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THE EFFECTIVENESS OF USING THE EDUCATIONAL SCAFFOLDING MODEL IN TEACHING CHEMISTRY IN DEVELOPING PROBLEM-SOLVING SKILLS AMONG 9th STUDENTS

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Abstract

This study aimed to investigate the effectiveness of using the educational scaffolding model in teaching chemistry, focusing on the development of problem-solving skills among ninth-grade students. The study employed a quasi-experimental design, consisting of two groups (experimental and control), with pre- and post-measurements. The sample consisted of (50) students 9th Graders, randomly divided into two groups: experimental (25) students studied using the educational scaffolding model, and control (25) students studied traditionally. The problem-solving skills test consisting of five sub-skills (problem identification understanding, making assumptions, collecting and analyzing information, interpretation, and proposing solutions) The results showed that there were significant differences at the level of significance (α = 0.05) between the individuals of the two groups in favor of the experimental group, which indicates the effectiveness of the educational scaffolding model in improving problem-solving skills. The study recommended using the educational scaffolding model in teaching chemistry and training teachers to use it to enhance students ' higher thinking skills.

Keywords: Educational Scaffolding, Problem Solving, Teaching Chemistry, 9th Graders.

INTRODUCTION

The 21st Century is witnessing cognitive and technological transformations with a remarkable acceleration, forcing educational systems to adopt new methods of education to enable learners to acquire higher thinking skills, most notably the skill of "problem solving".

Teaching knowledge alone is no longer enough to face the complex challenges of contemporary life, but it has become necessary to provide students with mental skills that help them think critically and analytically, and make appropriate decisions in a variety of educational and life situations. Therefore, strengthening the problem-solving skill has become a central goal in modern pedagogical curricula, and a key goal in the outputs of qualitative education.

Problem-solving skills are one of the main pillars that should be developed among students, especially at the basic academic stages, where students begin to form their scientific thinking patterns, and form methods in dealing with educational and daily problems. This skill is defined as the ability of an individual to deal with new or complex situations, through the use of previous knowledge and experience, relying on logical and

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analytical thinking to explore solutions, evaluate them and choose the most appropriate ones.

The educational literature indicates that students with advanced problem-solving skills show better performance in study situations and achievement tests, and they have a greater ability to adapt to new developments and life challenges. (Jakhoor, 2023).

Despite this growing importance, the observations of the educational field and the results of many studies show a clear weakness in the level of problem-solving skills of students, especially in scientific subjects that require a high level of understanding and analysis, such as chemistry. This is largely due to the adoption of traditional methods of teaching that focus on memorizing facts and indoctrination, and do not provide students with real opportunities for critical thinking or practical application of scientific concepts. Knowledge is often presented as Final facts without involving the learner in the process of building it or linking it to life or contextual situations (Ahmed, 2020).

The scaffolding model, based on Vygotsky's zone of proximal development (Koehler et al., 2013), provides temporary support that is gradually removed as learners gain independence. This support includes hints, questions, and structured activities. Studies confirm its effectiveness in developing skills like critical thinking and problem-solving. In science education, the constructivist model is seen as most effective (Hewson & Hewson, 1998). Many definitions have tried to clarify the concept of educational scaffolding, and the following is a presentation of some of these definitions:

Wood, Bruner & Ross (Wood, Bruner & Ross, 1976) defined it as: a support process provided to the learner to help him perform tasks that he cannot accomplish on his own, through instructions or hints that are gradually reduced until he reaches independence in learning, and he also referred to this definition as Damani (2021). Jakhuor (2023) defined it as: temporary support provided by the teacher to help the learner overcome the gap between his current knowledge and the new knowledge that he seeks to acquire, this is done by gradually assisting, and then reducing it until the learner can solve his problems independently based on his personal experiences.

Educational scaffolding aims to enhance the higher thinking skills of learners, including the skills of analysis, linking concepts, criticism, and creativity. It also contributes to enabling the learner to face complex problems and deal with them in innovative ways based on deep understanding and logical analysis (Baluchia, 2020).

Educational scaffolding can be classified based on several criteria pointed out by Muhammad (2020), as follows:

- Depending on the nature of the support: verbal, visual, and practical scaffolding.
- According to the degree of teacher intervention: direct, partial, and subjective scaffolding.
- According to its continuity: temporary and permanent scaffolding.

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Application of educational scaffolding

Both Anwar and Nasr (2024) pointed out that the process of applying educational scaffolding goes through a number of methodological stages aimed at achieving effective learning, including the following:

- Diagnose the learner's performance level and identify the knowledge gap.
- Provide initial support appropriate to his needs.
- Gradually adjust the level of support in proportion to the development of the learner's performance.
- Promote the independence of the learner and encourage him to self-reliance.
- Withdraw support permanently after achieving the required efficiency.

Problem-solving is one of the higher mental skills that contribute to enabling an individual to face complex situations through the use of critical thinking and appropriate cognitive strategies. (Polya, 2020) defined it as a mental process that involves understanding, planning, implementing, and evaluating to choose the best possible solutions.

Many models addressed the stages of problem solving, the most prominent of which is the Apulia model (2020), which identified four successive stages: (understanding the problem, developing a plan, implementing the plan, and finally reviewing the results). Jonassen (2020) has presented a more concise model that includes: recognizing the problem, using critical thinking to choose solutions, then evaluating the results, and readjusting when needed.

Importance of problem-solving in education

Teaching problem-solving skills is one of the main goals of contemporary education because of its role in developing higher thinking skills and enabling students to employ their knowledge in new life and scientific situations. Studies have shown that the development of these skills contributes to better academic and professional adaptation (Al-Damani, 2021).

This study examines the effectiveness of the educational scaffolding model in teaching chemistry to ninth-grade students by assessing its impact on their problem-solving skills compared to traditional methods. It aims to offer an effective approach that enhances students' thinking abilities and supports self-directed learning.

Statement of the Problem

Problem-solving skills are crucial for logical thinking, decision-making, and applying knowledge in new contexts. However, many basic students, especially in chemistry, struggle with analytical scientific problems due to reliance on traditional memorization-based teaching. Thus, the educational scaffolding model, which offers progressive support to enhance learner autonomy and cognitive skills, is essential. This study

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examines its effectiveness in developing problem-solving skills among ninth-grade chemistry students.

Specifically, the study seeks to answer the following question:

What is the effectiveness of using the educational scaffolding model in teaching chemistry in the development of problem-solving skills among ninth- graders?

Significance of the Study

The significance of the study came as a theoretical and practical importance, while:

The theoretical significance of this study stems from its contribution to deepening the understanding of the concept of problem solving as one of the components of complex cognitive thinking, and its relationship with problem-solving skills, especially in scientific educational contexts. The study also adds to the educational literature by studying the impact of the educational scaffolding model on the development of these skills, which contributes to expanding the knowledge base about the effectiveness of contemporary educational models, and provides a theoretical basis on which to build in subsequent studies.

The Practical importance of this study is highlighted in the possibility of benefiting from its results in improving educational practices within the classrooms, by providing teachers with practical teaching methods that contribute to raising the efficiency of students in problem-solving skills. The results of the study may also contribute to reconsidering the traditional teaching strategies used in teaching chemistry at the basic stage, and encourage those involved in the curriculum to integrate advanced modern educational models that promote active thinking and self-learning among students. These results are expected to help in the development of teacher training programs towards the adoption of more effective teaching strategies based on systematic cognitive support such as educational scaffolding.

Operational Definitions:

The current study includes the definition of the following terms:

Educational scaffolding model: the educational scaffolding model is defined as a set of educational procedures and steps followed by the teacher within the classroom, with the aim of providing support and gradual assistance to students in their learning. Without the need for outside help, which enhances their ability to self-learn and develop critical and analytical thinking skills (Jakhuor, 200:2023).

The researcher defines it procedurally: a set of practical procedures in which the teacher relies on the applications of constructive theory, with the aim of providing continuous cognitive support to students while they are exposed to educational situations that require reflection and analysis, as it aims to transfer students from one learning stage to another gradually, up to complete independence in the learning process.

Problem solving: both Tanos and Khatib (2019: 45) defined "problem solving as a complex mental process that requires individuals to use their previous knowledge, as well

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as critical and creative thinking skills, to come up with solutions to situations that involve challenges or ambiguities, as it enhances students 'ability to think critically and apply knowledge in different contexts".

The researcher defines it procedurally: the ability of ninth graders to apply their previous knowledge and intellectual skills in the face of unfamiliar educational situations, with the aim of identifying appropriate solutions to the problems they face in chemistry.

Many study were conducted by other researchers related to variables of this study such as:

Rubik and Polgar (2025) also conducted a study aimed at exploring the impact of teaching puzzles and mind games in schools on the development of problem-solving skills of students. The two researchers used the qualitative approach by analyzing the content of educational programs and interviews with teachers. The results showed that the integration of puzzles into the school curriculum enhances strategic thinking and mental flexibility, which contributes to the development of problem-solving skills in students.

Mubarak (2024) conducted a study aimed at identifying the role of problem-solving strategy in the development of creative reading skills among secondary school students in Islamic education in Beirut schools. The researcher used the descriptive-analytical approach, applied a questionnaire to a sample of subject teachers. The results showed a positive role of the problem-solving strategy in the development of creative reading skills, without statistically significant differences attributable to the variables of academic qualification or years of experience.

Ekoyo and Ngwu (2024) conducted a study aimed at identifying the impact of using a problem-solving strategy on the achievement of Secondary second-graders in computer subject in Nigeria. The two researchers used the semi-experimental method, and applied an achievement test to two groups: experimental and control. The results showed statistically significant differences in favor of the experimental group, which indicates the effectiveness of the problem-solving strategy in improving academic achievement in the computer subject.

Al-muhannawi (2024) conducted a study aimed at identifying the impact of using a problem-solving strategy in the acquisition of Arabic grammar and improving survey skills among basic seventh graders in Jordan. The researcher used the semi-experimental method, applied an achievement test to two groups: experimental and control. The results showed statistically significant differences in favor of the experimental group, which indicates the effectiveness of the strategy in improving achievement and survey skills.

Studies that addressed the variant of educational scaffolding

Conducted by Van de Pol and colleagues (van de Pol et al., 2015) a study aimed at analyzing the impact of the educational scaffolding strategy on students ' achievement, their effort in assignments, and their assessment of support in the classroom. The researchers used the experimental curriculum in Dutch schools, and found that gradual

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and appropriate support for the needs of students enhances their independence and academic achievement.

Arisha (2023) also conducted a study aimed at identifying the impact of the use of educational scaffolding in the development of creative solving skills of mathematical problems among students of the third grade of Azhari preparatory, the study used the experimental curriculum, and the sample consisted of (60) students divided into two groups, control and experimental. The results found statistically significant differences between the average scores of the two groups in favor of the experimental group.

Khan and colleagues (Khan et al., 2023) a study aimed at exploring the impact of the educational scaffolding strategy on student achievement in mathematics in secondary schools in Pakistan. Using the semi-experimental approach, the researchers found that students who learned using educational scaffolding showed a significant improvement in their academic performance compared to students who learned by the traditional method.

Kamel (2024) conducted a study aimed at identifying the effectiveness of educational scaffolding in the development of productive mathematical tendency and academic achievement in mathematics among secondary school students, the study used a semi-experimental curriculum, and the sample consisted of (60) students. The results indicated the effectiveness of educational scaffolding in improving productive sportsmanship and academic achievement.

Bayoumi (2024) also conducted a study aimed at identifying the effectiveness of educational scaffolding using infographic technology in the development of cognitive achievement and learning football skills, the study used an experimental curriculum, and the sample consisted of (30) students. The results showed that there were statistically significant differences in favor of the experimental group.

METHODOLOGY

This part includes a presentation of the study methodology, steps, community, sample, data collection tool, procedures for verifying its truthfulness and consistency, and methods of statistical analysis, as follows:

Study design: the study used the Quasi-experimental approach for its suitability to the nature of the study, where a pre-and post-test was applied to two groups: experimental and control.

Study Sample: The study sample consisted of (50) students from BA'oun secondary school for boys in Jordan, who were randomly distributed into two equal groups: experimental (25) and control (25) students.

Study Instrument: A test was built to measure the problem-solving skills of ninth-grade students, consisting of (25) multiple-choice paragraphs, covering five main areas: identifying and understanding the problem, setting hypotheses, testing hypotheses, explanation, and proposing solutions. The test was prepared based on the analysis of the content of the module "activity of metals" from the chemistry textbook for the ninth grade

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used by Ministry of Education in Jordan, and on the basis of the relevant pedagogical literature.

Validity of the instrument

The problem solving test in its initial form consists of (25) paragraphs distributed over five main areas: identifying and understanding the problem (5 paragraphs), making assumptions (5 paragraphs), testing assumptions (5 paragraphs), explanation (5 paragraphs), and proposing solutions (5 paragraphs).

The truthfulness of the content of the test was verified by presenting it to (15) competent arbitrators from the teaching staff in the curricula and methods of teaching science, measurement and evaluation, in addition to teachers and supervisors specialized in science from the Jordanian Ministry of education, in order to assess the appropriateness of paragraphs, their clarity, the integrity of their wording, and their harmony with the field you are measuring.

Based on the arbitrators ' comments, which were approved with an acceptance rate (80%) or more, the language wording of some paragraphs was amended (215 ،7 ،5 ،) four paragraphs (10, 13, 14, 18) were deleted and replaced with new paragraphs. Thus, the test tool in its final form consists of (25) paragraphs evenly distributed over the five fields, with (5) paragraphs for each fiel

Instrument Reliability

To Calculate the reliability of the internal consistency of the problem-solving skills acquisition test with its overall significance and its subfields; the Cooder-Richardson equation 20 (KR-20) was used on the data of the first application of the survey sample of (25) students from (osrah secondary school for boys), as shown in Table (1).

Table (1): Internal Consistency for the Problem-Solving Skills Test

Domains	Internal Consistency	Number of Items
Problem Identification and Understanding	0.87	5
Hypothesis Formulation	0.88	5
Hypothesis Testing	0.86	5
Interpretation	0.87	5
Suggesting Solutions	0.87	5
(Total)	0.89	25

It is clear from Table (1) that the values of the coefficients of the constancy of the internal consistency of the test subdomains ranged from (0.86 – 0.88), and for the test as a whole amounted to (0.89).

First, the results related to the study question, which stated: what is the effectiveness of using the educational scaffolding model in teaching chemistry in developing problem-solving skills among ninth-grade basic students. To answer this question, the hypothesis of which states: "there are no significant differences at the level of significance (α=0.05) between the average scores of ninth-graders studying using the educational scaffolding model and the average scores of students studying by traditional methods in problem-

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solving skills"; the values of arithmetic averages and standard deviations problem-solving skills (as a whole) were found in the pre -, post-and adjusted measurements, for members of the experimental and control groups, as shown in Table (2).

Table (2): Means and standard deviations of problem-solving skills (total score) of experimental and control groups in pre-and post-test and adjusted means according to the group variable

Group	N	Pre-test Mean	Pre-test SD	Post-test Mean	Post-test SD	Adjusted Mean	Standard Error
Control	25	8.60	3.85	12.40	4.45	12.09	0.41
Experimental	25	7.92	3.44	16.84	3.21	17.15	0.41

It is clear from Table (2) that there are apparent differences between the arithmetic averages of problem solving skills in their overall significance among the members of the experimental and control groups of ninth-graders in the tribal and dimensional measurement depending on the group variable, and to verify the essence of the apparent differences, the accompanying mono-variance analysis (One way ANCOVA) was used, after taking into account the degrees of tribal measurement of problem solving skills(as a whole), for each of the two groups, as an accompanying variable, as shown in Table (3).

Table (3): ANCOVA unidirectional results of the subsequent test of problem-solving skills (total score) sample according to the group variable

Source of Variance	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level	Eta Squared (η^2)
Pre-test	5.626	1	5.626	1.372	0.247	—
Teaching Method	317.086	1	317.086	*77.325	0.000	0.622
Error	192.734	47	4.101			
Total	515.446	49				

* A statistically significance at (α=0.000)

** (The size of the effect according to Kilani and sherifin, 2014: weak (less than 0.06), medium (0.15-0.06), large (0.16 and above).

It is clear from Table (3) that there is a statistically significant difference at the level of significance (α=0.05) between the two computational averages of the dimensional measurement of problem-solving skills with their total significance in the sample of ninth-graders depending on the group variable (experimental, control) in favor of the experimental group that was taught using the educational scaffolding model. The effect of using the educational scaffolding model in raising the level of problem-solving skills (as a whole), which is indicated by the value of the ETA square (**(η^2)**) (62.20%), is high, according to Al-Kilani and Al-sharifin (2014). In general, this means that the educational scaffolding model has contributed to raising the level of problem-solving skills of ninth-graders to a high degree.

The Mean and standard deviations of the pre -, post-and average measurements of the problem-solving sub-skills were also calculated depending on the group variable (experimental, control), as shown in Table (4).

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Table (4): Means and standard deviations of the problem-solving sub-skills of the members of the experimental and control groups in the pre-and post-measurement and adjusted according to the group variable

Sub-skills	Group	N	Pre-test Mean	Pre-test SD	Post-test Mean	Post-test SD	Adjusted Mean	Standard Error
Problem Identification and Understanding	Control	25	1.56	1.60	2.66	0.83	2.67	0.13
	Experimental	25	1.76	1.36	4.52	0.65	4.51	0.13
Hypothesis Formulation	Control	22	1.84	1.61	2.68	1.25	2.72	0.14
	Experimental	25	1.60	1.19	3.96	0.79	3.92	0.14
Information Gathering and Analysis	Control	25	1.44	1.04	2.64	1.11	2.68	0.17
	Experimental	25	1.28	0.98	3.32	0.95	3.28	0.17
Interpretation	Control	25	1.72	1.14	1.92	1.00	1.93	0.13
	Experimental	25	1.88	0.88	2.88	0.88	2.87	0.13
Suggesting Solutions	Control	25	1.04	0.89	1.40	1.04	1.41	0.13
	Experimental	25	1.40	0.91	2.16	0.94	2.15	0.13

It is evident from Table (4) that there are apparent differences between the arithmetic averages of the problem-solving sub-skills of the experimental and control groups in the tribal and dimensional measurement depending on the group variable to verify the essence of the apparent differences, the multiple accompanying single variance analysis (one way MANCOVA) was used, to find out the impact of the educational scaffolding model on each problem-solving skill, after taking into account the degrees of tribal measurement on the problem-solving sub-skills of both groups, as an accompanying variable, as shown in Table (5).

Table (5): The results of the analysis of the multiple accompanying unilateral variation (one way MANCOVA) for the dimensional measurement of the problem-solving sub-skills of the study sample members depending on the group variable

Source of Variance	Sub-skill	Sum of Squares	df	Mean Square	F Value	Sig. Level	Eta Squared (η^2)
Pre-test	Problem Identification & Understanding	1.056	1	1.056	2.736	0.105	
	Hypothesis Formulation	0.752	1	0.752	1.717	0.196	
	Information Gathering & Analysis	1.746	1	1.746	2.541	0.118	
	Interpretation	0.110	1	0.110	0.271	0.605	
	Suggesting Solutions	0.985	1	0.985	2.450	0.124	
Teaching Method Hotelling's Trace=4.025F= 21.396 Sig. = 0.000*	Problem Identification & Understanding	21.197	1	21.197	*54.915	0.000	**0.561**

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	Hypothesis Formulation	16.398	1	16.398	*37.451	0.000	**0.466**
	Information Gathering & Analysis	4.224	1	4.224	*6.144	0.017	**0.125**
	Interpretation	10.110	1	10.110	*24.931	0.000	**0.367**
	Suggesting Solutions	6.199	1	6.199	*15.427	0.000	**0.264**
Error	Problem Identification & Understanding	16.615	43	0.386			
	Hypothesis Formulation	18.827	43	0.438			
	Information Gathering & Analysis	29.562	43	0.687			
	Interpretation	17.438	43	0.406			
	Suggesting Solutions	17.278	43	0.402			
Total	Problem Identification & Understanding	38.868	49				
	Hypothesis Formulation	35.977	49				
	Information Gathering & Analysis	35.532	49				
	Interpretation	27.658	49				
	Suggesting Solutions	24.462	49				

* Statistically significant at significance level (α = 0.05) ** (Effect size according to Al-Kilani & Al-Sharifain, 2014: Small < 0.06, Medium = 0.06–0.15, Large > 0.16).

From Table (18) it is clear that there are statistically significant differences at the level of significance (0.05= α) between the arithmetic averages of the telemetry of the problem-solving sub-skills depending on the group (experimental, control) in favor of the experimental group taught using the educational scaffolding model.

The size of the effect resulting from the use of the educational scaffolding model in raising the level of problem-solving sub-skills was indicated by the value of the ETA square (**(η^2)**) (56.10%) for the skill (identifying and understanding the problem), (46.60%) for the skill (making assignments), (12.50%) for the skill (collecting and analyzing information), (36.70%) for the skill (explanation) and(26.40%) for the skill (proposing solutions), and the level of this effect was high in all skills except a skill (information collection and analysis) in which the size of the impact was average, according to Al-Kilani and al-sharifin (2014).

This means that the teaching strategy followed in this study contributed to the improvement and development of all the sub-skills of problem solving among the study sample, and was more influential in the skill of identifying and understanding the problem, followed by the skill of making assumptions, followed by the skill of interpretation, followed by the skill of proposing solutions, and least of all the skill of collecting and analyzing information.

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DISCUSSION OF THE RESULTS

Discussion of the results of the study question, which stated: what is the effectiveness of using the educational scaffolding model in teaching chemistry in developing problem-solving skills among ninth graders

The results of the study showed that there was a statistically significant difference at the level of significance (α = 0.05) between the performance of students of the experimental group who learned using the educational scaffolding model, and students of the control group who learned by the traditional method of telemetry of problem-solving skills, and this difference came in favor of the experimental group. The total effect size of the model was (**(η^2)** = 0.622), which is a very high value according to the classification of Al-Kaylani and Al-sharifin (2014), which indicates the great effectiveness of the educational scaffolding model in enhancing these skills.

This result is one of the most prominent indicators of the study, as problem solving skills are classified among the higher levels of learning outcomes, and are directly related to the reality of the learner. Anwar and Naseer (2024) emphasize that the effectiveness of educational scaffolding is not limited to improving understanding and achievement, but extends to the development of practical and flexible thinking skills, most notably problem-solving skills that require gradual and systematic support that helps the learner to move from orientation to independence.

These results indicate that the scaffolding model has provided a safe and encouraging learning environment for experimentation, which provided students with real opportunities to engage in educational situations that call for reflection, analysis and practical application without fear of making mistakes. The khawalda study (2023) supported this trend, as it showed that the cognitively and methodically supportive classroom environment is one of the main factors in motivating students to take the initiative to solve problems and generate ideas.

The results of the study also indicate that there are statistically significant differences between the two groups in all the sub-skills of problem solving, in favor of the experimental group, namely: identifying and understanding the problem, making assumptions, interpretation, collecting and analyzing information, and proposing solutions. The highest impact size was in the skill of "identifying and understanding the problem" (**(η^2)**) = 0.561), followed by the skill of "making assumptions" (0.466), then "explanation" (0.367), and "proposing solutions" (0.264), while "collecting and analyzing information" ranked last in terms of impact size (0.125), which is an average effect compared to other skills.

The differences in impact among sub-skills are due to their nature. For example, proposing solutions is a complex skill requiring creative thinking, decision-making, and integration of prior skills, thus needing more time and experience to develop. Similarly, collecting and analyzing information demands critical scrutiny and organization, developing gradually through ongoing support and practice. These findings align with Al-Harthy (2021), who noted that educational scaffolding moves learners from superficial

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understanding to deeper analysis and application by considering individual differences and cognitive levels.

The core of scaffolding progressive support enhances learners' autonomy, motivation, and self-efficacy, as confirmed by Al-Awad (2020), which is essential for developing problem-solving skills. Overall, these results reflect a shift in education goals from rote memorization to fostering critical thinking and effective real-world action, achievable only through active, constructive models like educational scaffolding.

Recommendations

In light of the results of this study the researchers recommend that importance of Integrating scaffolding strategies into ninth-grade curricula to support problem-solving, and train teachers in applying scaffolding to develop students' thinking and active learning.

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