

Development and Evaluation of Interactive Multimedia Assisted by Edugames for Natural and Social Sciences (IPAS) Learning in Elementary Schools

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Abstract: This study aims to develop and evaluate interactive multimedia assisted by Edugames for Natural and Social Sciences (IPAS) learning in elementary schools. The study employed a Research and Development (R&D) approach using the Alessi and Trollip model, which comprises the stages of planning, design, and development. The research subjects consisted of 36 fifth-grade students and 14 expert validators. Data collection techniques included questionnaires, observations, interviews, and learning outcome tests. Validity was analyzed using the Fuzzy Delphi method, while practicality and effectiveness were evaluated through descriptive quantitative analysis with N-Gain. The results demonstrated that the product possessed a high level of validity, showing a defuzzification value of 0.71 and a consensus level of 96.40%. The practicality rate reached 93.41%, placing it in the highly practical category. The effectiveness of the product was evidenced by an increase in learning outcomes from a pretest average of 55.37 to a posttest average of 84.44, yielding an N-Gain score of 0.68 (medium category). Consequently, the developed Edugame-assisted interactive multimedia is declared valid, practical, and effective in enhancing students' conceptual understanding in IPAS learning. This study contributes to the advancement of technology-based learning media by integrating a comprehensive product development and evaluation process using the Fuzzy Delphi approach.

Keywords: Edugame; Fuzzy delphi; Interactive multimedia; IPAS; Learning outcomes

Introduction

The 21st-century educational transformation demands learning that is oriented not only toward content mastery but also toward the development of higher-order thinking skills, such as critical thinking, creativity, communication, and collaboration (Hati & Karo, 2025). The integration of technology into learning stands as a strategic component in creating interactive and student-centered learning experiences, particularly through the utilization of interactive media based on information technology (Mahdi & Dewi, 2025). The use of interactive multimedia is also considered capable of actively engaging students while optimizing the development of 21st-century skills within the learning process (Joshi et al., 2025). At the elementary school

level, the implementation of technology-based interactive media has been proven to contribute to enhancing students' critical thinking skills and the overall quality of instruction (Resti et al., 2024). Interactive multimedia has emerged as an innovation capable of meeting the demands of 21st-century learning by presenting material dynamically and adaptively to student needs (Zapušek, 2024). Combining elements of text, images, audio, animation, and video allows for an engaging and comprehensible presentation of material, aligning with the principles of multimedia learning to improve students' cognitive processing (Gan et al., 2015). In the learning of Natural and Social Sciences (IPAS), the utilization of interactive multimedia carries high urgency because it can visualize abstract concepts, thereby supporting effective knowledge construction

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(Jong et al., 2023). One topic requiring such an approach is the concept of "eating and being eaten" within ecosystems, which demands a systematic and contextual understanding of relationships between living things in science education (Jong & Lazonder, 2014).

Empirical facts in the field show that the implementation of IPAS learning has not yet fully utilized the potential of technology optimally. Observations and interviews with fifth-grade educators at SD Negeri 1 Sumber Harum, Tungkal Jaya District, Musi Banyuasin Regency, revealed that learning is still dominated by the use of textbooks as the primary resource. The available materials are considered incomplete and their presentation lacks engagement, failing to foster active student involvement. This condition has led to boredom in the learning process, low student participation, and suboptimal achievement of learning outcomes. Limitations in the development of learning media also aggravate these issues, especially in the context of suboptimal technology integration within elementary education environments (Wang et al., 2025). Educators still face difficulties in designing and developing innovative media tailored to the characteristics of elementary school students, a challenge linked to teachers' low digital pedagogical competence (Instefjord & Munthe, 2017). The use of media that tends to be simple and unvaried fails to create interactive and meaningful learning experiences for students (Schindler et al., 2017). This situation indicates a gap between the demands of 21st-century learning and classroom teaching practices, particularly in leveraging technology to support active learning (Darling-Hammond et al., 2020).

Integrating Edugames into interactive multimedia offers a potential alternative solution to enhance the quality of technology-based learning. Edugames do not merely deliver instructional content; they offer game-based learning experiences capable of boosting students' motivation, engagement, and active participation (Qian & Clark, 2016). The interactive and enjoyable characteristics of Edugames align with the learning needs of elementary school students, particularly since game-based approaches have proven effective in supporting active and meaningful learning processes (Maryati et al., 2024). This approach becomes increasingly relevant when teaching ecosystem concepts, which require visualization and simulation to help students systematically understand the relationships between components (Daria et al., 2026). The development of Edugame-assisted interactive multimedia requires a systematic process to ensure that the resulting media matches student needs and instructional characteristics. A widely adopted model in multimedia development research is the Alessi and Trollip model, which consists of three primary phases:

planning, design, and development (Gardezi, 2024). This model emphasizes the importance of ongoing evaluation and revision at every developmental stage, allowing the resulting product to be more valid, practical, and effective in supporting the learning process. Validation is a crucial step in developmental research to ensure that the produced media meets eligibility criteria across content, visual, linguistic, and user-appropriateness aspects before being implemented in classrooms (Meylinda & Reinita, 2023). Furthermore, practicality testing is required to assess ease of use and the alignment of the media with user needs in a digital learning context (Yaseen et al., 2025). Analyzing the potential impact is also essential to determine how the use of the media contributes to increasing student motivation, conceptual understanding, and active participation in technology-based learning (Sailer & Homner, 2020).

Although numerous studies have examined the use of interactive multimedia and Edugames in learning, the focus of these investigations tends to remain partial. A systematic literature review by Satari et al. (2024) indicated that the use of Edugames provides an enjoyable learning experience and has the potential to improve conceptual understanding; however, it remains generic and does not explicitly target the structural design of interactive multimedia. Research by Rahayu & Ansori (2025) developed Canva-based interactive multimedia using a Problem-Based Learning model, yet it did not optimize the integration of Edugame elements as part of a game-based learning experience. Meanwhile, Khoiri et al. (2023) developed an Android-based Edugame application for quantity and unit concepts, focusing heavily on game app development without examining its integration with interactive multimedia within the context of IPAS learning in elementary schools. These studies indicate that the development of technology-based learning media is still carried out separately across interactive multimedia, edugames, and learning evaluations. Research that fully integrates the design of Edugame-assisted interactive multimedia, accompanied by validity testing, practicality testing, and potential impact analysis within a unified research framework—especially for the topic of "eating and being eaten" in elementary IPAS learning—remains limited.

Based on this gap, this study focuses on the development and evaluation of interactive multimedia assisted by edugames for the topic of "eating and being eaten" in elementary school IPAS learning. This research does not merely produce an interactive multimedia product but also comprehensively evaluates its viability through validity, practicality, and effectiveness testing. The novelty of this study lies in the integration of a systematic development process with a rigorous product evaluation using quantitative methods and a

Fuzzy Delphi approach within a single research framework. This study is expected to yield interactive multimedia that is valid, practical, and effective, while providing a methodological contribution to technology-based learning media development research. Additionally, the findings are intended to offer empirical contributions toward enhancing student motivation, conceptual understanding, and active participation in elementary school IPAS learning.

Method

This study employed a Research and Development (R&D) approach aimed at producing a product in the form of interactive multimedia assisted by edugames for the topic of "Eating and Being Eaten" in elementary school IPAS learning, as well as testing its feasibility across aspects of validity, practicality, and potential impact. This approach focuses not only on product creation but also on a systematic process of evaluation and refinement based on inputs from experts and users. The development model adapted the Alessi and Trollip model, which consists of three main stages: planning, design, and development. This model is iterative, emphasizing continuous evaluation at each stage, thereby allowing ongoing product revisions to produce high-quality media in terms of content, appearance, navigation, and the integration of multimedia elements.

This research was conducted at SD Negeri 1 Sumber Harum, Tungkal Jaya District, Musi Banyuasin Regency, South Sumatra. The research subjects consisted of fifth-grade students, with 6 students involved in the small-group tryout stage and 30 students in the field trial. Furthermore, this study involved 14 expert validators, including content experts, media experts, and language experts, alongside one fifth-grade teacher acting as a practitioner. Student selection was heterogeneous based on ability levels to ensure a representative overview of media usage. The research procedures followed the stages of the Alessi and Trollip model. In the planning stage, the scope of the material was established based on the IPAS curriculum, student characteristics were identified, and teacher and student needs were analyzed. This stage also encompassed drafting the initial concept of the media and creating a style manual. In the design stage, material was organized, layouts and prototypes were generated, and flowcharts and storyboards were developed to ensure a systematic presentation flow. Subsequently, in the development stage, the media was built by integrating text, images, audio, video, and Edugame-based interactive elements.

The resulting product underwent alpha testing by experts, followed by revisions, and beta testing with students to ascertain its level of practicality and potential

impact. Data collection was carried out through observations, interviews, questionnaires, validation sheets, and learning outcome tests. Qualitative data, derived from observations, interviews, and validators' comments and suggestions, were analyzed using the Miles and Huberman model, which includes data reduction, data display, and conclusion drawing/verification. Quantitative data were obtained from validation sheets, practicality questionnaires, and student responses. Quantitative data analysis to measure validity, practicality, and user responses utilized the following percentage formula:

$$P = \frac{\sum X}{\sum X_i} \times 100\% \quad (1)$$

Where: P = percentage,

$\sum X$ = total score obtained,

$\sum X_i$ = maximum possible score.

The interpretation criteria for the results are presented in Table 1.

Table 1. Validity and practicality criteria

Percentage (%)	Category
81-100	Highly Valid/Practical
61-80	Valid/Practical
41-60	Moderate
21-40	Insufficient
0-20	Invalid/Impractical

Additionally, this study utilized the Fuzzy Delphi Method (FDM) to analyze data from expert assessments more comprehensively by accounting for subjectivity and uncertainty in evaluations. Likert scale data were first converted into Triangular Fuzzy Numbers (TFN) in the format:

$$A = (l, m, u) \quad (2)$$

The conversion of the Likert scale to TFN can be seen in Table 2.

Table 2. Conversion of Likert scale to TFN

Score	TFN (l, m, u)
1	(0.0, 0.0, 0.2)
2	(0.0, 0.2, 0.4)
3	(0.2, 0.4, 0.6)
4	(0.4, 0.6, 0.8)
5	(0.6, 0.8, 1.0)

The average fuzzy value was calculated using the formula:

$$A = \left(\frac{\sum l}{n}, \frac{\sum m}{n}, \frac{\sum u}{n} \right) \quad (3)$$

Next, a defuzzification process was performed to obtain a crisp value using the formula:

$$A = \frac{l + m + u}{3} \quad (4)$$

The defuzzification value was used to determine the product's feasibility. Consensus among experts was deemed achieved if the threshold value (d) was ≤ 0.2 and the consensus percentage was $\geq 75\%$. With this approach, data analysis became more accurate in representing expert evaluations regarding the quality of the developed edugame-assisted interactive multimedia.

Result and Discussion

The results of this study cover two main aspects: the results of developing the Edugame-assisted interactive multimedia product and the results of the product evaluation, which includes validity, practicality, and effectiveness. The developed product is an interactive multimedia system that integrates material presentation with Edugame activities into a unified digital learning framework. The media is systematically designed with a structure that includes a main menu, material presentation, Edugame activities, and learning evaluations, all interconnected in a continuous learning flow. The media design was tailored to the characteristics of elementary school students through a simple, attractive, and user-friendly visual interface. Materials are presented progressively from basic to more complex concepts, enriched with multimodal elements such as text, images, animation, and audio. The edugames within the media serve to reinforce concepts through problem-solving activities, contextual visualization, and the provision of immediate feedback to students. The complete structure and interface of the media are presented in Figure 1 through Figure 5.



Figure 1. Main page view of the interactive multimedia



Figure 2. Material menu view



Figure 3. Food chain material view



Figure 4. Food web material view



Figure 5. Food chain and food web Edugame view

The design of this Edugame demonstrates that the integration of learning and play can increase student engagement and foster more active learning.

Product Validity

The validity of the Edugame-assisted interactive multimedia in this study was determined through an alpha test involving 14 expert validators consisting of lecturers, educators, and educational practitioners. Assessments were conducted across three primary aspects: media, content, and language, to ensure the product's alignment with pedagogical, technical, and linguistic standards. The evaluation results showed that all aspects fell into the highly feasible category, detailed as follows.

Table 3. Recapitulation of product validity results

Aspect	Percentage (%)	Category
Media	93.46	Highly Feasible
Content	95.07	Highly Feasible
Language	92.21	Highly Feasible

Quantitatively, the content aspect obtained the highest score compared to the other areas. This indicates that the substance of the content presented in the interactive multimedia met the principles of conceptual accuracy, curricular alignment, and depth of material appropriate for the cognitive development stage of elementary school students. The high score in this aspect also shows that integrating content with edugames did not compromise academic quality, maintaining the rigor of scientific concepts. In the media aspect, the high score reflects that the visual design, layout, navigation, and integration of multimedia elements fulfilled the principles of usability and user experience. This indicates that the media was not only visually engaging but also functionally designed to support the learning process. Meanwhile, the language aspect received a slightly lower score compared to the others, though it remained well within the highly feasible category. This shows that, overall, the language used was communicative and suited to the students' level of understanding, despite minor corrections needed regarding writing consistency and grammatical rules. In addition to descriptive analysis, validity was reinforced through the Fuzzy Delphi Method, which provided an overview of the consensus level among validators.

Table 4. Recapitulation of FDM calculation results

Analysis Component	Result	Criteria	Description
Average m_1	0.52	High	Initial expert evaluation is high
Average m_2	0.72	High	Score 4-5
Average m_3	0.90	Very High	Expert optimism is excellent
Threshold Value (d)	0.18	≤ 0.2	Consensus achieved
Consensus Percentage	96.4%	$\geq 75\%$	Very high
Defuzzification	0.71	≥ 0.5	Accepted
Value Range A	0.66-0.78	High	All items feasible
Number of Items Accepted	46 items	≥ 0.5	100% accepted

The results of the analysis using the Fuzzy Delphi method indicated that the average value of m_1 at 0.52, m_2 at 0.72, and m_3 at 0.90 fell within the high to very high categories. This implies that the experts' evaluations of the instrument tended to be positive, with scores dominating the high categories. The analysis yielded a defuzzification value of 0.71 (≥ 0.50), meaning that all items were declared valid and acceptable. The threshold value of 0.18 (≤ 0.20) indicated that a consensus among experts had been reached, while the consensus percentage of 96.4% reflected a remarkably high level of evaluation uniformity. These findings show that the developed edugame-assisted interactive multimedia is not only valid in terms of content but also exhibits a high

level of evaluation consistency among experts. Thus, the product can be declared to have met robust validation standards as an educational medium.

Product Practicality

Product practicality was evaluated through beta testing conducted in two stages: individual (one-to-one) evaluation and small-group evaluation. This testing aimed to assess ease of use, display clarity, and the level of student engagement when using the interactive multimedia. The results of the practicality test showed that the product fell into the highly practical category, with details as follows.

Table 5. Practicality test results

Stage	Percentage (%)	Category
One-to-One	91.67	Highly Practical
Small Group	95.14	Highly Practical
Average	93.41	Highly Practical

During the individual testing stage, a practicality score of 91.67% indicated that students were capable of using the media independently with low levels of difficulty. The aspect of ease of understanding the material obtained the highest score, implying that presenting material in an interactive format was more capable of helping students understand concepts effectively compared to conventional methods. In the small-group evaluation stage, the practicality score increased to 95.14%. This increase indicates that in a broader context of use, the media remained consistent in providing an easy and enjoyable learning experience. The student engagement aspect achieved the highest score, demonstrating that integrating edugames into the media successfully fostered active participation during the learning process. The difference in values between individual and group testing also shows that the media has a good level of usage stability, both in personal and group usage contexts. This indicates that the navigation design, instructions, and interactions within the media were effectively structured to support use by diverse user conditions. Furthermore, comments from students stating that the media could be used without the educator's assistance indicate that the developed interactive multimedia has fulfilled self-instructional principles, enabling students to learn independently. Thus, the practicality test results demonstrate that the Edugame-assisted interactive multimedia is not only easy to use but also capable of creating an engaging and interactive learning experience.

Product Effectiveness

The effectiveness of the Edugame-assisted interactive multimedia was measured through the improvement of student learning outcomes using a

pretest and posttest design. Analysis was conducted to observe changes in conceptual understanding before and after utilizing the media. The results showed a significant increase in student learning outcomes, with details as follows.

Table 6. Recapitulation of student effectiveness test results

Indicator	Value
Pretest Average	55.37
Posttest Average	84.44
N-Gain	0.68
Category	Medium

The increase in the average score from 55.37 to 84.44 indicates a substantial change in students' understanding of the "Eating and Being Eaten" material. The N-Gain value of 0.68, which falls into the medium category, shows that the media possesses a reasonably high level of effectiveness in improving learning outcomes. Looking at the distribution of the N-Gain categories, the majority of students fell into the high (52.78%) and medium (41.67%) categories, while only a small fraction fell into the low category (5.56%). This indicates that the impact of using the media did not just occur in a small minority of students but was distributed evenly across most of the group. Additionally, the increase in the number of students achieving the Minimum Mastery Criterion (KKM) from 2.70% on the pretest to 54.05% on the posttest shows that the media helped students achieve the expected competency standards. The significant drop in the low-score category also reinforces that the media was effective in assisting students who previously experienced learning difficulties. In a deeper sense, this effectiveness can be attributed to the design characteristics of the interactive multimedia that integrates visualization, interaction, and edugames. Presenting concrete material through animations and images helped students comprehend abstract concepts, while Edugame activities provided opportunities to apply knowledge directly. Consequently, the developed Edugame-assisted interactive multimedia is not only effective in improving learning outcomes quantitatively but also supports a more meaningful learning process through active student engagement (Eliyanti et al., 2025; Mebert et al., 2020).

Discussion

The results of this study indicate that the development of interactive multimedia assisted by edugames for the topic of "Eating and Being Eaten" produces a high-quality product based on the evaluation of validity, practicality, and effectiveness. This finding reinforces that the success of learning media is determined not only by content presentation but also by

the quality of the developed product tested empirically within real learning contexts. Based on the validity test results, the developed Edugame-assisted interactive multimedia falls into the highly valid category. Analysis using the Fuzzy Delphi method yielded a defuzzification value of 0.71, a threshold value of 0.18, and a consensus level of 96.40%, indicating an exceptionally strong consensus among the experts. This demonstrates that the product has met eligibility standards across content, visual, and language aspects. This finding aligns with previous research stating that the Fuzzy Delphi method is effective in producing high consensus levels through the defuzzification process and is capable of converting subjective assessments into more stable and reliable quantitative data (Krishnan et al., 2022; Chen et al., 2025). Regarding practicality, the beta test results showed that the Edugame-assisted interactive multimedia falls into the highly practical category, with an average score of 93.41%. High scores in the aspects of ease of use, visual clarity, and student engagement indicate that the product possesses excellent usability.

Students were able to use the media independently without teacher assistance, proving that the product fulfills self-instructional characteristics. This finding is consistent with research stating that learning media with high usability levels significantly influences learning satisfaction and effectiveness (Sung et al., 2016; Alqurni, 2023). Moreover, the use of game-based interactive media has been proven effective in increasing student engagement and active participation in the learning process (Wang & Zhang, 2025; Khaldi et al., 2023). In terms of effectiveness, the study showed a significant improvement in student learning outcomes. The pretest average of 55.37 increased to 84.44 on the posttest, with an N-Gain value of 0.68 sitting in the medium category. The N-Gain distribution revealed that most students were in the medium-to-high categories, indicating that the developed product is effective in enhancing students' conceptual understanding. This finding is consistent with previous research stating that game-based learning can significantly improve learning outcomes because it integrates cognitive, motivational, and emotional aspects into the instructional process (Lo et al., 2022; Martin, 2023).

The effectiveness of this product is inseparable from the characteristics of interactive multimedia that integrates various instructional elements into a unified system. Presenting material enriched with visualization, animation, and audio helps students understand concepts that are abstract, particularly within ecosystem topics (Mulyasaroh et al., 2026; Azrai et al., 2025). Furthermore, Edugame activities offer students the chance to apply knowledge directly through interactive learning experiences. This aligns with constructivist

theory, which emphasizes that knowledge is actively constructed through interaction and learning experiences (Hu, 2024; Dahl & Mørch, 2025). Moreover, game-based learning has been proven capable of creating contextual and immersive learning experiences, thereby driving deeper engagement and conceptual understanding (Okasha, 2025; Feriyanto & Anjariyah, 2024). Overall, the results of this study indicate that the developed Edugame-assisted interactive multimedia has met the criteria of being valid, practical, and effective as a learning medium for elementary school IPAS.

The resulting product is not only viable for use but also capable of improving learning quality by increasing student engagement and understanding (Bhardwaj et al., 2025; Walter, 2024). The implications of this study indicate that Edugame-assisted interactive multimedia can serve as an innovative alternative learning medium for elementary school educators, particularly in teaching abstract material like ecosystem concepts. Using this media can support learning that is more interactive, enjoyable, and student-centered. In addition, this research contributes to the development of technology-based learning media that focuses not only on the development process but also on comprehensive product evaluation.

Conclusion

The results of this study indicate that the interactive multimedia assisted by Edugames developed for elementary school IPAS learning possesses excellent quality based on validity, practicality, and effectiveness evaluations. The product was proven valid through Fuzzy Delphi analysis with a high level of expert consensus, practical for independent use by students, and effective in improving learning outcomes with N-Gain achievements in the medium-to-high categories. These findings confirm that integrating interactive multimedia with Edugames can enhance conceptual understanding while fostering active student engagement in learning. This study contributes to the development of technology-based learning media through the integration of a comprehensive product development and evaluation process, including the use of Fuzzy Delphi as a more systematic validation approach. In the future, similar research needs to be conducted on a broader scope of materials and subjects to obtain more generalizable results.

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Author Contributions

Conceptualization, methodology, data curation, writing—review and editing, B.P.K., E.R.S., and Y.; validation,

supervision, E.R.S. and Y.; formal analysis, investigation, resources, writing—original draft preparation, B.P.K.

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