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Interactive Educational Games: Boosting Numeracy Skills in 4-5 Year-Olds Through Multimedia

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ABSTRACT

Developing numeracy skills in early childhood is crucial for cognitive growth. However, children aged 4-5 often struggle with number recognition, counting, and distinguishing numerical symbols. This study aims to develop interactive multimedia educational games to enhance numeracy skills in young learners. This research employed the Research and Development (R&D) method using the ADDIE development model. A small-scale sample of five children with numeracy difficulties was involved. Observations at TPA Idola Bangsa Cilegon revealed that existing numeracy learning media were limited to conventional tools such as whiteboards, number cards, and books, highlighting the need for engaging digital alternatives. The developed multimedia game was validated by experts, with material experts rating it at 80% and media experts at 88%. The effectiveness of the game was assessed using the N-Gain Score, yielding a medium improvement category (0.65) in children's numeracy skills. Additionally, children's responses to the game reached **91%**, indicating strong engagement and acceptance. The findings suggest that interactive multimedia games provide a more effective and engaging alternative to traditional learning methods, addressing children's numeracy challenges. Interactive multimedia educational games are feasible, effective, and well-received by young learners. Future research should explore the long-term impact of these tools on children's cognitive development and adapt them for broader educational settings.

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1. INTRODUCTION

Numeracy not only prepares children for more complex mathematics learning in the future but also provides a strong foundation for overall cognitive development (Ekowati & Suwandayani, 2019). Numeracy plays a crucial role in stimulating children's cognitive development. Early numeracy skills help children learn problem-solving and develop critical thinking skills. Additionally, children can recognize patterns, which serve as an essential foundation for learning mathematics and other cognitive skills. Pattern recognition also helps children predict cause-and-effect relationships. Early numeracy also

contributes to memory development, for example, through counting activities and number recognition (Maghfirah et al., 2022). At the informal numeracy stage, children are able to perform sequential counting and recognize the characteristics of objects (Yuliantina, 2023).

Early numeracy, or numeracy in early childhood, aims to support children in observing, managing, and making sense of their environment. It provides a foundation for sharpening reasoning skills, connecting various ideas, and thinking logically (Wahyuni & Herlina, 2023). Numeracy also supports children in developing the mathematical thinking needed to actively participate in everyday life (Hasrawati, 2023). In early childhood education, numeracy is expected to develop not only cognitively but also mentally, socially, and emotionally (Maghfirah et al., 2022).

Although numerous studies have proven that early numeracy is essential for children's development, challenges remain in effectively implementing numeracy learning in early childhood education (PAUD) settings. Based on observations and interviews conducted by researchers at TPA Idola Bangsa Cilegon, several issues were identified in the numeracy skills of children aged 4-5 years. Some children struggled with number naming, counting, understanding number concepts, recognizing shapes and sizes, and distinguishing between similar-looking numbers such as 6 and 9. These difficulties affect children's cognitive development, particularly in their numeracy skills. In addition to internal factors within children, issues were also found in teaching methods. Teachers tended to use monotonous activities to enhance children's numeracy skills, such as providing worksheets from magazines and teaching numbers and shapes by writing on the board. As a result, children's motivation to improve their numeracy skills declined. This decline was caused by a lack of engaging activities that could capture children's attention, as well as the absence of innovative media to motivate them. Teachers realized that using conventional teaching media was not sufficient to boost children's enthusiasm for numeracy activities.

In response to these challenges, this study focuses on the development of innovative technology-based learning media, specifically interactive multimedia-based educational games. In recent years, technological advancements have opened new opportunities in the field of education, including numeracy learning. However, research specifically highlighting the effectiveness of interactive multimedia-based educational games in enhancing young children's numeracy skills remains limited. Therefore, this study aims to examine how the implementation of this innovative media can improve both motivation and numeracy skills in early childhood. Thus, this study offers a new approach to numeracy learning that not only focuses on cognitive aspects but also enhances motivation and children's engagement in the learning process.

Given these challenges, educators must innovate in their use of learning media to keep pace with technological advancements. In the 21st century, Indonesia has experienced rapid progress in science and technology, influencing how children engage with learning materials (Arsyad Azhar, 2017). As digital tools become an integral part of daily life, educators can harness technology to support exploration and maximize children's developmental potential (Rasmani et al., 2023). One effective approach is the integration of interactive multimedia, which not only enhances learning experiences but also has a significant psychological impact on students. Research suggests that interactive multimedia can sustain children's attention and improve engagement in classroom activities (Suryadi, 2020).

To address the research gap and assess the effectiveness of interactive multimedia-based educational games, this study explores the challenges faced by 4-5-year-old children in understanding numeracy concepts in early childhood education. It examines how the use of interactive multimedia influences children's motivation in numeracy learning and evaluates its effectiveness in improving numeracy skills compared to conventional teaching methods. By investigating these aspects, this research aims to provide insights into how technology-driven learning tools can enhance early childhood education and support cognitive development.

Educational games have been shown to increase motivation and enhance conceptual understanding. Komang Ayu & Surya Manuaba (2021) found that "educational games create an interactive and enjoyable learning environment, ultimately increasing student engagement." Similarly, Raharjo et al. (2022)

demonstrated that educational games improve students' grasp of abstract mathematical concepts by providing a more concrete and relatable context for practice. Additionally, Novia et al. (2023) found that educational games not only enhance cognitive skills but also foster social development, helping students build communication and collaboration skills.

These findings highlight the potential of educational games as effective learning tools, reinforcing cognitive, social, and motivational aspects of child development. This study builds upon previous research to explore the impact of interactive multimedia-based educational games on numeracy skills in early childhood education.

2. METHODS

This study adopts the Research and Development (R&D) methodology. This approach aims to create instructional models and educational media designed to address challenges in the educational context, such as classroom learning processes, rather than to test theories. The primary focus of this development research is to create interactive educational game multimedia that can enhance the numeracy skills of children aged 4-5 years.

The development method applied in this study is the ADDIE model. The ADDIE model, which stands for Analysis, Design, Development, Implementation, and Evaluation, is used as the framework for the development process in this study (Branch & Maribe, 2009). The first stage is Analyze, where a needs analysis or problem identification is conducted. This analysis involves field studies, such as observations, and literature reviews. The second stage, Design, focuses on designing a product that meets the needs identified in the field. Development, the third stage, involves creating and testing the designed product. The fourth stage, Implementation, includes applying the created product to the field subjects. The final stage, Evaluation, involves evaluating the product at each development stage to identify necessary product revisions and assess the suitability of each activity and created product. The ADDIE model was chosen for this research because it is considered an effective, flexible development framework that supports overall program performance.

Below is an illustration of the ADDIE development model used in this study, as shown in Figure 1

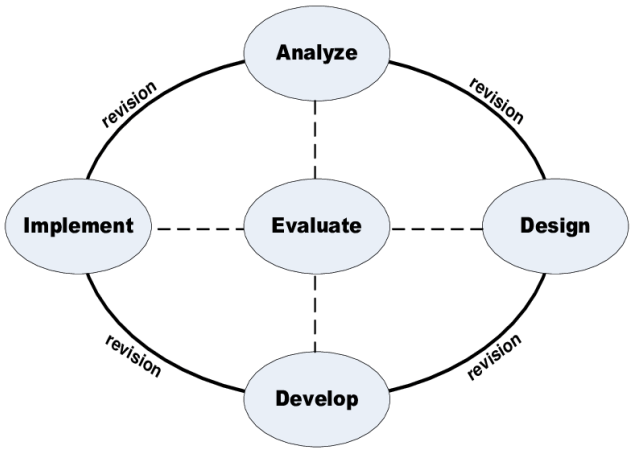

Figure 1. The ADDIE Development Model
(Branch & Maribe, 2009)

Data analysis in this study involves both qualitative and quantitative approaches. The qualitative analysis includes evaluating the product quality through feedback or suggestions from field experts, media experts, practitioners, and children aged 4-5 years, as well as through observation results. The quantitative analysis consists of scores obtained from questionnaires evaluated using percentage tests and the Likert Scale.

The research was conducted at TPA Idola Bangsa Cilegon from November 2023 to June 2024. Data collection was carried out by the researcher using data collection techniques including observation, questionnaires, and documentation.

The research instruments used for data collection in this development include questionnaires and observation sheets. The questionnaires consist of assessment checklists accompanied by suggestions for improving the interactive educational game multimedia. The questionnaires are distributed to experts, while the observation sheets are used to observe the children as test subjects. There are three types of questionnaires used:

1. Questionnaire for media experts
2. Questionnaire for subject matter experts
3. Q uestionnaire for children filled out by teachers.

The data analysis techniques in this study include:

1. Qualitative data analysis, which involves evaluating interview result sheets, observation results, and suggestions from validators.
2. Quantitative data analysis, based on validation results from media experts, subject matter experts, and practitioners, evaluated using the Likert Scale.

Subsequently, a descriptive analysis is conducted to describe the validity and suitability of the developed learning media. For validity testing, data is taken from filled validation sheets and processed using established formulas and criteria as follows:

$$\text{Percentage (\%)} = \frac{\sum R}{N} \times 100\%$$

Explanation:

P = Percentage score (rounded result)

$\sum R$ = Total responses given by validators

N = Maximum or ideal score

The obtained scores are then interpreted to assess the validity of the interactive multimedia educational games by referring to the feasibility criteria table structured in Table 1, as shown below :

Table 1. Criteria for Interpreting Feasibility

Percentage	Criteria	Description	Explanation
81 - 100%	5 = Excellent	Highly feasible/highly valid/no need for revision	Results within this range indicate that the evaluated aspect meets the expected standards and contributes significantly to learning outcomes or the desired objectives. This range suggests that the aspect is functioning well and requires little to no improvement.
61 - 80%	4 = Good	Feasible/valid/no need for revision	Results within this range indicate that the evaluated aspect has several elements that meet the standards, but there are still areas that need improvement. While this aspect is adequate, it has not yet fully maximized its contribution to the desired outcomes.
41 - 60%	3 = Fairly good	Feasible/valid/needs revision	In this range, some elements have not been met, indicating the need for improvement in certain areas.
21 - 40%	2 = Not Very Good	Infeasible/invalid/ needs revision	Results within this range indicate that the evaluated aspect still requires

			improvement in certain elements.
< 20%	1 = Very Poor	Highly infeasible/invalid/needs revision	Results within this range indicate that the evaluated aspect does not meet the expected standards. There are still many deficiencies that need to be addressed for this aspect to make a significant contribution to learning outcomes or the desired objectives.

The criteria used to process student response data can be seen in the following table :

Table 2. Criteria for Children's Response Questionnaire Data

Percentage	Criteria	Description	Explanation
81 - 100%	4 = Developing Very Well	Very Interested / Really Like	A high percentage suggests that the children were highly engaged and responded very well to the content or activity. The material is effective and well-suited to the children's needs and interests, with little to no need for changes.
61 - 80%	3 = Developing as Expected	Interested / Like	A good percentage indicates that the children responded positively to most of the content or activities. While the results are generally favorable, there may still be areas where minor adjustments could further improve engagement and learning outcomes.
41 - 60%	2 = Starting to Develop	Fairly Interested / Somewhat Like	A moderate percentage shows that some elements resonated with the children, but overall, the engagement or understanding was limited. Improvements in content, presentation, or interaction could enhance the children's response.
21 - 40%	1 = Starting to Develop	Less Interested / Less Like	A low percentage indicates that the children did not engage well with the material or activity. This suggests that the content or delivery may not have been appropriate for their age or interests, requiring significant revisions.

Effectiveness was tested through the analysis of N-Gain scores, which represent the difference between post-test and pre-test scores. The purpose of using the N-Gain test in this study was to evaluate the effectiveness of interactive multimedia educational games using the following formula:

$$\text{N-Gain} = \frac{(\text{Post Test Score} - \text{Pre Test Score})}{(\text{Ideal Score} - \text{Pre Test Score})}$$

To determine or assess the effectiveness level of a method or system used, there is a table that can be used as a guide, as follows:

Table 3. *N-Gain*

N- Gain Score	Criteria
g > 0,7	High
0,3 ≤ g ≤ 0,7	Medium
g < 0,3	Low

(Wahab et al., 2021)

Table 4. Interpretation of N-Gain Effectiveness

Percentage	Category
< 40	Not Effective
40 - 55	Less Effective
56 - 75	Quite Effective
> 76	Effective

3. FINDINGS AND DISCUSSION

3.1 Findings

The development process of interactive multimedia educational games followed the ADDIE model, consisting of five stages: Analysis, Design, Development, Implementation, and Evaluation. The first step in the ADDIE development model is the analysis stage. At this stage, the researcher conducted observations and found that the available teaching materials still used conventional play tools with less engaging media.

The second stage is the design stage. At this stage, the design of interactive multimedia educational games was created with storyboards and prototypes of interactive multimedia educational game products.

Next is the development stage. At this stage, interactive multimedia educational games were validated by subject matter experts and media experts. The evaluation results from subject matter experts and media experts showed that the interactive multimedia educational game product met the criteria for testing.

The fourth stage is the implementation stage. The implementation of interactive multimedia educational game usage was carried out at TPA Idola Bangsa Cilegon with the participation of 20 students aged 4-5 years, conducted in two class meetings, each lasting for 1 hour of lessons (40 minutes).

The final stage is the evaluation stage, where an assessment of the achievement of product creation goals is conducted. At this stage, measurements were made of the effectiveness of the product and its benefits in the development of children's numeracy skills.

The validation result from media experts was 88%. This percentage indicates that interactive multimedia educational games are highly suitable for use by children aged 4-5 years. Meanwhile, the validation test result from subject matter experts obtained a result of 80%, indicating that interactive multimedia educational games are good or suitable for testing. This can be observed in the following two tables.

Table 5 . Table of Summary Results for Media Expert Validation

Aspects Evaluated	Statement	Score
Appearance	The cover of the educational game is attractive	5
	The cover colors are bright and engaging	5
	The size and quality of the images are appropriate	4
	The type and size of text fonts are suitable for children aged 4-5 years	4
	The text color is clear and easy to read	4
	The text position is proportional on the slide pages	4
	The composition of images and text is proportional	5
Presentation	Easy for children and teachers to use	5
	Includes audio features	4
	Quality of sound and music	4
Total		44
Percentage		88%
Average		**4.4**
Category		**Highly Suitable**

Table 6. Table of Summary Results for Subject Matter Expert Validation

Aspects Evaluated	Statement	Score
Alignment with curriculum	The material presented aligns with the indicators	4
	The concept aligns with the material	4
Material	The material is appropriate for the numeracy skills of children aged 4-5 years	4
	The material is easy for children to understand	4
	The depth of content in numeracy skills for children	4
	The relevance of questions to numeracy skill indicators	4
	The material is meaningful	4
Context	The images and colors are attractive to children	4
	The images align with the text	4
	The information in the image illustrations and animations is clear	4
Total		**40**
Percentage		**80%**
Average		**4**
Category		**Suitable**

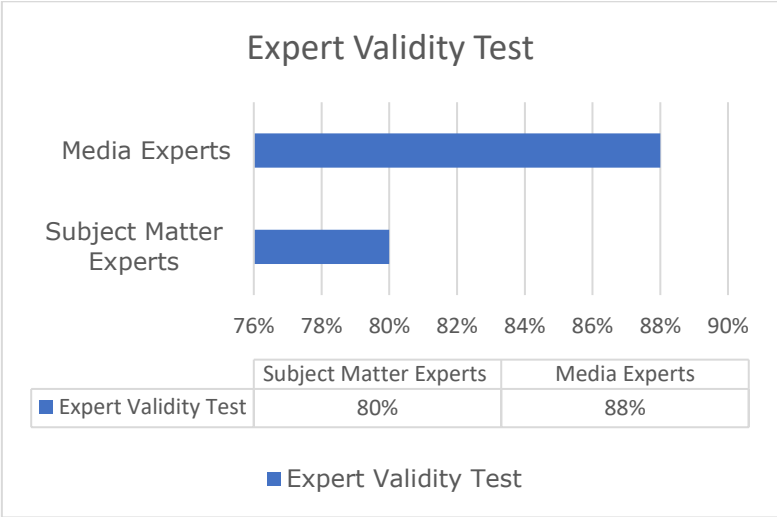

Figure 2. Graph of Expert Validation Test Percentage

Based on the calculation results, it was found that students' responses to the use of interactive multimedia educational games to improve numeracy skills for children aged 4-5 years at TPA Idola Bangsa Cilegon reached a total percentage of 91%. This means it falls within the achievement range of 81-100%, categorized as "very interested / very fond".

Table 7. Children's Response Results to the Utilization of Interactive Educational Game Multimedia

Total	72	75	72	73	74	73	71	73	74
Percentage (%)	90	93.8	90	91	92.5	91.3	88.8	91.3	93
Average percentage	**91%**								
Interpretation category	**Very interested**								

The effectiveness of learning using interactive multimedia educational games was evaluated through pre-test and post-test results. These test results were processed using the N-Gain Score formula, which aims to determine the improvement in learning effectiveness after using the developed media. The average N-Gain Score from the pre-test and post-test results was 0.65, which falls into the "Medium" category according to the reference value, where $0.3 \leq g \leq 0.7$. This can be demonstrated by the pre-test, post-test, and N-Gain test results shown in the following table.

Table 8. Pre Test, Post-Test, and N-Gain Score

Name	Pre Test	Post Test	N- Gain Score	N- Gain Score %
S1	63	91	0.756756757	75.67567568
S2	61	86	0.641025641	64.1025641
S3	66	88	0.647058824	64.70588235
S4	61	83	0,564102564	56.41025641
S5	66	86	0.588235294	58.82352941
S6	66	83	0.5	50
S7	63	86	0.621621622	62.16216216

S8	61	86	0.641025641	64.1025641
S9	63	88	0.675675676	67.56756757
S10	61	86	0.641025641	64.1025641
S11	63	91	0.756756757	75.67567568
S12	69	86	0.548387097	54.83870968
S13	61	86	0.641025641	64.1025641
S14	66	91	0.735294118	73.52941176
S15	61	88	0.692307692	69.23076923
S16	63	86	0.621621622	62.16216216
S17	63	88	0.675675676	67.56756757
S18	63	91	0.756756757	75.67567568
S19	63	86	0.621621622	62.16216216
S20	63	94	0.837837838	83.78378378
Mean	63.3	87.5	0.658190624	65.81906238

Based on the visualization of the N-Gain Score data above, it can be concluded that the learning process was quite effective, with the N-Gain percentage reaching 65.81% after the use of interactive multimedia educational games to enhance numeracy skills in children aged 4-5 years.

Discussion

Observations and interviews conducted at TPA Idola Bangsa Cilegon revealed that teachers predominantly rely on conventional teaching media. This underscores the need for technology-enhanced learning tools, such as interactive multimedia educational games, to improve numeracy skills in children aged 4-5 years. The use of interactive multimedia games makes numeracy learning more engaging, as children can explore early numeracy concepts independently and reinforce their understanding through interactive quizzes. These games provide instant feedback, allowing children to retry questions until they grasp the concepts. This aligns with Kaffah (2020), who found that interactive multimedia serves as an effective alternative for early childhood educators, transforming traditional teaching methods into game-focused learning experiences that enhance engagement and understanding.

The integration of interactive multimedia educational games is also highly practical in classroom settings. Teachers can set up one or two laptops or PCs and launch numeracy games in PowerPoint format, allowing children to engage with them independently or in small groups. Those with stronger numeracy skills gain confidence through self-directed learning, while children who struggle may seek assistance from teachers or peers, fostering a collaborative learning environment. This peer interaction not only supports numeracy development but also strengthens social and communication skills, as children learn to help and guide one another. Vega Vitianingsih (2016) similarly noted that educational games enhance enthusiasm for learning and stimulate creativity by incorporating elements of challenge, accuracy, and reasoning.

Additionally, the use of visually appealing graphics, bright colors, and interactive features captures children's attention and sustains their motivation. Research by Rahmawati & Sari (2021) supports this, stating that digital learning tools with engaging visuals enhance early childhood cognitive development by making abstract concepts more tangible. The positive responses observed in children further validate the effectiveness of these educational games in improving numeracy skills. Given these benefits, integrating interactive multimedia into early childhood education should be prioritized to foster both cognitive and social development. Future research could explore the long-

term impact of these games on mathematical reasoning and problem-solving abilities, as well as their adaptability to diverse learning styles and needs.

4. CONCLUSION

This study employed the Research and Development (R&D) methodology utilizing the ADDIE model to successfully design and develop interactive multimedia educational games aimed at enhancing numeracy skills among children aged 4–5 years. Expert evaluations by media and subject matter specialists affirmed that the games were pedagogically sound, visually appealing, and aligned with early childhood curriculum standards. The games' intuitive interface and engaging content contributed to their effectiveness as a learning tool. Observational data revealed that children exhibited high levels of enthusiasm and engagement, largely attributed to the interactive and visually stimulating nature of the games. Quantitative analysis demonstrated a 24% improvement in numeracy skills, as evidenced by pre-test and post-test comparisons, with an N-Gain score indicating moderate effectiveness.

However, the study's findings should be interpreted in light of certain limitations, including a relatively small sample size and a short evaluation period, which may constrain the generalizability and understanding of the long-term impacts on cognitive and academic development. Future research is recommended to incorporate longitudinal designs to assess the sustained influence of interactive multimedia tools. Moreover, integrating these games with traditional instructional methods and adapting them to suit various learning styles could enhance their applicability. Expanding the scope of research to include more diverse populations and educational contexts would also offer a broader perspective on their effectiveness. Overall, the findings suggest that interactive multimedia educational games hold considerable promise in supporting early numeracy development, fostering learning motivation, and contributing to cognitive growth in early childhood education.

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