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Feasibility of Augmented Reality Media for Ecosystem Learning in Primary Education: Expert Validation and User Trials

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Abstract: Science learning in primary education often remains abstract and less engaging, leading to low student achievement in understanding complex topics such as ecosystems. To address this issue, this study aims to develop augmented reality application technology as a learning medium for ecosystem material in science subjects at the primary education level. The research belongs to a Research and Development (R&D) study employing the Holistic 4D Model (Define, Design, Develop, Deploy), limited to the Develop stage. Data were collected using an open ended questionnaire to evaluate media feasibility. The subjects included six experts (two subject matter experts, two media experts, and two instructional design experts), three fifth grade students for the one on one trial, and 24 students for the field test. Results showed high feasibility levels, with validation scores of 3.80 from subject matter experts, 3.83 from media experts, and 3.81 from instructional design experts, all categorized as very valid. Student responses were also highly positive, reaching 91% in the one on one trial and 87% in the field test. These findings indicate that the AR-based ecosystem learning media is feasible and valid for use in primary education. The AR media can be integrated into classroom science instruction to improve conceptual understanding, science literation, and engagement among students.

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Introduction

Science learning in primary education serves as a foundational stage for developing students' scientific literacy, critical thinking, and ecological awareness. However, current learning outcomes show that many students still struggle to understand complex and abstract scientific concepts (Alfatonah et al., 2023). The Programme for International Student Assessment (PISA, 2022) reported that Indonesia's average science score was 383, far below the OECD average of 489, placing the country 69th out of 80 participating nations (OECD, 2023). Further studies reveal that elementary school students often perceive science as a difficult and abstract subject, including the ecosystem topic, which involves interactions between biotic and abiotic components (Kuroru & Rahmah, 2023; Wahyuni et al., 2023). Conventional learning media such as textbooks and static images are inadequate for representing the dynamic processes within ecosystems, causing students to experience difficulties visualizing the interconnections among ecosystem components, food chains, and energy flows (Nasir et al., 2018; Qorimah et al., 2022; Reizal et al., 2020).

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As a solution to these challenges, innovative learning media are needed to provide students with concrete and interactive experiences. Augmented Reality (AR) offers significant potential to visualize abstract science learning in a realistic and immersive way. AR allows learners to manipulate 3D ecosystem components, observe the interactions between living and non living elements, and explore cause and effect relationships through active learning. This multisensory engagement bridges the gap between abstract representation and tangible experience, a crucial process for conceptual development in primary education. Previous studies have demonstrated that AR based media enhance students' motivation, conceptual understanding, and classroom engagement (Sari et al., 2024; Vari & Bramastia, 2021). In primary education, AR has the potential to transform passive instruction into experiential exploration, empowering students to become active participants in constructing their own knowledge.

Although research on AR in education has continued to expand, several gaps remain that limit its broader implementation in primary schools. Most previous studies have focused on AR media for general science topics and have adopted linear development models such as ADDIE or Borg & Gall, which follow sequential phases and provide limited opportunities for iterative evaluation and refinement (Frasnyaigu et al., 2023; Nurachmadani et al., 2025). Few studies have examined the feasibility of AR media development through systematic expert validation and user testing, particularly in the early stages of product design. Consequently, there is still a need for research that not only develops AR learning media but also rigorously assesses their validity and usability before large scale implementation. Another underexplored area concerns the integration of physical and digital learning experiences. Many AR applications rely solely on screen based visualization without incorporating tangible materials that can enhance sensory engagement. Integrating AR with 3D physical dioramas can offer a more holistic learning experience by linking virtual visualization with hands on exploration.

Therefore, this study aims to develop and assess the feasibility of Augmented Reality (AR) Media for Ecosystem Learning in primary education by applying the Holistic 4D Model (Define, Design, Develop, Deploy), limited to the Develop stage. The novelty of this study lies in the methodological integration of the Holistic 4D framework which emphasizes iterative design improvement with hybrid AR implementation that combines physical dioramas. The expected outcome is a feasible and valid learning medium that can effectively support the teaching of ecosystem materials. The novelty of this research lies in two main aspects. First, it integrates the Holistic 4D Model as a methodological foundation for iterative, learner-centered development of AR based learning media. Second, it combines virtual visualization with physical dioramas as AR markers. Practically, the developed AR media can be integrated into classroom science instruction to improve students' conceptual understanding, motivation, and engagement, thereby supporting the broader goal of enhancing scientific literacy in Indonesian primary schools.

Research Method

This research belongs to the type of Research and Development (R&D). The development study includes the processes of product development, product validation, and product testing. The development model employed is the Holistic 4D Model (Define, Design, Develop, and Deploy) (Roman, 2022).

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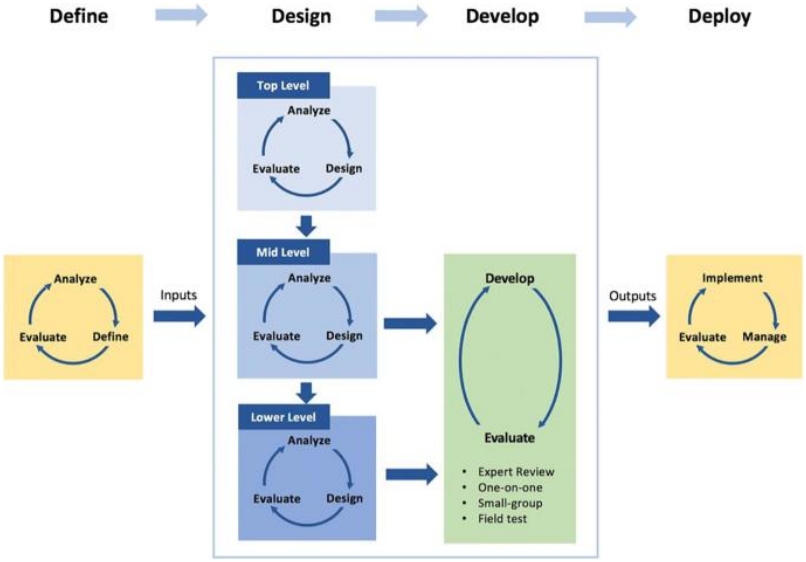

Figure. 1. The Holistic 4D Model adapted from Reigeluth & An, (2021)

The Define stage involved needs analysis, problem identification, and the formulation of learning objectives as the foundation for development. The Design stage was carried out at three levels top-level, mid-level, and lower-level by applying the analyze–design–evaluate cycle to ensure that the design could be reviewed and refined before moving forward. In the Develop stage, the design was developed into a prototype of the learning media and evaluated iteratively to assess the feasibility of the Augmented Reality Media for Ecosystem Learning through expert review (media experts, subject matter experts, and instructional design experts), a one-on-one trial, and a field test to evaluate aspects of content, appearance, functionality, and user acceptance. Meanwhile, the Deploy stage, which includes full implementation and long-term evaluation in learning, was not conducted in this study but will serve as the basis for future development. The data collection technique employed was an open-ended questionnaire. The research sample consisted of six experts for the expert review (two media experts, two subject matter experts, and two instructional design experts). The one-on-one trial involved three students, while the field test involved 24 fifth-grade students in primary education. The study was conducted at SDN Lidah Kulon 1 Surabaya. Sampling was based on the findings of the needs analysis, ensuring that the selected participants had relevant characteristics. Data analysis employed descriptive statistics using a Likert scale. The data were analyzed by calculating the mean scores and determining the corresponding criteria, which are detailed in Table 1.

Table 1. Validation Score Criteria

Interval Score	Category Rating	Description
3.60 ≤ score ≤4.00	Very valid	Can be used without revision
2.60 ≤ score ≤3.59	Valid	Useable with minor revisions
1.60 ≤ score ≤2.59	Not valid	Can be used with multiple revisions
1.00 ≤ score ≤1.59	Invalid	Can't be used yet and still needs consultation

After the product was validated, limited trials were conducted in learning activities (one-on-one and field tests). At this stage, students completed an open-ended questionnaire to measure their responses to the Augmented Reality Media for Ecosystem Learning. The

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students' responses were then analyzed using the percentage formula of the mean score, as presented below:

$$\%Score = \frac{Score\ obtained}{Total\ Score} x100\%$$

The percentage criteria for questionnaire scores are described in table 2.

Table 2. Criteria for the percentage of questionnaire scores

Percentage	Category
80% < score ≤ 100%	Very Well/Strongly agree
65% < score ≤ 80%	Well/Agree
55% < score ≤ 65%	Enough
40% < score ≤ 55%	Not Enough/Disagree
0% < score ≤ 40%	Less Once/Totally Disagree

Result

The define stage was carried out to identify the needs and problems in ecosystem learning at the primary education level. Documentation of science achievement scores on the ecosystem theme at SDN Lidah Kulon showed that student learning outcomes were still low. In Sub-theme 1 on food chains and food webs, the average score reached only 68.7 (fair category), and in Sub-theme 2 on energy flow in ecosystems, the score further decreased to 65.6 (needs guidance category). These scores were below the Learning Objectives Achievement Criteria, indicating a gap between the intended learning objectives and the actual outcomes in the classroom. Observations during the learning process also revealed that teachers tended to rely on verbal explanations and static illustrations, resulting in limited student engagement and difficulty in understanding abstract concepts. This condition highlights the need for more innovative learning media. The low learning outcomes were not solely due to students' limitations but also to the absence of media that could help them visualize the material more concretely. Augmented Reality (AR) is considered a relevant alternative, as it provides interactive and immersive learning experiences that are expected to increase students' motivation and facilitate deeper conceptual understanding.

From the instructional perspective, the development of the Augmented Reality Media for Ecosystem Learning was aligned with the fifth-grade science curriculum, particularly on the topics of food chains, food webs, and energy flow in ecosystems. These materials were selected because of their relatively high level of difficulty and their contribution to students' low learning outcomes. From the non-instructional perspective, classroom observations indicated that teachers had not yet utilized interactive media in their teaching practices, which also became an important consideration. Therefore, the Augmented Reality Media for Ecosystem Learning was designed to be easily integrated into teachers' classroom practice without requiring complex technical skills. By taking into account the curriculum analysis, student achievement data, and field observations, it can be emphasized that the development of the Augmented Reality Media for Ecosystem Learning is an urgent need. The evaluation of the define stage provides a strong foundation that technological media innovations are required to improve the quality of ecosystem learning, reduce learning achievement gaps, and encourage active student engagement in the learning process.

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The design stage focused on planning the Augmented Reality Media for Ecosystem Learning before further development. The design process was carried out in stages, starting from the top-level (defining learning objectives and strategies), mid-level (designing usage flow and media structure), and lower-level (designing the interface and AR objects), by applying the analyze–design–evaluate cycle to ensure the appropriateness of the design before moving to development. The learning objectives were formulated based on the needs analysis results in the define stage, namely the topics of food chains, food webs, and energy flow in ecosystems in the fifth-grade science curriculum. The objectives were designed so that students would be able to understand the interrelationships among ecosystem components, referring to a student-centered learning approach in which understanding is achieved through more concrete, visual, and interactive learning experiences by directly exploring ecosystem objects within the Augmented Reality Media for Ecosystem Learning.

From the media design perspective, a flowchart was developed to illustrate the usage flow, depicting how students interact with the Augmented Reality Media for Ecosystem Learning application.

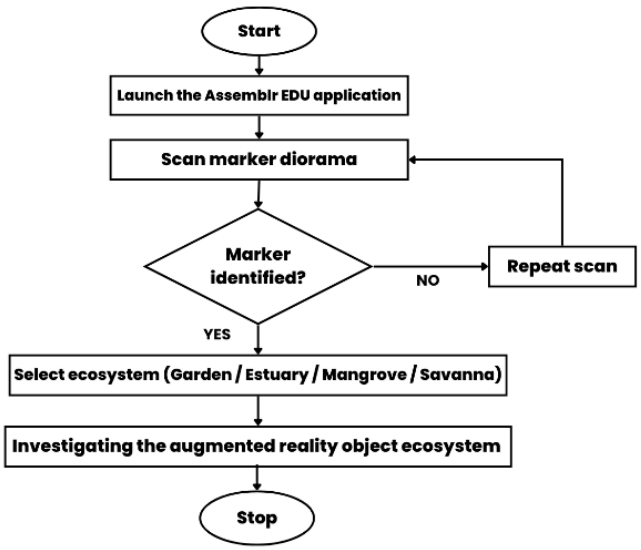

Figure. 2. Augmented Reality Media Flowchart Ecosystem Material

The assessment instruments were also designed at this stage, consisting of expert validation sheets and student response questionnaires. The validation instruments covered three categories. Subject matter experts assessed the alignment of content with learning objectives, the accuracy of concepts, the structure of presentation, and the readability of language. Media experts evaluated the content quality, technical aspects, instructional features, and visual appearance of the application. Meanwhile, instructional design experts examined the completeness of learning components and their conformity with the principles of designing engaging, relevant, and coherent modules. The results of the evaluations from these three groups of experts served as the basis for product revision before the trials with students were conducted.

The develop stage was the process of realizing the media design into an initial product that could be used in learning. At this stage, the previously designed plans were implemented in the form of a product, namely a marker-based augmented reality application with a diorama as the supporting medium. The application was developed using Assembler Studio, while

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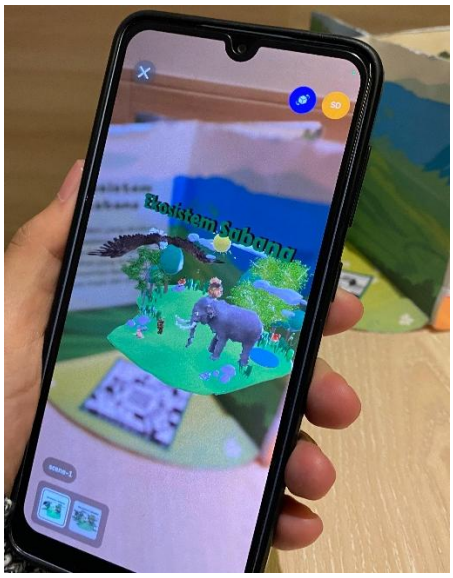
students accessed and interacted with the media through Assembler Edu, which can be downloaded on mobile devices.

Dioramas as AR marker media



Ecosystems in AR

Learning materials in AR

Figure. 3. Display Augmented Reality Media for Ecosystem Learning

Subsequently, the media was assessed for feasibility through validation by subject matter experts, media experts, and instructional design experts. The data obtained from the validation results served as the basis for product improvement and refinement. The revision

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stage was essential to ensure that the developed media was not only aligned with the curriculum but also effective and practical for use in primary education learning. The final outcome of the develop stage was a prototype of the Augmented Reality Media for Ecosystem Learning application (Figure 3), which had been validated by experts and revised based on their feedback, making it ready for further testing through the one-on-one trial and field test. The validation results from the experts are presented in Table 3.

Tabel 3. Validation Results by Expert review

No.	Assessment Aspects	Score	Category Rating
1.	Material Expert Validation	3.80	Very valid
2.	Learning Media Expert Validation	3.83	Very valid
3.	Learning Design Expert Validation	3.81	Very valid

Based on the validation results, the Augmented Reality Media for Ecosystem Learning was declared feasible for use with minor revisions according to the experts' suggestions. The validation results indicated that all aspects obtained mean scores above 3.80 (highly valid category). The highest score was obtained in the media aspect (3.83), showing that the visual appearance, navigation, and clarity of AR features had met the criteria of being very good. However, item-level analysis revealed notes on the structured aspect, particularly in the user instructions, which still needed improvement to be more easily understood by users. After undergoing expert validation and revisions, the Augmented Reality Media for Ecosystem Learning was tested with students through two stages: one-on-one and field test. The one-on-one trial involved three fifth-grade primary education students, aimed at obtaining an initial overview of usability, attractiveness, and students' comprehension of the presented material. Subsequently, the field test was conducted with 24 fifth-grade students to examine responses on a larger group scale. The detailed results of the product trials are presented in Table 4.

Tabel 4. Results of Response Questionnaire

No.	Assessment Aspects	Score	Category Rating
1.	One-On-One	91%	Strongly agree
2.	Field Test	87%	Strongly agree

The trial results with students showed variations across the assessed aspects. The highest score was obtained in the field test for the indicators of ecosystem content clarity and language clarity. This confirms that the AR media, supported by physical dioramas, was able to represent the interrelationships among ecosystem components comprehensively while presenting communicative language appropriate for primary education students. Conversely, the lowest score appeared in the aspect of scientific terminology usage. This finding indicates that although AR effectively supports the visualization of concepts, the use of scientific terms still requires simplification to better match the comprehension level of primary school students.

The research findings indicate that the Augmented Reality (AR) ecosystem learning media for primary schools is feasible and valid for use. Expert validation demonstrated high scores across all categories: subject matter experts (3.80), media experts (3.83), and instructional design experts (3.81), all of which fall within the "very valid" category. In addition, user trials produced highly positive responses, with an average score of 91% in the one-on-one test and 87% in the field test. These results confirm that the AR-based ecosystem

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learning media is well-received by students, both on a small scale and in a larger group setting. This strengthens the expert validation outcomes and affirms that the media is suitable as an instructional tool for teaching science at the primary school level.

Discussion

The findings of this study are consistent with prior research that highlights the effectiveness of Augmented Reality (AR) in enhancing student motivation, conceptual understanding, and learning engagement. Previous studies have shown that AR-based learning experiences significantly increase motivation, student involvement, and technology acceptance (Aji & Purbojo, 2023). Similarly, AR has been reported as effective in early childhood education by fostering motivation and concept acquisition from an early age(Cahyaningtyas, 2020). In the context of primary schools, AR has demonstrated great potential in visualizing abstract concepts, making them more comprehensible to students (Frasnyaigu et al., 2023). The integration of AR in science learning at the primary level was also found to enhance learning interest, clarify abstract concepts, and stimulate students' creativity and motivation (Hidayat, 2024). Likewise, AR media for geometry learning achieved expert validation scores above 90% with highly positive student responses (Dinayusadewi & Agustika, 2020).

Furthermore, AR media in primary science learning has been validated as highly feasible by experts (92–100%) and rated very practical by both teachers and students, with an average response of 93%, while also demonstrating improved learning outcomes with an N-gain score of 73.58% (Nurachmadani et al., 2025). Even in the context of students with special needs, AR was reported as valid (3.32) and highly practical with a score of 91.8%, indicating its potential to assist students with learning difficulties in understanding science concepts (Angreni et al., 2023). These findings further confirm that AR can be broadly applied across different education levels and subjects to enhance motivation, engagement, and learning outcomes. The contribution of this study lies in providing empirical evidence that Augmented Reality Media for Ecosystem Learning is feasible for use in primary education, a domain that has been relatively underexplored. The integration of AR in primary science education has the potential to bridge gaps in students' understanding of abstract topics such as food chains, food webs, and energy flow through concrete and interactive visualization.

The findings of this study highlight several aspects of novelty. The use of the Holistic 4D Model in developing AR media for primary education provides a more comprehensive and iterative approach compared to conventional models such as ADDIE or Borg & Gall. The integration of physical dioramas with AR technology also introduces a hybrid learning format that is rarely explored, allowing students not only to observe virtual representations but also to interact with tangible ecosystem models. From a literature perspective, this study expands the application of AR to ecosystem topics in primary science education, which have been relatively under-researched, and is also policy-relevant given Indonesia's low science achievement in international assessments such as PISA. Therefore, although this study is limited to the feasibility stage, the expert validation results and positive student responses provide a strong basis for future research employing experimental designs to examine the effectiveness of the media.

Conclusion

The study findings indicate that learning achievement in ecosystem topics at the primary education level still exhibits gaps, particularly in subtopics such as food chains, food webs, and energy flow, which remained in the "fair" category. This highlights the need for

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innovative media, such as the Augmented Reality Media for Ecosystem Learning, to support science learning. Validation results demonstrated that the developed AR media is highly feasible, with average scores of 3.80 from subject matter experts, 3.83 from media experts, and 3.81 from instructional design experts. User trials also showed highly positive responses, with 92.2% in the one-on-one test and 90.8% in the field test. It can be concluded that the Augmented Reality Media for Ecosystem Learning is valid and feasible for use in primary education. By providing interactive and concrete visualizations aligned with 21st-century learning demands, the media has the potential to enhance student motivation, engagement, and conceptual understanding. Combined with the methodological novelty of employing the Holistic 4D Model and integrating physical dioramas as AR markers, this study provides empirical evidence supporting the broader adoption of AR in primary science education.

Recommendation

Building on the novelty of integrating physical dioramas with AR through the Holistic 4D Model, this study provides evidence that Augmented Reality Media for Ecosystem Learning is feasible and effective for primary education. Based on these findings, it is recommended that teachers utilize AR media as an alternative tool to support the teaching of complex and abstract science concepts, particularly ecosystem topics. Schools and policymakers should consider incorporating technology-based learning media into the curriculum to enhance student engagement and promote interactive, inquiry-based learning experiences. For future research, it is advised to extend the Holistic 4D development to the deployment stage and conduct broader trials across multiple schools to evaluate the effectiveness of AR media on learning outcomes, student motivation, and long-term retention. Further innovations in AR features, such as ecological dynamics simulations and enhanced interactivity, could enrich inquiry-based learning and deepen conceptual understanding.

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References

Aji, K. A., & Purbojo, R. (2023). Learning Through Augmented Reality: The Indonesia Open University Experience. *Jurnal Teknologi Pendidikan : Jurnal Penelitian Dan Pengembangan Pembelajaran*, *8*(3), 678. https://doi.org/10.33394/jtp.v8i3.7800

Alfatonah, I. N. A., Kisda, Y. V., Septarina, A., Ravika, A., & Jadidah, I. T. (2023). Kesulitan Belajar Peserta Didik pada Mata Pelajaran IPAS Kurikulum Merdeka Kelas IV. *Jurnal Basicedu*, *7*(6), 3397–3405. https://doi.org/10.31004/basicedu.v7i6.6372

Angreni, S., Sari, R. T., & Masyitah, I. (2023). Development of Augmented Learning Media Reality for Students Learning Difficulties in Elementary School. *Journal of ICSAR*, *7*(2), 271. https://doi.org/10.17977/um005v7i22023p271

Cahyaningtyas, A. S. (2020). Pembelajaran Menggunakan Augment Reality Untuk Anak Usia Dini Di Indonesia. *Jurnal Teknologi Pendidikan : Jurnal Penelitian Dan Pengembangan Pembelajaran*, *5*(1), 20. https://doi.org/10.33394/jtp.v5i1.2850

Oktober 2025 Vol. 10 No. 4
E-ISSN: 2656-1417
P-ISSN: 2503-0602
pp. 711-721

Dinayusadewi, N. P., & Agustika, G. N. S. (2020). Development Of Augmented Reality Application As A Mathematics Learning Media In Elementary School Geometry Materials. *Journal of Education Technology*, *4*(2), 204. https://doi.org/10.23887/jet.v4i2.25372

Frasnyaigu, R., Mulyahati, B., & Aprilia, R. (2023). Design of Augmented Reality (AR) Learning Media in Ecosystem Meteri in Elementary School Inclusion Classroom. *Jurnal Penelitian Pendidikan IPA*, *9*(10), 8539–8545. https://doi.org/10.29303/jppipa.v9i10.5298

Hidayat, L. (2024). Pengembangan Media Belajar IPA Materi Tata Surya melalui Aplikasi Augmented Reality untuk Peningkatan Motivasi Belajar Siswa SD Negeri di Kecamatan Adiwerna Kabupaten Tegal. *Journal of Education Research*, *5*(1), 781–794.

Kuroru, M. M., & Rahmah, N. (2023). Analisis Kesulitan Kognitif Siswa Sekolah Dasar dalam Memahami Materi Ekosistem pada Pembelajaran IPA. *Jurnal Studi Guru Dan Pembelajaran*, *6*(1), 74–84. https://doi.org/10.30605/jsgp.6.1.2023.2357

Nasir, M. A., Sanjaya, R., Studi, P., & Informatika, T. (2018). Augmented Reality Rantai Makanan Ekosistem Laut. *Jurnal Informatika*, *4*(2), 1–7.

Nurachmadani, N., Sahudra, T. M., & Mulyahati, B. (2025). Development of Augmented Reality (AR) Based Learning Media to Improve Educational Outcomes for Elementary School Students. *ALACRITY : Journal of Education*, *5*(1), 592–608. https://doi.org/10.52121/alacrity.v5i1.692

OECD. (2023). Education in Indonesia a decade on Transforming Education in Indonesia: Examining the landscape of current reforms. *Directorate for Education and Skills*, *88*, 5. https://www.oecd.org/pisa/data/2022database

Qorimah, E. N., Laksono, W. C., Hidayati, Y. M., & Desstya, A. (2022). Kebutuhan Pengembangan Media Pembelajaran Berbasis Augmented Reality (AR) pada Materi Rantai Makanan. *Jurnal Pedagogi Dan Pembelajaran*, *5*(1), 57–63. https://doi.org/10.23887/jp2.v5i1.46290

Reigeluth, C. M., & An, Y. (2021). Merging the instructional design process with learner-centered theory: The Holistic 4D Model. In *Merging the Instructional Design Process with Learner-Centered Theory: The Holistic 4D Model*. Routledge. https://doi.org/10.4324/9781351117548

Reizal, H., Agustiningsih, & Hutama, F. S. (2020). Pengembangan Buku Ajar Berbasis Infografis pada Tema Ekosistem untuk Meningkatkan Hasil Belajar Siswa Kelas V SD. *Muallimuna : Jurnal Madrasah Ibtidaiyah*, *5*(2), 54–65. https://ojs.uniska-bjm.ac.id/index.php/jurnalmuallimuna/article/view/2879

Roman, T. A. (2022). Review of Merging the Instructional Design Process with Learner-Centered Theory: The Holistic 4D Model by Charles M. Reigeluth and Yunjo An. *TechTrends*, *66*(3), 560–562. https://doi.org/10.1007/s11528-022-00723-y

Sari, Y., Abidin, Z., Kusumadewi, R. F., Ismiyanti, Y., & Ulia, N. (2024). The Effectiveness of Virtual Augmented Reality-Based Media to Improve Students' Critical Thinking Skill: An Experimental Study in Elementary School. *JIP (Jurnal Ilmiah PGMI)*, *10*(2), 76–86. https://doi.org/https://doi.org/10.19109/jip.v10i1.25572

Vari, Y., & Bramastia, B. (2021). Pemanfaatan Augmented Reality Untuk Melatih Keterampilan Berpikir Abad 21 Di Pembelajaran Ipa. *INKUIRI: Jurnal Pendidikan IPA*, *10*(2), 132. https://doi.org/10.20961/inkuiri.v10i2.57256

Wahyuni, S., Hariandi, A., & Alirmansyah, A. (2023). Upaya Meningkatkan Pemahaman Konsep Peserta Didik pada Muatan IPA Ekosistem Kelas V Sekolah Dasar Menggunakan

Oktober 2025 Vol. 10 No. 4
E-ISSN: 2656-1417
P-ISSN: 2503-0602
pp. 711-721

Video Interaktif. *Journal on Education*, *5*(2), 5152–5172. https://doi.org/10.31004/joe.v5i2.1254