Development of the Taksinusa educational card game assisted by augmented reality to improve junior high school students' science literacy skills

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Abstract
Indonesian students' science literacy remains below the OECD average, while the topic of biological classification in junior high school is often perceived as abstract and difficult to visualize through conventional instruction. This study developed the Taksinusa educational card game assisted by Augmented Reality (AR) to improve science literacy skills. The objectives were to (1) develop the product, (2) evaluate its feasibility, and (3) analyze its effect on students' science literacy. This Research and Development study employed an exploratory sequential design based on the ADDIE model. Product effectiveness was assessed using a one-group pretest-posttest design involving 32 seventh-grade students from a public junior high school in Central Java, Indonesia. Data were analyzed using the Wilcoxon Signed-Rank Test and N-Gain. The Taksinusa product combines physical taxonomy cards representing seven biological classification levels with AR features displaying 3D models of Indonesian endemic fauna and scientific information. Supporting materials included a user guide, teaching module, student worksheet, and science literacy test. Feasibility validation results indicated that the product was highly feasible, with scores of 93.47% from material experts, 96.73% from media experts, and 87.50% from instructional design experts. The Wilcoxon test showed a significant difference between pretest and posttest scores (Asymp. Sig. = 0.000 < 0.05). N-Gain analysis revealed moderate improvement in explaining scientific phenomena (0.6469) and using scientific information for decision-making (0.5114), while improvement in scientific inquiry skills was low (0.2563). These findings indicate that Taksinusa is a feasible and effective learning medium for enhancing junior high school students' science literacy.

1. Introduction

Science literacy is one of the essential 21st-century competencies that junior high school students need to master, since scientific knowledge serves as a foundation for decision-making and problem-solving in daily life (Gultepe & Kilic, 2015). The PISA 2025 framework positions competency as the core construct of scientific literacy, comprising three main abilities, namely explaining phenomena scientifically; constructing and evaluating designs for scientific inquiry and critically interpreting scientific data and evidence; and researching, evaluating, and using scientific information for decision-making and action (OECD, 2023). These three competencies are measured in an integrated manner through the PISA assessment and summarized into a single science literacy score as an indicator of students' overall scientific ability.

Indonesia's science literacy score on PISA 2022 stood at 383, a 13-point decline from PISA 2018 (396), and remained far below the OECD average of around 490 (OECD, 2023). Several studies at the junior high school level across various regions in Indonesia have reinforced this condition (Andriani et al., 2018; Maulina et al., 2022; Mellyzar et al., 2022; Sari & Nurwahyunani, 2017). This low achievement is thought to stem from instruction that has not been oriented toward developing science literacy (Putra, 2016), as well as the dominance of conventional, teacher-centered instruction that fails to promote higher-order thinking (Lazonder & Harmsen, 2016).

One topic that particularly demands stronger science literacy is the classification of living things, as understanding taxonomic concepts underlies several other biological concepts (Pangsuma & Hidayat, 2023). Seventh-grade students have been found to still experience high rates of misconception across various subtopics of classification (Yona & Ilhami, 2022), along with difficulty memorizing taxonomic ranks and scientific names (Setyorini, 2021; Mustaqimah et al., 2023), a problem exacerbated by lecture-based instruction that lacks concrete visualization (Prihatmoko, 2012).

In response to these challenges, this study developed a learning medium in the form of an educational card game assisted by Augmented Reality, named Taksinusa, an acronym for Taksonomi Nusantara (Archipelagic

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Taxonomy). This name reflects two main pillars of the medium: scientific content in the form of the seven levels of biological taxonomy, and contextualization of learning through Indonesian endemic fauna as the object of classification. Junior high school students' preference for active and interactive learning environments underlies the choice of a card game format (Chan et al., 2019, in Andika et al., 2025), whose gameplay mechanism was structurally adapted from a classic card game and thoroughly modified for educational purposes, thereby being entirely free of gambling or betting elements.

The added value of this medium lies in its hybrid combination of a physical card game and Augmented Reality technology. The card game component sparks students' active engagement through competitive and peer-to-peer interaction (Hardina, 2024), while Augmented Reality addresses the challenge of visualizing abstract concepts (Muzanni et al., 2024) and offers a solution to the limited opportunity for direct observation of endemic fauna that are largely rare and protected. The three PISA 2025 science literacy competencies are specifically trained through the features of this medium: the first competency through exploration of 3D animal models and information panels in the Augmented Reality feature; the second through gameplay mechanics that require strategic thinking in classifying cards; and the third through analysis of contextual information as a basis for decision-making during gameplay.

Prior studies have explored card games, Augmented Reality, and local-wisdom contextualization separately or in pairs (Prasetyaningtyas, 2020; Alfarizi et al., 2024; Pangestuti, 2021; Rani, 2025; Gustini et al., 2026; Maziyah & Zumrotun, 2025), yet no study has been found that combines card gameplay, Augmented Reality, contextualization through Indonesian endemic fauna, and a design specifically intended to train the three core PISA 2025 science literacy competencies in the topic of classification of living things at the junior high school level. This gap constitutes the novelty and contribution of the present study.

Based on the foregoing, this study aimed to (1) produce the Taksinusa educational card game assisted by Augmented Reality possessing specific characteristics as a science learning medium for junior high school students, (2) analyze its level of feasibility, and (3) analyze the improvement in junior high school students' science literacy skills after using the product.

2. Method

2.1. Research Type and Design

This study is categorized as Research and Development (R&D) combined with an exploratory sequential design (Creswell & Clark, 2007). The product development process followed the ADDIE model (Analysis, Design, Development, Implementation, Evaluation; Reiser & Molenda), with formative evaluation during the Development stage following Tessmer's (2013) framework, comprising self-evaluation, expert review, one-to-one evaluation, small group evaluation, and expert judgment. The improvement in students' science literacy skills was measured using a one-group pretest-posttest design, without a control group for comparison.

2.2. Participants and Research Site

The study was conducted at a selected public junior high school in Sragen Regency, Central Java, Indonesia. The participants consisted of 32 seventh-grade students in the 2025/2026 academic year who were involved in the implementation trial. In addition, three experts (material, media, and instructional design) evaluated the product feasibility, while a science teacher participated as a learning practitioner.

2.3. Product Development Procedure

The Analysis stage was carried out through a review of PISA data and relevant literature, classroom observation, and interviews with the science teacher to identify learning needs, student characteristics, curriculum alignment, and subject matter. The Design stage covered the card design (56 cards representing the seven taxonomic levels plus 1 AR marker card, sized 9.6 × 6.6 cm, printed on 310 gsm art carton), Augmented Reality content (3D animal models, information panels, flowcharts, and storyboards) developed on the Assemblr Edu platform, the game system (rules, a point system based on taxonomic hierarchy weighting, and gameplay instructions), and supporting learning materials (a user guide, a teaching module, a student worksheet, and a science literacy test).

The Development stage realized all the designs into a product tested through the five formative evaluation steps described above. The Implementation stage was conducted over two meetings (5 class periods) in class VII A using a Game Based Learning model combined with a scientific approach: the first meeting for the pretest and product introduction, and the second for group card gameplay, worksheet completion, and the posttest. The Evaluation stage analyzed the implementation data to determine the extent to which the research objectives were achieved.

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2.4. Instruments and Data Collection Techniques

Data were collected through questionnaires (expert review, expert judgment, student responses, and teacher responses), interviews, observation, documentation studies, and a science literacy test (pretest-posttest, 20 multiple-choice items). Item validity was calculated using the point-biserial correlation coefficient (Alfansuri et al., 2025), with all 20 pretest and posttest items declared valid (r calculated > r table of 0.349; N = 32). Reliability was calculated using Cronbach's Alpha (Yusup, 2018), yielding 0.739 for the pretest and 0.757 for the posttest, both in the acceptable category (George & Mallery, 1999).

2.5. Data Analysis Techniques

Qualitative data from the formative evaluation were analyzed descriptively using the interactive model of Miles et al. (2014), comprising data condensation, data display, and conclusion drawing/verification. Product feasibility data from expert judgment (1–4 scale) were processed using the percentage in Equation 1 (Rahmat et al., 2021),

$$P = \frac{F}{N} \times 100\% \quad (1)$$

With feasibility categories following Arikunto (2010, in Hakky et al., 2018): 76–100% Highly Feasible, 51–75% Feasible, 26–50% Fairly Feasible, 0–25% Not Feasible.

The normality prerequisite test for the pretest-posttest data used Shapiro-Wilk (Razali & Wah, 2011). As the data were not normally distributed, hypothesis testing was conducted using the Wilcoxon Signed-Rank Test (Field, 2024) at a 5% significance level. Improvement in science literacy was analyzed using normalized gain (N-Gain) (Latif, 2014; Katili & Yassin, 2022), categorized as: $g > 0.7$ High, $0.3 \leq g \leq 0.7$ Medium, $g < 0.3$ Low (Hake, 1999, in Husna et al., 2020).

3. Results and Discussion

3.1. Product Description

The Taksinusa educational card game assisted by Augmented Reality consists of a set of playing cards (56 cards representing the seven taxonomic levels plus 1 marker card), an Augmented Reality feature built on Assemblr Edu displaying 3D models of eight Indonesian endemic fauna (Sumatran elephant, proboscis monkey, Bornean orangutan, Javan leopard, Javan rhinoceros, Mahakam River dolphin, sun bear, and cassowary) along with information panels covering biological lineage, conservation status, and habitat, as well as supporting learning materials comprising a user guide, teaching module, student worksheet, and science literacy test. The game system adapts the grouping mechanism of a classic card game, modified purely for educational purposes, with scoring based on taxonomic hierarchy weighting (Kingdom = 7 through Species = 1).

3.2. Product Development Process

The development process through the five ADDIE stages showed that most revisions during the Development stage stemmed from scientific content aspects, such as the completeness of citations in the Augmented Reality information panels and the reference list in the teaching module, rather than purely technical issues. Table 1 summarizes the improvement suggestions from the three experts during the expert review stage.

Table 1. Summary of Product Improvement Suggestions Based on Expert Review

No	Expert	Number of Suggestions	Improvement Focus
1.	Learning Material	3	Fauna distribution map on the worksheet; citations in AR information panels; reference list in the teaching module
2.	Learning Media	2	Card design aesthetics; visual quality of 3D animal models
3.	Instructional Design	2	Alignment of Learning Objectives with the ABCD components; development of higher-order-reasoning test items

The one-to-one evaluation (3 students) and small group evaluation (8 students) trials revealed several technical issues, such as an overly small marker size, device limitations, unstable internet connectivity, poor text readability on the "Family" card, and the absence of explicit winning conditions in the user guide, all of which were addressed prior to the expert judgment stage. These findings reinforce that developing Augmented Reality-based media requires repeated technical testing before it is trialed on a larger scale, consistent with the usability challenges reported by Buchner et al. (2022).

3.3. Product Feasibility

The expert judgment results in Table 2 show that the product achieved the "Highly Feasible" category from all three experts.

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Table 2. Product Feasibility Percentages Based on Expert Assessment

No	Assessment Aspect	Percentage	Category
1.	Learning Material	93.47%	Highly Feasible
2.	Learning Media	96.73%	Highly Feasible
3.	Instructional Design	87.5%	Highly Feasible

The relatively lower feasibility score for instructional design, although still Highly Feasible, indicates that supporting learning materials require alignment across a larger number of components than the material and media aspects alone. This result is consistent with Pangestuti (2021), who obtained material validity of 95.4% and media validity of 87.5%, and Maziyah and Zumrotun (2025), who reported material validity of 90% and media validity of 92%, reinforcing the tendency that integrating Augmented Reality into learning media yields high feasibility when subjected to rigorous expert validation. The media feasibility score of Taksinusa (96.73%) was higher than most of the comparison studies, likely attributable to the multiple rounds of visual revision conducted prior to the expert judgment stage.

3.4. Improvement in Science Literacy Skills

The Shapiro-Wilk normality test showed significance values of 0.005 (pretest) and 0.000 (posttest), both ≤ 0.05, indicating that the data were not normally distributed; hypothesis testing therefore proceeded using the Wilcoxon Signed-Rank Test. The test results showed an Asymp. Sig. (2-tailed) value of 0.000 (< 0.05), leading to the rejection of H_0 and confirming a significant difference between students' pretest and posttest science literacy scores. The N-Gain values for each competency are presented in Table 3.

Table 3. N-Gain Values per Science Literacy Competency

No	Competency	N-Gain	Category
1.	Explaining phenomena scientifically	0.6469	Medium
2.	Constructing and evaluating designs for scientific inquiry and interpreting data and evidence scientifically	0.2563	Low
3.	Researching, evaluating, and using scientific information for decision-making	0.5114	Medium

The positive N-Gain values across all competencies indicate that this difference represents an improvement, consistent with Maziyah and Zumrotun's (2025) findings on the Augmented Reality-based Kartu Ajaib medium. Nevertheless, the pattern of improvement was uneven across competencies. The lower achievement in Competency II is consistent with its characteristics within the PISA framework, which places it at a higher cognitive level than Competency I. Drawing on Edgar Dale's Cone of Experience (Dale, 1969), exploring 3D models and information panels in the Augmented Reality feature provided effective visual and symbolic experiences supporting Competencies I and III, but was less adequate for training Competency II, which requires repeated analytical experience.

Limited implementation time also contributed to the lower achievement in Competency II. The reduction of one class period during the first meeting, due to a National Awakening Day ceremony, caused the group card gameplay stage, which was intended to train strategic thinking in evaluating taxonomic classification, to be delayed and compressed into the second meeting, compounded by technical issues such as response lag in the Augmented Reality feature during implementation.

4. Conclusion

The Taksinusa educational card game assisted by Augmented Reality was successfully developed through five ADDIE stages, characterized by the integration of physical classification cards and an Augmented Reality feature displaying 3D models of Indonesian endemic fauna, and was declared Highly Feasible as a science learning medium (93.47% material, 96.73% media, 87.5% instructional design). The product also proved to significantly improve students' science literacy, although the improvement was lower in the competency of constructing and evaluating designs for scientific inquiry, which demands higher analytical ability. More adequate implementation time allocation and more thorough testing of the technical stability of Augmented Reality are recommended for future research.

Author Contributions

Mahmud Anas: Conceptualization, Methodology, Investigation, Software, Data curation, Formal analysis, Writing – original draft. Bayu Antrakusuma: Supervision, Validation, Writing – review & editing. All authors have equal contributions to the paper. All the authors have read and approved the final manuscript.

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Declaration of Conflicting Interests

The author declared no potential conflicts of interest with respect to the research, authorship, and/ or publication of this article.

Data Availability

The datasets generated during and/ or analysed during the current study are available from the corresponding author on reasonable request.

Declaration on AI Use

The authors declare that no artificial intelligence (AI) or AI-assisted tools were used in the preparation of this manuscript.

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