	0.007	0.017		
	Reasoning	0.723	1	0.723	1.857		
	Evaluation	15.284	1	15.284	48.072		
Instructional module Hotelling's Trace=7.365.p=0.0 *00	Interpretation	6.195	1	6.195	**45.545*	*0.000*	*0.520*
	inference	17.432	1	17.432	**43.679*	*0.000*	*0.510*
	Reasoning	64.793	1	64.793	**166.282*	*0.000*	*0.798*
	Evaluation	4.974	1	4.974	**15.646*	*0.000*	*0.271*
Error	Interpretation	5.713	42	0.136			
	inference	16.762	42	0.399			
	Reasoning	16.366	42	0.390			
	Evaluation	13.353	42	0.318			
Adjusted total	Interpretation	18.979	47				
	inference	69.917	47				
	Reasoning	103.813	47				
	Evaluation	41.479	47				

**Statistically significant at (α = 0.05)*

Results presented in Table (8) reveal that the statistical significance value of the Hotelling's Trace test for the educational module variable reached (0.000), which is less than (α=0.05). This suggests a statistically significant difference in at least one of the critical thinking skills attributed to the instructional module used. To identify which critical thinking skill was influenced by the educational module, a one-way analysis of variance (ANOVA) was conducted. The results revealed that the

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statistical significance value of the effect of the instructional module at each skill level reached (0.000), which is less than (α=0.05), indicating the rejection of the null hypothesis related to thinking skills alone.

From table (7), it is clear that the statistically significant difference favoured the performance of the experimental group who were taught using an AI-based computerized instructional Module in each skill, as the value of the effect size for the skill (interpretation) reached (0.520), for the skill (inference) (0.510), for the skill (reasoning) (0.798) and the skill (evaluation) (0.271); all of which indicate that the percentage of variance (improvement) in the performance of the study members after each skill is due to the use of an AI-based computerized instructional Module.

5. Discussion

5.1. Discussion of first question (Acquiring Scientific Concepts)

This result may be attributed to the fact that the Google Classroom platform is characterized by a number of positive features, including the effective organization of educational content, which facilitates students' access to educational materials and assignments at any time and from anywhere. The platform also offers an interactive platform for instant communication between the teacher and students. This feature typically enhances interaction and provides an opportunity to solve problems immediately. It also includes an evaluation and immediate feedback feature, which allows the teacher to follow up on students' progress and provide the necessary guidance to improve their performance.

In addition, Google provides integrated apps enabling users to organize their files and projects more efficiently. The recording lessons feature also allows students to review lessons at any time, which supports continuous learning and helps them understand scientific concepts more deeply. The application also enhances collaborative learning by providing tools for group projects and sharing ideas. Google applications generally contribute to providing a comprehensive and flexible educational experience that meets students' individual needs and helps them acquire scientific concepts in innovative and effective ways and at their own pace.

In the study of science, especially within the "Light" module, which embraces multiple concepts such as reflection, refraction, mirrors and their types, characteristics of rays, and others, the Google Classroom platform considerably enhances students acquisition of scientific concepts through the use of virtual simulations and interactive tools. The Google Classroom platform typically allows learners to explore how light works and interacts with different objects practically and directly. Learners could also conduct virtual experiments, enhancing their understanding of light phenomena more deeply and broadly. For example, students used the simulation to examine how light reflects on different mirrors and the effect of refraction angles on light transmission. This direct and experimental interaction is not provided by traditional learning, which makes learning more enjoyable and effective.

The computerized module also offers additional educational tools such as videos, presentations, search engines, interaction with the teacher, and tests, all of which contribute to improving the learning experience and better understanding of scientific concepts. The presentation tool enables users to organize and present information logically and in an organized manner. The teacher can create interactive presentations containing images, graphs, and text slides to explain light concepts simply and straightforwardly. Videos are a good way to define and present scientific concepts visually and quickly. The computerized module encompasses a variety of educational videos that illuminate light concepts interactively and interestingly. Moreover, search engines enable learners to explore related scientific information quickly and access reliable sources and high-quality educational materials on light topics to expand their understanding of concepts by researching multiple sources.

This result is also attributed to the computerized module providing spaces for direct interaction with the teacher via live chat, email, or social media platforms. This typically allows students to ask questions and obtain additional guidance from the teacher. The computerized module also offers interactive assessment tests that help identify students' strengths and weaknesses and guide them to improve, leading to them acquiring better concepts.

The findings can also be explained by the fact that the computerized module provided an interactive and inspiring learning environment that encouraged interaction and exploration, as it relied on advanced technologies such as artificial intelligence and augmented reality to provide realistic and stimulating educational experiences for students. With the help of the computerized module, learning can be tailored to meet the needs of each student, ensuring that they gain a solid and long-lasting comprehension of scientific topics. The computerized educational module improved students' critical thinking and practical skills, allowing them to engage directly with instructional materials and apply theoretical ideas in real-world settings.

Furthermore, the educational module presented students with challenging and rigorous learning scenarios that required them to use the resources to come up with adequate answers. These module s have features that make them an effective tool for improving the learning process, and their advanced capabilities allow them to combine individual customisation with technical innovation to provide an exceptional learning experience. This represents a qualitative shift in the field of education. By encouraging students to learn independently and fostering an exploratory attitude, clever computerized educational devices help learners develop their talents and succeed in various spheres of life.

However, the findings of this research are consistent with the results of Al-Qudat (2023), which found statistically significant differences between the average scores of students in acquiring scientific concepts, attributed to the use of artificial intelligence apps (Kahoot application) favouring of the post-application, and the study of Al-Jariwi (2020), which concluded that the use of artificial intelligence technology in the e-learning environment had a positive impact on the development of both: future thinking skills and academic achievement in science.

5.2. Discussion of second question (Acquiring Critical Thinking Skills)

This result may be attributed to the fact that the AI-based computerized instructional module provided interactive and innovative learning experiences that encouraged students to think deeply and analytically about various aspects of the concept of light by providing diverse and innovative educational content that enabled students to understand the concepts of light in different ways. Interactive technologies and virtual simulations allow students to explore and understand optical phenomena in depth, enhancing their ability to interpret them accurately and comprehensively. The computerized educational module also developed students' analytical skills by providing exercises and applied activities that required them to analyze data and results and infer causal and symmetrical relationships between various optical phenomena. The analytical tools in the computerized module enable students to acquire the skills necessary to analyze data accurately and effectively.

In the domain of "interpretation and analysis", the Google Classroom platform provided comprehensive educational content that facilitated students to recognize how light works and interacts with different objects. Students were able to examine how light affects mirrors and other objects and comprehend how light is reflected and refracted using the information at hand, thanks to interactive media and virtual simulations. Students were able to use the clever application to deduce rules and patterns in the behaviour of light by using the evidence and observations they gathered from virtual experiments. For example, they can use data on angles of reflection and refraction to confirm their hypotheses about the behavior of light in different conditions. In observation and evaluation, the smart application enabled students to use virtual experiments and data to accurately monitor and evaluate light interactions. Regarding the teacher, this tool allowed them to use these observations to give prompt feedback, which aids students in better comprehending the course material.

The AI-based computerized module also enables female students to develop their reasoning skills, as it provides students with the opportunity to use the information and data available to them to infer possible outcomes and extract basic laws and concepts in the field of light through practical learning experiences and virtual simulations, which enabled students to apply the concepts they learned and infer results based on practical experiences.

The computerized educational module also provided multiple opportunities for students to use logic and reasoning to solve light-related problems through challenges and interactive games, which helped students learn how to use logic to analyze light phenomena and reach correct solutions logically and scientifically.

Compared to conventional learning methods, the AI-based computerized module is remarkably proven to develop critical thinking. In traditional methods, learning is typically practiced through two skills, namely listening and reading. Students rarely engage in interactive learning and practical discussions that encourage critical thinking. Additionally, students are not inspired to analyse or reason. In contrast, the AI-based computerized instructional module facilitates students' access to educational resources and interacts with academic content in innovative and collaborative ways. It also plays a key role in stimulating creative thinking by allowing students to engage in practical experiments, acquire experience, explore phenomena themselves, and obtain immediate evaluation. This fundamentally supports students' deep understanding and comprehensive comprehension, as well as their performance and more profound comprehension of the subject.

As a result, the computerized instructional module offers a more engaging and dynamic learning environment than conventional teaching techniques, which helps students develop their critical thinking abilities. This study supported the findings of Al-Otaibi et al. (2022), which demonstrated that artificial intelligence affects the development of critical thinking and its sub-skills.

6. Conclusion

The study concludes the importance of using smart applications in education, especially in the field of science teaching, due to their significant impact on achieving interactivity and practical experience, which contributes to enhancing students' understanding and motivating them to discover more scientific concepts innovatively and enjoyably and developing their critical thinking. The use of Google Classroom is in line with contemporary global trends in the need to enrich science curricula with artificial intelligence technologies. This application helped students learn independently and encouraged them to research, contemplate, and think through its interactive software, mobile applications, educational games, and explanatory notes.

6.1. Limitations

The study focused on one specific region in Jodan. Replicating this study in other regions with similar diverse population participation could be considered beneficial. Also, the generalization of the study results is limited to the extent of the accuracy of the lesson design according to the artificial intelligence apps strategy, the design of the tools used and their validity and reliability, and the extent of the seriousness of the study sample members in responding to the study tools.

7. Recommendations and Suggestions

Based on the results of the study, it recommends the ministry of education to train educators, offer ongoing assistance in using smart applications in the classroom efficiently, and create interactive learning opportunities that promote active engagement. Those in charge of modifying and creating curricula are expected to provide instructional materials that facilitate the integration of smart applications into the learning process and are suitable for their use. Encourage cooperation between the Ministry of Education and companies academic and research institutions to develop smart applications that meet the needs of the educational environment and enhance the quality of education. Conducting more research on issues regarding artificial intelligence platforms not addressed in this study and investigating the impact of their use in teaching on other dependent variables.

Declarations

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