Development of Jenga Collaboration with Combo Cards Learning Media on Ecosystem Material for Grade VII Students

Sri Ayu Finanda, Bayu Antrakusuma*, Kadek Dwi Hendratma Gunawan, Budi Utami, Suciati

Universitas Sebelas Maret, Ir. Sutami St. No. 36A, Surakarta, Central Java, 57126, Indonesia
*Corresponding author, email: antrakusumabayu@staff.uns.ac.id

https://doi.org/10.17977/um065.v6.i12.2026.9

Article history
Submitted: 7 July 2026
Revised: 23 July 2026
Accepted: 25 July 2026
Published: 26 July 2026

Keywords
Learning media
Jenga collaboration
Combo cards
Ecosystem

Abstract
The low level of student engagement and collaboration in group-based science learning, particularly on the abstract topic of ecosystems, underlies this study. Preliminary observations at three junior high schools in Majenang District, Indonesia revealed limited use of interactive learning media that supports collaboration among students, consistent with data showing that 75% of students had not reached the Minimum Mastery Criteria (MMC) on ecosystem material. This study aims to develop the Jenga Collaboration with Combo Cards learning media and to examine its feasibility and effectiveness. The study employed a Research and Development (R&D) approach using the 4-D model (Define, Design, Develop, Disseminate), limited to the Develop stage. Data were collected through expert validation sheets, user-trial questionnaires, and pretest-posttest instruments, then analyzed through product validation, reliability testing, item difficulty and discriminating power analysis, statistical testing, and N-Gain analysis. The results show that the learning media was rated Highly Feasible based on Expert Judgement, with feasibility percentages of 84.44% (media expert), 85.45% (content expert), and 85.83% (instructional design expert). The Paired Samples T-Test yielded t = -9.377 with Sig. (2-tailed) = 0.000 < 0.05, indicating a significant effect between students' pretest (mean 44.29) and posttest (mean 70.00) scores. The mean N-Gain obtained was 0.47, categorized as Medium. These findings demonstrate that the Jenga Collaboration with Combo Cards learning media is feasible and effective for improving students' learning outcomes on ecosystem material in Grade VII.

1. Introduction

Twenty-first-century education is expected to produce learners who are not only academically competent but also proficient in critical thinking, creativity, communication, and collaboration the so-called 4Cs underpinning Higher Order Thinking Skills (HOTS) (Isnaini et al., 2023). Indonesian Government Regulation No. 19 of 2005 on National Education Standards mandates that learning be designed in an active, inspiring, and enjoyable manner, partly through the presence of innovative and engaging learning media (Helda & Syahrani, 2022). Thus, the central challenge in science education is to design innovative and engaging learning media that not only deliver content effectively but also promote active participation, collaboration, and higher-order thinking among students.

However, observations at three junior high schools in Majenang District, Indonesia revealed low student cooperation and engagement during group learning, evidenced by passive participation, loss of focus, and disruptive behavior. All science teachers interviewed attributed this to the limited use of media in group learning, consistent with data showing that 75% of students had not reached the Minimum Mastery Criteria (MMC) on ecosystem material a pattern also reported by Wahyu et al. (2020), who found that although science learning media is generally available in schools, its use remains low due to limited teacher training and initiative.

Learning media serves to convey instructional content and facilitate interaction in the learning process (Kustyarini, Utami, & Koesmijati, 2020), yet classroom observations show that conventional tools such as whiteboards, textbooks, and worksheets still dominate, while visual and projector-based media remain underused. Game-based media offers a promising alternative, as it sustains students' attention and interest (Hussein, Sulaiman, Noroozi, Elaish, & Alhasan, 2025). A meta-analysis by Huang et al. (2020) confirmed that gamification significantly improves material retention and intrinsic motivation, while Othman et al. (2025) found that board games enhance student engagement, motivation, and social interaction more than conventional methods.

© 2026 The Author(s)
This is an Open Access article under the Creative Commons Attribution-ShareAlike 4.0 International License
ISSN: 2797-3174

One game-based medium with potential for development is Jenga, a wooden block tower game created by Leslie Scott, whose name derives from the Swahili word "*kujenga*," meaning "to build" (Carvalho, Neto, & Dos Santos, 2020). A systematic review of 76 studies (2000–2024) by Othman et al. (2025) confirmed that both digital and physical board games enhance scientific knowledge acquisition, engagement, and collaboration in science learning. Jenga's mechanics require careful, cooperative block removal to keep the tower standing and make it well suited to training teamwork and interactive learning (Kusumaningsih, Buchori, & Cahyono, 2020). Grade VII ecosystem material, which addresses interactions among organisms and their environment under Phase D Learning Outcomes, is considered abstract and prone to misconception, particularly regarding energy flow and biogeochemical cycles (Cardak & Dikmenli, 2016). Such abstract concepts require a learning approach based on direct experience and interactive visual modeling (Bransford, Brown, & Cocking, 2000), given that changes in one ecosystem component can affect the overall balance of the ecosystem (Chapin, Kofinas, & Folke, 2009). As board game-based learning has been shown to improve students' problem-solving competency more effectively than conventional instruction (Othman et al., 2025).

Although Jenga-based and card-based media have each been explored separately in prior research for instance, as a vehicle for cultural-diversity content in elementary school or as sorting cards used to build cooperative attitudes (Widya, Rofiq, & Khosiah, 2024). These studies generally treat the game component and the content component as loosely linked add-ons rather than a single, tightly integrated system. The Jenga Collaboration with Combo Cards media developed in this study differs in three respects. First, the Jenga blocks and Combo Cards are cross-referenced through a matching numbering system, so that each block corresponds to a specific question card, ensuring systematic content-mechanic integration rather than incidental pairing. Second, gameplay is structured around defined collaborative roles including a consultant role grounded in Vygotsky (1978) Zone of Proximal Development that deliberately scaffold peer support rather than leaving cooperation to chance. Third, tiered scoring (10/20/30 points) combined with a digital leaderboard introduces measurable, competitive incentives absent from earlier Jenga or card-based designs. To date, no published study has combined these three elements specifically for Grade VII ecosystem material, a gap this study addresses.

This study adopted the 4-D model (Define, Design, Develop, Disseminate) developed by Thiagarajan et al. (1974), chosen for its structured stages that allow an in-depth needs analysis prior to design and validation. Accordingly, this study aims to (1) develop the Jenga Collaboration with Combo Cards learning media for Grade VII ecosystem material, (2) determine its feasibility based on Expert Judgement, and (3) determine its effectiveness in improving students' learning outcomes.

2. Method

This study employed a Research and Development (R&D) approach that combines qualitative and quantitative approaches (mixed methods) within a single research design (Sugiyono, 2019). The qualitative approach was used in the needs analysis stage through interviews and observations, while the quantitative approach was used to measure media feasibility through Expert Judgement and to measure media effectiveness through a comparison of pretest and posttest scores. The development model applied was the 4-D Model proposed by Thiagarajan et al. (1974), comprising the Define, Design, Develop, and Disseminate stages. Given time and scope limitations, this study was limited to the Develop stage, which included Expert Review by three experts (media, content, and instructional design experts), One-to-One trials, Small Group trials, and a Field Test.

The study was conducted at one of the public junior high school in Majenang, Cilacap Regency, Central Java, Indonesia with 28 students of Grade VII F in the 2025/2026 academic year serving as the trial subjects. The sample was determined using purposive sampling based on the recommendation of the science teacher, who considered the class representative of the research needs. The study was carried out from September 2025 to June 2026, beginning with the needs analysis stage and continuing through product development, validation, trials, and report preparation.

Data collection techniques included observation, written tests, and questionnaires. Observations were conducted during the Define stage to identify learning problems through direct observation and informal interviews with teachers at the three junior high schools. A written test consisting of 20 multiple-choice items on ecosystem material was used as the pretest and posttest instrument to measure students' cognitive learning outcomes. Questionnaires were used to gather assessments from the media, content, and instructional design experts, as well as students' responses during the One-to-One and Small Group trials.

Qualitative data in the form of critiques and suggestions from the Expert Review, as well as students' responses, were analyzed descriptively. Quantitative data in the form of Expert Judgement scores were converted into a five-point scale based on Widoyoko's (2018) criteria to obtain validity categories (Very Good, Good, Fair, Poor, Very Poor), after which the feasibility percentage was calculated to obtain feasibility categories (Highly Feasible, Feasible, Fairly Feasible, Less Feasible, Not Feasible) based on Sugiyono's (2020) criteria.

© 2026 The Author(s)
This is an Open Access article under the Creative Commons Attribution-ShareAlike 4.0 International License
ISSN: 2797-3174

The quality of the pretest-posttest instrument was analyzed in terms of validity using the Pearson Product Moment correlation (compared with the r-table value at a 5% significance level), reliability using the Kuder-Richardson 20 (KR-20) method suitable for dichotomously scored items, item difficulty, and discriminating power, based on Arikunto's (2009) criteria. Prior to hypothesis testing, a normality test of the pretest and posttest data was conducted using the Shapiro-Wilk test. If the data were normally distributed, hypothesis testing proceeded using a Paired Sample T-Test at a significance level of $\alpha = 0.05$ with the aid of SPSS. The learning media was considered effective if the Sig. (2-tailed) value was < 0.05. The magnitude of the improvement in learning outcomes was further analyzed using the Normalized Gain (N-Gain) formula developed by Meltzer (2002), with categories of Low ($g \leq 0.3$), Medium ($0.3 < g \leq 0.7$), and High ($g > 0.7$).

3. Results and Discussion

3.1. Results

In the Define stage, interviews and observations at the three junior high schools in Majenang District identified the main problem as the limited use of collaboration-based interactive learning media. The learner analysis showed that Grade VII students had entered Piaget's formal operational stage (Santrock, 2011), enabling them to address conceptual problems more independently. The task and concept analyses produced eight learning objectives on ecosystem material based on Phase D Learning Outcomes, covering cognitive levels from C1 (explaining) to C6 (designing solutions), which were subsequently formulated into operational learning objectives integrated with the mechanics of the *Jenga* Collaboration with *Combo Cards* game.

In the Design stage, an initial draft of the media was produced, consisting of five components: one set of *Jenga* blocks, one set of *Combo Cards*, one game guidebook, one digital leaderboard, and one set of role cards. The physical *Jenga* component consisted of 54 colored wooden blocks measuring 7.5 cm × 2.5 cm × 1.5 cm, arranged by color and supported by a storage box, as shown in Figure 1. The *Combo Cards* consisted of 60 cards measuring 9 cm × 6 cm and were designed using CorelDRAW X7 with front, back, and packaging layouts, as presented in Figure 2. These cards were organized into six categories: Concept, Interaction, Damage, Preservation, Bonus, and Challenge, each with a distinctive color scheme to support category recognition, as illustrated in Figure 3. The *Jenga* blocks were numbered to correspond directly with the numbers on the *Combo Cards*, ensuring systematic integration between the physical components and the question cards. The questions on the *Combo Cards* were arranged with tiered difficulty levels: easy (10 points), medium (20 points), and difficult (30 points).



Figure 1. Jenga Block Components: (a) Blocks Arranged by Color, (b) Block Storage Box



Figure 2. Front, Back, and Packaging Box Views of the Combo Cards

© 2026 The Author(s)
This is an Open Access article under the Creative Commons Attribution-ShareAlike 4.0 International License
ISSN: 2797-3174



Figure 3. Combo Cards in Six Categories: Concept, Interaction, Damage, Preservation, Challenge, and Bonus

In the Develop stage, the product was validated through Expert Review by three experts (media, content, and instructional design), followed by One-to-One trials focusing on the readability and ease of individual use of the media, and Small Group trials focusing on the interactivity and effectiveness of the media in a group-learning context. Revisions were made iteratively at each trial stage, covering improvements to the guidebook, question grids, game mechanics, and card readability, until the media was declared feasible for use in the Field Test stage.

3.2. Media Feasibility Based on Expert Judgement

The validation results from the three experts showed that the *Jenga* Collaboration with *Combo Cards* learning media fell into the Very Good category on the five-point scale and the Highly Feasible category in terms of feasibility percentage, as presented in Table 1.

Table 1. Summary of Expert Judgement Validation Results

Validator	Number of Items	Total Score	Mean Score	Five-Point Category	Feasibility Percentage	Feasibility Category
Media Expert	18	76	4.22	Very Good	84.44%	Highly Feasible
Content Expert	11	47	4.27	Very Good	85.45%	Highly Feasible
Instructional Design Expert	24	103	4.29	Very Good	85.83%	Highly Feasible

The media expert gave the highest scores on the aspects of appearance, ease of use, and durability, with a feasibility percentage of 84.44%. The content expert rated the media as Highly Feasible (85.45%), particularly regarding the correctness and accuracy of the ecosystem content and its alignment with the learning objectives. The instructional design expert gave the highest feasibility percentage (85.83%), particularly on indicators of the media's ability to foster teamwork and develop fairness in role distribution. The consistency of assessments from these three different perspectives indicates that the *Jenga* Collaboration with *Combo Cards* learning media possesses good quality, not only in terms of appearance and ease of use, but also in terms of content accuracy and an instructional design that supports student collaboration, thus confirming its feasibility for use in science learning on Grade VII ecosystem material.

The *Jenga* Collaboration with *Combo Cards* media was designed based on Vygotsky's (1978) social constructivism theory, which emphasizes the importance of social interaction and collaboration in the learning process. The concepts of the Zone of Proximal Development (ZPD) and scaffolding formed the basis for designing the role system within the game, in which the Consultant role enables more competent students to guide peers within their ZPD (Slavin, 2018). This is consistent with the Very Good validation score given by the instructional design expert on the indicator measuring the media's ability to foster cooperation and develop tolerance toward differing opinions within the group.

3.3. Test Instrument Quality

The instrument quality analysis of the 20 pretest-posttest items trialed on 28 students showed that all items (100%) were valid, with r-calculated values ranging from 0.414 to 0.781, all exceeding the r-table value of 0.374 at a 5% significance level. The reliability test using the KR-20 method yielded a coefficient of r_{11} = 0.735, which falls into the High category based on Arikunto's (2009) criteria. The item difficulty analysis showed that 4 items were categorized as Difficult and 16 items as Medium, with no items categorized as Easy, while the discriminating power analysis showed that 16 items were categorized as Very Good, 3 items as Good, and 1 item as Fair, with no items categorized as Poor. These results indicate that the developed test instrument was suitable for measuring students' learning outcomes in the Field Test.

3.4. Media Effectiveness in Learning Outcomes

Prior to hypothesis testing, a normality test of the pretest and posttest data was conducted using the Shapiro-Wilk test, with the results presented in Table 2.

© 2026 The Author(s)
This is an Open Access article under the Creative Commons Attribution-ShareAlike 4.0 International License
ISSN: 2797-3174

Table 2. Shapiro-Wilk Normality Test Results

Data	Statistic	df	Sig.
Pretest	0.951	28	0.205
Posttest	0.961	28	0.362

The Shapiro-Wilk significance values for the pretest (0.205) and posttest (0.362) data both exceeded the 0.05 threshold, indicating that both datasets were normally distributed, allowing hypothesis testing to proceed using the paired t-test. The Paired Samples T-Test results showed a mean pretest score of 44.29 and a mean posttest score of 70.00, an increase of 25.71 points, as presented in Table 3.

Table 3. Paired Samples T-Test Results

	Paired Samples Test					
	Mean	N	Std. Deviation	t	df	Sig. (2-tailed)
Pretest	44.29	28	24.218			
Posttest	70.00	28	16.216			
Pretest–Posttest	-25.71	28	14.511	-9.377	27	0.000

The Sig. (2-tailed) value of 0.000 (< 0.05) led to the rejection of H_0, confirming a significant difference between students' pretest and posttest scores after use of the *Jenga* Collaboration with *Combo Cards* media, with mean scores rising from 44.29 to 70.00 a 58.05% improvement and 27 of 28 students showing gains.

In addition to the significance test, the improvement in students' learning outcomes was analyzed using the Normalized Gain (N-Gain) formula proposed by Meltzer Meltzer (2002). Based on the calculation, the students' mean pretest score was 44.28, while the mean posttest score was 70.00 (see Table 4). This indicates an increase of 25.71 points after students used the Jenga Collaboration with Combo Cards learning media. The mean N-Gain obtained was 0.47, which falls into the medium category.

Table 4. N-Gain Results

Mean Pretest Score	Mean Posttest Score	Score Increase	Mean N-Gain	Category
44.29	70.00	25.71	0.47	Medium

3.5. Discussion

The findings indicate that the effectiveness of the Jenga Collaboration with Combo Cards learning media is supported by two complementary forms of evidence: product quality and improvement in students' learning outcomes. The product was developed using the 4-D model of (Thiagarajan et al., 1974), which consists of Define, Design, Develop, and Disseminate stages; however, this study was limited to the Develop stage because of time and research-scope constraints. The Define stage revealed the actual classroom problem, namely the limited availability of interactive learning media that supported student collaboration in ecosystem learning. This finding became the basis for the Design stage, in which the Jenga blocks, Combo Cards, guidebook, role cards, scoring system, and digital leaderboard were integrated into one instructional product. The iterative revisions during Expert Review, One-to-One trials, and Small Group trials strengthened the quality of the media before the Field Test was conducted.

In terms of product quality, the media was rated Highly Feasible by the media expert (84.44%), content expert (85.45%), and instructional design expert (85.83%). These results show that the product met feasibility standards not only in appearance, durability, and ease of use, but also in content accuracy and collaborative learning design. The instructional design expert's high assessment is particularly important because the media was designed based on Vygotsky's (1978) social constructivist theory, especially the concepts of the Zone of Proximal Development and scaffolding. The Consultant role allowed students with stronger understanding to guide peers during group discussion, while the Recorder and other group roles supported individual responsibility and fair participation. Thus, the media can be interpreted as an integrated instructional system rather than a collection of separate game components.

The improvement in students' learning outcomes is reflected in the increase of the mean pretest score from 44.28 to the mean posttest score of 70.00, with an average score increase of 25.71 points. Before hypothesis testing, the Shapiro-Wilk test showed that the pretest and posttest data were normally distributed, allowing the use of a Paired Samples T-Test. The t-test result showed t = -9.377, df = 27, and Sig. (2-tailed) = 0.000 (< 0.05), indicating a statistically significant difference between students' scores before and after using the media. In addition, the mean N-Gain of 0.47 shows that the improvement was in the Medium category. This result is important because the t-test confirms the significance of the difference, while the N-Gain indicates the magnitude of learning improvement. Therefore, the media produced a meaningful learning gain, although the improvement had not yet reached the High category.

© 2026 The Author(s)
This is an Open Access article under the Creative Commons Attribution-ShareAlike 4.0 International License
ISSN: 2797-3174

The Medium N-Gain should be interpreted as evidence of partial but meaningful conceptual improvement. Most students experienced improvement in the Medium category, while only a small proportion reached the High category and several students remained in the Low category. This pattern suggests that the media was effective in supporting learning for the majority of students, but that one implementation was not sufficient to ensure complete mastery for all learners. Such a result is reasonable because ecosystem material includes abstract concepts such as energy flow, food webs, and biogeochemical cycles, which often require repeated exposure, teacher reinforcement, and opportunities for further discussion.

Several mechanisms may explain the observed improvement. First, the numbering system that links each Jenga block to a specific Combo Card transformed abstract ecosystem concepts into concrete learning tasks. Students did not only answer questions individually, but also removed blocks, selected corresponding cards, discussed possible answers, and justified their reasoning within the group. Second, the tiered scoring system of 10, 20, and 30 points encouraged students to engage with questions at different cognitive levels, while the leaderboard provided immediate feedback and created healthy competition. Third, the role system supported cooperative learning because students were required to depend on one another, communicate face to face, take individual responsibility, and process answers as a group. These elements are consistent with the core principles of cooperative learning, which emphasize positive interdependence, promotive interaction, individual accountability, interpersonal skills, and group processing.

The concrete and visual characteristics of the media also help explain the learning gains. The physical manipulation of Jenga blocks provided direct learning experience, while the illustrations, symbols, and text on the Combo Cards provided visual support for understanding ecosystem concepts. This combination is relevant for Grade VII students because ecosystem material is complex and cannot always be observed directly in the classroom. The card categories, including Concept, Interaction, Damage, Preservation, Challenge, and Bonus cards, also helped students encounter ecosystem content in varied forms. At the same time, the use of points, feedback, and a leaderboard reflected gamification principles that can increase engagement when combined with social interaction and clear learning goals.

The results are in line with previous studies showing that collaborative game-based learning can improve students' science learning achievement, motivation, attitude, and self-efficacy because students are given opportunities to share and organize knowledge during game play (Peregudin et al., 2022; Velaora & Kakarountas, 2021). The findings also support studies on gamification and board-game-based learning, which report that game elements such as feedback, competition, points, and group interaction can increase motivation, engagement, social interaction, and learning achievement (Aldalur & Perez, 2023; Othman et al., 2025; Suartama et al., 2023). In this study, those elements were not used as decorative additions but were embedded directly into the learning mechanics through numbered blocks, question cards, group roles, scoring, and the digital leaderboard.

Compared with previous Jenga-based or card-based media, the contribution of this study lies in the integration of three components: a manipulative physical game, visual ecosystem content, and a structured collaborative role system. Earlier studies generally used games or cards as supplementary learning activities, whereas the Jenga Collaboration with Combo Cards media required students to learn through the game mechanics themselves. This integration helps explain why the product was rated Highly Feasible and why students showed a statistically significant and moderately meaningful improvement in learning outcomes. Therefore, the study fills a gap in science learning media development by producing a simple, low-cost, collaborative game-based medium specifically designed for Grade VII ecosystem material.

Nevertheless, the findings should be interpreted proportionally. The Medium N-Gain indicates that the media supported meaningful learning improvement but did not produce complete mastery after a single implementation. In addition, the one-group pretest-posttest design without a control group limits the extent to which the improvement can be attributed solely to the media. Even so, the combination of expert validation, valid and reliable test instruments, normally distributed data, significant pretest-posttest improvement, and Medium N-Gain provides coherent initial evidence that the Jenga Collaboration with Combo Cards media is feasible and effective as a collaborative game-based learning medium for Grade VII ecosystem material.

3.6. Implications

The findings of this study suggest that the Jenga Collaboration with Combo Cards media can be used as a practical alternative for teaching ecosystem material in junior secondary science classrooms. The media helps teachers present abstract ecosystem concepts in a more concrete, interactive, and collaborative way. Through the combination of game mechanics, question cards, group roles, and a leaderboard, students are encouraged to participate actively, discuss answers, and support one another during learning.

Theoretically, these findings support the idea that collaborative game-based learning can improve students' understanding when learning activities are designed to include peer interaction and scaffolding. From

© 2026 The Author(s)
This is an Open Access article under the Creative Commons Attribution-ShareAlike 4.0 International License
ISSN: 2797-3174

a broader educational perspective, this study indicates that simple and low-cost game-based media can be developed and adapted for other abstract science topics. Therefore, teachers, schools, and curriculum developers may consider integrating similar collaborative media to support active learning and improve students' learning outcomes.

3.7. Limitations

This study has several limitations. First, the development process was limited to the Develop stage of the 4-D model and did not proceed to the Disseminate stage, so the media has not yet been tested in broader educational settings. Second, the field test involved only one Grade VII class consisting of 28 students in one junior high school, which limits the generalizability of the findings. Third, this study used a one-group pretest-posttest design without a control group; therefore, the improvement in students' learning outcomes should be interpreted carefully. In addition, the study focused only on ecosystem material and mainly measured cognitive learning outcomes. Future studies are recommended to involve more schools, use a control group or experimental design, test the media on other science topics, and examine students' collaboration and motivation more comprehensively.

4. Conclusion

Based on the results of the research and development conducted, it can be concluded that the Jenga Collaboration with Combo Cards learning media on Grade VII ecosystem material was successfully developed using the 4-D model (Define, Design, Develop), consisting of one set of Jenga blocks (54 colored wooden blocks), 60 Combo Cards across six card categories, and a game guidebook, all integrated through a numbering and color system. This media was declared Highly Feasible for use in science learning based on Expert Judgement, with feasibility percentages of 84.44% from the media expert, 85.45% from the content expert, and 85.83% from the instructional design expert. The learning media also proved effective in improving students' learning outcomes, as evidenced by the Paired Samples T-Test results ($t = -9.377$; Sig. = 0.000 < 0.05) and a mean N-Gain of 0.47 in the medium category. This study was limited to the Develop stage of the 4-D model and used a one-group pretest-posttest design without a control group in a single trial class; therefore, future researchers are recommended to proceed to the Disseminate stage, expand the trial scope to more schools, and develop similar media for other abstract science topics.

Author Contributions

All authors contributed equally to this paper. All authors have read and approved the final manuscript.

Funding

This research was funded by Universitas Sebelas Maret through the 2026 RKAT Research Grant under the Research Group Capacity Strengthening Scheme (PKGR-UNS C), Research Contract No. 462/UN27.22/PT.01.03/2026.

Declaration of Conflicting Interests

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

Ethics and Consent Declarations

This study was conducted in accordance with institutional and school research procedures. Permission to conduct the research was obtained from a public junior high school in Central Java, Indonesia. Since the participants were Grade VII students, informed consent was secured through school approval and participant assent prior to data collection. The students were informed about the purpose of the study, the learning activities involved, and their right to participate voluntarily. Participant confidentiality and privacy were protected throughout the study. Students' names and personal identities were not reported in the manuscript, and all data were presented in aggregate form. The data collected was used only for research purposes. No identifiable images, names, or personal information of participants are included in this article; therefore, consent for publication of identifiable information was not required.

Data Availability

The datasets generated during and/ or analyzed 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.

© 2026 The Author(s)
This is an Open Access article under the Creative Commons Attribution-ShareAlike 4.0 International License
ISSN: 2797-3174

Acknowledgement

The authors gratefully acknowledge the financial support provided by Universitas Sebelas Maret for conducting this research.

References

Aldalur, I., & Perez, A. (2023). Gamification and discovery learning: Motivating and involving students in the learning process. *Heliyon, 9*(1), e13135. https://doi.org/10.1016/j.heliyon.2023.e13135

Arikunto, S. (2009). *Prosedur penelitian: Suatu pendekatan praktik* (Edisi revisi 6). Jakarta, Indonesia: Rineka Cipta.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (2000). *How people learn: Brain, mind, experience, and school* (Expanded ed.). Washington, DC: National Academy Press.

Cardak, O., & Dikmenli, M. (2016). Student science teachers' ideas about the degradation of ecosystems. *International Education Studies, 9*(3), 95–103. https://doi.org/10.5539/ies.v9n3p95

Carvalho, A., Neto, J. P., & dos Santos, C. P. (2020). Combinatorics of Jenga. *Australasian Journal of Combinatorics, 76*(1), 87–104. Retrieved from http://hdl.handle.net/10400.21/13577

Chapin, F. S., Kofinas, G. P., & Folke, C. (Eds.). (2009). *Principles of ecosystem stewardship: Resilience-based natural resource management in a changing world*. New York, NY: Springer. https://doi.org/10.1007/978-0-387-73033-2

Helda, H., & Syahrani, S. (2022). National standards of education in content standards and education process standards in Indonesia. *Indonesian Journal of Education, 3*(2), 257–269. https://doi.org/10.54443/injoe.v3i2.32

Huang, R., Ritzhaupt, A. D., Sommer, M., Zhu, J., Stephen, A., Valle, N., … Li, J. (2020). The impact of gamification in educational settings on student learning outcomes: A meta-analysis. *Educational Technology Research and Development, 68*(4), 1875–1901. https://doi.org/10.1007/s11423-020-09807-z

Hussein, M. H., Sulaiman, N. L., Noroozi, O., Elaish, M. M., & Alhasan, A. (2025). Value-added digital game-based learning in K–12 science education: A systematic literature review. *Interactive Learning Environments, 33*(5), 3282–3316. https://doi.org/10.1080/10494820.2025.2450652

Isnaini, I., Atmazaki, A., Ahda, Y., Lufri, L., Elizar, E., Amran, A., … Hasan, A. (2023). Analysis of critical thinking, creativity, communication, and collaboration skills (4C) for junior high school students. In *Proceedings of the 3rd International Conference on Biology, Science and Education (IcoBioSE 2021)* (pp. 191–197). Atlantis Press. https://doi.org/10.2991/978-94-6463-166-1_27

Kustyarini, K., Utami, S., & Koesmijati, E. (2020). The importance of interactive learning media in a new civilization era. *European Journal of Open Education and E-Learning Studies, 5*(2). https://doi.org/10.46827/ejoe.v5i2.3298

Kusumaningsih, W., Buchori, A., & Cahyono, H. G. (2020). Uno Stacko based on realistic mathematics: Developing learning media for trigonometry. *Journal of Physics: Conference Series, 1663*(1), 012044. https://doi.org/10.1088/1742-6596/1663/1/012044

Meltzer, D. E. (2002). The relationship between mathematics preparation and conceptual learning gains in physics: A possible "hidden variable" in diagnostic pretest scores. *American Journal of Physics, 70*(12), 1259–1268. https://doi.org/10.1119/1.1514215

Othman, M. K., Mat, R., & Sim, K. C. (2025). A systematic review of paper-based and digital board games for collaborative science learning. *Review of Education, 13*, e70107. https://doi.org/10.1002/rev3.70107

Peregudin, A. A., Popov, A. M., Akhmetgaliev, E. R., Bugrova, A. D., Bystramovich, M. A., Stakanov, V. A., & Dunaev, V. A. (2022). Virtual laboratory for game-based control systems education. *IFAC-PapersOnLine, 55*(17), 344–349. https://doi.org/10.1016/j.ifacol.2022.09.303

Santrock, J. W. (2011). *Life-span development: Perkembangan masa-hidup* (13th ed.). Jakarta, Indonesia: Erlangga.

Slavin, R. E. (2018). *Educational psychology: Theory and practice* (12th ed.). New York, NY: Pearson.

Suartama, I. K., Simamora, A. H., Susiani, K., Suranata, K., Yunus, M., & Tisna, G. D. (2023). Designing gamification for case- and project-based online learning: A study in higher education. *Journal of Education and E-Learning Research, 10*(2), 86–98. https://doi.org/10.20448/jeelr.v10i2.4432

Sugiyono. (2019). *Metode penelitian kuantitatif, kualitatif, dan R&D*. Bandung, Indonesia: Alfabeta.

Sugiyono. (2020). *Metode penelitian kualitatif*. Bandung, Indonesia: Alfabeta.

Thiagarajan, S., Semmel, D. S., & Semmel, M. I. (1974). *Instructional development for training teachers of exceptional children: A sourcebook*. Bloomington, IN: Indiana University.

Velaora, C., & Kakarountas, A. (2021). Game-based learning for engineering education. In *Proceedings of the 6th South-East Europe Design Automation, Computer Engineering, Computer Networks and Social Media Conference (SEEDA-CECNSM 2021)*. https://doi.org/10.1109/SEEDA-CECNSM53056.2021.9566215

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Wahyu, Y., Edu, A. L., & Nardi, M. (2020). Problematika pemanfaatan media pembelajaran IPA di sekolah dasar. *Jurnal Penelitian Pendidikan IPA, 6*(1), 107–112. https://doi.org/10.29303/jppipa.v6i1.344

© 2026 The Author(s)
This is an Open Access article under the Creative Commons Attribution-ShareAlike 4.0 International License
ISSN: 2797-3174

Widoyoko, E. P. (2018). *Penilaian hasil pembelajaran di sekolah*. Yogyakarta, Indonesia: Pustaka Pelajar.

Widya, S., Rofiq, A. A., & Khosiah, N. (2024). Implementasi media card sorting untuk membentuk sikap kerja sama siswa dalam pembelajaran IPA di MI. *Satya Widya, 40*(2), 155–164. https://doi.org/10.24246/j.sw.2024.v40.i2.p155-164

© 2026 The Author(s)
This is an Open Access article under the Creative Commons Attribution-ShareAlike 4.0 International License
ISSN: 2797-3174