MJP Journal of Education and Teaching Learning
Vol.4, No.1 (2026): 1631 – 1638
https://jurnalilmiah.co.id/index.php/MJPJETL

Hybrid-Immersive Learning Media: Validity, Practicality, and Effectiveness of an Audio-Comic Video Integrated with Marker-Based Augmented Reality

[1] Suriyah Satar, [2] Nurbaya, [3] Hanida Listiani, [4] Cartika Candra Ledoh, [5] Rosaniya E. Rehiara

[1,2,3,4,5] Program Study of Biology Education, Universitas Cenderawasih, Indonesia
Email: satarsurya@gmail.com

***Correspondence Author:** satarsurya@gmail.com

Article Info

Keywords:

ADDIE; Augmented Reality; Audio-Comic; Excretory System; Hybrid-Immersive Learning.

ABSTRACT

The Human Excretory System is an abstract, microscopic topic that often causes student misconceptions. This R&D study, using the ADDIE model, developed an Audio-Comic Video integrated with Marker-Based Augmented Reality (AR), using Assemblr 3D assets to interactively visualize excretory organs. The subjects were eleventh-grade students at SMAS Muhammadiyah Jayapura. Validation results showed the medium was very valid according to the material expert (92.22%) and valid according to the media expert (81.25%). Practicality tests with students (93.57%) and teachers (88.57%) fell into the very practical category. The effectiveness test on 35 students showed scores increasing from 50.02 (pretest) to 84.07 (posttest), with an N-Gain of 0.626 (medium category) and a significant difference (Sig. 2-tailed = 0.000). The medium proved feasible and effective as an alternative biology learning medium accommodating visual, auditory, and kinesthetic learning styles.

Informasi Artikel

Kata Kunci:

ADDIE; Augmented Reality; Audio-Komik; Sistem Ekskresi; Hybrid-Immersive Learning.

ABSTRAK

Materi Sistem Ekskresi Manusia bersifat abstrak dan mikroskopis sehingga sering memicu miskonsepsi pada peserta didik. Penelitian R&D dengan model ADDIE ini mengembangkan media Video Audio-Komik terintegrasi Marker-Based Augmented Reality (AR) menggunakan aset 3D Assemblr untuk memvisualisasikan organ ekskresi secara interaktif. Subjek penelitian adalah peserta didik kelas XI SMAS Muhammadiyah Jayapura. Hasil validasi menunjukkan media sangat valid oleh ahli materi (92,22%) dan valid oleh ahli media (81,25%). Uji kepraktisan pada peserta didik (93,57%) dan guru (88,57%) menunjukkan kategori sangat praktis. Uji efektivitas pada 35 peserta didik menunjukkan peningkatan nilai dari 50,02 (pretest) menjadi 84,07 (posttest), dengan N-Gain 0,626 (kategori sedang) dan perbedaan yang signifikan (Sig. 2-tailed = 0,000). Media ini terbukti layak dan efektif sebagai alternatif pembelajaran biologi yang mengakomodasi gaya belajar visual, auditori, dan kinestetik.

Article History

Received : 20/07/2026
Revised : 22/07/2026
Accepted : 25/07/2026

✉ ***Corresponding Author:*** (1) Suriyah Satar, (2) Department of Biology Education, (3) Universitas Cenderawasih, (4) Papua, Indonesia (5) Email: corresp-author@mail.com

1. Introduction

The transformation of education in the era of Industrial Revolution 4.0 and Society 5.0 demands the integration of digital technology not merely as a supplement, but as a core component of immersive and meaningful learning. Immersive technologies such as Virtual Reality (VR) and Augmented Reality (AR) have been shown to increase engagement and conceptual understanding through more authentic and interactive learning experiences [1]. Theoretically, this is reinforced by the Cognitive Affective Model of Immersive Learning (CAMIL), which asserts that immersion and interactivity play a significant role in improving learning outcomes through cognitive and affective engagement [2]. A review of recent research trends also confirms that publications on the use of AR in biology learning increased sharply from 2020–2024, with cells, viruses, the skeletal system, and the human digestive system being the most widely developed topics, while cognitive learning outcomes, motivation, and critical thinking skills were the most frequently researched variables [3]. This situation indicates that other human anatomy-physiology topics, including the Excretory System, still offer ample research potential for further development.

In implementing the *Merdeka* Curriculum, educators are required to provide differentiated learning that accommodates the diversity of student learning profiles: Visual, Auditory, and Kinesthetic (V-A-K). AR-based media in STEM learning shows great potential for increasing motivation, engagement, and learning outcomes by integrating spatial visualization with digital interactivity [4]. Various marker-based AR development applications, one of which is Assemblr Edu, have been widely utilized by teachers and researchers in Indonesia to present three-dimensional objects in biology lessons without requiring complex programming skills, while also being proven to encourage students' critical thinking skills [5].

In the Human Excretory System, the processes of glomerular filtration, tubular reabsorption, and augmentation occur at the microscopic level within the complex organ structure. Conventional media such as two-dimensional textbooks and passive videos have not been able to facilitate active student interaction to build in-depth spatial understanding [2]. However, immersive and interactive learning experiences have been shown to significantly improve cognitive processing and concept retention compared to passive media [6] This problem is exacerbated by the findings of a four-level diagnostic in secondary school students, which revealed that nearly all subtopics of human excretion from kidney filtration mechanisms to skin function and body thermoregulation remain riddled with significant misconceptions, with the proportion of pure misconceptions reaching nearly one-third of the total respondents. This fact underscores the urgency of developing more concrete and interactive visualization media for this material [7,8].

Based on the Cognitive Theory of Multimedia Learning (CTML), learning will be more effective when information is presented in an integrated manner through visual-pictorial and verbal-auditory channels. This principle aligns with Mayer's initial ideas on multimedia learning, which assert that structuring multimedia messages into meaningful segments and adjacent word-image pairs can reduce extraneous cognitive load while optimizing learners' generative processing [9] Empirical studies have shown that AR designs aligned with multimedia learning principles can reduce extraneous cognitive load and increase germane cognitive processing [10,11]. Visual narrative media such as digital comics and audio-comics have also been shown to be effective in packaging abstract science concepts into structured stories, increasing learners' engagement, scientific literacy, and conceptual understanding [12–14].

On the other hand, the integration of three-dimensional virtual objects through AR allows students to explore the structure and relationships between organs in more depth. Systematic reviews and meta-analyses show that AR significantly improves learning outcomes and spatial abilities in science and biology learning, especially in material that requires three-dimensional visualization such as human anatomy ([15–17]. The approach of embedding AR markers into comics media is not entirely new; [18], for example, developed comic books as AR markers and proved that this integration was able to significantly improve students' critical thinking abilities. However, studies that integrate narrative audio-comics (equipped with dubbing and sound effects) with interactive AR in a hybrid system based on cognitive theory, especially on Excretory System material, are still very limited. This is the novelty that underlies this research: combining a Narrative Layer in the form of a comic animated video equipped with dubbing and sound effects, with an Interactive Layer in the form of AR Markers embedded in the video frame, so that when the video is paused at a certain scene students can scan the screen to reveal a 3D model of the excretory organs that can be manipulated (rotated, enlarged).

Based on the description above, this study aims to: (1) produce a prototype of an Audio-Comic Video learning medium integrated with Marker-Based AR on Human Excretory System material; (2) examine the validity of the product through expert validation; (3) measure the practicality of the medium as a support for differentiated learning; and (4) evaluate the effectiveness of the medium on students' learning outcomes. The findings of this study are expected to contribute to the growing body of empirical research on the integration of narrative media and immersive technology in secondary-level biology education, as well as to serve as a practical reference for teachers in designing differentiated learning media that align with the demands of the Merdeka Curriculum.

2. Method

This research is a Research and Development (R&D) study that adapts the ADDIE (Analysis, Design, Development, Implementation, Evaluation) model as developed by [19]. The ADDIE model was chosen because it is systematic but remains flexible to be revised at each stage, so that it is in accordance with the characteristics of technology-based learning media development which requires design iteration and multilevel testing [19].

In the analysis stage, researchers identified abstract concepts in the Excretory System material - including nephron structure, glomerular filtration mechanism, tubular reabsorption, and augmentation - and examined the needs of students and the characteristics of the V-A-K learning style at the research location. At this stage, a study was also carried out on the availability of 3D excretory organ assets in the Assemblr application library, a marker-based AR development application that has been widely used in biological media development research in Indonesia [5]. At the design stage, the researcher prepared an integration storyboard to map the audio-comic video frames that would be inserted with markers, determined the dialogue script and scientific narrative, and designed a scanning interaction scenario that referred to the principles of segmenting and spatial contiguity in multimedia learning [9], namely breaking the material into meaningful segments and placing AR visual elements at break points that were relevant to the narrative.

At the development stage, the selected 3D assets are embedded in the markers specified in the AR project, then the audio-comic video prototype and AR application are integrated into a single product. The prototype was then validated by material experts and media experts using a Likert scale validation sheet to ensure the accuracy of the scientific content and technical quality of the media before being tested on students. At the implementation stage, the media is tested in stages, starting from small-scale trials to obtain initial input to large-scale trials to measure effectiveness. At the evaluation stage, formative evaluations are carried out at each stage (revisions based on validator input and the results of small trials) as well as summative evaluations in the form of analysis of media effectiveness on student learning outcomes in large-scale trials.

The research was carried out at SMAS Muhammadiyah Jayapura, Papua, with validation subjects consisting of one biology teacher as a material expert validator and two Biology Education lecturers as media expert validators. The small-scale trial involved 12 students, while the effectiveness test involved 35 class Data collection instruments include expert validation sheets, student and teacher practical response questionnaires, as well as learning outcomes test questions (pretest-posttest) which have been tested for validity and reliability before being used.

Validity and practicality data were analyzed by calculating the score percentage using the formula NP = (R/SM) × 100%, where R is the score obtained and SM is the maximum score (modified from Purwanto) [20,21], which is then categorized based on the criteria in Table 1.

Table 1 Criteria for Interpretation of Validation and Practicality Scores

Interval	Criteria Interval
≤ 54%	Very Invalid / Not Practical
55% - 64%	Less Valid / Not Practical
65% - 79%	Fairly Valid / Quite Practical
80% - 89%	Valid / Practical
90% - 100%	Very Valid / Very Practical

Data on the effectiveness of learning outcomes were analyzed using the normalized N-Gain score test to see the increase in understanding before and after media use. The N-Gain formula used refers to the Hake formula (1998) [22], namely the difference between the posttest and pretest scores divided by the difference between the ideal maximum score and the pretest score ⟨g⟩ = (%posttest − %pretest) / (100% − %pretest). Hake classified N-Gain results into three categories, namely high ($g \geq 0.7$), medium ($0.3 \leq g < 0.7$), and low ($g < 0.3$), which became the reference for interpreting categories in this study [22]. In addition, a Paired Sample t-Test was carried out to see the significance of differences in pretest and posttest scores, with the help of SPSS 30. Before the t-test was carried out, the data was first tested for normality using the Shapiro-Wilk test to ensure that parametric statistical assumptions were met.

3. Result and Discussion

3.1. Media Validity

Material expert validation was carried out by a biology teacher at SMAS Muhammadiyah Jayapura regarding the suitability of the Excretory System content presented in AR integrated audio-comic videos. Aspects assessed include the accuracy of scientific concepts, suitability to learning outcomes, clarity of story narrative flow, and suitability of AR marker placement to the stages of the concept being explained. The results are presented in Table 2.

Table 2. Results of Material Expert Validation

Validation	Assessment Items	Total Score	Percentage	Criteria

Subject Experts	19	83	92,22%	Very Valid

The results of the material expert assessment of the Excretory System content presented in the media obtained a percentage of 92.22% with very valid criteria, indicating that the audio-comic narrative and AR marker placement have accurately represented the concepts of glomerular filtration, tubular reabsorption, and the structure of the excretory organs. This high validity score is important to ensure that the media does not reinforce misconceptions that have been identified as occurring frequently in the topic of human excretion, especially regarding the mechanism of kidney filtration and the function of other excretory organs. In other words, the accuracy at the validation stage of the material expert plays a role in maintaining scientific quality before the media is widely used by students.

Table 3. Media Expert Validation Results

Validation	Assessment Items	Total Score	Percentage	Criteria
Media Expert (Validator 1)	16	65	81,25%	Valid
Media Expert (Validator 2)	16	65	81,25%	Valid

The two media expert validators gave a consistent assessment, namely 81.25%, with valid criteria. Aspects assessed include the visual quality of the comic, audio synchronization (dubbing and sound effects), ease of scanning markers, and the quality of the 3D model of the excretory organs in the AR application. The consistency of validation results from material experts and media experts strengthens the theoretical justification that the integration of multimodal audio-comic narratives with 3D AR visualization is in line with CTML principles in presenting visual and verbal information cohesively [9,10,23]. The media validity score which is in the valid category, although slightly lower than the material validity, indicates that there is still room for technical improvement, for example in the aspect of marker tracking stability when mobile devices are used in less than ideal lighting conditions, a technical challenge that has also been widely reported in other marker-based AR development research [18].

3.2. Media Practicality

Small-scale trials were carried out on 12 students to obtain input before large-scale trials. The practicality response questionnaire was prepared to include aspects of ease of operation of the media, clarity of marker scanning instructions, visual appeal, and the benefits of the media in helping understand concepts. A recapitulation of the results of the response questionnaire is presented in Table 4.

Table 4. Recapitulation of Students' Practical Responses (Small Scale)

Aspect	Number of Respondents	Average Score	Percentage	Criteria
Student Responses	12	65,5	93,57%	Very Practical

From 12 respondents, a total score of 786 was obtained with an average of 65.5, equivalent to a percentage of 93.57% (very practical). Students stated that the AR integrated audio-comic video media was easy to operate, the markers were easy to scan, and the 3D display of excretory organs helped them imagine organ structures that were previously abstract. These findings strengthen the argument that interactive three-dimensional visualization can bridge the gap between textual representations and actual microscopic biological structures [15].

Table 5. Biology Teachers' Practical Responses

Validation	Assessment Items	Total Score	Percentage	Criteria
Biology Teacher Response	14	62	88,57%	Very Practical

Biology teachers also gave a very practical assessment (88.57%), noting that this media has the potential to be used as a variety of differentiated learning strategies because it accommodates visual (comics and 3D models), auditory (dubbing and sound effects), and kinesthetic (activities of scanning markers and manipulating 3D objects) learning styles. This finding is in line with the results of previous research that the development of audio-comic media received a very positive response in the field because it combined storytelling elements with science visualization [13,14,24]. Apart from that, these findings are also in line with the results of the development of comics as AR markers which reportedly received enthusiastic responses from students and teachers because they provided a more participatory learning experience than conventional printed comics [18]. The high level of practicality in both groups of respondents - students and teachers - shows that this media is not only accepted technically, but is also considered relevant pedagogically to support learning differentiation as mandated by the *Merdeka* Curriculum.

3.3. Effectiveness of Media on Learning Outcomes

Media effectiveness was measured through pretest and posttest on 35 class XI students. The average pretest score of 50.02 (SD = 22.393) increased to a posttest average of 84.07 (SD

= 12.531) after using AR integrated audio-comic video media. The decrease in the standard deviation value from pretest to posttest also indicates that this media not only increases the average achievement, but also narrows the gap in understanding between students, which indicates equal understanding of concepts in the class.

Table 6. Summary of N-Gain Test Results

Indicator	Value
N-Gain Score	0,626
N-Gain Percent (%)	62,59%
Category	Moderate

The results of the N-Gain test show an increase in student learning outcomes of 62.59% after implementing the integrated Marker-Based AR audio-comic video media, which according to Hake's (1998) criteria is classified in the medium category ($0.3 \leq g < 0.7$), and even approaches the high category threshold ($g \geq 0.7$). This indicates that the media is quite effective in increasing students' understanding of the abstract and microscopic Human Excretory System material. As a comparison, [22] reported that conventional lecture-based learning methods consistently only produced N-Gain in the low category (average around 0.23), while interactive-engagement methods were able to reach the medium to high category; The position of N-Gain media in this research which is in the medium category confirms that the hybrid-immersive approach which combines audio-comic narration with AR interactivity has succeeded in placing learning in a group of methods that are more active and participatory than conventional learning.

Table 7. Paired Sample t-Test Results

Variabel	Mean	Std. Deviation	df	Sig. (2-tailed)
Pretest	50,02	22,393	-	-
Posttest	84,07	12,531	-	-
Selisih	-33,051	21,669	34	0,000

The Paired Sample t-Test yielded a significance value (2-tailed) of 0.000 (< 0.05), indicating a significant difference between students' learning outcomes before and after using the Marker-Based AR-integrated audio-comic video on the Human Excretory System material.

This improvement in learning outcomes reinforces the finding that AR designed in accordance with CTML principles can reduce extraneous cognitive load and enhance germane cognitive processing, thereby positively impacting learning outcomes [25]. Interactive three-dimensional visualization through AR has likewise been shown to surpass two-dimensional images in facilitating spatial understanding of human body organs [26–28]. These effectiveness findings are also consistent with research trends on AR in biology education, which consistently report significant improvements in cognitive learning outcomes as the most frequently studied variable [3], while further extending the scope of human anatomy topics shown to benefit from AR—previously concentrated mainly on the skeletal and digestive systems. The combination of audio-comic narration with AR interactivity in this study represents a Hybrid-Immersive Learning approach that fosters a more comprehensive and participatory learning experience, consistent with findings that pedagogically designed AR integration can enhance student participation and academic performance [25,28], and aligns with evidence that comic media embedded with AR markers can promote high levels of student cognitive engagement [18].

Nevertheless, the medium N-Gain category—rather than a high one—should be interpreted proportionally. Several contextual factors, such as the limited number of mobile devices compatible with the AR application, variation in internet connectivity quality at the research site, and the relatively brief duration of media exposure (a single trial session), are thought to have constrained the extent of the improvement in learning outcomes. This aligns with observations from various systematic reviews indicating that the effectiveness of AR in biology education is largely shaped by the quality of instructional design rather than by technological sophistication alone ([3,15].

Several studies on the development of comic/video-based and Augmented Reality (AR) learning media show consistent patterns in terms of validity, practicality, and effectiveness. For example, Pratiwi & Bayu reported that AR-comics with a metacognitive approach were deemed valid and able to improve cultural literacy and reading engagement based on student responses [29–31]. Swarjawa et al. found that AR-assisted comics based on local wisdom were also deemed highly valid and practical, and effective in improving learning outcomes in reading and story comprehension [32,33]. In media that combine physical-digital elements with marker-based AR, Ibrahim S et al. reported hybrid media that were declared valid and practical for ecosystem learning, supported by stable marker-based tracking performance [34,35]. In another context, Muttakin et al. confirmed that AR science media in elementary schools was deemed feasible and practical by teachers and students, accompanied by positive responses during use [36,37]. For science material, Nurachmadani et al. also reported that AR media was deemed feasible/valid, practical, and effective in improving student learning outcomes [38,39]. Meanwhile, studies of video comics (without AR) continued to show that the integration of visual-story and audio elements could make the media deemed valid and practical and impact learning outcomes [40,41]. In a more controlled evaluation, Firdaus et al. reported

that contextual e-comics were deemed valid and practical, and had the effect of improving student learning performance [42–44].

Overall, the results regarding validity, practicality, and effectiveness demonstrate that the Marker-Based Augmented Reality-integrated Audio-Comic Video is suitable for use as an alternative learning medium for the Human Excretory System material, as well as serving as an edutainment solution that supports differentiated learning in line with the demands of the Merdeka Curriculum.

4. Conclusion

The findings of this study demonstrate that the Marker-Based Augmented Reality-integrated Audio-Comic Video developed for the Human Excretory System material is highly valid according to the material expert (92.22%) and valid according to the media expert (81.25%). The medium was also rated highly practical based on both student responses (93.57%) and biology teacher feedback (88.57%). In terms of effectiveness, its use significantly improved students' learning outcomes, as reflected in an N-Gain score of 0.626 (medium category) and a statistically significant result from the Paired Sample t-Test (Sig. 2-tailed = 0.000). These findings collectively confirm that the Hybrid-Immersive medium is both feasible and effective as an alternative approach to biology instruction, accommodating visual, auditory, and kinesthetic learning styles.

The primary contribution of this study lies in the integration of two distinct media layers—the Narrative Layer of the audio-comic and the Interactive Layer of Marker-Based AR—into a single hybrid product grounded in the Cognitive Theory of Multimedia Learning, a combination that remains rarely explored specifically for Human Excretory System material. This finding extends the empirical evidence that a hybrid-immersive approach can serve as a viable solution to the persistent challenge of visualizing microscopic biological concepts that have long contributed to student misconceptions.

This study is nonetheless limited by its relatively small sample size and its scope, which was confined to a single school, meaning that generalization of the findings should be approached with caution. Future research is recommended to test this medium on a larger sample scale and across other abstract biology topics, to consider a quasi-experimental design with a control group to strengthen causal claims, and to further explore contextual factors—such as device availability and duration of media exposure—that may influence the magnitude of learning gains.

References

[1] Radianti J, Majchrzak TA, Fromm J, Wohlgenannt I. Computers & Education A systematic review of immersive virtual reality applications for higher education : Design elements , lessons learned , and research agenda. Comput Educ 2020;147:103778. https://doi.org/10.1016/j.compedu.2019.103778.

[2] Petersen GB. The Cognitive Affective Model of Immersive Learning (CAMIL): a Theoretical Research-Based Model of Learning in Immersive Virtual Reality 2021:937–58.

[3] Indrati DA, Masing FA. Research trends of augmented reality in biology learning: A systematic literature review from 2020-2024. Biosfer 2025;18:145–59. https://doi.org/10.21009/biosferjpb.53911.

[4] Sırakaya M, Sırakaya DA. Augmented reality in STEM education : a systematic review. Interactive Learning Environments 2020;0:1–14. https://doi.org/10.1080/10494820.2020.1722713.

[5] Oktafiani R, Haka NB, Roniawati. The Impact of The Jurisprudential Analytical Inquiry Learning Model Assisted by Augmented Reality (Assemblr Edu) on Critical Thinking Abilities in Biology For 10th Grade High School Students. International Journal Education and Computer Studies (IJECS) 2024;4:1–9. https://doi.org/10.35870/ijecs.v4i1.1949.

[6] Parong J, Mayer RE. Cognitive and affective processes for learning science in immersive virtual reality 2020:1–16. https://doi.org/10.1111/jcal.12482.

[7] Hala Y, Arifin AN, Satar S, Saenab S. Identification of Biology Student's Misconception in Makassar State University on Cell Biology by Applying Two-Tier MCQs Method. J Phys Conf Ser 2019;1387. https://doi.org/10.1088/1742-6596/1387/1/012004.

[8] Hala Y, Saenab S, Novia Arifin A, Satar S. Identification of senior high school student'smisconceptions in makassar city on cell concepts by using the certainty of response index (CRI) method. J Phys Conf Ser 2019;1317. https://doi.org/10.1088/1742-6596/1317/1/012194.

[9] Mayer RE. The Past , Present , and Future of the Cognitive Theory of Multimedia Learning. Educ Psychol Rev 2024;36:1–25. https://doi.org/10.1007/s10648-023-09842-1.

[10] Candido V, Cattaneo A. Computers in Human Behavior Reports Applying cognitive theory of multimedia learning principles to augmented reality and its effects on cognitive load and learning outcomes. Computers in Human Behavior Reports 2025;18:100678. https://doi.org/10.1016/j.chbr.2025.100678.

[11] Staneviciene E. The Use of Multimedia in the Teaching and Learning Process of Higher Education : A Systematic Review 2025:1–26.

[12] Bahameish M, Khowaja K, Abdelaal Y, Al-thani D, Bahameish M, Khowaja K, et al. Pathways to learning : exploring the impact of augmented reality on vocabulary development in children with autism spectrum disorder disorder. Interactive Learning Environments 2025;34:4–27. https://doi.org/10.1080/10494820.2025.2485407.

[13] Satar S, Irdyana FW, Tanta C. Pengembangan Media Pembelajaran Berbasis Audio-Comic Pada Materi Klasifikasi Makhluk Hidup. Jurnal Bioeduin 2024;14:22–32.

https://doi.org/10.23969/biosfer.v4i1.1356.
[14] Satar S, Mawara RE, Irianti M, Ledoh CC, Listiani H, Permadi RW, et al. Digital Creativity Based on Local Wisdom: Creating Science Audio Comics for Science Teachers Using Canva and AI. Bulletin of Pedagogical Research 2025;5:84–93.
[15] Faria A, Miranda GL. Augmented Reality in Natural Sciences and Biology Teaching : Systematic Literature Review and Meta-Analysis 2024;8:1666–85.
[16] Putra KI, Dawa PJL, Burgos YD, Maulana FIM. Implementation of Augmented Reality in Study for Human Anatomy. Procedia Comput Sci 2023;227:709–17. https://doi.org/10.1016/j.procs.2023.10.575.
[17] Staniˇ K, Sprenjak A. Augmented Reality in Biology Education : A Literature Review 2025:10–2.
[18] Damopolii I, Febrianto Paiki F, Hendriek Nunaki J. The Development of Comic Book as Marker of Augmented Reality to Raise Students' Critical Thinking. TEM Journal 2022:348–55. https://doi.org/10.18421/TEM111-44.
[19] Branch RM. Instructional Design: The ADDIE Approach. Boston, MA: Springer US; 2009. https://doi.org/10.1007/978-0-387-09506-6.
[20] Purwanto MN. Prinsip-prinsip dan teknik evaluasi pengajaran. Remaja Rosdakarya; 2000.
[21] Purwanto P. METODOLOGI PENELITIAN KUANTITATIF. Pustaka Belajar; 2010.
[22] Hake RR. Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. Am J Phys 1998;66:64–74. https://doi.org/10.1119/1.18809.
[23] Anugrah S. The Validity and Practicality of Augmented Reality Based Learning Media for Computer Basics Courses. J Phys Conf Ser 2021;1779:012010. https://doi.org/10.1088/1742-6596/1779/1/012010.
[24] Sastrawan IPO, Margunayasa IG, Bayu GW. Credibility of Digital Comic Media in Audio Visual Form on Style Topic for Elementary School Students. Indonesian Journal Of Educational Research and Review 2021;4:213. https://doi.org/10.23887/ijerr.v4i2.39665.
[25] Kazlaris GC, Keramopoulos E. Augmented Reality in Education Through Collaborative Learning : A Systematic Literature Review 2025.
[26] Eshuis EH, Vrugte J. Expert examples and prompted reflection in learning with self-generated concept maps 2022:350–65. https://doi.org/10.1111/jcal.12615.
[27] Gustav B, Petkakis G, Makransky G. Computers & Education A study of how immersion and interactivity drive VR learning 2022;179. https://doi.org/10.1016/j.compedu.2021.104429.
[28] Al-ansi AM, Jaboob M, Garad A, Al-ansi A. Social Sciences & Humanities Open Analyzing augmented reality (AR) and virtual reality (VR) recent development in education. Social Sciences & Humanities Open 2023;8:100532. https://doi.org/10.1016/j.ssaho.2023.100532.
[29] Pratiwi NKD, Bayu GW. Augmented Reality-Based Comic Media: A Metacognitive Approach to Enhance Cultural Literacy and Reading Engagement in Elementary Education. International Journal of Elementary Education 2024;8:536–46. https://doi.org/10.23887/ijee.v8i3.89796.
[30] I Kadek Aris Prayoga, Basilius Redan Werang, I Nyoman Jampel. Indonesia Comic Video Learning Media on Animal Ecosystem Material to Improve Science Learning Outcomes in Grade V Elementary School Students. Jurnal Media Dan Teknologi Pendidikan 2025;5:105–13. https://doi.org/10.23887/jmt.v5i1.92420.
[31] I Made Raditya Iswanta, Kadek Suranata, Kadek Yudiana. Interactive Comic Video Media in Solar System Material Science Content for Grade VI Elementary School. International Journal of Elementary Education 2025;9:432–42. https://doi.org/10.23887/ijee.v9i3.94992.
[32] Swarjawa IWE, Arnyana IBP, Gading IK. Development of an Augmented Reality-Based Comic Integrating Balinese Local Wisdom for Enhancing Elementary Students' Learning Outcomes. Jurnal Paedagogy 2026;13:625–36. https://doi.org/10.33394/jp.v13i2.19657.
[33] Dini R, Ade Kurnia Yusri M, Hendri N, Masnur A. Pengembangan Media Augmented Reality Berbasis Pop-Up Book pada Mata Pelajaran Seni Budaya Kelas III SD. Jurnal BELAINDIKA (Pembelajaran Dan Inovasi Pendidikan) 2025;7:254–65. https://doi.org/10.52005/belaindika.v7i2.370.
[34] Ibrahim S MB, Pramono SE, Fakhruddin F, Subali B. Design, Development, and Performance Evaluation of an Augmented Reality-Based Hybrid Pop-Up Media System for Elementary Ecosystem Learning. Journal of Educational Technology and Learning Creativity 2026;4:235–51. https://doi.org/10.37251/jetlc.v4i1.3045.
[35] Sri Asmini NK, Rati NW, Paramartha WE. Interactive Multimedia Based on Augmented Reality for Photosynthesis Material to Improve Science Learning Outcomes of Fourth Grade Elementary School Students. MIMBAR PGSD Undiksha 2025;13:297–307. https://doi.org/10.23887/jjpgsd.v13i2.93922.
[36] Muttakin M, Dewi UM, Sari AM. FEASIBILITY AND PRACTICALITY ANALYSIS OF AUGMENTED REALITY (AR) AS A SCIENCE LEARNING MEDIA IN ELEMENTARY SCHOOLS. Chimica Didactica Acta 2024;12:85–90. https://doi.org/10.24815/jcd.v12i2.41190.
[37] Muh. Ihsan Zulfikar, Riska M. Enhancing Pedagogical Deep Learning in Vocational High Schools Through Multimarker Augmented Reality Media. Information Technology Education Journal 2025:282–7. https://doi.org/10.59562/intec.v4i2.9249.
[38] Nurachmadani N, Sahudra TM, Mulyahati B. Development of Augmented Reality (AR) Based Learning Media to Improve Educational Outcomes for Elementary School Students. ALACRITY : Journal of Education 2025:592–608. https://doi.org/10.52121/alacrity.v5i1.692.
[39] Syafar AM, Gani HA, Agung M. The Utilization and Practicality of Learning Media Based Augmented Reality. Asian Journal of Education and Social Studies 2023;49:326–32. https://doi.org/10.9734/ajess/2023/v49i41211.
[40] Sari LM, Huda A, Effendi H, Giatman M. Canva-Based Animation Comic Video Media in Informatics Learning. Jurnal Penelitian Pendidikan IPA

2024;10:7852–60. https://doi.org/10.29303/jppipa.v10i10.8514.

[41] Huda A, Sari LM, Effendi H, Giatman M, Firdaus -, Sukmawati M. Canva-based Animation Comic Video Media in Informatics Learning at SMP Negeri 14 Padang. JOIV : International Journal on Informatics Visualization 2025;9:120. https://doi.org/10.62527/joiv.9.1.3177.

[42] Firdaus Z, Zubaidah S, Fahmi MIN, Setiawan D, Chang C-Y. E-comic geneius: Contextual genetics learning media to enhance cognitive learning outcomes. Edubiotik : Jurnal Pendidikan, Biologi Dan Terapan 2025;10:304–19. https://doi.org/10.33503/ebio.v10i01.1251.

[43] Putri BM, Indriasari BA, Kurniawati AF. Development of E-Comic Learning Media for Students in Grade IV of Xaverius 1 Elementary School Jambi. Jurnal Evaluasi Dan Pembelajaran 2026;8:35–43. https://doi.org/10.52647/jep.v8i1.496.

[44] Salam S, Ramly RA, P S, Marwan M, Irwan I. Development and Validation of an Augmented Reality-Based Learning Module to Enhance Historical Understanding in Secondary Education. QALAMUNA: Jurnal Pendidikan, Sosial, Dan Agama 2026;18:601–16. https://doi.org/10.37680/qalamuna.v18i1.8975.