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Enhancing Elementary Students' Science Achievement through the Snowball Throwing Model with Visual Cue Cards: A True Experimental Study

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Abstract

This study investigated the effectiveness of integrating the Snowball Throwing cooperative learning model with visual cue cards in improving elementary students' science achievement on ecosystem concepts. The study employed a true experimental pretest–posttest control group design involving 66 fifth-grade students randomly assigned to experimental and control groups. Student achievement was measured using a validated multiple-choice test. Prior to hypothesis testing, data met parametric assumptions, as indicated by normal distribution (Shapiro–Wilk, $p > .05$) and homogeneous variance (Levene's test, $p = .651$). Data were analyzed using independent samples t-tests and effect size estimation. The results revealed that the experimental group achieved significantly higher posttest scores than the control group ($t(64) = 6.12$, $p < .001$), with a large effect size (Cohen's $d = 1.46$). Gain score analysis also showed a significant difference ($t(64) = 7.22$, $p < .001$; Cohen's $d = 1.80$), indicating substantially greater learning improvement among students exposed to the cooperative–visual approach. These findings suggest that combining structured peer interaction with visual scaffolding effectively enhances conceptual understanding in elementary science learning. The study provides empirical support for implementing multimodal cooperative strategies to improve science achievement in primary education.

Keywords: cooperative learning, elementary education, science achievement, snowball throwing, visual cue cards

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INTRODUCTION

The accelerating demands of twenty-first-century education require learners to develop higher-order thinking competencies, including critical, creative, collaborative, and communicative skills, as essential foundations for navigating complex social and technological environments (Adnyana et al., 2025; Nadawina et al., 2025). In response to these demands, the role of teachers has shifted from knowledge transmitters to facilitators who foster students' reasoning, creativity, and active engagement in learning processes (Vitrianti et al., 2025; Yuniarti, 2021). Consequently, instructional approaches must intentionally activate students' cognitive, social, and communicative capacities from early schooling.

In Indonesia, these global educational shifts are reflected in the 2013 Curriculum and the Merdeka Curriculum, both of which emphasize competency-based and student-centered learning aligned with the *Profil Pelajar Pancasila*, particularly critical reasoning (Kemendikbudristek, 2022). However, classroom practices in many elementary schools remain dominated by teacher-centered instruction, rote memorization, and limited dialogic interaction. Such practices restrict opportunities for deep conceptual processing and higher-order thinking, creating a persistent gap between curricular aspirations and pedagogical realities (Mahmudah, 2016).

This gap is especially evident in elementary science education. Despite its potential to develop scientific literacy and reasoning, science instruction is often constrained by lecture-based methods that limit inquiry, exploration, and conceptual construction. These approaches hinder students' ability to develop meaningful scientific understanding and reduce their motivation and interest in science learning (Handhika et al, 2020; Kusumawati, 2022). Abstract topics such as ecosystems require students to connect interrelated concepts with observable phenomena, making both active engagement and conceptual scaffolding essential for effective learning.

Empirical observations at Public Elementary School 1 Batu Mekar illustrate this challenge. Grade V science instruction remains largely conventional, resulting in limited student participation and persistently low achievement in ecosystem topics. Students frequently struggle to visualize interactions among biotic and abiotic components when instruction relies predominantly on verbal explanation. This condition is consistent with findings Yanti et al. (2024), who reported that insufficient media support and limited pedagogical innovation hinder the development of critical thinking in elementary science classrooms.

One instructional approach that addresses these limitations is the Snowball Throwing model. As a cooperative learning strategy, Snowball Throwing promotes active participation by engaging students in generating questions, engaging in interactive movement, and collaborating on problem-solving (Arends, 2012; Suprijono, 2009). Previous studies have demonstrated its effectiveness in improving communication skills, reflective thinking, participation, and learning outcomes across subject areas (Mashuri, Fauzi, & Mufidah, 2024; Siagiana et al, 2025; Suhendra, Wahyuningtyas, & Andjajani, 2024). Nevertheless, for conceptually complex science content, cooperative interaction alone may be insufficient without adequate representational support.

Visual cue cards provide complementary instructional support with concrete, visually engaging representations that align with the developmental characteristics of elementary learners. Visual depictions of ecological interactions and food-chain sequences can scaffold understanding through representational modes described in Bruner's theory (Bruner, 1974) and dual coding principles articulated by Mayer (2002).

When integrated into Snowball Throwing activities, visual cue cards create a multisensory learning environment that combines physical activity, social interaction, and visual processing, consistent with active learning principles (Bonwell & Eison, 1991).

Recent empirical studies and meta-analyses have increasingly emphasized the effectiveness of cooperative learning models and visual media in elementary science education. Cooperative learning has been shown to significantly enhance higher-order thinking skills, conceptual understanding, and student engagement when learners actively construct knowledge through peer interaction and structured collaboration (Gillies, 2019; Kyndt et al., 2013). In the context of science learning, cooperative models facilitate cognitive elaboration, argumentation, and shared problem solving, which are essential for understanding abstract and systemic concepts such as ecosystems.

At the same time, research on visual scaffolding demonstrates that visual supports such as diagrams, cue cards, and representational media play a critical role in helping elementary students bridge concrete experiences and abstract scientific ideas (Schneider et al, 2018; Sung et al, 2021). Visual media reduce cognitive load, support dual-channel processing, and improve long-term retention, particularly when integrated with active learning strategies. Studies conducted in elementary science classrooms indicate that visually supported instruction significantly improves students' conceptual clarity, reasoning, and learning outcomes compared to text-based or verbal instruction alone (Yildirim, 2022).

Recent studies reinforce the importance of innovative pedagogies for developing higher-order thinking and science achievement. Problem-Based Learning (PBL), for example, has enhanced critical thinking in elementary science (Amri & Rosnawati, 2024; Rambe, Khaeruddin, & Ma'ruf, 2024) and improved numeracy performance in middle school (Boangmanalu & Nasution, 2023). Systematic reviews highlight PBL's effectiveness at the secondary level (Novitasari et al, 2024), while digital media have been shown to support analytical skills in primary science learning (Yanti et al., 2024). Further studies on Snowball Throwing and PBL-based learning materials likewise demonstrate gains in reflection, participation, and conceptual understanding (Mashuri et al., 2024; Maulita et al, 2023; Munika et al, 2021; Rahmawati & Asri, 2023; Siagian et al., 2025; Yuliani et al, 2024). Despite these advances, prior studies typically investigate cooperative learning approaches or instructional media in isolation. Little empirical work examines the combined pedagogical value of integrating Snowball Throwing with visual cue cards, especially in elementary science and ecosystem learning.

Despite the growing body of research on cooperative learning models and the use of visual media in science education, existing studies predominantly examine these approaches as separate instructional strategies. Prior research has largely focused on the effects of cooperative learning models in isolation or on the use of visual media in isolation, without empirically testing their combined impact within a single instructional design. Moreover, experimental studies that integrate cooperative questioning strategies with structured visual scaffolding remain limited, particularly in the context of elementary science learning.

In the Indonesian educational context, this gap is even more evident. While several studies have reported positive effects of Snowball Throwing or other cooperative models on student engagement and achievement, no true experimental study to date has specifically investigated the integration of the Snowball Throwing model with visual cue cards for teaching ecosystem concepts in elementary schools. As a result, empirical evidence regarding the synergistic effects of cooperative interaction and visual scaffolding on elementary students' science achievement remains insufficient.

Therefore, the originality of this study lies in its theoretical and practical contributions. Theoretically, this research extends the literature on cooperative learning and multimedia learning by empirically demonstrating that integrating peer-generated questioning through the Snowball Throwing model and visual scaffolding through cue cards jointly supports conceptual understanding in elementary science learning. In practice, the study offers a pedagogically sound, low-cost, and feasible instructional model for classroom implementation, particularly in Indonesian elementary schools. By aligning cooperative learning processes with visual supports, the proposed approach provides teachers with a concrete strategy to teach abstract ecosystem concepts more effectively and to foster active, student-centered learning in accordance with the Merdeka Curriculum.

METHOD

This study employed a true-experimental quantitative design to examine the effectiveness of the Snowball Throwing learning model, enhanced with visual cue cards, on elementary students' science achievement. A pretest–posttest control group design with random assignment was applied to strengthen internal validity and minimize selection bias. The research was conducted at Public Elementary School 1 Batu Mekar during the 2024/2025 academic year and involved all 66 fifth-grade students. Using simple random assignment, 33 students were allocated to the experimental group and 33 to the control group. Table 1 presents the characteristics of the research participants.

Table 1.
Characteristics of Research Participants

Characteristic	Experimental Group (n = 33)	Control Group (n = 33)
Mean Age (years)	10.8	10.9
Gender (Male)	17	16
Gender (Female)	16	17
Grade Level	Grade V	Grade V
School	Public Elementary School 1 Batu Mekar	Public Elementary School 1 Batu Mekar

The experimental treatment consisted of a Snowball Throwing cooperative learning sequence integrated with visual cue cards illustrating ecosystem components, food-chain relationships, and biotic–abiotic interactions. The instructional procedures were implemented over three to four sessions, each approximately 70 minutes long. During the Snowball Throwing activities, students generated questions, exchanged them through a structured throwing process, and collaboratively discussed the answers, while the visual cue cards functioned as cognitive scaffolds to support conceptual visualization. The control group received conventional instruction emphasizing teacher explanation, textbook-based examples, and limited questioning, with identical content coverage and instructional time.

To ensure treatment fidelity, the implementation of the Snowball Throwing model with visual cue cards was monitored using an observation checklist. The checklist evaluated adherence to instructional stages, appropriate use of visual cue cards, student engagement, and time allocation. Observations were conducted collaboratively by the researcher and the classroom teacher during each session, confirming consistent implementation across meetings.

The visual cue cards were developed based on the Grade V science curriculum, particularly ecosystem content covering biotic and abiotic components, food chains, and ecological interactions. Each card contained concise textual prompts accompanied by illustrative visuals designed to support students' conceptual understanding. The development process involved three stages: content selection, visual design, and expert validation. Content validity was assessed by two experts in elementary science education, with a focus on relevance, clarity, and accuracy. Revisions were made in response to expert feedback before classroom implementation, and the finalized cue cards were deemed appropriate for instructional use.

The stages of the Snowball Throwing learning model integrated with visual cue cards are summarized in Table 2.

Table 2.
Snowball Throwing Learning Stages with Visual Cue Cards

Stage	Learning Activities	Teacher Role	Student Role	Use of Visual Cue Cards
Orientation	Teacher introduces learning objectives and ecosystem topics	Explains objectives and motivates students	Listen and respond	Cue cards introduced as learning aids
Group Formation	Students are divided into heterogeneous groups	Organizes groups	Join assigned groups	Cue cards distributed to each group
Question Construction	Students write questions related to ecosystem concepts	Guides question formulation	Generate questions collaboratively	Cue cards used as reference
Snowball Throwing	Questions are exchanged through throwing activity	Facilitates and monitors activity	Throw, receive, and read questions	Cue cards help interpret questions
Group Discussion	Groups discuss answers to received questions	Provides scaffolding	Discuss and formulate answers	Cue cards support concept visualization
Presentation & Feedback	Groups present answers	Gives feedback and clarification	Present and respond	Cue cards used during explanation
Reflection & Conclusion	Teacher summarizes key concepts	Reinforces learning outcomes	Reflect on learning	Cue cards reviewed collectively

Student achievement was measured using a 20-item multiple-choice test aligned with the Grade V science curriculum, covering ecosystem concepts such as biotic–abiotic interactions, ecological interactions, and food-chain systems. Content validity was ensured through expert review, and pilot testing confirmed acceptable item clarity and internal consistency. Each correct answer was scored as one point, yielding a maximum raw score of 20, which was subsequently converted to a 100-point scale. Parallel forms of the test were administered for the pretest and posttest to reduce recall bias. The validity and reliability of the achievement test are presented in Table 3.

Table 3.
Validity and Reliability of Science Achievement Test

Aspect	Description	Result
Content Validity	Evaluated by two science education experts	Valid
Construct Validity	Alignment with ecosystem learning indicators	Appropriate
Number of Items	Multiple-choice questions	20 items
Reliability Test	Cronbach's Alpha	0.82
Reliability Category	Internal consistency	High

Data collection was conducted in three stages: pretest administration, implementation of instructional treatments, and posttest administration. Data analysis included descriptive statistics and inferential testing. Normality was assessed using the Shapiro–Wilk test, and homogeneity of variance was examined using Levene's test. Because the data met parametric assumptions, independent-samples t-tests were used to compare posttest and gain scores between groups at the significance level $\alpha = 0.05$. Effect sizes were calculated using Cohen's d to determine the magnitude of the intervention's impact. All analyses were performed using SPSS version 27.

Ethical principles were upheld throughout the study. Permission was obtained from the school administration, and all participants were informed of the research purpose and procedures. Participation posed no foreseeable risks, and confidentiality was ensured through data anonymization. The study complied with institutional and national guidelines for research involving human participants.

RESULTS AND DISCUSSION

Results

The study involved 66 fifth-grade students at Public Elementary School 1 Batu Mekar who were randomly assigned to an experimental group (n = 33) and a control group (n = 33). Prior to the instructional intervention, both groups completed a pretest to assess their initial understanding of ecosystem concepts. After the intervention, a posttest with an equivalent assessment structure was administered. Descriptive statistics for pretest and posttest scores are presented in Table 4.

Table 4.
Summary of Pretest and Posttest Scores

Group	N	Mean Pretest	SD Pretest	Mean Posttest	SD Posttest
Experimental	33	61.06	9.87	84.85	7.76
Control	33	62.12	9.66	72.88	8.57

The mean pretest scores differed by only 1.06 points, indicating comparable initial achievement between the two groups. Following the intervention, both groups demonstrated improved performance; however, the increase was substantially greater in the experimental group than in the control group, suggesting a greater improvement in science achievement among students taught using the Snowball Throwing model supported by visual cue cards.

Before conducting inferential analyses, the assumptions for parametric testing were examined. Normality of posttest scores was assessed using the Shapiro–Wilk test, as shown in Table 5.

Table 5.
Shapiro–Wilk Normality Test Results

Group	Shapiro–Wilk Statistic	Sig. (p-value)
Experimental	0.963	0.268
Control	0.977	0.589

All p-values exceeded the 0.05 threshold, indicating that the posttest data were normally distributed. Homogeneity of variance was subsequently tested using Levene's test (see Table 6).

Table 6.
Levene's Test for Homogeneity of Variance

Variable	Levene Statistic	df1	df2	Sig. (p-value)
Posttest IPA	0.206	1	64	0.651

The non-significant Levene's test result (p = 0.651) confirmed homogeneity of variance. With both assumptions satisfied, independent samples t-tests were conducted to compare posttest scores and gain scores between groups. The results of the independent samples t-test for posttest scores are presented in Table 7.

Table 7.
Independent Samples t-Test for Posttest Scores

Group	Mean	Std. Deviation	N
Experimental	84,85	7,76	33
Control	72,88	8,57	33
t(64)	Sig. (2-tailed)		
6,118	0,000		

The analysis revealed a statistically significant difference in posttest scores between the two groups, $t(64) = 6.118$, $p < 0.001$, favouring the experimental group. The effect size was large (Cohen's $d = 1.46$), indicating a substantial practical impact of the Snowball Throwing model supported by visual cue cards on students' science achievement.

To examine the magnitude of learning improvement, gain scores were compared using an independent samples t-test. The results are summarized in Table 8.

Table 8.
Independent Samples t-Test for Gain Scores

Group	Mean Gain	Std. Deviation	N
Experimental	23,79	8,18	33
Control	10,76	6,17	33
t(64)	Sig. (2-tailed)		
7,220	0,000		

The comparison of gain scores showed a significant difference between groups, $t(64) = 7.220$, $p < 0.001$, with the experimental group exhibiting a markedly greater increase in scores. The effect size for gain scores was also large (Cohen's $d = 1.80$), indicating a strong instructional effect.

To further interpret the magnitude of learning improvement, a normalized gain (N-gain) analysis based on Hake's criteria was conducted. The results are presented in Table 9.

Table 9.
Normalized Gain (N-Gain) Classification Based on Hake Criteria

Group	Mean Pretest	Mean Posttest	Mean N-gain (g)	Gain Category
Experimental	61.06	84.85	0.61	Medium
Control	62.12	72.88	0.28	Low

Based on Hake's classification, the experimental group achieved a medium level of learning gain ($g = 0.61$), whereas the control group demonstrated a low gain category ($g = 0.28$). These findings reinforce the gain score analysis, confirming that the Snowball Throwing model supported by visual cue cards resulted in substantially greater conceptual improvement than conventional instruction.

Correlation analysis between learning activities and posttest scores was not conducted in this study because learning activities were documented qualitatively for treatment fidelity monitoring rather than quantified for statistical analysis. The observation data focused on instructional adherence, appropriate use of visual cue cards, and overall student engagement, which did not yield numerical indicators suitable for correlational testing. To provide a clearer visualization of learning improvement across groups, the interaction between pretest and posttest mean scores for the experimental and control groups is illustrated in Figure 1, which highlights a steeper increase in performance for the experimental group compared to the control group.

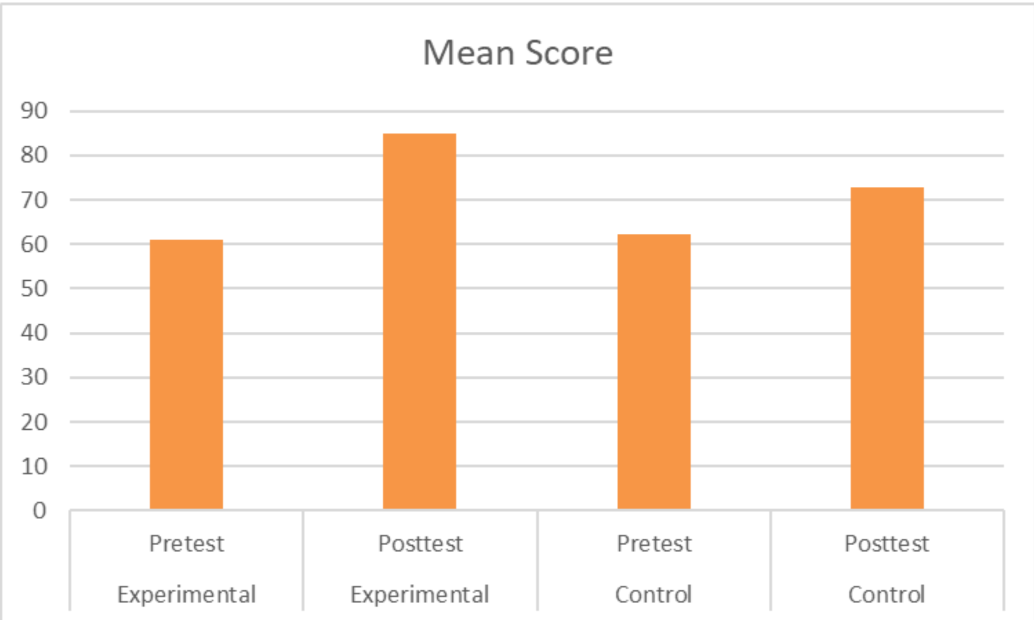

Figure 1. Pretest–Posttest Score Comparison Between Experimental and Control Groups

The figure shows a steeper increase in mean scores for the experimental group compared to the control group, indicating greater learning improvement following the Snowball Throwing intervention supported by visual cue cards.

Discussion

The findings of this study indicate that integrating the Snowball Throwing cooperative learning model with visual cue cards significantly improves elementary students' science learning outcomes compared with conventional instruction. The experimental group consistently outperformed the control group across posttest scores, gain scores, and normalized gain categories, suggesting that the observed improvement reflects meaningful conceptual understanding rather than short-term memorization. This result aligns with constructivist learning theory, which emphasizes that knowledge is actively constructed through interaction and engagement with learning tasks (Arends, 2012; Suprijono, 2009), and is supported by empirical studies demonstrating the effectiveness of cooperative learning models in elementary science classrooms (Bonwell & Eison, 1991; Mashuri et al., 2024; Siagian et al., 2025).

In relation to previous empirical research, the results of this study corroborate findings that Snowball Throwing enhances student participation, questioning skills, and academic achievement by encouraging active peer interaction (Mashuri et al., 2024; Suhendra et al., 2024). Studies on cooperative and problem-based learning in science education have similarly reported positive effects on students' critical thinking and conceptual understanding, particularly when learning activities emphasize dialogue and inquiry (Amri & Rosnawati, 2024; Boangmanalu & Nasution, 2023; Novitasari et al., 2024; Rambe et al., 2024). However, most prior studies have focused on cooperative learning strategies without systematically integrating visual media, leaving a gap regarding how representational support may strengthen cooperative processes in elementary science learning.

From a cognitive perspective, the intervention's effectiveness can be explained by cognitive load theory. Ecosystem concepts require learners to process multiple abstract relationships simultaneously, which can overload working memory when instruction relies heavily on verbal explanation (Paas et al, 2003). The visual cue cards used in this study functioned as cognitive scaffolds that externalized essential information, reduced extraneous cognitive load, and allowed students to allocate more cognitive resources to germane processing. This interpretation is consistent with research showing that visual scaffolding supports schema construction and improves conceptual understanding in elementary science education (Bruner, 1974; Schneider et al., 2018).

In addition, dual coding and multimedia learning principles help explain why the integration of verbal interaction and visual representation was particularly effective. According to dual coding theory, learning is enhanced when information is processed through both verbal and visual channels, as this creates multiple cognitive pathways for understanding and retention (Fiorella & Mayer, 2021; Mayer, 2002). During Snowball Throwing activities, students simultaneously engaged in verbal questioning and discussion while interpreting visual representations on the cue cards. This complementary processing likely strengthened memory traces and facilitated deeper conceptual integration, as reflected in the higher learning gains achieved by the experimental group (Maulita et al., 2023; Munika et al., 2021).

Beyond cognitive mechanisms, social processes embedded in the Snowball Throwing model also contributed substantially to the observed learning gains. Social interdependence theory posits that cooperative learning environments promote positive interdependence, individual accountability, and promotive interaction, which are essential for deep learning (Johnson & Johnson, 2014). By requiring students to generate questions, respond to peers' inquiries, and collaboratively negotiate answers, Snowball Throwing fostered meaningful peer interaction and collective knowledge construction. Similar social–cognitive benefits have been reported in studies showing that structured cooperative questioning enhances reasoning and conceptual understanding in science learning (Gillies, 2019; Kyndt et al., 2013).

The core contribution of this study lies in demonstrating the synergistic effect of integrating cooperative learning and visual scaffolding within a single instructional design. While Snowball Throwing promotes engagement and interaction, visual cue cards provide representational support that anchors discussion in concrete conceptual references. This synergy helps explain why the experimental group achieved a medium normalized gain, whereas the control group remained in the low gain category. Previous research has suggested that multimodal instructional designs are more effective than single-strategy approaches because they simultaneously address cognitive processing and social interaction (Rahmawati & Asri, 2023; Schneider et al., 2018; Sung et al., 2021), and the present findings provide empirical support for this claim in the context of elementary ecosystem learning.

Finally, the findings of this study are closely aligned with the goals of 21st-century learning, which emphasize critical thinking, collaboration, communication, and active learner engagement. The Snowball Throwing model encourages students to articulate ideas, evaluate peers' responses, and engage in collaborative dialogue, while visual cue cards support analysis and explanation of abstract scientific relationships. This approach aligns with contemporary curricular frameworks, such as the Merdeka Curriculum, which advocate student-centered and inquiry-oriented learning (Kemendikbudristek, 2022), and with research highlighting the importance of active, visually supported instruction in elementary science education (Yanti et al., 2024).

CONCLUSION

This study concludes that integrating the Snowball Throwing cooperative learning model with visual cue cards effectively enhances elementary students' science learning outcomes, particularly in understanding ecosystem concepts, as evidenced by consistently higher posttest performance and learning gains compared to conventional instruction. These findings directly address the research questions by confirming that structured peer interaction, combined with visual scaffolding, yields more meaningful conceptual learning than teacher-centered approaches. From a theoretical perspective, this study contributes to the literature by empirically demonstrating how cognitive and social learning mechanisms, such as dual coding, cognitive load reduction, and cooperative interaction, can be integrated synergistically within elementary science instruction. Practically, the results suggest that educational institutions should encourage instructional innovation by revising campus and school performance evaluation systems, including the SKP framework, to emphasize quality-based indicators such as instructional effectiveness, learning impact, and pedagogical creativity rather than solely administrative outputs. Such policy adjustments would better support lecturers and teachers who implement evidence-based, student-centered learning models. For future research, longitudinal studies are recommended to examine the sustainability of learning gains over time, and mixed-methods approaches are recommended to explore students' cognitive, affective, and social development in greater depth. Overall, this study underscores the importance of integrating cooperative learning and visual media as a scalable, pedagogically sound strategy for improving science education amid contemporary educational demands.

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