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Design and Preliminary Evaluation of Augmented Reality Multimedia for Grade VIII Science Learning

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A B S T R A C T

Grade VIII science instruction at SMPN 4 Padang Panjang relied largely on textbooks and slides, motivating the development of an augmented-reality (AR) multimedia resource for visualizing difficult scientific concepts. This research-and-development study used the ADDIE model to design an application incorporating three-dimensional representations, animation, and quizzes. Product appraisal involved three experts; practicality responses were obtained from 45 students and three science teachers; and pretest-posttest scores were presented for 25 students. The expert ratings totaled 216 of 225 possible points, corresponding to a rescaled mean of 0.95. The user-response tables reported an overall coefficient of 0.91. The 25 reported student gain indices averaged approximately 0.85, whereas the initial summary gave 0.83. Item-level data needed to verify Aiken's V and rater-agreement data required for Cohen's Kappa were unavailable. These findings offer preliminary support for continued development and classroom testing, but the single-group design does not establish that AR independently caused the score changes. Further evaluation requires transparent instrument reporting and technical testing.

Abstrak

Pembelajaran sains kelas VIII di SMPN 4 Padang Panjang sebagian besar masih mengandalkan buku teks dan slide, yang mendorong pengembangan sumber daya multimedia berbasis *augmented reality* (AR) untuk memvisualisasikan konsep-konsep sains yang sulit dipahami. Studi penelitian dan pengembangan ini menggunakan model ADDIE untuk merancang aplikasi yang mencakup representasi tiga dimensi, animasi, dan kuis. Penilaian produk melibatkan tiga orang ahli; data mengenai kepraktisan diperoleh dari 45 siswa dan tiga guru sains; serta skor *pretest* dan *posttest* disajikan untuk 25 siswa. Penilaian dari para ahli mencapai 216 dari total 225 poin, yang setara dengan nilai rata-rata 0,95 setelah disesuaikan. Tabel respons pengguna menunjukkan koefisien keseluruhan sebesar 0,91. Indeks peningkatan (*gain index*) dari 25 siswa tersebut memiliki rata-rata sekitar 0,85, sementara ringkasan awal menunjukkan angka 0,83. Data pada tingkat butir soal yang diperlukan untuk memverifikasi nilai Aiken's V, serta data kesepakatan penilai (*rater agreement*) yang diperlukan untuk perhitungan Cohen's Kappa, tidak tersedia. Temuan ini memberikan dukungan awal untuk pengembangan lebih lanjut dan pengujian di dalam kelas; namun, desain penelitian kelompok tunggal (*single-group design*) tidak dapat memastikan bahwa perubahan skor tersebut disebabkan secara langsung oleh penggunaan AR. Evaluasi lebih lanjut memerlukan pelaporan instrumen yang transparan serta pengujian teknis.

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1. Introduction

Science learning in lower secondary schools often requires students to understand processes that cannot readily be observed through conventional classroom demonstrations. Diagrams and textbook descriptions are useful, but some biological structures and dynamic processes are difficult to communicate through static representations alone. Research on immersive technologies in school-level

STEM education suggests that these tools may make such concepts more tangible, although learning benefits depend on instructional quality and implementation [1] [2]. Accordingly, the educational rationale for developing augmented reality (AR) resources is not simply to introduce novel technology; it is to provide clearer visual explanations of concepts that students otherwise find difficult to represent.

AR superimposes digital information on a physical environment, allowing learners to inspect three-dimensional representations while remaining situated in their immediate surroundings. Reviews have documented the growing use of AR in education and its potential benefits for science learning, including interactive exploration and embodied engagement [3] [4]. However, comparative syntheses indicate that interactive environments differ in their cognitive and affective outcomes, and their effectiveness cannot be assumed solely from the inclusion of three-dimensional content [5] [6]. This distinction is important in Grade VIII science, where visual explanations must suit the subject matter, learners, and classroom conditions.

An expanding body of evidence cautions against assuming that AR is inherently superior to other instructional approaches. Evidence-based reviews indicate that interface design, guidance, and interaction choices influence cognitive load [7], while meta-analytic findings show that the magnitude and direction of AR-related effects on cognitive load vary across studies [8]. In one controlled investigation, mobile AR increased engagement but did not produce better learning outcomes than alternative materials [9]. At the same time, science-focused research has reported promising outcomes when AR is combined with pedagogical scaffolding and self-regulated learning [10]. Teachers' willingness and readiness to adopt mobile AR are also important practical considerations [11]. These findings indicate a need to evaluate both product design and classroom use rather than relying on technological novelty. Exposure duration may also influence cognitive load and how students process augmented information [12].

Recent studies offer further examples from science education. AR applications have been examined in secondary biology classrooms [13], as part of science-literacy modules for junior secondary students [14], and alongside virtual reality in learning about the digestive system [15]. Other development studies have addressed the human respiratory system [16], ethnoscience-based science modules [17], and the interpretation of cognitive learning outcomes in science through meta-analysis [18]. Although these investigations suggest that immersive media can support appropriately designed learning activities, their research settings, subject matter, measurement instruments, and intervention designs differ. Consequently, their reported effects cannot automatically be generalized to a new school-based AR application. Indonesian classroom evaluations in Grade VIII science provide useful comparisons of student outcomes when explicit control-group designs are available [19].

The broader literature provides further context for this development study. Reviews of immersive STEM tools report diversity in educational settings and research approaches [20], while analyses involving educators and learners identify ongoing challenges in adoption and evaluation [21]. Bibliometric and topic-modelling studies show that educational AR research has expanded across subjects and methods, yet the growth of this research literature does not establish the effectiveness of any particular classroom product [22] [23]. At a more specific level, evidence on students' visual attention to augmented 3D science representations suggests that the relationship between representations and understanding depends on how learners inspect and connect different sources of information [24]. Thus, attention to navigation, instructional guidance, and the selected scientific concept remains essential. Reported experiences in AR-supported STEAM environments demonstrate diverse implementations rather than a universal design template [25]. Evaluations of open educational AR platforms [25] and AR-supported representation across subject areas [26] also highlight the importance of documenting application functions rather than relying on screenshots alone.

At SMPN 4 Padang Panjang, the needs analysis identified a continued reliance on textbooks and presentation slides in Grade VIII science, with limited opportunities for interactive visualization. This local need motivated the design of an AR multimedia application. Related investigations into AR display modality [27], digital-literacy opportunities [28], and the diversity of forms used in Indonesian science education [29] reinforce the importance of context-sensitive design. Studies using web-based AR for scientific concepts [30] and AR-guided laboratory visualization [31] likewise illustrate that the instructional task and delivery format must be specified. The research gap is therefore practical and context-specific: the development and preliminary evaluation of a Grade VIII science multimedia resource aligned with local learning needs, rather than an assertion that AR applications or ADDIE-based evaluations are entirely new. Classroom-focused research on spatial visualizations and design choices further suggests that age group, device, and representational format require explicit consideration [27] [28] [29] [30] [31] [26]. Work on AR use across disciplinary settings, including chemistry, provides additional examples of visualizing processes not readily observed in a school laboratory [31]; studies with secondary learners in other subjects also illustrate that motivation and test performance should be assessed separately [26]. School-based innovation in introductory informatics offers additional local context for media development and user appraisal [32].

This study aimed to design an AR-supported multimedia resource for Grade VIII science at SMPN 4 Padang Panjang and to describe its expert appraisal, user responses, and short-term pretest-posttest scores. The development process followed the Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model. The product combined explanatory text, images, three-dimensional representations, animation, and interactive questions. The study contributes a context-specific account of instructional-media development and a critical appraisal of the evidence available from its preliminary evaluation. It does not seek to establish that AR is causally superior to conventional instruction. Related school-level media evaluations address both the affordances of the interface and the practical requirements for adoption [32] [33]. Research on mixed-reality interventions and learner confidence also highlights the influence of instructional conditions on observed outcomes [34] [35]. The evaluation remains preliminary and is limited to the available school-level records.

2. Method

2.1. Research Design

This study used a research-and-development (R&D) approach organized around the five stages of ADDIE to design an AR-based multimedia resource for Grade VIII science. The evaluation combined expert ratings of the developed resource, questionnaire responses from intended users, and a single-group pretest-posttest comparison. These measures were intended to document product development, perceived suitability and practicality, and changes in recorded test scores. The study did not include a non-AR comparison group; therefore, the pretest-posttest evidence cannot establish an independent causal effect of AR.

2.2. Research Setting and Participants

The study was conducted at SMPN 4 Padang Panjang during the second semester of the 2025/2026 academic year. The study records describe three validators with expertise in subject matter, systems, and instructional media, each with at least five years of experience. The practicality evaluation involved 45 Grade VIII students distributed evenly across five classes (nine students per class) and three science teachers. The pretest-posttest table presented paired scores for 25 students and three teachers. These groups served different evaluative purposes and should not be pooled as a single learning-outcome population.

- 2.2.1. Expert validation: three assessors (one subject-matter expert, one systems expert, and one media expert), described as having at least five years of experience.
- 2.2.2. Practicality assessment: 45 Grade VIII students and three science teachers, reported as selected purposively; the precise inclusion criteria and recruitment steps were not documented.
- 2.2.3. Pretest-posttest assessment: paired scores were reported for 25 students, together with three teacher entries. Random sampling was reported, but the study did not document the sampling frame, allocation method, or overlap with the practicality participants.

2.3. Development Procedure

Development followed the five ADDIE stages. The reported activities at each stage were as follows:

- 2.3.1. Analysis: identifying students' learning needs, curriculum-related content, and the school's available facilities through observation and conversations with teachers and students.
- 2.3.2. Design: preparing a storyboard, screen layouts, navigation sequence, interactive questions, and plans for three-dimensional visualizations.
- 2.3.3. Development: assembling the application and multimedia elements. The screenshots show development in Unity; the exact software versions and supporting AR packages were not documented. Expert appraisal and subsequent revisions were reported, but item-level feedback and revision logs were unavailable.
- 2.3.4. Implementation: presenting the AR multimedia resource in science learning activities and gathering teacher and student responses. The number and duration of lessons were not specified.
- 2.3.5. Evaluation: compiling expert ratings, practicality responses, and pretest-posttest scores. The available documentation does not establish whether separate formative evaluations were conducted at every ADDIE stage.



Figure 1. ADDIE instructional development model

2.4. Research Instruments

Three types of research instruments were reported, although some specifications require clarification:

- 2.4.1. Expert appraisal: a five-point rating scale covering science content, media design, and system characteristics. The methodological description specified 25 items, whereas the results table lists 15 items for each of the three validators. Because the item-level rating matrices are unavailable, the number of shared or domain-specific items cannot be confirmed.
- 2.4.2. Practicality questionnaire: a reported 20-item, five-point response instrument administered to the 45 students and three science teachers. Item wording, individual responses, and the procedure used to derive the reported group coefficients were not provided.
- 2.4.3. Learning-outcome test: a reported 30-item multiple-choice assessment administered before and after the media-based learning activity. The results table includes scores as high as 48, suggesting a scoring maximum greater than 30; the weighting or conversion procedure for the apparent 50-point scale was not documented.

2.5. Data Collection Procedures

Data collection followed the reported sequence of school-based activities:

- 2.5.1. Institutional access: the researchers sought permission from the principal and explained the purpose of the study to participating teachers and students.
- 2.5.2. Participant information: the manuscript states that participation was voluntary and that explanations were provided to validators, teachers, and students. Documentation of parental or guardian consent and student assent was not supplied.
- 2.5.3. Expert appraisal: three experts individually reviewed the developed media using the evaluation forms, and their scores were compiled for analysis.
- 2.5.4. Practicality responses: teachers and students used or examined the media in the instructional setting and subsequently completed the questionnaire.
- 2.5.5. Pretest-posttest: students completed a test before the AR-supported learning activity and a posttest afterward. The timing, equivalence of the two forms, and interval between measurements were not specified.

2.6. Data Analysis

Three quantitative procedures were reported. The following descriptions distinguish the reported indices from the evidence available to verify them:

- 2.6.1. Expert rating summary: the study reported Aiken's $V = 0.95$ based on three expert summaries. Aiken's V is an item-based content-validity coefficient [36]; however, the results provide only aggregate scores (67, 74, and 75 over 15 items per evaluator). These totals correspond to a rescaled mean rating of 0.95 if the same scale minimum and maximum were used, but they are insufficient to verify an item-level Aiken's V calculation. Accordingly, the value of 0.95 is reported as an index rather than as independently verified content validity.

$$V = \sum s / [n(c-1)] \dots \dots \dots [\text{Aiken's } V] \quad (1)$$

- 2.6.2. Practicality summary: group indices from 0.88 to 0.95 were reported, with an overall value of 0.91. These values were labeled as Kappa coefficients. Cohen's Kappa measures agreement between categorical raters and requires observed and chance-expected agreement [37]. Because observed and expected agreement and rater-pair data were not reported, the reported indices cannot be independently verified as Kappa statistics and are therefore described as reported user-response indices.

$$\text{Moment Kappa } (k) = \frac{P - Pe}{1 - Pe} \quad (2)$$

2.6.3. Pretest–posttest scores: the study used normalized gain to describe change relative to the maximum attainable score [38]. The results table lists individual student G-scores and separate teacher entries. The mean of the 25 listed student G-scores is approximately 0.85, whereas the mean including three teachers is approximately 0.84; the reported overall summary gives 0.83. The numerical discrepancy and maximum-score definition remain unresolved. The normalized-gain estimates are therefore interpreted as preliminary descriptive indicators rather than causal effect sizes.

$$G = \frac{Sf - Si}{Skor\ Ideal - Si} \quad (3)$$

2.7. Instrument Quality and Reproducibility

The study reports expert appraisal of the media and refers to content validity, construct validity, and reliability assessment using Cronbach’s alpha. However, item-level validation matrices, reliability coefficients, and the evidence required to audit the named procedures were not included in the available manuscript. The reported assessments therefore support only a preliminary evaluation of the product. Consequently, reliability and technical-test performance remain unverified.

- 2.7.1. Content and construct considerations: the three expert domains are identified, but the item-level structure of the instrument and the basis for aggregating their scores remain unavailable.
- 2.7.2. Reliability: Cronbach’s alpha was mentioned in the method; neither a coefficient nor item-level reliability results were presented, so instrument reliability cannot be regarded as empirically established.

2.8. Ethical Considerations

The study reports institutional permission, voluntary participation, and efforts to maintain confidentiality. Because the student participants were minors, procedures for parental or guardian consent, student assent, and data storage require explicit confirmation. Participant codes replace personal identifiers in the table of paired scores.

- 2.8.1. Voluntary participation: participation was described as optional, with the possibility of withdrawal.
- 2.8.2. Confidentiality: responses and pretest–posttest results are reported using anonymous codes rather than students’ names.
- 2.8.3. Informed consent: participants were reportedly informed about the aims; the specific consent and assent procedures for minors were not documented.
- 2.8.4. Participant welfare: the study described the activities as not intended to cause physical or psychological harm.

3. Results and Discussion

3.1. Results

3.1.1. Needs Analysis

The needs analysis at SMPN 4 Padang Panjang indicated that Grade VIII science instruction relied substantially on textbooks and presentation slides. Observations and interviews with science teachers and students identified a perceived need for more interactive explanations of topics that are difficult to visualize using static media. The Merdeka Curriculum and the Grade VIII science textbook were reviewed to align the planned content with material taught in the second semester. The findings

are presented as a narrative summary rather than through interview quotations or a structured needs-assessment matrix.

The material plan included text, images, three-dimensional objects, animation, and interactive quizzes. The school's learning facilities were considered sufficient to support a classroom trial of the AR media. These observations informed the storyboard and interface design, although the records did not specify device inventories or minimum hardware requirements. The prototype was intended to cover second-semester Grade VIII science; however, the discussion and conclusion focused primarily on the human respiratory system.

3.1.2. Media Design and Development

The needs analysis informed a storyboard outlining the content sequence, screen layout, navigation, and intended function of each application page. The storyboard included a starting screen, a main menu, an interactive quiz, and a three-dimensional scan interface. These design decisions align with prior research indicating that the quality of an AR learning experience depends on the relationship between content, interfaces, and guided activity rather than on technological presentation alone [39]. Figures 2–5 show the initial storyboard components.

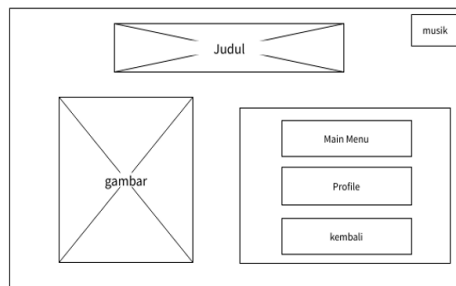


Figure 2. Start-screen storyboard

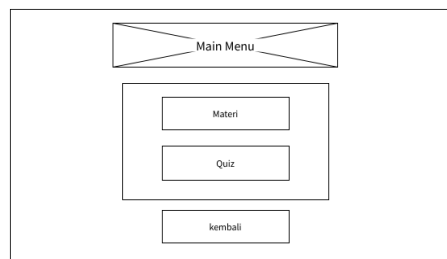


Figure 3. Main-menu storyboard

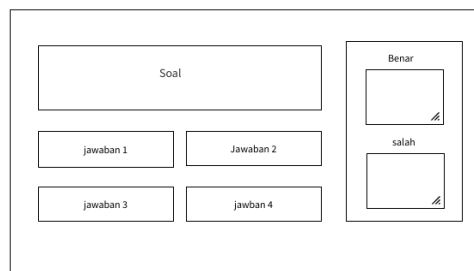


Figure 4. Quiz-screen storyboard

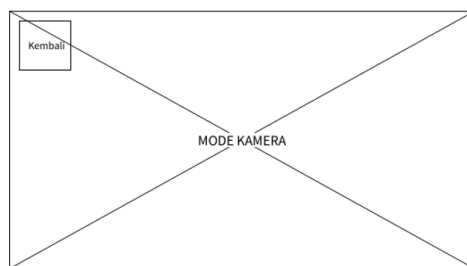


Figure 5. Three-dimensional scan storyboard

The storyboard guided development of a multimedia application documented through screenshots from Unity. The screenshots show the initial screen, main menu, quiz interface, and animated learning content (Figures 6–9). The application was designed to provide straightforward navigation and visual representations of scientific concepts. The screenshots demonstrate the presence of interface elements but do not, on their own, establish successful marker detection, device compatibility, or error-free operation on students' devices. These aspects were not verified by the documented technical tests.



Figure 6. Initial application interface in Unity



Figure 7. Main-menu interface in Unity



Figure 8. Interactive quiz interface in Unity



Figure 9. Animated science-content interface in Unity

3.1.3. Preliminary Product Evaluation

The completed prototype underwent three reported forms of evaluation: expert appraisal by three validators, a practicality questionnaire involving 45 students and three science teachers, and a pretest-posttest assessment represented by 25 student records and three teacher records. Tables 1–3 present the recorded data and clarify the status of the reported indices. These measures assess different aspects of the product and should not be interpreted as interchangeable evidence of instructional effectiveness.

Table 1. Summary of expert ratings

Evaluator / index	Items	Total score	Mean item rating	Mean rating – 1
Expert 1	15	67	4.47	3.47
Expert 2	15	74	4.93	3.93
Expert 3	15	75	5.00	4.00
Reported validity index	0.95 (rescaled mean based on the aggregate ratings; item-level Aiken's V not verifiable)			

Table 2. Reported practicality indices by respondent group

Respondent group	Participants	Reported index	Reported category
Grade VIII class 1	9	0.92	Very high (original categorization)
Grade VIII class 2	9	0.92	Very high (original categorization)
Grade VIII class 3	9	0.88	Very high (original categorization)
Grade VIII class 4	9	0.95	Very high (original categorization)
Grade VIII class 5	9	0.90	Very high (original categorization)
Science teachers	3	0.91	Very high (original categorization)
Students (reported mean)	45	0.91	Very high (original categorization)
Overall index	Reported overall value: 0.91; Po and Pe were not provided, so the Kappa interpretation cannot be confirmed.		

Table 3. Recorded pretest-posttest scores and reported gain indices

Participant code	Pretest score	Posttest score	Reported G-score
S01	21	43	0.76
S02	25	40	0.60
S03	20	47	0.90
S04	19	48	0.94
S05	23	46	0.85
S06	24	47	0.88
S07	25	45	0.80
S08	20	48	0.93
S09	27	45	0.78
S10	22	47	0.89
S11	23	48	0.93
S12	22	46	0.86
S13	21	41	0.69
S14	18	48	0.94
S15	19	46	0.87
S16	17	42	0.76

Participant code	Pretest score	Posttest score	Reported G-score
S17	20	44	0.80
S18	21	47	0.90
S19	19	47	0.90
S20	21	48	0.93
S21	23	43	0.74
S22	17	46	0.88
S23	21	48	0.93
S24	20	47	0.90
S25	19	44	0.81
T01	21	42	0.72
T02	19	43	0.77
T03	24	44	0.81
Reported summary	Original summary: 0.83; mean of listed student G-scores: 0.85; mean of all listed G-scores: 0.84. Scale maximum and aggregation method require confirmation.		

The three expert raters assigned totals of 67, 74, and 75 across 15 listed items each, corresponding to mean item ratings of 4.47, 4.93, and 5.00 out of five. The initial evaluation reported a validity coefficient of 0.95; however, item-level scores are needed to confirm its interpretation as Aiken's V. The practicality table reports values of 0.88–0.95 across five student groups and 0.91 for teachers, with a reported overall value of 0.91; their interpretation as Cohen's Kappa coefficients cannot be verified from the available data. The 25 listed student G-scores range from 0.60 to 0.94 and average approximately 0.85, rather than the reported overall value of 0.83. Because the maximum possible score and calculation protocol have not been fully documented, these values are descriptive and should be interpreted cautiously.

3.2. Discussion

The completed prototype illustrates the feasibility of organizing a Grade VIII science learning resource around an AR-enabled interface, animated content, quizzes, and a storyboard-led workflow. This development process is comparable to that described in other school-based studies of AR learning resources [32], including applications focused on specific science concepts such as the structure of Earth's layers [33]. Unlike evidence from controlled evaluations, these findings primarily describe a locally developed product and its initial appraisal. The high aggregate expert ratings are encouraging, but without item-level results they should not be interpreted as independently established item-level content validity. The distinction between feasibility and comparative benefits is also emphasized in meta-analytic evaluations of mixed-reality interventions [34].

The five student groups and three teachers provided favorable user-response indices. Nevertheless, the reported questionnaire data do not provide the contingency information needed for a Cohen's Kappa analysis. Teacher adoption research underscores the importance of ease of use, instructional context, and available support, but those factors require appropriately defined measures [40]. Studies of immersive educational platforms also show that interface access and teacher preparation can affect implementation [25]. The findings therefore support a cautious interpretation of favorable user responses, not a definitive claim that the application operated without technical problems or was universally easy to use. Classroom research exploring pre-service teachers' attitudes toward immersive tools provides a complementary perspective on adoption barriers [40].

Student scores increased between the two assessments, and the listed G-scores indicate a substantial descriptive change. Research in secondary school science has also reported positive AR-related learning outcomes under stronger comparative designs [19]; more broadly, mixed-reality syntheses suggest that instructional duration and support may moderate effectiveness [34]. The current study, however, used a single group, so testing effects, ordinary instruction, and temporary interest in new technology remain plausible alternative explanations. The reported N-Gain of 0.83 was not reproduced by averaging the recorded individual indices, and the score conversion for the reported 30-item

test was not specified. These uncertainties prevent the observed change from being interpreted as a verified causal effect of AR. Student confidence and learning outcomes are distinct constructs and should not be conflated [35].

The findings provide preliminary evidence of an implemented instructional-media design and favorable ratings within one school. Cognitive and motivational outcomes can depend on media exposure duration, teaching strategies, and students' existing learning approaches [12] [35]. Because this investigation did not include a comparison group or delayed follow-up, the findings cannot establish long-term retention or generalizability across schools. The implications for practice are therefore limited to the potential usefulness of context-sensitive 3D visualization and interactive review activities, subject to technical testing, instrument clarification, and an appropriate evaluation of learning outcomes. Further research could use independently validated instruments, documented AR functionality tests, a comparison condition, and a delayed retention assessment. In school settings, exploratory studies of immersive presentations have also emphasized the value of matching media design to a clearly defined lesson rather than pursuing technological novelty alone [31].

4. Conclusion

This study designed a preliminary AR-based multimedia learning resource for Grade VIII science at SMPN 4 Padang Panjang through an ADDIE-guided development process. The application included storyboard-based navigation, three-dimensional visualization, animated materials, and quizzes. Aggregate expert scores were high, and user responses were favorable; student pretest-posttest scores also showed a positive descriptive change. However, the item-level basis for the reported Aiken's V coefficient, the appropriateness of the reported Kappa values, and the discrepancy in the summarized normalized gain require clarification before stronger validity or effectiveness conclusions can be justified. The findings are limited to one school and a short-term, single-group evaluation, with no evidence of comparative effectiveness or long-term retention. The product provides a basis for further instructional refinement and more rigorous classroom evaluation rather than definitive proof that AR independently improves learning outcomes.

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Declarations

Author Contributions

Khalif Janathan contributed to study conceptualization, design, data collection, analysis, and drafting. Firdaus Annas contributed to supervision, methodological review, critical manuscript revision, and final approval.

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Data Availability Statement

The article presents summarized expert ratings, user-response indices, and anonymized pretest-posttest scores. The availability of item-level response files, complete learning materials, and executable AR application files remains unconfirmed; any access arrangements require confirmation from the corresponding authors.

Conflict of Interest

The authors declare no financial or nonfinancial conflicts of interest that could influence the interpretation or reporting of the study.

Declaration of Generative AI Use

Generative AI disclosure: To be confirmed by the authors before submission. No specific statement of AI use was verifiable from the documents supplied.

Additional Information

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