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FLORAVIA: an augmented reality flipbook for assessing students' conceptual understanding and motivation in fern morphology

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ABSTRACT

This study examined changes in students' conceptual understanding of fern morphology and characterized their learning motivation following the implementation of FLORAVIA, an augmented reality flipbook. A quantitative pre-experimental one-group pretest–posttest design involved 52 eleventh-grade students in Indonesia. Data were collected using cognitive tests and an ARCS-based motivation questionnaire. Cognitive scores were analyzed using descriptive statistics, normalized gain, Shapiro–Wilk, and Wilcoxon signed-rank tests, while motivation was analyzed descriptively. Mean cognitive scores increased from 62.31 to 89.81 ($Z = -5.998$, $p < 0.001$), with a moderate N-Gain of 0.6980. Learning motivation reached 3.49 out of 4.00, indicating very high post-intervention motivation. FLORAVIA demonstrates potential as an interactive medium for supporting conceptual understanding and favorable motivational responses in fern morphology learning. However, controlled studies with baseline motivation measurements are needed to establish causal effects and broader educational applicability.

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Introduction

Biology education plays a fundamental role in developing students' scientific literacy, conceptual understanding, and learning motivation by facilitating the acquisition of biological knowledge and the interpretation of relationships between organisms and their environment (Sari *et al.*, 2023; Wabula *et al.*, 2020). However, learning biological concepts frequently requires advanced observational, interpretative, and visualization skills, particularly when students encounter complex biological structures that cannot be adequately represented through verbal explanations or static two-dimensional images. Conventional instructional approaches and inadequate learning media may restrict students' opportunities to construct meaningful knowledge, resulting in difficulties in conceptual understanding and reduced learning engagement (Fitriana *et al.*, 2023; Fitriyah *et al.*, 2020). These challenges are particularly relevant to botany education, which tends to receive relatively limited attention despite its importance in understanding plant diversity, structural characteristics, and ecological functions (Barreiro *et al.*, 2024). Consequently, instructional approaches that integrate interactive visualization with structured learning experiences are needed to address the cognitive and motivational challenges associated with plant morphology education.

One of the persistent challenges in botany education is plant blindness, a phenomenon characterized by individuals' limited awareness, recognition, and appreciation of plants compared with other organisms. Limited knowledge and experience in plant identification may further restrict students' ability to recognize morphological diversity and understand the biological significance of plant structures (Velazco *et al.*, 2022). This challenge is particularly relevant to fern morphology, which requires students to distinguish leaf characteristics, sporophylls, and the distribution and arrangement of sori while interpreting their relationships with reproductive functions and environmental adaptation. The systematic presentation of morphological characteristics through plant identification keys can facilitate students' identification skills and strengthen their understanding of structural diversity (Wisanti *et al.*, 2023). Nevertheless, limited access to real specimens and the representational constraints of conventional learning materials may hinder students' ability to observe and compare these characteristics comprehensively. Learning media that provide interactive and detailed visual representations are therefore needed to bridge the gap between theoretical knowledge and morphological observation while promoting meaningful engagement with plant biology.

Advances in educational technology offer opportunities to address these challenges through the integration of digital flipbooks and augmented reality (AR). Digital flipbooks facilitate the systematic organization of instructional content, whereas AR enables students to explore biological structures through interactive three-dimensional representations and multiple viewing perspectives. The integration of digital technologies into biology education can support conceptual understanding and learning engagement by providing more accessible and visually meaningful learning experiences (Tuarez & Oviedo, 2023). From a cognitive perspective, interactive visualization may facilitate the integration of verbal information and visual representations, helping students establish relationships between morphological characteristics and biological functions. In response to these instructional needs, Bawain *et al.* (2026) developed FLORAVIA, an AR-based flipbook specifically designed for fern morphology learning using the ADDIE development model. The medium obtained content and media expert validation scores of 85% and 100%, respectively, alongside favorable practicality assessments. Although these findings establish its preliminary feasibility, they do not independently demonstrate improvements in students' conceptual understanding or characterize their motivational responses during classroom implementation.

Despite growing empirical evidence supporting AR integration in education, important gaps remain concerning its application to subject-specific learning outcomes and motivational dimensions. Lai *et al.* (2022) emphasized that educational technology evaluation should extend beyond technological functionality and instructional design to encompass cognitive and affective learning outcomes. Furthermore, meta-analytical studies have reported positive contributions of AR to knowledge acquisition, academic performance, and learning motivation across educational contexts (Chang *et al.*, 2022; Lin & Yu, 2023). However, these broader findings do not necessarily establish the educational contribution of AR-based flipbooks to fern morphology learning, where students must integrate visual identification, structural comparison, and functional interpretation. The existing evaluation of FLORAVIA has primarily addressed product validity and practicality, leaving its classroom implementation and associated learning outcomes insufficiently examined. This gap highlights the need for an empirical investigation that considers both changes in conceptual understanding and students' motivational responses while recognizing that technological feasibility alone does not guarantee meaningful learning outcomes.

Accordingly, this study aims to examine changes in students' conceptual understanding of fern morphology and characterize their learning motivation following the implementation of FLORAVIA at SMA Muhammadiyah 1 Taman, Indonesia. The study extends previous product development research by integrating cognitive assessment with a multidimensional evaluation of learning motivation based on the Attention, Relevance, Confidence, and Satisfaction (ARCS) framework. Its distinctive contribution lies in examining the classroom application of structured digital learning materials combined with interactive three-dimensional visualization within the specific context of fern morphology education. Rather than establishing definitive causal relationships, this investigation provides preliminary empirical evidence regarding changes in students' conceptual understanding and their post-intervention motivational responses. The findings are expected to inform the pedagogical integration of AR-based flipbooks into secondary school biology education and provide a foundation for subsequent controlled investigations examining their effectiveness across diverse instructional contexts.

Method

This study employed a quantitative pre-experimental approach using a one-group pretest–posttest design (Nurbaya *et al.*, 2025) to examine changes in students' conceptual understanding and characterize their learning motivation following the implementation of FLORAVIA, an augmented reality (AR)-based flipbook. The

participants comprised 52 eleventh-grade students from two classes at SMA Muhammadiyah 1 Taman, Indonesia. Both classes received the same instructional treatment and were analyzed as a single intervention group. The research procedure consisted of three stages: pretest administration, instructional activities using FLORAVIA, and posttest and motivation questionnaire administration. Given the absence of a control group, the study focused on examining cognitive changes and post-intervention motivational responses rather than establishing causal relationships.

Data were collected using a conceptual understanding test and a learning motivation questionnaire. The conceptual understanding test consisted of ten items assessing students' ability to identify, explain, compare, and analyze fern morphological characteristics, reproductive structures, biological functions, and environmental adaptations, with total scores ranging from 0 to 100. Learning motivation was measured using a 16-item questionnaire based on Keller's Attention, Relevance, Confidence, and Satisfaction (ARCS) model, as reviewed by Fang *et al*. (2024). Responses were recorded using a four-point Likert scale. Conceptual understanding was assessed before and after the intervention, whereas learning motivation was measured exclusively after the intervention.

Data were analyzed using descriptive and inferential statistics. Descriptive statistics summarized students' conceptual understanding and learning motivation, while normalized gain (N-Gain) was used to determine the magnitude of cognitive improvement based on high, moderate, and low categories (Ariana *et al.*, 2026). Participants with maximum pretest scores were excluded from the N-Gain calculation. The Shapiro–Wilk test was applied to assess the normality of paired difference scores, followed by the Wilcoxon signed-rank test because the normality assumption was not satisfied. Statistical significance was established at the 0.05 level, and effect size was calculated to determine the magnitude of cognitive change. Learning motivation was analyzed descriptively across the four ARCS dimensions and interpreted as post-intervention motivational responses rather than evidence of motivational improvement.

Table 1. Categories of Students' Learning Motivation Scores

Score	Criteria
3,26−4,00	Very High
2,51−3,25	High
1,76−2,50	Low
1,00−1,75	Very Low

Because the ARCS questionnaire was administered only after the intervention, the findings describe students' reported learning motivation following the implementation of FLORAVIA rather than an increase in motivation. The analysis therefore provided a descriptive account of students' learning motivation alongside the statistical examination of changes in conceptual understanding.

Results and Discussions

Descriptive Analysis of Students' Conceptual Understanding

The descriptive analysis involved 52 eleventh-grade students at SMA Muhammadiyah 1 Taman. The results showed an increase in students' conceptual understanding scores following the implementation of the FLORAVIA augmented reality-based flipbook (Table 6). The mean pretest score was 62.31 (SD = 22.89), whereas the mean posttest score increased to 89.81 (SD = 9.60). The mean difference between the pretest and posttest scores was 27.50 points (SD = 20.18), with individual differences ranging from −10 to 80 points. Posttest scores were also more homogeneous than pretest scores, as indicated by the smaller standard deviation. These findings indicate that students obtained higher conceptual understanding scores after participating in the learning activities using FLORAVIA.

Table 2. Descriptive Statistics of Students' Conceptual Understanding Scores

Statistic	Pretest	Posttest	Difference
N	52	52	52
Mean	62,31	89,81	27,50
Standard Deviation	22,89	9,60	20,18
Minimum	20	70	−10
Maximum	100	100	80

To describe which aspects of conceptual understanding changed, students' responses were also examined for each of the ten indicators measured by the test (Table 7). Because each item was worth 10 points, the overall

mean percentage of correct answers (62.31% in the pretest and 89.81% in the posttest) corresponds to the mean scores in Table 6. The percentage of correct answers increased in nine of the ten indicators. The largest gains occurred in the higher-order indicators, namely analyzing the morphological similarity between two ferns (indicator 8; from 28.85% to 98.08%), analyzing the relationship between morphological similarity and kinship (indicator 9; from 34.62% to 96.15%), and determining morphological characters or functions based on leaf shape and sori (indicator 7; from 53.85% to 98.08%). Indicators concerning the explanation of morphological, reproductive, and functional concepts (indicators 1–4) already had relatively high pretest percentages (69.23%–82.69%) and reached 96.15%–100% in the posttest. In contrast, the percentage of correct answers on indicator 6, identifying and differentiating ferns based on leaf characters, sporophylls, and sorus patterns, decreased from 71.15% to 63.46%, and indicator 10, relating leaves and sori to function and environmental adaptation, reached only 65.38% in the posttest. Indicator 5 showed a marginal increase (from 78.85% to 82.69%). Each indicator was represented by a single item; the item-level percentages are therefore descriptive and should not be interpreted as scale scores.

Table 3. Percentage of Students Answering Each Conceptual Understanding Indicator Correctly

No	Conceptual Understanding Indicator	Pretest (% correct)	Posttest (% correct)
1	Explaining the morphological and reproductive characteristics of ferns	76,92% (40)	98,08% (51)
2	Explaining the relationship between moist environments/sori and fern life and reproduction	69,23% (36)	100% (52)
3	Explaining the functions of trophophylls and sporophylls	73,08% (38)	100% (52)
4	Explaining the function of sori and morphological variation among species	82,69% (43)	96,15% (50)
5	Identifying ferns based on leaf shape and sorus position	78,85% (41)	82,69% (43)
6	Identifying and differentiating ferns based on leaf characters, sporophylls, and sorus patterns	71,15% (37)	63,46% (33)
7	Determining morphological characters and functions based on leaf shape and sori	53,85% (28)	98,08% (51)
8	Analyzing the morphological similarity between two ferns (Adiantum in the posttest)	28,85% (15)	98,08% (51)
9	Analyzing the relationship between morphological similarity and kinship (Pteris in the posttest)	34,62% (18)	96,15% (50)
10	Analyzing the relationship of leaves and sori to function and environmental adaptation	53,85% (28)	65,38% (34)
	Overall mean	62,31%	89,81%

Normality Test and Differences in Pretest-Posttest Scores

The normality test was conducted to determine the appropriate statistical procedure for analyzing the differences between students' pretest and posttest scores. The Shapiro–Wilk test indicated that the pretest scores ($W = 0.915$, $df = 52$, $p = 0.001$), the posttest scores ($W = 0.833$, $df = 52$, $p < 0.001$), and the difference scores ($W = 0.936$, $df = 52$, $p = 0.008$) all deviated significantly from a normal distribution, which was consistent with the Kolmogorov–Smirnov test with Lilliefors correction (pretest, $p = 0.001$; posttest, $p < 0.001$; difference scores, $p = 0.002$). Because the normality assumption was not met, the Wilcoxon Signed-Rank test was applied instead of the paired-samples t-test. The analysis showed that 47 students obtained higher scores in the posttest than in the pretest (positive ranks; mean rank = 24.89, sum of ranks = 1,170.00), one student obtained a lower posttest score (negative rank; mean rank = 6.00, sum of ranks = 6.00), and four students obtained identical pretest and posttest scores (ties). The test yielded $Z = -5.998$ with an asymptotic significance of $p < 0.001$ (two-tailed). These results indicate a statistically significant difference between students' conceptual understanding scores before and after the implementation of FLORAVIA.

Analysis of Students' N-Gain Scores

The N-Gain analysis was conducted to describe the improvement in students' conceptual understanding based on their pretest and posttest scores. Of the 52 students, 50 had valid individual N-Gain scores, while two students were excluded because their pretest scores were already at the maximum value of 100, resulting in a zero denominator in the individual N-Gain calculation. The analysis showed a mean N-Gain of 0.6980 (SD = 0.35866), equivalent to 69.80% (Table 8). Individual N-Gain scores ranged from −1.00 to 1.00, reflecting

substantial variation among students. Based on the individual N-Gain classifications, 28 students (56%) were categorized as high, 19 students (38%) as moderate, and three students (6%) as low. Thus, most students demonstrated high individual N-Gain scores following the learning intervention, whereas the mean N-Gain fell in the moderate category, just below the 0.70 threshold.

Table 4. Distribution of Students' N-Gain Categories

Category	N-Gain Range	Frequency	Percentage
High	($g \geq 0.70$)	28	56%
Moderate	($0.30 \leq g < 0.70$)	19	38%
Low	($g < 0.30$)	3	6%
Total		50	100%
Mean N-Gain		0.6980 (SD = 0.35866)	69.80%

Analysis of Students' Learning Motivation Based on the ARCS Model

Students' learning motivation was measured using a questionnaire based on Keller's ARCS model, comprising four dimensions: Attention, Relevance, Confidence, and Satisfaction. The questionnaire was administered to 52 students after the implementation of FLORAVIA. The results showed an overall mean score of 3.49 out of 4.00 (SD = 0.53), which was classified as very high. Relevance and Satisfaction obtained the highest mean scores, both at 3.51, followed by Confidence at 3.50 and Attention at 3.43 (Table 9). At the statement level, all 16 statements were classified as very high, with mean scores ranging from 3.37 (A1) to 3.60 (C4). The highest-rated statements were C4 (3.60; successfully identifying fern morphological structures using FLORAVIA increased confidence in learning Biology), R2 (3.56; fern species in FLORAVIA are relevant to plants in the students' surroundings), and S3 (3.56; the learning experience met expectations for engaging and interactive Biology learning media), whereas the lowest-rated statement was A1 (3.37; interest in fern morphology after seeing the FLORAVIA display), which also had the largest standard deviation (0.79). The relatively small differences among the four dimensions indicate that students reported consistently positive responses across the motivational aspects measured during learning with FLORAVIA.

Table 5. Students' Learning Motivation Based on the ARCS Dimensions and Statements

Code	ARCS Dimension and Statement	Mean Score	SD	Category
	Attention – AES	3,43	0,65	Very High
A1	I am interested in learning about fern morphology after seeing the FLORAVIA display.	3,37	0,79	Very High
A2	The flipbook display and Augmented Reality (AR) visualizations in FLORAVIA help me stay focused on the learning material.	3,42	0,72	Very High
A3	The 3D visualization of ferns through AR makes me want to learn more about fern morphology.	3,50	0,73	Very High
A4	Observing various fern species using FLORAVIA helps me avoid feeling bored while learning.	3,42	0,75	Very High
	Relevance – RES	3,51	0,52	Very High
R1	The fern morphology material presented in FLORAVIA is useful for helping me understand plants in my surroundings.	3,52	0,64	Very High
R2	Observing fern species in FLORAVIA is relevant to plants that I may encounter in my surroundings.	3,56	0,50	Very High
R3	After using FLORAVIA, I understand the importance of learning about the characteristics and functions of fern morphological structures.	3,50	0,61	Very High
R4	FLORAVIA helps meet my learning needs by enabling me to study fern morphology in a more interactive way.	3,48	0,67	Very High
	Confidence – CES	3,50	0,54	Very High
C1	I am confident that I can understand the morphological characteristics of ferns after learning with FLORAVIA.	3,40	0,72	Very High

Code	ARCS Dimension and Statement	Mean Score	SD	Category
C2	The instructions for using the flipbook and AR in FLORAVIA make me confident that I can participate in the learning activities successfully.	3,54	0,58	Very High
C3	I feel capable of completing activities and answering questions about fern morphology after using FLORAVIA.	3,48	0,67	Very High
C4	Successfully identifying fern morphological structures using FLORAVIA makes me feel more confident in learning Biology.	3,60	0,50	Very High
	Satisfaction – SES	3,51	0,56	Very High
S1	I feel satisfied after learning about fern morphology using FLORAVIA.	3,54	0,67	Very High
S2	I enjoy the learning process when using FLORAVIA to observe ferns through AR.	3,46	0,70	Very High
S3	The learning experience with FLORAVIA meets my expectations for engaging and interactive Biology learning media.	3,56	0,57	Very High
S4	I am willing to use FLORAVIA again in future Biology lessons.	3,48	0,67	Very High
	Overall mean	3,49	0,53	Very High

The findings demonstrate a statistically significant difference in students' conceptual understanding following the implementation of the FLORAVIA augmented reality-based flipbook. The mean score increased from 62.31 in the pretest to 89.81 in the posttest, with the Wilcoxon Signed-Rank test confirming a significant difference between the two measurements ($Z = -5.998$, $p < 0.001$). The selection of this non-parametric procedure was based on the normality test results: the difference scores deviated from a normal distribution (Shapiro–Wilk $p = 0.008$), which rendered the paired-samples *t*-test inappropriate. The Wilcoxon Signed-Rank test therefore ensured that the inferential analysis corresponded to the distributional characteristics of the observed data.

The findings indicate that FLORAVIA implementation was associated with improvements in students' conceptual understanding of fern morphology. The integration of structured digital materials and interactive three-dimensional visualizations may facilitate the observation and interpretation of complex morphological characteristics. This finding aligns with Stanič and Špernjak (2025), who emphasized the potential of augmented reality (AR) to support biology learning through interactive visualization. However, improvements were not consistent across all cognitive indicators. The percentage of correct answers on indicator 6, which assessed the identification and differentiation of ferns based on leaf characters, sporophylls, and sorus patterns, decreased after the intervention. Thorén Williams and Cederqvist (2025) emphasized that appropriate pedagogical scaffolding is essential for meaningful technology-assisted learning. Therefore, interactive visualization should be complemented by instructional guidance, while potential differences in assessment difficulty should be considered when interpreting cognitive changes.

Indicator 6 was the only indicator for which the percentage of correct answers decreased, from 71.15% (37 students) in the pretest to 63.46% (33 students) in the posttest. This indicator required students to identify and differentiate ferns based on leaf characters, sporophylls, and sorus patterns, which means that students had to apply several morphological characters to a specific specimen at the same time. Because each indicator was represented by a single item, a difference of four students corresponds to 7.69 percentage points, and this difference was not tested statistically. The decrease should therefore be interpreted as a descriptive signal rather than as evidence that students' knowledge declined. Thus, the improvement was concentrated in indicators that involved explaining concepts and comparing morphological similarity (indicators 1–4, 8, and 9), whereas indicators that required identification from specific characters (indicators 5 and 6) and relating leaves and sori to environmental adaptation (indicator 10) showed smaller gains or a decline.

Three explanations may account for this result. First, the posttest items were not identical to the pretest items, as indicated by the different fern species used in indicators 8 and 9 (Adiantum and Pteris in the posttest). Items that differ in specimens or answer options may differ in difficulty, and the difficulty level of an item directly affects the proportion of students who answer it correctly (Fitriani, 2021). Second, identification based on sori

is demanding because the location and shape of sori vary among fern species, for example between leaf veins or along the leaf margin, and in round or elongated forms (Utami *et al.*, 2023). In addition, students frequently hold misconceptions about the special characteristics of ferns (Firdaus & Wisanti, 2021), so confusion between similar characters may persist after a single learning session. Third, identification skills have been reported to improve when learning media include real plant parts (Raida *et al.*, 2024), whereas FLORAVIA presents specimens only as digital representations. Interactive three-dimensional models may also draw students' attention to manipulating the model instead of to the key concept when guidance is limited (Ilham *et al.*, 2026). Therefore, the use of FLORAVIA should be accompanied by guided observation and comparative identification exercises that train students to differentiate ferns based on leaves and sori. Future studies should also use parallel items of equivalent difficulty, verified through item analysis, to determine whether the decline in indicator 6 reflects a learning problem or an instrument effect.

The findings reinforce previous research on the pedagogical potential of AR in biology education. Fauziah *et al*. (2025) reported favorable learning outcomes in AR-assisted Pteridophyta classification, while Lidiastuti *et al*. (2025) highlighted its contribution to critical thinking. Furthermore, Indrati and Masing (2025) identified opportunities to expand AR applications beyond cellular structures, viruses, and human organ systems. FLORAVIA addresses this opportunity by integrating textual explanations with interactive spatial representations of fern morphology.

The observed cognitive improvements are consistent with meta-analytical findings demonstrating the educational potential of AR in supporting cognitive and motivational outcomes (Chang *et al.*, 2022; Xu *et al.*, 2022; Faria & Miranda, 2024). The large effect size indicates a substantial change in students' conceptual understanding within the intervention group. However, variations in individual normalized gains suggest differences in students' responses to the instructional intervention. These variations may be associated with prior knowledge, spatial visualization abilities, digital literacy, and instructional guidance, although these factors were not directly examined. Furthermore, the absence of a control group limits causal interpretation because repeated testing, teacher support, and other uncontrolled factors may have contributed to the observed cognitive improvements.

Students demonstrated favorable motivational responses across all ARCS dimensions, reflecting positive perceptions of FLORAVIA-assisted learning. Interactive visualization and contextualized learning materials may support attention, relevance, confidence, and satisfaction, consistent with previous studies (Tamam & Qomaria, 2023; Yusa *et al.*, 2023). Prasetya *et al*. (2024) similarly reported favorable outcomes across ARCS dimensions, while Silanto *et al*. (2025) emphasized attention and satisfaction in technology-assisted instruction. Nevertheless, motivational responses may be influenced by technological novelty, social desirability bias, and ceiling effects. As Çiloğlu and Üstün (2023) demonstrated, positive perceptions do not necessarily indicate significant motivational improvements. Therefore, the findings should be interpreted as favorable post-intervention motivational responses rather than evidence of increased learning motivation.

This study extends the preliminary development and feasibility evaluation of FLORAVIA conducted by Bawain *et al*. (2026) by providing empirical evidence of its classroom implementation. Its pedagogical contribution lies in integrating structured digital materials with interactive visualization to support fern morphology learning. However, effective implementation requires guided observation, comparative identification tasks, and formative feedback. The absence of a control group, limited institutional setting, potential differences in assessment difficulty, and post-intervention motivation measurements restrict causal interpretation and generalizability. Future research should employ controlled experimental designs, validated equivalent instruments, baseline motivation assessments, and delayed retention tests to establish stronger evidence regarding the effectiveness and broader applicability of AR-based flipbooks in biology education.

Conclusions

This study shows a statistically significant change in students' conceptual understanding of fern morphology between the pretest and posttest following the use of the FLORAVIA augmented reality-based flipbook. Mean cognitive scores increased from 62.31 to 89.81 (Wilcoxon $Z = \square 5.998$, $p < 0.001$), with a mean N-Gain of 0.6980 in the moderate category, just below the high threshold. The gains were largest in higher-order indicators, particularly analyzing morphological similarity and its relationship to kinship, whereas the identification and differentiation of ferns based on leaf characters, sporophylls, and sorus patterns did not improve. Separately from these cognitive results, students reported very high learning motivation across all ARCS dimensions (mean = 3.49 out of 4.00). Because motivation was measured only after the intervention, this finding describes favorable post-intervention motivational responses and does not indicate an increase in motivation or a relationship with the cognitive gains. FLORAVIA combines interactive flipbook content with three-dimensional augmented

reality visualizations; however, the contribution of the three-dimensional visualization itself was not tested separately, so the observed changes cannot be attributed to this feature alone. The one-group design without a control group, the single institutional setting, and possible differences in assessment difficulty also limit causal inference and generalizability. Future research should employ controlled experimental designs, equivalent validated instruments, baseline motivation measurements, and delayed retention tests, and should examine the specific contribution of three-dimensional visualization to conceptual understanding.

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