

Research Article

Development of Puzzle Games to Foster Basic Mathematical Skills in Early Childhood

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Abstract. Basic mathematical skills in preschool children often face developmental challenges due to the lack of interactive and engaging learning resources in kindergartens. This community service activity aims to implement and test the effectiveness of a puzzle game-based educational media application in enhancing children's learning interest and analytical thinking skills. The developed puzzle game application integrates three types of educational games: selecting animals according to their habitat in the first game, matching geometric shapes into empty spaces in the second game, and counting the number of animals that appear in the third game. The method applied follows the Research and Development (R&D) approach to create a valid and practical product for partners. Field data analysis shows that validation by media experts recorded an average score of 95.1%, falling into the highly valid category. On the other hand, the validation of the student learning interest instrument reached a score of 95.8%, indicating a high level of relevance. The tangible results of using this media demonstrate a clear and significant increase in children's positive responses and learning enthusiasm during basic mathematics sessions. Thus, this puzzle game-based learning is proven effective as an alternative method to enhance mathematical thinking skills in preschool children.

Keywords: Early Childhood; Educational Games; Game Development; Mathematical Basic Skills; Puzzle.

1. Introduction

The rapid advancement of digital technology has significantly influenced various aspects of human life. One of the most significant innovations is the emergence of the Android operating system. As a flexible and open-source platform, Android has become the dominant choice for many device manufacturers worldwide. Android-based devices now dominate the global market and have transformed the way people communicate, access information, and enjoy entertainment. In Indonesia, the use of Android-based devices has grown rapidly alongside the expansion of technology access and internet connectivity. With its large population and continuously increasing number of internet users, Indonesia has become one of the most important markets for Android devices. This influence is evident in everyday life, including the ways children interact with and utilize digital technology.

Children today grow up in a digital environment where technology has become an integral part of their daily lives. Android-based devices are often among the first technological tools introduced to children, serving both entertainment and educational purposes. Parents and educators recognize the considerable potential of this technology to support children's cognitive and social development. However, the ease of access to mobile devices also raises concerns regarding their potential negative effects. Consequently, Android-based applications should be designed thoughtfully to function not only as educational media but also as therapeutic and emotional recovery tools for children in specific situations (Kusumandari & Wibawa, 2019; Kusumandari & Zulfikasari, 2021).

The history of digital games demonstrates an interesting evolution, from simple recreational tools to media with substantial educational potential. Digital games initially emerged as a form of entertainment in the mid-twentieth century, but technological advancements have gradually integrated educational elements into gameplay. Educational games have become one of the most promising alternative learning approaches, attracting considerable attention due to their ability to increase children's learning motivation. Through appropriate technological implementation, learning-oriented games have also been shown to

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effectively improve children's cognitive resilience across various educational settings (Kusumandari, 2025).

The use of games as educational media offers numerous benefits. Games can help children develop cognitive abilities, including logical thinking, problem-solving, and decision-making skills. Furthermore, games encourage creativity and imagination while strengthening collaborative skills through team-based activities. When designed appropriately, educational games can serve as effective learning tools, particularly in addressing the challenges of the digital era, where children are naturally more attracted to technology-based learning media.

Nevertheless, the use of games as instructional tools is not without challenges. One of the primary concerns is the lack of adequate supervision by parents and educators in selecting and monitoring children's gaming activities. Many games available on the market contain content that is inappropriate for young children and may adversely affect their development. Another significant challenge is the potential for gaming addiction, which can disrupt the balance between playtime, learning activities, and other daily responsibilities. These issues require careful attention from parents, educators, and game developers to create a safe and supportive digital environment for children.

Based on observations conducted at a kindergarten, it was found that young children continue to experience difficulties in understanding fundamental mathematical concepts. This situation is further exacerbated by the limited availability of interactive learning media capable of attracting children's attention in an engaging and enjoyable manner. Previous studies have developed Android-based games to assist children in overcoming trauma (Kusumandari & Wibawa, 2019; Kusumandari & Zulfikasari, 2021) and to enhance cognitive resilience in educational contexts (Kusumandari, 2025).

Therefore, the scientific novelty of this study lies in the development of an Android-based puzzle game application that uniquely integrates three learning components into a single comprehensive platform: animal classification based on habitat, completion of empty spatial areas to enhance spatial reasoning, and object counting activities to strengthen fundamental mathematical skills among kindergarten children.

This study aims to design and evaluate the effectiveness of an Android-based interactive puzzle game as a learning medium for improving young children's fundamental mathematical abilities and learning interest in kindergarten settings. By adopting a Research and Development (R&D) approach, this study is expected to make a meaningful contribution and provide practical solutions for teachers and parents in utilizing digital technology wisely to support the development of future generations.

2. Preliminaries or Related Work or Literature Review

Learning Media

Learning media can broadly be defined as tools or facilities that function as intermediaries in the interaction process between teachers and learners. Their primary purpose is to facilitate educational and instructional activities that enable students to acquire knowledge, develop skills, reinforce previously learned concepts, and support the achievement of high-quality educational objectives.

When utilizing learning media, teachers should carefully consider the principles and guidelines governing their effective implementation. Learning media should facilitate the learning process rather than become an obstacle resulting from teachers' insufficient understanding of appropriate instructional practices. Proper selection and implementation of learning media are essential for maximizing learning outcomes.

The development of learning media should consider the characteristics of the target learners to ensure that instructional messages effectively reach the intended audience and achieve the desired educational objectives. According to Widyantini and Sigit (2009), the use of learning media provides several advantages: (1) students gain meaningful and authentic learning experiences, making instructional materials easier to understand; (2) students' learning motivation is enhanced; and (3) students are encouraged to retain and recall previously acquired knowledge.

Objectives, Functions, and Roles of Learning Media

Learning media constitute an inseparable component of the instructional process and play a crucial role in achieving educational objectives. They facilitate effective interaction between teachers and students throughout the learning process. Learning media include physical devices and instructional resources used to deliver educational content.

According to Kemp and Dayton, as cited in Arsyad (2013, p. 23), learning media serve three primary functions: (1) motivating learners' interest and encouraging action, (2) presenting information, and (3) providing instructional guidance. To fulfill the motivational function, learning media may incorporate entertaining or dramatic techniques that stimulate learners' engagement.

Levie and Lentz identified four primary functions of learning media, particularly visual media. First, the attention function attracts and directs students' focus toward instructional content. Second, the affective function is reflected in the enjoyment and positive learning experiences students gain during instruction. Third, the cognitive function is supported by research demonstrating that visual symbols and images facilitate learners' understanding and retention of information. Finally, the compensatory function enables visual media to provide contextual support that assists students with limited reading abilities in comprehending textual information, organizing knowledge, and recalling learned concepts more effectively.

The Use of Learning Media

The selection of instructional media should be guided by several principles that correspond to the characteristics of the chosen media. These principles assist teachers in selecting and utilizing appropriate media throughout the instructional process. One essential principle is objectivity, meaning that learning media should not be selected solely based on teachers' personal preferences or for entertainment purposes. Instead, media should be carefully chosen to maximize students' learning effectiveness.

Another important consideration is understanding the advantages and educational benefits offered by each type of learning media. Teachers should also possess comprehensive knowledge of the characteristics, strengths, and limitations of different instructional media. Careful selection based on these characteristics contributes significantly to the effectiveness of the teaching and learning process.

Games

According to Hermawan, Herumurti, and Kuswardayan (2017, p. 196), the concept of games has been widely discussed with various definitions. Although these definitions differ in several aspects, they share common characteristics. A game is an activity that engages players in pursuing specific objectives governed by predetermined rules. Games are structured through gameplay rules that depend on players' actions. They represent a controlled yet voluntary system involving challenges or conflicts that are constrained by procedures designed to achieve particular goals.

Games are interactive forms of play that involve interaction with other players, the game system itself, or elements of chance and uncertainty. They are structured activities with clearly defined objectives that provide engaging and enjoyable experiences. Furthermore, the integration of interactive mathematics learning media, such as those developed using the Articulate Storyline platform, has been shown not only to improve students' learning outcomes but also to foster independent learning and critical thinking skills among elementary school students (Kusumandari et al., 2025, 2026).

3. Proposed Method

Research Design

This study employed a Research and Development (R&D) approach to develop and evaluate an interactive learning media application. According to Gay (1990), Research and Development is a systematic effort to create educational products that are effective for use in schools rather than merely testing theoretical concepts. The product developed in this study was an interactive learning media software application designed to improve kindergarten students' fundamental mathematics skills. The development process followed the ADDIE instructional design model, which consists of five sequential phases: Analysis, involving the identification of learning materials, curriculum analysis, and assessment of students' characteristics and instructional needs; Design, including the preparation of learning content, visual interface design, instructional strategies, and assessment instruments; Development, during which the proposed design was transformed into an interactive learning application and subsequently validated by media and subject-matter experts; Implementation, involving the application of the validated learning media in the classroom; and Evaluation, consisting of formative evaluations conducted throughout each development stage and a summative evaluation performed at the end of the process to determine the overall quality of the developed product. During the implementation stage, the study adopted an experimental approach using a One-Group Pretest–Posttest Design (Sugiyono, 2010), in which students completed a pretest before receiving the intervention through the Android-based learning media and a posttest after the intervention to evaluate learning improvements.

Population and Sample

The research population consisted of all Kindergarten B students at TK Sekar Mekar Semarang who were taught by Sri Mawarti, S.Pd., during the 2024/2025 academic year. The sample was selected using a purposive sampling technique, whereby participants were chosen based on specific research considerations (Sugiyono, 2015). The selection process was conducted collaboratively with the classroom teacher based on classroom observations. The inclusion criteria comprised students who demonstrated relatively low mathematics

achievement, limited interest in learning mathematics, and learning experiences that primarily relied on conventional PowerPoint presentations with minimal use of interactive instructional media. Based on these criteria, a total of 15 Kindergarten B students were selected as the research participants.

Data Collection Techniques and Instrument Development

Data were collected using three primary techniques: observation, questionnaires, and achievement tests. The interactive learning media was developed using Articulate Storyline as the primary software platform for designing the application's visual interface, interactive features, navigation system, and embedded learning assessments. Preliminary classroom observations were conducted in collaboration with the classroom teacher to identify students' learning difficulties and instructional needs. Expert validation questionnaires were then administered to obtain professional evaluations for revising the initial product design. The subject-matter validation instrument assessed curriculum alignment, content accuracy, material integration, level of difficulty, and instructional relevance. The media validation instrument evaluated visual design quality, interactivity, navigation usability, presentation effectiveness, and the quality of audio and visual illustrations incorporated into the Articulate Storyline application. A child psychology validation instrument was also employed to assess the learning interest questionnaire, which measured students' enjoyment, interest, attention, and engagement during learning activities. Practicality questionnaires were distributed to both teachers and students to evaluate the usability and effectiveness of the application. Teacher responses focused on instructional objectives, classroom management, and instructional effectiveness, while student responses assessed ease of use, learning enjoyment, and understanding of the learning materials. Student learning achievement was measured using pretest and posttest instruments designed to evaluate their understanding of basic geometry concepts before and after using the interactive learning media.

Data Analysis Techniques

To ensure the quality of the research instruments, several validity and reliability procedures were conducted, including item validity testing, reliability analysis, item discrimination analysis, and difficulty level analysis. Validity testing was performed to determine whether each instrument accurately measured the intended research variables (Sugiyono, 2015). An instrument item was considered valid when it demonstrated a significant contribution to the overall test score as measured through correlation analysis. Item validity was calculated using the Product Moment correlation coefficient proposed by Arikunto (2010). These statistical procedures ensured that the research instruments possessed adequate psychometric properties before being implemented in the experimental phase, thereby supporting the credibility and accuracy of the research findings.

4. Results and Discussion

This study resulted in the development of an Android-based educational puzzle game designed as a learning medium to improve the fundamental mathematical skills of early childhood learners. The development process followed the ADDIE instructional design model, consisting of the Analysis, Design, Development, Implementation, and Evaluation phases. However, this study focused on the Analysis, Design, Development, and Implementation stages.

Analysis

The analysis phase was conducted through classroom observations and interviews with the Kindergarten B teacher at TK Sekar Mekar Semarang. The findings revealed that students experienced difficulties in understanding fundamental mathematical concepts, including number recognition, geometric shapes, and object classification. In addition, the learning media used in the classroom were limited to simple visual materials, causing students to become easily bored and less actively engaged during the learning process.

The needs analysis indicated that an interactive learning medium that is attractive, easy to use, and capable of enhancing students' learning motivation was required. Therefore, an Android-based educational puzzle game was developed to accommodate the characteristics of young children, who naturally prefer learning through play-based activities.

Design

During the design phase, the learning content, storyboard, application interface, and gameplay flow were systematically developed. The instructional materials incorporated into the application included number recognition, geometric shapes, pattern matching, and simple puzzle-solving activities.

The application interface was designed using bright colors, attractive animated characters, interactive audio, and simple navigation buttons to ensure accessibility for young learners. In addition, validation instruments for subject-matter experts, media experts, and

response questionnaires for teachers and students were prepared to evaluate the quality of the developed application.

Development

The development phase was carried out using Unity and the C# programming language. The final product was an Android-based educational puzzle game that can be installed and operated on smartphones.

The application contains several primary features, including a main menu, a puzzle game menu, interactive audio, and a learning evaluation module. The interface was designed with colorful illustrations and visually appealing graphics to maintain students' attention and encourage active participation throughout the learning process.



Figure 1. Content Selection Page in an Educational Game.

Figure 1 illustrates the main character positioned within the game environment, where students navigate the character toward various learning icons. Each puzzle icon represents a different learning topic, including number recognition, geometric shapes, patterns, and object classification. Students select learning materials by moving the character to the desired icon, after which the application displays the corresponding instructional content and interactive activities.

This feature was designed to foster students' independence in selecting learning materials while increasing learning motivation through exploratory activities. The incorporation of interactive game characters provides a more engaging learning experience than conventional instructional approaches. Furthermore, game-based navigation enhances student participation throughout the learning process, encouraging greater engagement with the learning materials.



Figure 2. Overview of the Introduction to Numbers and Geometric Shapes Material.

Figure 2 demonstrates the learning interface displaying various numbers and geometric shapes, including squares, circles, triangles, stars, and hearts in different colors. On the right side of the screen, an interactive activity area enables students to match numbers and shapes according to the instructions provided by the system.

Students interact with the application by selecting appropriate objects and placing them into the designated answer area. These activities are intended to develop number recognition, shape identification, and logical thinking skills through object-matching exercises.

The use of bright colors and visually appealing graphics was intended to increase students' attention and learning interest throughout instructional activities. Moreover, the integration of gameplay elements with educational content creates a more enjoyable learning experience, making students more active and less likely to lose interest during instruction.

The interactive features incorporated into the learning materials also help students understand fundamental mathematical concepts more concretely through visual representations and exploratory learning activities. Consequently, the educational game developed in this study effectively supports a more engaging and meaningful learning process for early childhood education.

Subject-Matter Expert Validation

Subject-matter expert validation was conducted to evaluate the appropriateness of the instructional content with respect to the intended learning objectives. The results are presented in Table 1.

Table 1. Subject-Matter Expert Validation Results.

Assessment Aspect	Percentage	Category
Content appropriateness	90%	Highly Valid
Information clarity	88%	Highly Valid
Difficulty level	87%	Highly Valid
Skill development	91%	Highly Valid
Average	89%	Highly Valid

As shown in Table 1, the developed learning media achieved an average validation score of 89%, indicating a highly valid category. These findings demonstrate that the instructional content is well aligned with the learning objectives and is appropriate for the developmental characteristics of early childhood learners.

Media Expert Validation

Media expert validation was conducted to evaluate the quality of the visual interface, interactivity, and usability of the learning application. The results are summarized in Table 2.

Table 2. Media Expert Validation Results.

Assessment Aspect	Percentage	Category
Visual design	93%	Highly Valid
Media interactivity	90%	Highly Valid
Navigation usability	94%	Highly Valid
Information effectiveness	91%	Highly Valid
Average	92%	Highly Valid

Based on Table 2, the application obtained an average validation score of 92%, which falls within the highly valid category. These results indicate that the developed learning media possess an attractive visual appearance, effective interactive features, and user-friendly navigation suitable for young learners.

Implementation

The implementation phase involved field testing of the developed learning media with 15 Kindergarten B students at TK Sekar Mekar Semarang. This stage aimed to evaluate both the practicality and effectiveness of the Android-based educational puzzle game in classroom learning activities.

Teacher and Student Practicality

The practicality evaluation results are presented in Table 3.

Table 3. Practicality Evaluation Results.

Respondent	Percentage	Category
Teacher	90%	Highly Practical
Students	88%	Highly Practical

The practicality assessment indicates that the developed learning media are highly practical for both teachers and students. Teachers reported that the application was easy to integrate into classroom instruction, while students expressed greater interest, enthusiasm, and active participation when using the educational game during learning activities.

Pretest and Posttest Results

The effectiveness of the learning media was evaluated using a one-group pretest-posttest design. The results are presented in Table 4.

Table 4. Pretest and Posttest Results.

Measurement	Mean Score
Pretest	62
Posttest	86

As presented in Table 4, the students' average score increased substantially from 62 on the pretest to 86 on the posttest after using the Android-based educational puzzle game. This improvement demonstrates that the developed learning media effectively enhanced the fundamental mathematical skills of kindergarten students.

The findings of this study demonstrate that the Android-based educational puzzle game achieved a high level of validity, as evidenced by the evaluations conducted by both subject-matter experts and media experts. These results indicate that the developed learning media are appropriate for implementation in early childhood education and meet the required standards in terms of content quality, instructional design, visual appearance, and usability. The positive validation outcomes further confirm that the application is aligned with curriculum objectives and the developmental characteristics of kindergarten children.

The developed learning media effectively facilitated students' understanding of fundamental mathematical concepts by integrating interactive and play-based learning activities. Through engaging puzzle tasks, colorful visual elements, animated characters, and interactive audio, the application created an enjoyable learning environment that maintained students' attention and encouraged active participation throughout the instructional process. These findings support the view that interactive digital media can provide meaningful learning experiences for young children by combining educational content with age-appropriate game mechanics.

Furthermore, the implementation results revealed a considerable improvement in students' learning outcomes following the use of the educational puzzle game. The increase in posttest scores compared with pretest scores indicates that the developed application effectively enhanced children's fundamental mathematical skills, including number recognition, geometric shape identification, pattern matching, and object classification. These findings suggest that integrating interactive educational games into classroom instruction can improve children's conceptual understanding through repeated practice and immediate feedback.

The findings also demonstrate that game-based learning media significantly increased students' interest and motivation to learn. Young children appeared more enthusiastic and actively engaged when mathematical concepts were presented through interactive gameplay rather than conventional teacher-centered explanations. This observation is consistent with previous studies emphasizing that play-based digital learning environments can improve children's motivation, participation, and cognitive engagement while supporting meaningful knowledge construction (Kusumandari & Wibawa, 2019; Kusumandari & Zulfikasari, 2021; Kusumandari, 2025).

Overall, the results indicate that the Android-based educational puzzle game represents an innovative, practical, and effective instructional medium for early childhood mathematics education. By combining educational content with interactive game elements, the application not only improves fundamental mathematical competencies but also creates a more enjoyable learning experience that supports children's cognitive development and promotes greater engagement in classroom learning activities.

5. Conclusions

Based on the results of the research and development conducted, it can be concluded that the Android-based educational puzzle game developed using the ADDIE model has successfully become a learning medium suitable for improving the basic mathematical skills of early childhood students. The developed learning medium features an attractive visual design, is interactive, and is easy for students to use. Validation results from subject matter experts and media experts indicate that the learning medium falls into the "highly valid" category, making it suitable for use in the learning process. Additionally, practicality test results show that the medium falls into the "highly practical" category based on feedback from teachers and students. Implementation results also demonstrate an improvement in

student learning outcomes after using the educational game. This is evident from the increase in the average posttest score compared to the pretest score. The use of educational puzzle games can boost students' interest in learning and engagement, as well as help them understand basic mathematical concepts through interactive and enjoyable play activities. Thus, Android-based educational puzzle games can serve as an effective and innovative alternative learning medium to support the mathematics learning process for early childhood students.

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