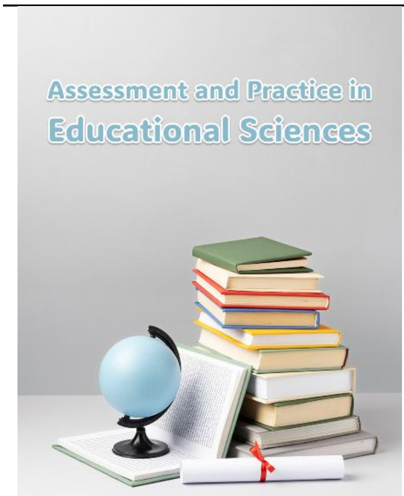
Assessment and Practice in Educational Sciences



The Effect of Scaffolding Method on Self-Regulation, Retention, and Comprehension of Sixth-Grade Science

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Article type:
Original Research

Article history:
Received 05 May 2025
Revised 19 August 2025
Accepted 24 August 2025
Published online 01 September 2025

How to cite this article:
Mirasi, R., Mesrabadi, J., & Aghdasi, A. (2025). The Effect of Scaffolding Method on Self-Regulation, Retention, and Comprehension of Sixth-Grade Science. *Assessment and Practice in Educational Sciences*, *3*(3), 1-13.
https://doi.org/10.61838/japes.3.3.10

ABSTRACT

Human life is fundamentally grounded in educational processes, and transformations in learning are inseparably linked to individuals' social, cultural, and occupational advancement. Therefore, the application of the scaffolding method in teaching and learning can serve as an influential factor in learners' educational outcomes. The aim of the present study was to examine the effect of instructional scaffolding, compared with traditional teaching, on self-regulation, retention, and comprehension in the subject of experimental sciences. This research employed a quasi-experimental design with pretest-posttest and both experimental and control groups. The participants were assigned to two groups (the experimental group receiving instructional scaffolding and the control group). They were evaluated using the Self-Regulation Questionnaire developed by Bouffard (1995) and teacher-made tests of retention and comprehension administered before and after the intervention. The experimental group received eight sessions of instruction through educational packages designed and optimized by a university lecturer specializing in educational psychology and instructional design, whereas the control group received traditional teaching. The traditional teaching consisted of instruction delivered by the classroom teacher without any research intervention, specific strategies, or educational packages. The statistical population consisted of sixth-grade female students in Marand city, and the sampling method was convenience sampling. The results of covariance analysis indicated that scaffolding-based instruction had a significant effect on students' self-regulation, retention, and comprehension. These findings suggest that scaffolding as an instructional method can be effectively employed to improve self-regulation, retention, and comprehension among students.

Keywords: scaffolding method, self-regulation, retention, comprehension

Introduction

Education has long been recognized as one of the most fundamental drivers of human progress, social mobility, and collective development. The pursuit of effective teaching methods is not only a pedagogical concern but also a strategic imperative for preparing learners to navigate increasingly complex societies. Over the last decades, research in educational psychology has underscored the need for instructional models that can support students' diverse learning needs, foster independence, and cultivate higher-order cognitive skills. Among these models, scaffolding stands out as a critical instructional approach designed to provide learners with structured support that gradually diminishes as competence is achieved, ultimately enabling learners to develop autonomy and self-regulation (1).

The theoretical foundations of scaffolding can be traced to Vygotsky's concept of the Zone of Proximal Development (ZPD), which emphasizes that learners can achieve higher levels of understanding and performance when guided by a more knowledgeable other (2). This perspective revolutionized modern educational psychology by suggesting that effective learning occurs through interaction, mediation, and progressive withdrawal of external assistance (3). The scaffolding approach aligns with constructivist principles in which knowledge is co-constructed through experience and reflection, rather than transmitted passively (4). In contemporary educational contexts, scaffolding has been applied across disciplines, grade levels, and modalities, from face-to-face classrooms to computer-based environments (5).

Recent meta-analyses and systematic reviews have confirmed the robust impact of scaffolding strategies on academic achievement, motivation, and self-regulation. For example, Shao et al. (6) demonstrated that regulated learning scaffolds significantly improve both strategic learning and academic performance across diverse student populations. Similarly, Sharma and Nguyen (7) emphasized that self-regulation and shared regulation in collaborative learning are greatly enhanced when adaptive scaffolding systems are integrated. This echoes earlier findings by Theobald (8), who showed through a meta-analysis that self-regulated learning training programs rooted in scaffolding principles improved university students' academic outcomes and motivation.

At the primary and secondary education levels, scaffolding has proven to be particularly effective in science and language learning. Adebisi (9) showed that scaffolding teaching strategies improved secondary school students' performance in physics, while Putri et al. (10) found that Jerome Bruner's scaffolding method enhanced speaking skills in primary education. These studies align with Gahihite (11), who argued that scaffolding functions as a keystone in chemistry teaching by linking abstract concepts to tangible experiences. Likewise, Thuratham (12) reported that scaffolding techniques significantly improved undergraduate learners' mastery of English conditional sentences, underscoring its relevance for second language acquisition.

In addition to disciplinary learning, scaffolding has been shown to foster meta-cognitive awareness and transferable learning skills. Ilves et al. (13) highlighted how visualizations used in online learning environments can scaffold learners' ability to monitor and regulate their own learning processes. Mezek et al. (14) similarly found that scaffolding tasks and feedback in academic reading not only improved comprehension but also promoted self-regulation. These findings complement Sun et al. (15), who explored digital game-based learning in mathematics and observed that scaffolding positively influenced students' perceptions and engagement. In digital collaborative settings, Zabolotna et al. (16) confirmed that scaffolding enhances both knowledge construction and group-level regulation, emphasizing its importance in computer-supported learning tasks.

From a curriculum and instructional design perspective, scholars have emphasized that scaffolding strategies should be carefully aligned with the content and cognitive demands of specific subjects. Behrad (17) examined concept map-based instruction in sixth-grade science and found that scaffolding through mapping fostered entangled learning of curricular content. This aligns with Masr-Abadi and Alilu (18), who confirmed that concept mapping as a scaffolding tool significantly improved retention, comprehension, and application of scientific concepts. Similarly, Mansouri Talebi (19) demonstrated that concept map-based teaching enhanced intellectual beliefs and self-regulated learning in Persian language courses, pointing to the cross-disciplinary utility of scaffolding.

Other Iranian studies confirm the transformative potential of scaffolding for local educational contexts. Arefi et al. (20) found that scaffolding strategies were particularly effective for students with mathematical learning disabilities, improving both learning outcomes and achievement motivation. Babayi (21) showed that scaffolding in science lessons increased satisfaction and academic motivation in students with intellectual disabilities. Bahrami Khamsalouei (22) compared inquiry-based teaching with scope teaching and reported that both methods improved motivation and self-regulation, but scaffolding strategies provided clearer structural supports. Similarly, Bakhshi (23) highlighted that both teacher scaffolding and peer scaffolding were critical in developing reading comprehension skills, especially in blended classrooms.

Beyond motivation and comprehension, scaffolding has strong implications for self-regulation. Self-regulation is increasingly regarded as a cornerstone of successful learning, as it enables learners to set goals, monitor progress, and reflect on outcomes. Zabolotna et al. (16) emphasized that scaffolding supports group-level regulation in collaborative contexts, while Yang (24) demonstrated its effectiveness in improving argumentative writing through Toulmin-model-based scaffolds. At the same time, Murphy et al. (25) argued that reading apprenticeship models infused with scaffolding not only strengthened comprehension but also cultivated disciplinary habits of mind. These insights align with Souri et al. (26), who designed a qualitative model of educational scaffolding specifically tailored to secondary school students, showing its applicability across developmental stages.

Despite its wide recognition, scaffolding is not a one-size-fits-all solution. Its effectiveness depends on factors such as the learner's prior knowledge, the type of task, and the mode of delivery. Zhang (27) observed that during the COVID-19 pandemic, disruptions in education highlighted the importance of flexible scaffolding strategies to maintain students' learning satisfaction under stress. Similarly, Behrad (17) cautioned that while concept map-based scaffolding enhanced learning, its success required deliberate alignment with cognitive levels and curricular goals. This perspective resonates with Heydari Moghaddam et al. (28), who analyzed sixth-grade science textbooks and stressed the need to calibrate scaffolding strategies to Bloom's taxonomy for optimal learning outcomes.

Internationally, scaffolding has also been applied through innovative methods that blend discovery, inquiry, and technology. Maysara et al. (29) demonstrated that scaffolding worksheets in discovery learning improved learning outcomes in stoichiometry, while Hattan and Alexander (30) illustrated how scaffolding reading comprehension tasks benefited competent readers. Likewise, Delen and Liew (5) confirmed through a meta-analysis that scaffolding in computer-based environments significantly enhanced self-regulated learning. These findings support the argument that scaffolding provides a flexible framework adaptable to both traditional and technology-enhanced learning environments.

The potential of scaffolding is also evident in its long-term effects on motivation and persistence. Souri et al. (26) and Bahrami Khamsalouei (22) both underscored how scaffolding interventions encouraged self-regulation and sustained motivation, leading to better academic outcomes. Moreover, Setari Maleki (31) found in a meta-analytic study that scaffolding consistently improved outcomes in second language learning, confirming its broad cross-linguistic applicability.

In sum, the literature demonstrates that scaffolding is an indispensable instructional strategy that bridges cognitive, motivational, and metacognitive dimensions of learning. Its effectiveness has been confirmed across disciplines such as science, mathematics, and language, and in varied contexts ranging from primary education to university-level instruction. By offering structured yet flexible support, scaffolding enhances not only comprehension and retention but also fosters independence and lifelong learning skills. However, it also requires careful calibration to learners' developmental stages, curricular demands, and contextual factors. These complexities underscore the need for ongoing empirical investigations into scaffolding practices to better inform educational policy and classroom application (16, 17, 29).

The present study contributes to this growing body of research by examining the impact of scaffolding instructional strategies on sixth-grade science learning, specifically focusing on their effects on self-regulation, retention, and comprehension.

Methods and Materials

The present study employed a quasi-experimental design with pretest-posttest and both experimental and control groups. The participants were assigned to two groups (the experimental group receiving instructional scaffolding and the control group). They were evaluated using the Self-Regulation Questionnaire developed by Bouffard (1995) and teacher-made tests of retention and comprehension administered before and after the intervention. The experimental group received eight instructional sessions using the intended educational packages, while the control group received their instruction in line with the official school program taught by the classroom teacher. This instruction did not include any research intervention, educational packages, or structured scaffolding strategies and was limited to conventional teaching. In contrast, the experimental group was taught using structured instruction based on packages designed in accordance with scaffolding principles. The design and optimization of the scaffolding-based instructional package were carried out with the participation of a university lecturer specializing in educational psychology and instructional design. This lecturer carefully examined the design stages, provided revision suggestions to enhance the scientific quality of the package components, and played a crucial role in its theoretical and practical validation. In addition, two certified teachers from the Ministry of Education participated in the project: one as a consultant in designing classroom activities and tools, and the other as the implementer of the instructional package in the real teaching setting. This collaboration between the university lecturer and schoolteachers facilitated the integration of theoretical knowledge with practical experience in the design and implementation of the instructional intervention.

In this design, a comparison was made between a group exposed to the independent variable and a group not exposed to it. The statistical population consisted of all sixth-grade female students in Marand city enrolled during the 2024–2025 academic year. The sample was selected through convenience sampling. Two girls' elementary schools in Marand (Roshdieh and Hakimzadeh), which met the study inclusion criteria, were chosen. From each school, one sixth-grade class was selected. Considering the difference in the number of students in these classes, 25 students were selected from each to balance the sample size. In Hakimzadeh School, where the sixth-grade class B had 35 students, a complete list of students was prepared, and then 25 were randomly selected using simple random assignment. In Roshdieh School, where the sixth-grade class A had 27 students, two students who did not meet the inclusion criteria (e.g., due to frequent absences) were excluded, and the remaining 25 were selected as the sample. After the final selection, students were assigned into two groups, experimental and control, with 25 students in each. This method helped control bias, increased internal validity, and ensured group equivalence.

The entire research process was conducted in four stages as follows:

Preparation stage: In this stage, the groundwork for conducting the experiment was established. After the samples were determined, the teacher was briefed on how to use the scaffolding method as an instructional approach, and the scaffolding educational package was prepared.

Pretest stage: In the first session, without prior notice, a pretest prepared from the content of lessons 7, 8, and 9 of the sixth-grade science textbook, along with Bouffard's Self-Regulation Questionnaire, was administered to students in both groups.

Implementation stage: In the experimental group, the teacher taught the intended lessons in class using the scaffolding educational package, while in the control group the teacher taught using conventional methods.

Posttest stage: In the final session of the experiment, without prior notice, a posttest prepared from the content of lessons 10, 11, and 12 of the sixth-grade science textbook, along with Bouffard's Self-Regulation Questionnaire, was administered to students in both groups.

The selection of lessons 7 to 9 for the pretest and lessons 10 to 12 for the posttest was based on the order of instruction in the classroom and the timing of the scaffolding-based intervention. The purpose of this study was to investigate the effect of scaffolding instruction on learning new concepts. Therefore, it was logical to conduct the posttest on the lessons taught after the intervention. Additionally, when the dependent variable involves academic achievement and performance, it is necessary to use different pretest and posttest items to prevent transfer of information and mutual influence between them. Based on the cognitive analyses conducted by Heydari-Moghadam, Behjati-Ardakani, and Nazemi-Ardakani (2016), as well as the study of Badakhshan (2016), lessons 7 to 12 of the sixth-grade science textbook are relatively uniform and equivalent in terms of content volume, type of instructional activities, and cognitive level of objectives. In other words, these lessons do not significantly differ in the amount of information presented, conceptual complexity, or required cognitive processing, and they fall within a "similar cognitive range." The activities of these lessons include observation, experimentation, modeling, design, and group discussion, which are primarily classified under the levels of "understanding," "application," and "analysis" (Anderson & Krathwohl, 2001). This cognitive equivalence demonstrates that using lessons 7 to 9 for the pretest and lessons 10 to 12 for the posttest provides a comparable level of difficulty.

The Bouffard Self-Regulation Questionnaire consists of 14 items and was developed by Bouffard et al. in 1995 and standardized in Iran by Kadivar in 2001. This questionnaire measures and evaluates self-regulation in individuals. The scoring method is based on a Likert-type scale ranging from "Strongly Agree," "Agree," "No Opinion," "Disagree," to "Strongly Disagree," which are assigned scores from 5 to 1, respectively. Items 5, 13, and 14 are reverse scored. The total score for each individual may range from 14 to 70. A higher score in each component indicates a stronger tendency of the individual to apply that component. The overall reliability coefficient of the Bouffard Self-Regulation Questionnaire, calculated using Cronbach's alpha, was reported as 0.71. In another study conducted by Gholami in 2003, the reliability was reported as 0.63. Kadivar (2001) also examined the validity and reliability of the Bouffard Self-Regulation Questionnaire. Construct validity of the questionnaire, assessed through correlation coefficients and factor analysis, as well as item discrimination indices, was reported to be satisfactory. The Cronbach's alpha coefficient for internal consistency was 0.80. Accordingly, it can be concluded that this questionnaire is capable of predicting the actual scores of participants.

To measure cognitive indicators, two teacher-made achievement tests were used as pretest and posttest, each consisting of two subtests: retention and comprehension. The pretest included 30 researcher-developed multiple-choice questions from the sixth-grade science textbook lessons "Motion and Force," "Let's Design and Build," and "The Journey of Energy," with 15 items measuring retention and 15 items measuring comprehension. The posttest also included 30 researcher-developed multiple-choice questions from the taught lessons "Very Small, Very Large," "The Wonders of Leaves," and "Why Do We Have Forests?" from the sixth-grade science textbook. The reliability of the pretest and posttest was calculated using the Kuder-Richardson 20 (KR-20) method. The reliability coefficients of both the pretest and posttest were above 0.70, indicating acceptable reliability of the measurement instruments.

In preparing these tests, three stages were carried out as follows:

1. **Formulating instructional objectives:** At this stage, the educational objectives of the six lessons ("Motion and Force (2)," "Let's Design and Build," "The Journey of Energy," "Very Small, Very Large," "The Wonders of Leaves," and "Why Do We Have Forests?") were prepared by instructors along with two senior science education supervisors of the sixth-grade curriculum in Marand. After formulating these final objectives for the lessons, entry or prerequisite objectives were also prepared.
2. **Preparing a two-dimensional table of specifications (objectives × content):** The table of specifications was developed with the purpose of selecting a representative sample of items for the pretest and posttest. This ensured the content validity of the tests.

3. **Designing the questions:** The pretest and posttest science questions were prepared by three science teachers in the Marand education district, under the supervision and final approval of two senior science education supervisors.

The scaffolding-based instructional package was developed from the sixth-grade science curriculum topics "Very Small, Very Large" (Lesson 10), "Wonders of Leaves" (Lesson 11), and "Why Do We Have Forests?" (Lesson 12) and delivered across eight sessions using a gradual release of responsibility with cognitive, visual, practical, social, and motivational supports that were systematically faded; Session 1 established study objectives for students and administered the Bouffard Self-Regulation Questionnaire (1995) alongside a researcher-designed academic pretest; Session 2 introduced and guided the use of a magnifying glass to observe small objects (e.g., reading fine print) to bridge prior knowledge with new content, formally introduced the concept of the cell, displayed images of cells and a microscope, and prompted guided questions to elicit experiences with microscopes and the purpose of multiple objective lenses; Session 3 began with targeted feedback on homework to consolidate prior learning, reviewed microscope parts to activate knowledge, and moved into "working with the microscope" using student-collected specimens (e.g., pond or pool water) so learners could observe cells directly, while the teacher provided step-by-step prompts, guided questions, and timely feedback that tapered as competence increased; volunteer students then explained microscope operation to peers to signal transfer of responsibility and strengthen scientific communication and confidence; Session 4 opened with corrective feedback and a brief review, then pivoted to "Wonders of Leaves" through a hands-on photosynthesis demonstration (pelargonium leaf, beaker, medical alcohol, iodine solution) adapted from the Grade-5 experiment to deepen conceptual understanding, embedded sequenced explanations and guiding questions, assigned a short inquiry on "carnivorous leaves" to promote autonomous learning, and used re-explanation and repetition (by the same student) to maintain supportive scaffolds while reinforcing accuracy; Session 5 consolidated prior content through student reporting and spot questions, extended leaf phenomena (carnivory, starch and oil granules, oxygen production), diagnosed needs for additional supports when hesitant or partial answers appeared, introduced a board drawing as a visual scaffold to depict oxygen production steps, and asked previously struggling students to re-explain with the drawing to stabilize learning and self-efficacy, closing with a volunteer explanation of photosynthesis reinforced by positive feedback; Session 6 began with homework reports and feedback, activated knowledge by discussing the importance of plants and trees for humans, launched "Why Do We Have Forests?" using short videos on food chains and webs, and organized small-group drawing of food chains that include humans, thereby adding visual and social scaffolds; the teacher temporarily provided supportive proximity and attention to a passive student, modeled a complete answer using a peer demonstration, then prompted the original student to restate the explanation—an overlearning scaffold—to build confidence, ending with written individual summaries to shift responsibility to independent practice; Session 7 again used homework reports, review, and peer questioning as initial scaffolds, advanced the forest unit by introducing decomposers and mold, conducted the Grade-6 experiment on page 86 with pre-arranged materials, supplemented with short clips showing rapid fungal/mold growth and spread, and orchestrated brief student mini-lessons; when a student faltered, another peer provided a correct model, after which the first student wrote and read a short response on "forest fungi," demonstrating progress and confidence, with teacher praise functioning as a motivational scaffold; Session 8 administered the posttests (Bouffard Self-Regulation Questionnaire and the researcher-designed academic test); across all sessions the teacher consistently front-loaded support (clarifying goals, activating prior knowledge, modeling and demonstrations, guided questioning, feedback, visual diagrams, peer modeling, collaborative drawing) and then strategically reduced assistance to encourage autonomy, ensure mastery of target concepts, and strengthen self-regulation, retention, and comprehension aligned with the scope and sequence of Lessons 10–12.

The collected data were analyzed using descriptive statistics (mean and standard deviation) and inferential statistics (analysis of covariance) with SPSS software.

Findings and Results

Table (1) presents the descriptive statistics (mean and standard deviation) of the research variables (self-regulation, retention, and comprehension).

Table 1. Descriptive Statistics of Research Variables

Variable	Group	Pretest Mean	Pretest SD	Posttest Mean	Posttest SD	N
Self-Regulation	Scaffolding	32.68	5.9	35.24	5.42	25
	Control	33.00	5.72	33.24	5.44	25
Retention	Scaffolding	8.28	2.35	9.20	2.20	25
	Control	8.04	1.99	8.64	1.93	25
Comprehension	Scaffolding	8.28	1.86	10.88	1.98	25
	Control	8.64	1.58	9.04	1.54	25

Based on the comparison of means (Table 3), it is observed that the mean scores of self-regulation, retention, and comprehension in the experimental group increased considerably. To determine whether this increase in means in the experimental group was due to the effect of instruction, a multivariate analysis of covariance (MANCOVA) was conducted. The results are presented in Tables 2 and 3. Prior to performing this test, assumptions were checked: normality using the Kolmogorov–Smirnov test, homogeneity of variances using Levene's test, homogeneity of regression slopes using the variance test, and equality of covariance matrices using Box's M test. All assumptions were confirmed with a significance level greater than 0.05.

Table 2. Multivariate Analysis of Covariance on the Effect of Scaffolding Method on Self-Regulation, Retention, and Comprehension

Value	df	Error df	F	Sig.	Effect Size
Wilks' Lambda	0.214	3	43	52.492	0.001

Based on the results of the above table, the calculated F value (52.492) is significant (P = 0.001). Therefore, the results show that the linear combination of the dependent variables (self-regulation, retention, and comprehension), after adjusting for the covariates (self-regulation, retention, and comprehension pretests), was influenced by the independent variable (scaffolding instructional method). Hence, the multivariate analysis of covariance is significant.

Table 3. Tests of Between-Subjects Effects

Source	Dependent Variable	Sum of Squares	df	Mean Square	F	Sig.
Group	Posttest Self-Regulation	58.265	1	58.265	75.128	0.001
	Posttest Retention	1.832	1	1.832	7.065	0.010
	Posttest Comprehension	54.619	1	54.619	99.371	0.001
Error	Posttest Self-Regulation	34.918	45	0.776		
	Posttest Retention	11.666	45	0.259		
	Posttest Comprehension	54.364	45	0.547		

To compare the posttest mean scores of the variables self-regulation, retention, and comprehension after controlling for the effect of the pretest in the three groups, a post hoc test was used (Table 3). Based on the results, a significant difference was observed between the posttest mean scores of the self-regulation variable after controlling for the pretest effect ($F(1,45) = 75.128$, $P = 0.023$). A significant difference was also observed between the posttest scores of the retention variable after controlling for the pretest effect ($F(1,45) = 7.065$, $P = 0.010$). Similarly, a significant difference was found between the posttest scores of the comprehension variable after controlling for the pretest effect ($F(1,45) = 99.371$, $P = 0.001$). Therefore, the posttest mean scores of the experimental group (scaffolding instructional method) were significantly higher than those of the control group in all three dependent variables (self-regulation, retention, and comprehension).

Discussion and Conclusion

The findings of this study demonstrated that the scaffolding instructional method had a significant impact on sixth-grade students' self-regulation, retention, and comprehension in science learning. Results from the multivariate analysis of covariance revealed that the experimental group, which received structured scaffolding instruction, outperformed the control group on all posttest measures even after controlling for pretest differences. These outcomes confirm that scaffolding provides structured supports that allow learners to bridge the gap between their current abilities and the desired level of performance. The observed improvements suggest that scaffolding is not only an effective pedagogical tool but also a transformative learning mechanism that enhances both cognitive and self-regulatory processes.

One of the most notable results was the increase in self-regulation scores among students exposed to scaffolding. This aligns with the broader literature that positions self-regulation as a critical outcome of structured educational supports. Shao et al. (6) found that regulated learning scaffolds significantly improved students' regulation strategies and academic performance, underscoring that scaffolding equips learners with the tools to manage their own learning processes. Sharma and Nguyen (7) further highlighted that scaffolding strengthens both self-regulation and shared regulation in collaborative environments, reinforcing the idea that scaffolding not only supports individual learners but also fosters collective learning dynamics. The present findings add to this body of evidence by showing that scaffolding interventions are equally powerful in primary school science classes, where self-regulation is still developing.

The improvement in retention scores observed in this study is also supported by prior research. Masr-Abadi and Alilu (18) demonstrated that concept mapping, a form of scaffolding, improved retention and comprehension of scientific concepts by providing students with structured cognitive frameworks. Similarly, Arefi et al. (20) showed that scaffolding strategies enhanced both learning and achievement motivation in students with mathematical learning disabilities, suggesting that retention benefits may extend to diverse learner populations. By gradually reducing support and requiring students to take greater responsibility for recall, scaffolding may strengthen memory consolidation processes, thereby explaining the improved retention outcomes.

In addition, comprehension scores improved significantly in the experimental group, confirming that scaffolding fosters deeper conceptual understanding. Gahihite (11) emphasized that scaffolding is a keystone for teaching chemistry because it connects abstract concepts to tangible activities, thereby promoting comprehension. This is consistent with the study by Behrad (17), which found that concept map-based scaffolding facilitated entangled learning in sixth-grade science. The findings of the present study are in line with these results, as students in the experimental group were able to grasp complex science topics such as cell structures, photosynthesis, and ecological systems more effectively when scaffolded through hands-on experiments, guided questioning, and peer teaching opportunities.

The results of this study can also be interpreted in light of meta-analytic findings that demonstrate the broad impact of scaffolding across disciplines and contexts. Delen and Liew (5) reported through a meta-analysis that scaffolding in computer-based environments significantly enhanced self-regulated learning. Although the present study focused on classroom-based instruction rather than technology-mediated learning, the consistency of positive outcomes across settings underscores the universal effectiveness of scaffolding principles. Likewise, Theobald (8) confirmed that scaffolding-based training improved university students' academic performance and motivation, demonstrating that scaffolding benefits extend across age groups and educational levels.

In addition to traditional classroom benefits, scaffolding has shown effectiveness in digital and collaborative learning environments. Zabolotna et al. (16) found that scaffolding enhanced group-level regulation and knowledge construction in computer-supported collaborative learning. Similarly, Sun et al. (15) reported that scaffolding in digital game-based learning improved primary students' perceptions of mathematics. These findings resonate with the results of the current study, suggesting that scaffolding is versatile and adaptable to multiple instructional environments, whether physical or virtual. By applying scaffolding to science content, this study confirms that the method is equally applicable in hands-on laboratory-style tasks and in conceptual discussions, thereby extending its documented effectiveness.

The enhanced self-regulation and comprehension observed here can also be connected to motivational aspects of learning. Bahrami Khamsalouei (22) found that inquiry-based teaching methods improved self-regulation and academic performance, while Babayi (21) reported that scaffolding strategies increased academic motivation and satisfaction in students with intellectual disabilities. The present findings confirm these motivational benefits by showing that students engaged more actively and confidently when supported by scaffolding. The gradual transfer of responsibility encouraged them to take ownership of their learning, thereby increasing intrinsic motivation.

Several studies also support the observed positive effects of scaffolding on language-related tasks, reinforcing the generalizability of these results. Putri et al. (10) showed that Bruner's scaffolding improved speaking skills in primary students, while Thuratham (12) demonstrated its impact on English grammar learning among undergraduates. Mezek et al. (14) similarly found that scaffolding tasks and feedback enhanced self-regulation in second language academic reading. Though the present study focused on science, the parallel improvement in comprehension indicates that scaffolding is not content-specific but rather a broadly effective pedagogical tool.

The contextual conditions of this study also warrant discussion. During the COVID-19 outbreak, Zhang (27) reported that educational disruptions negatively affected students' satisfaction and psychological well-being. These disruptions highlighted the need for instructional methods that could maintain learning continuity under stress. The success of scaffolding in this study illustrates how structured support strategies can provide stability and predictability in times of uncertainty, ensuring that students remain engaged and able to progress even under challenging conditions.

It is also important to note that the success of scaffolding in this study resonates with research on conceptual mapping and inquiry-based learning. Mansouri Talebi (19) and Masr-Abadi and Alilu (18) both confirmed that structured instructional tools improve comprehension and self-regulation. Moreover, Heydari Moghaddam et al. (28) emphasized the need for aligning instructional strategies with Bloom's taxonomy levels, a principle that underpinned the scaffolding design of this study. By aligning tasks with understanding, application, and analysis levels, the intervention ensured that scaffolding addressed both lower-order and higher-order thinking skills.

The present findings are further supported by evidence from global studies. Maysara et al. (29) showed that discovery learning models combined with scaffolding improved outcomes in chemistry, while Hattan and Alexander (30) demonstrated scaffolding's effectiveness in supporting reading comprehension for competent readers. These studies highlight the adaptability of scaffolding across content domains, reinforcing that its strength lies in structuring learning interactions rather than being tied to a specific subject.

Overall, the results of this study are consistent with a substantial body of literature that affirms the cognitive, motivational, and metacognitive benefits of scaffolding. By improving self-regulation, retention, and comprehension simultaneously, scaffolding demonstrates its capacity to address multiple learning dimensions in an integrated manner. This supports the view that scaffolding is not only an instructional technique but also a holistic pedagogical approach that empowers learners to construct knowledge, develop autonomy, and enhance long-term academic outcomes (24, 26).

Despite its promising results, this study is not without limitations. The research was conducted with a relatively small sample of sixth-grade female students from two schools in Marand, which limits the generalizability of findings to broader populations, including male students, other grade levels, and different cultural or regional contexts. The study also employed a quasi-experimental design with convenience sampling, which may have introduced selection biases that could influence internal validity. Another limitation concerns the reliance on researcher-made tests for measuring retention and comprehension, which, despite undergoing content validation, may not fully capture the complexity of students' cognitive growth. Moreover, the duration of the intervention was relatively short, consisting of only eight instructional sessions, and therefore does not provide insights into the long-term sustainability of the observed effects. Finally, the study did not incorporate qualitative data, such as classroom observations or student interviews, which might have provided richer insights into how students experienced scaffolding supports and how these shaped their learning trajectories.

Future research should seek to expand the scope and depth of scaffolding studies by addressing these limitations. First, larger-scale studies with diverse samples across gender, grade levels, and cultural contexts would improve the external validity of results. Comparative studies across subject areas—such as mathematics, language, and social sciences—could further demonstrate the transferability of scaffolding principles. Longitudinal research is also needed to examine whether improvements in self-regulation, retention, and comprehension are sustained over time and whether they translate into broader academic success. In addition, mixed-methods approaches that combine quantitative outcomes with qualitative insights could enrich understanding by capturing students' perspectives, teacher practices, and classroom dynamics. Future studies may also investigate the integration of digital scaffolding tools, particularly in blended and online learning environments, to determine how technology-mediated supports can complement traditional classroom scaffolding.

In practice, educators should consider incorporating scaffolding strategies into science instruction and beyond to enhance student learning. Teachers can begin by providing structured supports such as guided questioning, visual aids, and step-by-step modeling, and then gradually fade these supports as students gain independence. Embedding opportunities for peer collaboration, self-reflection, and active problem-solving can further strengthen self-regulation. Schools should also provide professional development for teachers to learn how to design and implement scaffolding effectively, ensuring alignment with curricular goals and cognitive levels. Finally, policymakers and curriculum developers should recognize the value of scaffolding as a pedagogical tool and integrate it into instructional guidelines and teacher training programs to foster deeper learning, improved retention, and enhanced self-regulation among students.

Acknowledgments

We would like to express our appreciation and gratitude to all those who helped us carrying out this study.

Authors' Contributions

All authors equally contributed to this study.

Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

All ethical principles were adhered in conducting and writing this article.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

Funding

This research was carried out independently with personal funding and without the financial support of any governmental or private institution or organization.

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