

Research Article

Cite this article: Rababa, H., & Al-Omari, A. (2025). Basic-Stage Students' Acquisition of Scientific Concepts in Light of Teachers' Use of Artificial Intelligence Applications. *Educational Process: International Journal*, 17, e2025405.
<https://doi.org/10.22521/edupij.2025.17.405>

Received 21 June, 2025

Accepted August 13, 2025

Published Online August 24, 2025

Keywords: Scientific concepts acquisition, basic-stage students, Artificial Intelligence

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Basic-Stage Students' Acquisition of Scientific Concepts in Light of Teachers' Use of Artificial Intelligence Applications

Hamza Rababa , Ali Al-Omari

Abstract

Background/purpose. This study aimed to measure the level of scientific concepts acquisition among basic-stage students in light of their teachers' use of artificial intelligence (AI) applications.

Materials/methods. A scientific concepts acquisition test was developed to collect data. The study sample consisted of 396 tenth-grade students, selected using stratified random sampling from Irbid.

Results. The results showed that the level of scientific concept acquisition among students, in the context of their teachers' use of AI applications, was "moderate" at both the advanced and intermediate levels, while it was "low" at the weak level. These results may be attributed to the fact that advanced use of AI does not necessarily imply effective or pedagogically sound use. The results indicated a statistically significant difference in the level of scientific concept acquisition in favor of the intermediate level compared to both the weak and advanced levels, while no significant differences were recorded between the weak and advanced levels.

Conclusion. The study recommends integrating AI applications into science teaching to enhance basic-level students' acquisition of scientific concepts.

1. Introduction

Technology and AI applications have influenced all aspects of life, especially education. The rise of AI and the global shift toward technologies such as the Internet of Things in education—accelerated by school closures during the COVID-19 pandemic—necessitate developing learning management systems and support tools. AI plays a key role in education, but its effectiveness depends heavily on how competently teachers use it. AI applications are defined as computerized systems that simulate human intelligent behavior to solve problems and make decisions. Teachers must actively involve learners in designing learning activities, especially in science, and adopt strategies that suit different learning styles. Teaching science aims to connect new scientific ideas to real-life applications, fostering deep understanding and concept acquisition.

Scientific concepts form the foundation of knowledge in science education. Developing these concepts requires clear definitions, illustrative examples, and varied instructional approaches. Challenges in acquiring scientific concepts often arise from traditional teaching methods. To overcome this, studies have highlighted effective strategies like using diagrams and visual aids to clarify conceptual relationships. Scientific concepts are fundamental in science education, as they enhance understanding and promote students' cognitive growth. They help facilitate information retention and enable meaningful connections between phenomena. Amoosh (2023, p. 1033) emphasized that scientific concepts play a crucial role in organizing knowledge meaningfully and represent a core objective in science teaching due to their impact on learners' comprehension and cognitive development.

Learning scientific concepts also relies on students' prior experiences and their ability to make meaningful connections between different scientific concepts (Al-Salmiya & Ambusaidi, 2021, p. 523). The level of teachers' understanding of scientific concepts has been considered one of the main factors determining what is taught in science classes and how it is taught (Abed, 2009, p. 188).

The study is built on this rationale to examine how AI applications used by teachers influence students' understanding of scientific concepts. Acquisition is defined as "a mental process aimed at forming a mental image of a set of educational stimuli that can be generalized to new learning situations" (Al-Saydawy & Ismail, 2021, p. 4232). Zeitoun (2003) emphasized the importance of diversifying teaching methods for concepts and using educational technology to connect new concepts with prior knowledge. Amidst the technological revolution, AI applications have proven effective in supporting the acquisition of scientific concepts, such as virtual laboratories (Tsihouridis et al., 2020) and electronic portfolios (Habeeb, 2019), due to their visual effects that aid concept formation. Barriers to acquiring scientific concepts include curriculum overload, which confuses learners, difficulties in mastering previous concepts that hinder learning new ones, reliance on traditional teaching methods, and ineffective assessment strategies (Rajab, 2012, p. 2).

The Jordanian curricula have undergone revisions and development across all educational stages. As a result, several difficulties have emerged in teaching academic subjects, especially science. Al-Jawda and Al-Kaabneh (2024) and Al-Samaki's (2017) studies have indicated various problems in students' achievement and challenges in math and science subjects, based on international assessment results such as PISA and TIMSS. These results reflect the urgent need for educators to employ strategies that develop students' conceptual understanding. Teachers are also expected to participate in preparing a generation that is educationally and practically competent. This goal can only be achieved by enabling students to take responsibility for their own learning through the use of AI applications. This is supported by studies such as Mohamed (2023), which demonstrated the impact of AI applications in enhancing educational strategies and their role as effective tools in developing traditional teaching approaches—one of the main challenges in knowledge advancement within learning environments, enabling learners to be better prepared for real-life roles.

With the growing expansion in the use of AI applications in education, the need has arisen to understand their impact on learning, particularly on the development of scientific concept acquisition among students. The level of teachers' use of these applications may directly affect their acceptance or rejection in classrooms. Positive use may encourage adopting methods that enhance individual student engagement and provide meaningful scientific experiences, while limited use may hinder the connection between theory and practice, thereby weakening deep understanding of scientific knowledge. Despite the widespread adoption of such applications, few studies have explored the effectiveness of AI in enhancing this educational aspect—especially for basic-stage students.

Accordingly, the problem of this study lies in investigating the impact of teachers' use of AI applications on students' level of scientific concept acquisition. This prompted the researcher to raise questions about the utility of these tools in improving educational quality and developing students' scientific understanding. Hence, the study's central research question is:

- What is the level of scientific concept acquisition among basic-stage students in light of their teachers' use of artificial intelligence applications?

From this main question, the following two sub-questions emerge:

- What is the level of scientific concept acquisition among basic-stage students based on their teachers' use of AI applications (advanced/intermediate/weak)?
- Does the level of scientific concept acquisition among students differ according to the level of their teachers' use of AI applications (advanced/intermediate/or weak)?

The theoretical significance of this study lies in being, to the best of the researcher's knowledge, one of the first studies to examine scientific concept acquisition in relation to teachers' level of AI application use (advanced, intermediate, weak). It is also important for enriching knowledge about the variation in students' acquisition of concepts based on the extent of AI integration in education. Therefore, this study offers a modern theoretical framework that can contribute to a more precise understanding of how AI can be utilized to enhance students' educational and scientific abilities.

Practically, this study attempts to provide evidence-based recommendations for researchers and policymakers in the Ministry of Education regarding the effectiveness of AI applications in enhancing scientific concept acquisition among basic-stage students. Additionally, the study can assist teachers in improving their instructional strategies using modern technology. It also benefits students and researchers in promoting the significance of using AI in education and keeping pace with the modern technological revolution. The study also provides researchers with a suitable measurement tool—the Scientific Concept Acquisition Test.

2. Literature Review

Previous studies have paid considerable attention to the topic of acquiring scientific concepts. Harahsheh (2019) investigated the effect of the WebQuest strategy on acquiring scientific concepts and enhancing creative thinking skills among sixth-grade female students in Al-Mafraq, Jordan. To achieve the study's goals, the author used a scientific concept acquisition test and a creative thinking test, along with a teacher's guide for implementing the WebQuest strategy. A purposive sample of 65 students was selected during the first semester of the 2015/2016 academic year. The students were divided into two groups: 33 students were taught using the WebQuest strategy, while 32 were taught using the traditional method. The results showed a statistically significant difference in favor of the experimental group.

Al-Hosani and Al-Balushi (2023) investigated the effect of a gamification-based mobile application on the acquisition of scientific concepts among fourth-grade students in Oman during the COVID-19 pandemic. The quasi-experimental design was used, with 108 students divided into an

experimental group (55 students) and a control group (53 students). A mobile app named *Dr. Science*, based on gamification principles, was designed and used with the experimental group. The results showed statistically significant differences in the post-test in favor of the experimental group, while no significant interaction effect was found between teaching method and gender.

Al-Osaimi's (2023) study aimed at identifying the effectiveness of using the Stepan's model in science teaching on the acquisition of scientific concepts in Mecca. The study targeted third intermediate-grade students and used the experimental method with a sample of 63 students randomly assigned to control and experimental groups. Results showed statistically significant differences ($\alpha = 0.05$) in favor of the experimental group in concept acquisition and productive thinking.

Tamas (2023) carried out a study aiming to explore the use of augmented reality technology in acquiring scientific concepts among fourth-grade female students in Jerusalem. A quasi-experimental method was used, and the sample was randomly divided into control and experimental groups, each consisting of 26 students. Equivalence was ensured based on academic performance and age. A pre-/post-achievement test was developed with the help of a science teacher. The results revealed statistically significant differences in favor of the experimental group.

Al-Mutairi et al.'s (2024) study aimed to develop scientific concepts among middle school students with learning difficulties using an AI-based simulation. The research group included 32 students. The tools included a concept acquisition test administered pre- and post-instruction. Instruction was carried out using an AI simulation program. The results showed statistically significant differences ($p < 0.01$) in favor of the post-test scores.

Ajlouni (2024) examined the effectiveness of an instructional program (IP) based on robotics and multimedia in developing scientific concepts during the 2019/2020 academic year. The study aimed to explore the impact of this program on concept acquisition and motivation toward science learning among fifth-grade female students. A sample of 75 students from university-affiliated schools was randomly divided into three groups: two experimental groups (one taught using robotics and multimedia, the other with multimedia only) and a control group. The results showed statistically significant differences ($\alpha = 0.05$) in favor of the experimental groups, especially the one using robotics, indicating the positive impact of enhanced programs on both concept acquisition and student motivation.

In light of the study's theoretical framework and a review of previous studies related to the acquisition of scientific concepts, it becomes evident—based on the researcher's knowledge—that there is a scarcity of studies that have addressed this variable in relation to teachers' varying levels of use of artificial intelligence applications. This highlights the research gap that this study aims to address. Thus, the study seeks to provide a deeper understanding of the level of scientific concept acquisition in light of teachers' use of artificial intelligence applications.

3. Methodology

3.1. Study Design

The descriptive survey method was employed as it is suitable for the nature of the study, which investigates the level of scientific concept acquisition among basic-stage students in light of their teachers' use of AI applications.

3.2. Population and Sample of the Study

The study population consisted of tenth-grade students in schools under the Directorate of Education of Irbid - 2024/2025. The study sample included 396 students randomly selected.

3.3. Instrument of the Study

The Scientific Concept Acquisition Test was developed for students based on Unit Four in the tenth-grade chemistry curriculum (Reactions and Chemical Calculations). The test comprised 25 items aligned with Zeitoun's (2013) standards for measuring concept acquisition: defining verbal meaning, interpreting observations, applying the concept in problem-solving, using the concept in inference and generalization, and discovering the scientific concept.

3.4. Validity of the Scale

The content validity of the test was verified by presenting it to a panel of experts and specialists, including faculty members in science curricula and teaching methods, as well as science teachers with bachelor's, master's, and doctoral degrees, and educational supervisors. They were asked to evaluate the clarity, linguistic accuracy, and appropriateness of each item according to the stated standards. Based on their feedback, linguistic modifications were made. Difficulty and discrimination indices for the test items were also calculated, as shown in Table 1:

Table 1. Difficulty and Discrimination Indices for the Scientific Concept Acquisition Test Items

Item	Difficulty Index	Discrimination Index	Item	Difficulty Index	Discrimination Index
1	0.57	0.37	14	0.80	0.33
2	0.40	0.40	15	0.67	0.43
3	0.57	0.20	16	0.60	0.40
4	0.53	0.33	17	0.60	0.43
5	0.63	0.40	18	0.80	0.27
6	0.57	0.70	19	0.70	0.47
7	0.53	0.30	20	0.30	0.43
8	0.73	0.20	21	0.60	0.37
9	0.57	0.40	22	0.67	0.47
10	0.60	0.40	23	0.80	0.43
11	0.57	0.33	24	0.60	0.60
12	0.67	0.20	25	0.63	0.43
13	0.87	0.33			

The table shows that the difficulty indices ranged between 0.40 and 0.87, and discrimination indices ranged between 0.20 and 0.70. According to Odeh (2014), acceptable ranges for difficulty and discrimination indices fall between 0.20 and 0.80, indicating that the test was appropriate for application to the study sample.

The Pearson correlation coefficient was calculated between the score on each item, the total test score, and the subscale to which each item belongs in the Scientific Concept Acquisition Test as shown in Table 2.

Table 2. Pearson Correlation Coefficients Between Item Scores, Subscale Scores, and Total Test Scores

Item	Correlation with Subscale	Correlation with Total Score	Item	Correlation with Subscale	Correlation with Total Score
1	.716**	.381*	14	.454*	.313*
2	.373*	.369*	15	.703**	.687**
3	.669**	.488**	16	.674**	.393*
4	.745**	.530**	17	.787**	.447*
5	.571**	.664**	18	.306*	.368*
6	.571**	.488**	19	.420*	.445*
7	.803**	.583**	20	.480**	.480**
8	.373*	.390*	21	.272*	.573**
9	.476**	.356*	22	.471**	.375*
10	.674**	.393*	23	.359*	.435*
11	.479**	.399*	24	.423*	.522*
12	.703**	.368*	25	.484**	.659*
13	.273*	.345*			

Table 2 shows that all correlation coefficients between each test item score and the corresponding subscale and total test score are statistically significant at the significance level of 0.01.

3.5. Reliability of the Scale

The internal consistency reliability coefficient of the Scientific Concept Acquisition Test was calculated using KR-20. Although no fixed cutoff value is universally agreed upon, a reliability coefficient greater than 0.60 is generally considered acceptable in humanities and educational research (Odeh, 2014), as shown in Table 3.

Table 3. KR-20 Reliability Coefficients

Subscale	Number of Items	KR-20 Coefficient
Defining verbal meaning	5	0.81
Interpreting observations in students' real-life environments	5	0.76
Applying the concept in problem-solving	5	0.75
Using the concept for inference and generalization	5	0.72
Discovering the scientific concept	5	0.79
Total Scientific Concept Acquisition Test	25	0.86

Table 3 indicates that the KR-20 reliability coefficient for the entire test is 0.86, while the reliability values for each subscale ranged between 0.72 and 0.81, confirming the test's reliability.

3.6. Statistical Analysis

The SPSS software package was used for data analysis. Means and standard deviations were calculated for the responses on each subscale of the Scientific Concept Acquisition Test based on their teachers' levels of AI application (advanced/intermediate / or weak). One-way ANOVA and MANOVA were used to determine whether the observed differences were statistically significant. Effect sizes were also calculated using eta squared.

4. Results

4.1. Results of the First Question

To answer the first research question which states, *“What is the level of scientific concept acquisition among basic-stage students in light of their teachers' use of AI applications (advanced/intermediate/weak)?”*, means and standard deviations were calculated for the test and its subscales according to AI usage level as shown in Table 4.

Table 4. Means and Standard Deviations on the Scientific Concept Acquisition Subscales According to Teachers' Use of AI Applications

AI Application Level	Weak	Intermediate	Advanced
Subscale	M	SD	Rank
Verbal meaning	.639	.287	1
Interpreting observations	.512	.270	2
Problem-solving	.385	.256	5
Inference/generalization	.450	.224	3
Discovering concept	.431	.226	4
Overall	.484	.186	—

From Table 4, it is evident that students whose teachers had a *low* level of AI application scored generally lower in scientific concept acquisition (overall $M = 0.484$). The highest subscale mean was for “defining verbal meaning” ($M = 0.639$), while the lowest was for “problem-solving” ($M = 0.385$).

The results also showed that the Scientific Concept Acquisition Test for the intermediate level was generally rated as “moderate,” with scores ranging between 0.491 and 0.672. The highest score was for the first dimension, “Defining Verbal Meaning,” with a mean of 0.672 at a moderate level. The fifth dimension, “Discovering the Scientific Concept,” ranked last with a mean of 0.491 at a low level. The overall mean for the intermediate level was (0.564).

As for the advanced level, results indicated that the Scientific Concept Acquisition Test fell between moderate and low levels, with mean scores for its dimensions ranging from 0.393 to 0.616. The highest mean was for the first dimension, “Defining Verbal Meaning,” with a mean of 0.616 at a moderate level, while the third dimension, “Applying the Concept in Problem-Solving,” came last with a mean of 0.393 at a low level. The overall mean for the advanced level was (0.225). The means and standard deviations of students' responses to the items of the Scientific Concept Acquisition Test were also calculated, as shown in Table 5.

Table 5. Means and Standard Deviations of Sample Members' Responses on the Total Scientific Concept Acquisition Test and Its Subdimensions

Dimension	Item No.	Mean	Std. Dev.	Rank	Level
Defining Verbal Meaning	1	0.62	0.486	4	Moderate
	2	0.68	0.468	2	Moderate
	3	0.75	0.435	1	Moderate
	4	0.67	0.470	3	Moderate
	5	0.49	0.501	5	Low
Interpreting Observations Based on the Concept	6	0.54	0.499	3	Moderate
	7	0.68	0.466	1	Moderate
	8	0.50	0.501	4	Moderate
	9	0.40	0.490	5	Low
	10	0.58	0.494	2	Moderate
Applying the Concept in Problem-Solving	11	0.50	0.501	1	Moderate
	12	0.40	0.490	5	Low
	13	0.41	0.490	4	Low
	14	0.42	0.495	3	Low
	15	0.45	0.499	2	Low
Using the Concept for Inference and Generalization	16	0.45	0.498	3	Low
	17	0.37	0.484	4	Low
	18	0.32	0.466	5	Low
	19	0.56	0.497	2	Moderate
	20	0.68	0.467	1	Moderate
Discovering the Scientific Concept	21	0.54	0.499	1	Moderate
	22	0.48	0.500	2	Low
	23	0.38	0.485	5	Low
	24	0.42	0.494	4	Low
	25	0.47	0.500	3	Low

Table 5 shows that all test items scored between low and moderate levels. Below are the results by dimension:

- Defining Verbal Meaning: Item 3 ranked first with a mean of 0.75 at a moderate level, while Item 5 ranked last with a mean of 0.49 at a low level.

- Interpreting Observations: Item 7 ranked first with a mean of 0.68 at a moderate level, while Item 9 ranked last with a mean of 0.40 at a low level.
- Applying the Concept in Problem-Solving: Item 11 ranked first with a mean of 0.50 at a moderate level, while Item 12 ranked last with a mean of 0.40 at a low level.
- Using the Concept for Inference and Generalization: Item 20 ranked first with a mean of 0.68 at a moderate level, while Item 18 ranked last with a mean of 0.32 at a low level.
- Discovering the Scientific Concept: Item 21 ranked first with a mean of 0.54 at a moderate level, while Item 23 ranked last with a mean of 0.38 at a low level.

The means and standard deviations of students' responses to the test items were also calculated according to their teachers' level of AI application (advanced / intermediate / weak), as shown in Table 6.

Table 6. Means and Standard Deviations of Sample Responses on the Acquisition of Scientific Concepts as a Whole and Its Sub-Dimensions in Light of Their Teachers' Use of Artificial Intelligence Tools (Advanced / Intermediate / Weak)

Level of AI Implementation		Weak			Intermediate			Advanced				
Dimension	Item No.	Mean	SD	Rank	Level	Mean	SD	Rank	Level	Mean	SD	Rank
Identifying Verbal Meaning	1	.63	.486	4	Moderate	.60	.491	4	Moderate	.64	.483	3
	2	.72	.453	1	Moderate	.72	.450	2	Moderate	.60	.492	4
	3	.69	.464	3	Moderate	.80	.400	1	Moderate	.74	.438	1
	4	.70	.460	2	Moderate	.65	.477	3	Moderate	.66	.474	2
	5	.46	.501	5	Low	.58	.495	5	Moderate	.44	.498	5
Interpreting Observations in the Student's Environment	6	.37	.486	5	Low	.68	.470	2	Moderate	.54	.500	2
	7	.63	.484	1	Moderate	.74	.443	1	Moderate	.67	.471	1
	8	.50	.502	3	Moderate	.53	.501	4	Moderate	.47	.501	4
	9	.45	.499	4	Low	.43	.496	5	Low	.33	.471	5
	10	.60	.492	2	Moderate	.62	.488	3	Moderate	.53	.501	3
Applying the Concept to Problem-Solving	11	.54	.500	1	Moderate	.57	.496	1	Moderate	.39	.490	3
	12	.43	.497	2	Low	.45	.499	5	Low	.32	.469	5
	13	.24	.431	5	Low	.51	.502	4	Moderate	.42	.496	2
	14	.37	.486	3	Low	.56	.498	2	Moderate	.34	.474	4
	15	.33	.473	4	Low	.53	.501	3	Moderate	.49	.502	1
Using the Concept for Inference and Generalization	16	.38	.488	3	Low	.51	.502	3	Moderate	.45	.500	3
	17	.33	.470	4	Low	.47	.501	4	Low	.32	.469	4
	18	.24	.431	5	Low	.43	.497	5	Low	.27	.446	5
	19	.53	.501	2	Moderate	.57	.497	2	Moderate	.57	.495	2

Level of AI Implementation		Weak			Intermediate			Advanced				
Dimension	Item No.	Mean	SD	Rank	Level	Mean	SD	Rank	Level	Mean	SD	Rank
Discovering the Scientific Concept	20	.77	.421	1	Moderate	.70	.461	1	Moderate	.58	.496	1
	21	.51	.502	1	Moderate	.58	.495	1	Moderate	.55	.500	1
	22	.50	.502	2	Moderate	.42	.495	4	Low	.53	.501	2
	23	.35	.481	5	Low	.40	.493	5	Low	.35	.483	5
	24	.36	.481	4	Low	.53	.501	2	Moderate	.36	.483	4
	25	.45	.499	3	Low	.52	.501	3	Moderate	.46	.500	3

4.2. Results of the Second Question

To answer the second research question which states, "Does the level of students' acquisition of scientific concepts differ according to their teachers' use of AI applications (advanced/moderate/weak)?", the means and standard deviations of the students' total scores on the Scientific Concepts Acquisition Test were calculated based on the level of their teachers' use of AI applications (advanced/moderate/weak), as shown in Table 7.

Table 7. Means and Standard Deviations of the Students' Total Scores on the Scientific Concepts Acquisition Test Based on Their Teachers' Use of AI Applications (Advanced/Moderate/Weak)

Group	N	Mean	Std. Deviation
Weak	123	0.484	0.186
Intermediate	136	0.564	0.244
Advanced	137	0.482	0.225

Table 7 shows apparent differences in the means of students' scores according to the study variable. To test the statistical significance of these differences, a One-Way ANOVA was conducted as shown in Table 8.

Table 8. One-Way ANOVA for Overall Student Scores by Teachers' Use of AI Applications (Advanced / Intermediate / Weak)

Source of Variance	Sum of Squares	d.f.	Mean Square	F Value	Sig.
Between Groups	0.591	2	0.296	6.076	0.003*
Error	19.116	393	0.049		
Total	19.707	395			

The results in Table 8 show statistically significant differences ($\alpha = 0.05$) in scientific concept acquisition based on the level of teachers' use of AI applications, where the F value = 6.076 and significance = 0.003. According to the Scheffé post hoc test in Table 9, the differences were in favor

of the intermediate level compared to the advanced level, indicating that moderate use of AI may be more effective in improving scientific understanding.

Table 9. Scheffé Post Hoc Comparisons for Scientific Concept Acquisition by AI Use Level

AI Application Level	Mean	Weak	Intermediate	Advanced
Weak	0.484	---		
Intermediate	0.564	0.08054*	---	
Advanced	0.482	0.00153	0.08207*	---

Next, the means and standard deviations of students' scores in the subdomains of the test were calculated based on their teachers' AI use level as shown in Table 10.

Table 10. Means and Standard Deviations of Student Responses on the Scientific Concept Acquisition Test by Teachers' AI Use Level

Dimension	AI Use Level	N	Mean	Std. Dev.
Defining Verbal Meaning	Weak	123	0.64	0.29
	Intermediate	136	0.67	0.29
	Advanced	137	0.62	0.30
Interpreting Observations Based on the Concept	Weak	123	0.51	0.27
	Intermediate	136	0.60	0.29
	Advanced	137	0.51	0.29
Applying the Concept in Problem Solving	Weak	123	0.39	0.26
	Intermediate	136	0.52	0.33
	Advanced	137	0.39	0.28
Using the Concept for Inference and Generalization	Weak	123	0.45	0.22
	Intermediate	136	0.54	0.28
	Advanced	137	0.44	0.27
Discovering the Scientific Concept	Weak	123	0.43	0.23
	Intermediate	136	0.49	0.32
	Advanced	137	0.45	0.30

Table 10 shows apparent differences between the means of the test's subdimensions according to the level of teachers' AI use. To test the statistical significance of these differences, a Multivariate Analysis of Variance (MANOVA) was conducted, as shown in Table 11:

Table 11. Multivariate Test Results for the Effect of AI Use Level on Students' Scores in the Scientific Concept Acquisition Test

Effect	Multivariate Test	Value	F	d.f. Hypothesis	d.f. Error	Sig.
AI Use Level	Hotelling's Trace	0.070	2.701	10	776	0.003*

Table 11 indicates a statistically significant effect at the ($\alpha = 0.05$) level in some subdimensions of the scientific concept acquisition test based on the level of AI use by teachers. To determine which specific dimensions were affected, another MANOVA was conducted, and the results are shown in Table 12:

Table 12. MANOVA Results for Students' Scores by Subdomain According to Teachers' AI Use Level

Source of Variance	Dependent Variable	SS	d.f.	MS	F	Sig.	Eta ²
AI Use Level	Defining Verbal Meaning	0.216	2	0.108	1.287	0.277	0.007
	Interpreting Observations	0.691	2	0.345	4.327	0.014*	0.022
	Applying the Concept in Problem Solving	1.649	2	0.825	9.821	0.000*	0.048
	Inference and Generalization	0.728	2	0.364	5.473	0.005*	0.027
	Discovering the Scientific Concept	0.241	2	0.121	1.451	0.236	0.007

Table 12 shows that there were no statistically significant differences at ($\alpha = 0.05$) in most subdimensions of the scientific concept acquisition scale based on AI use level by teachers, except for the following:

- Interpreting Observations
- Applying the Concept in Problem Solving
- Inference and Generalization

According to the Scheffé test in Table 13, a significant difference was found in the "Interpreting Observations" dimension between the intermediate and advanced levels, in favor of the intermediate level.

The results regarding the dimension of "applying the concept in problem-solving" showed statistically significant differences ($\alpha = 0.05$) between students whose teachers use AI applications at the intermediate level and those at the advanced level, in favor of students whose teachers use AI at the intermediate level. The results also showed statistically significant differences ($\alpha = 0.05$) between students whose teachers use AI at the intermediate and weak levels, again in favor of the intermediate level. Furthermore, in the dimension of "using the concept for inference and generalization," the results indicated statistically significant differences ($\alpha = 0.05$) between students

whose teachers use AI at the intermediate and advanced levels, also in favor of the intermediate level. Similarly, there were statistically significant differences ($\alpha = 0.05$) between students whose teachers use AI at the intermediate and weak levels, again favoring the intermediate level.

Table 13. Scheffé Post-Hoc Test for Subscale Comparisons of Scientific Concept Acquisition According to Teachers' Use of AI Applications (Advanced / Intermediate / Weak)

Subscale	AI Use Level	Mean	Weak	Intermediate	Advanced
Interpreting Observations Based on the Concept	Weak	.51	---		
	Intermediate	.60	.08486	---	
	Advanced	.51	.00563	.09049*	---
Applying the Concept in Problem Solving	Weak	.39	---		
	Intermediate	.52	.13963*	---	
	Advanced	.39	.00733	.13230*	---
Using the Concept in Inference and Generalization	Weak	.45	---		
	Intermediate	.54	.08489*	---	
	Advanced	.44	.00953	.09442*	---

5. Discussion

The results of the first question clarified that the items of the Scientific Concepts Acquisition Test ranged between moderate and low levels, particularly in the dimension of "Using the Concept in Problem-Solving." This can be attributed to the reliance on traditional methods that focus on memorization and the limited use of AI tools in developing analytical thinking. Al-Harashsheh's (2019) study confirmed that modern methods contributed to linking concepts with analytical thinking, while the study by Al-Mutairi et al. (2024) demonstrated the effectiveness of AI-based simulations in developing scientific concepts.

The results showed that students' performance in the dimension of "Identifying Verbal Significance" was at a moderate level across all levels of AI use, indicating their ability to link concepts with terminology due to repetition in the content. Their performance in the "Interpreting Observations" dimension was better among those whose teachers used AI at a moderate level, suggesting a need for deeper interaction to understand concepts. Meanwhile, their performance in the "Discovery of the Scientific Concept" dimension was generally low, reflecting weak scientific discovery skills.

It is noteworthy that the level of scientific concept acquisition did not reach a high level in any of the AI usage levels, and the results were relatively close across the three categories. This may be due to the fact that "advanced" use does not necessarily imply effective pedagogical integration, as it may focus on quantity rather than conceptual development. In contrast, the moderate level may achieve a better balance between technological use and the classroom environment.

These results align with some previous studies such as the study by Al-Hosani and Al-Balushi (2023), which showed that students who learned through a gamified mobile application outperformed others in acquiring scientific concepts. This supports the idea that intelligent

integration of technology contributes to enhancing scientific concept acquisition. Similar findings were observed in the studies of Al-Osaimi (2023), Al-Mutairi et al. (2024), and Ajlouni (2024), which used similar tools to measure scientific concept acquisition and its dimensions. However, the current study differed from the findings of Tams' (2023) study, which explored the use of augmented reality technology in acquiring scientific concepts and developed an achievement test accordingly.

With regard to the discussion of the second question, These findings align with Harahsheh's (2019) study, which showed significant differences in favor of students taught using the WebQuest strategy; with Ajlouni's (2024) study, which found significant differences favoring students in experimental groups using developed programs; and with Al-Mutairi et al. (2024) who investigated the enhancement of scientific concepts through AI-based simulations. These studies shared a similar use of measurement tools. However, the present study differs from the study by Al-Hosani and Al-Balushi (2023), which examined the effect of a gamification-based mobile app on scientific concept acquisition and discussed the interaction of gender with the teaching method. Their results showed no statistically significant gender-based differences, whereas the current study did not investigate gender as a variable but instead focused on the level of concept acquisition based on teachers' use of AI tools.

6. Conclusions and Recommendations

The results showed that students' level of scientific concept acquisition ranged between moderate and low across all dimensions, without reaching a high level in any of them. One of the weakest dimensions was the use of concepts in problem-solving, which indicates a limited application of analytical skills and insufficient use of AI tools in this area. The reliance on traditional teaching methods focused on memorization may be one of the main reasons for the weak performance, despite the availability of AI tools. This suggests that students were able to associate terms with concepts due to repetition, but not necessarily through deep understanding. Performance was relatively better among students whose teachers used AI at a moderate level, indicating a balance between technological integration and classroom practices. This was evident in the dimension of "scientific concept discovery," reflecting the need to develop students' exploratory and scientific thinking skills.

The results align with studies such as Harahsheh (2019), Al-Mutairi et al. (2024), and Ajlouni (2024), which confirmed the role of AI when used intelligently in enhancing concept acquisition. However, they differ from Tamas (2023), which focused on augmented reality, indicating that the type of technology alone is not sufficient — rather, the educational method of its implementation is what truly matters. These conclusions highlight the importance of focusing on how AI tools are effectively utilized in education, rather than merely using them as technical tools without a clear pedagogical purpose.

This study is limited to identifying the level of scientific concept acquisition among basic-stage students in light of their teachers' use of artificial intelligence applications (advanced, intermediate, weak). It was restricted to tenth-grade students in schools affiliated with the Qasabat Irbid Directorate during the second semester of the 2024/2025 academic year. The generalizability of the results depends on the accuracy, honesty, and objectivity of the study sample in responding to the study instrument.

Based on the study's results, the study recommends integrating AI applications into the content of science curricula, redesigning science units to include technology-based tasks supported by AI, and training teachers in the effective pedagogical use of AI applications.

Declarations

Author Contributions. All authors have read and approved the published version of the article.

Conflicts of Interest. The authors declare no conflict of interest.

Funding. The authors received no financial support for this research.

Ethical Approval. (Please provide information on respect for privacy and approval by the ethics committee/ethical approval with the reference number)

Data Availability Statement. The data can be supplied by the corresponding author upon request.

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