

Digital game in young children's numeracy skill: An innovation through learning media development

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Abstract

Children's numeracy skills significantly influence their readiness to enter primary school. However, teaching numeracy to children in concrete periods is still a big challenge for teachers. Moreover, technology-based learning media must still be considered appropriate for early introduction. This research aims to develop an interactive digital learning media to improve early childhood numeracy skills. This Research and Development (RD) method used the 4-D model, which consists of Defining, Designing, Developing, and Disseminating. Expert validators who test the feasibility of the product consist of material, media, and language experts. Respondents in this study were ten children aged 4–5 years at PAUD Nurul Aisyah, East Aceh. The results showed that this digital game is feasible as a learning media to improve early childhood numeracy skills. The average validator score for product feasibility is in the very good category, and children's numeracy skills are in the good category. With this learning media, "Numb Game," children learn the concepts of counting, grouping, and simple statistics. Through an interactive approach, the development of Numb Game media can stimulate children's engagement in the numeracy learning process by utilizing visual elements, games, and interactions that stimulate curiosity and desire to understand mathematical concepts. Therefore, this interactive digital learning media presents an interesting, adaptive, and effective learning experience according to children's needs in improving numeracy skills at an early age. Further research on the long-term effects of using digital learning media on the development of early childhood numeracy skills and the implications for their academic achievement is warranted.

Keywords: Numeracy, Early Math, Learning Media, Digital Games, Innovation, Early Childhood Education.

INTRODUCTION

Indonesia has held a mixed position in the Programme for International Student Assessment (PISA), a global assessment that measures student performance in reading, maths, and science. In recent years, Indonesia has often ranked relatively low compared to other countries (OECD., 2018). For example, in PISA 2018, Indonesia ranked 73rd out of 79 participating countries in maths. In Asian countries, Indonesia is in cluster 2 with below-average PISA acquisition (Pratama and Husnayaini, 2022), indicating a major numeracy challenge among Indonesian students. Although there was a

slight improvement in numeracy scores in the most recent PISA, the rankings, which are still far below the global average, show that there is great work to be done to improve maths education in Indonesia.

In general, various ideal preparations have been made by schools and teachers with a fairly large percentage and not mutually dominant, such as introducing more collaborative learning to providing assessments with questions that test students' reasoning or HOTS-level questions. Teachers also try to strengthen learning for students who generally experience learning loss due to the pandemic. Nevertheless, the variables affecting student achievement in mathematics showed that the most important for the 12 Asia-Pacific countries were parental educational status, access to educational resources, age, time allocated to weekly lessons, and kindergarten (Bayirli et al., 2023). Therefore, there is something equally important, which is the stimulation of early mathematics concepts from an early age.

Children's understanding of early mathematics is closely related to their next academic achievement (Neumann et al., 2013), so early childhood teachers have an important role in the early-stage stimulus process. In early childhood mathematics, numeracy is crucial to developing number sense and connecting numbers with concrete problems. Preparation for numeracy improvement will affect children's readiness to enter primary school. One of the early mathematical abilities in early childhood numeracy includes grouping objects with similarities, colours, shapes, and recognising numbers 1-20 and present them (Arab, 2022). Therefore, understanding preschool teachers in building children's readiness is also essential (Syarfina et al., 2018).

However, teaching numeracy to children in the concrete period is still challenging for most early childhood education (ECE) teachers. ECE Teachers should create an interesting learning process to improve children's numeracy skills, such as using interactive learning media (Khomsiyatun, 2019). Learning media is a means to produce an active learning atmosphere. Learning media development is an activity from science and technology to test effectiveness based on the rules and development itself (Kusumastuti et al., 2021). Learning media can channel messages from senders to recipients to stimulate early childhood thoughts, feelings, interests and attention to focus on the learning process (H. Wulandari et al., 2022; Kurniasih et al., 2020; Ayu et al., 2019).

Another fact from the field observations shows that some ECE institutions in Aceh also tend to use something other than digital-based learning media, even though digital media is no longer foreign to be applied in the current era. This is because teachers feel electronic media is unsuitable for early childhood. Teachers are worried that children will become addicted to using electronic media. The numeracy learning media introduced by ECE teachers is still in the form of worksheets for children to answer pictorial questions, so children quickly feel bored and need a higher sense of learning. Moreover, if learning while playing using audio-visual-based media, then children are more interested and want to focus on learning (Meo et al., 2022). Therefore, ECE institutions need innovations to develop learning for students so that learning is more fun and children can focus longer on the teaching and learning process.

Several studies on the development of digital-based learning media for early childhood have been studied previously, such as the development of electronic learning media educational games in supporting learning programmes from home in the era of the covid 19 pandemic in children (Maimunah, Gupita, et al., 2022). In addition, there is also the development of digital-based games. However, the purpose of applying ICT methods through digital educational games is to develop children's creativity and thinking skills (Humaida and Suyadi, 2021), children's cognitive abilities in the form of animal science literacy (Mahrizah et al., 2023), children's reading and writing skills (Nirwana, 2021), children's spatial abilities (A. D. Wulandari et al., 2018). There are also educational media in the form of books or digital objects, such as practical Al-Qur'an learning e-books (Saptiani and Sofyan, 2022), folklore e-books (Octaloca et al., 2023), saving alarm objects (Mawarni et al., 2022). However, this research aims to develop digital-based learning media designed in interactive

games to improve children's numeracy skills that focus on counting, classification, and simple statistics in children aged 4-5 years.

Research in the development of interactive digital learning media has made an important contribution to improving early childhood numeracy skills by presenting an engaging and powerful learning experience. This research can shape more adaptive, personalized, and effective learning methods according to each child's individual needs, improving overall numeracy skills by maintaining children's joy and motivation to learn at an important stage of their development.

METHOD

This research is research and development (RD). The development model in this research is the 4-D model, which consists of defining, designing, developing, and disseminating.

Stages of Development.

The activities carried out at each stage of development can be explained as follows:

Defining. The first activity at this stage was to analyze the product development needs. The analysis includes analysis of the 2013 and 2014 Minister of Education and Culture Regulations (MECR), material analysis, and student needs analysis. Analysis of 2013 and 2014 MECR aims to determine the standard level of achievement of cognitive development aspects of children aged 4-5 years in the numeracy section. The analysis includes core competencies and basic competencies. Material analysis aims to determine the content and appropriate learning materials. With this analysis, indicators and learning objectives are obtained. The analysis results are used as a reference to formulate the learning material in the game to improve numeracy in early childhood. Material analysis is also carried out to identify and compile learning materials related to numeracy that are packaged in the form of effective media. The analysis aims to determine children's characteristics, starting from the background of numeracy skills with an age range of 4-5 years, children's activities in ECE, learning motivation, and children's academic abilities. This needs to be studied to be the basis for developing digital-based game-learning media for early childhood.

Designing. At this stage, the researcher designs the product as a game with Microsoft PowerPoint after seeing the results of the material analysis, as well as the needs of children. The preparation of material in the learning media is guided by the 2013 and 2014 MECR, which includes core competencies, basic competencies, indicators, and learning objectives. The material refers to the standard level of achievement of child development in early childhood education units.

Developing. There are two activities at this stage: expert assessment and development trials. Expert assessment is a validity test technique used to validate or assess the feasibility of a product design. The development stage is intended to evaluate the product design by experts. Furthermore, development testing tests product designs on real target subjects, namely children. This trial intends to find data on target media users' responses, reactions, or comments. At the validity stage, the product is assessed by material, media, and language experts, followed by a revision process to improve learning media from various aspects. Validation activities are carried out by filling out validation sheets and improvement notes. Validation by experts aims to obtain assessments, suggestions, and comments regarding the suitability of the approach and form of media design developed. After the media is considered valid, trials are carried out with small and large field trials to determine the effectiveness of learning media. The product is tested to determine whether the learning media used effectively improves children's numeracy. Small and main trials were conducted on children aged 4-5 years. Respondents in this study were ten children aged 4-5 years at Nurul Aisyah ECE, East Aceh. The researcher observed children's playing and numeracy skills activities using the game, recorded important things, and discussed them with the teacher.

Disseminating. After obtaining effective learning media, the final stage in developing learning media is to disseminate learning media. The goal is to introduce this learning media as a digital game to improve children's numeracy skills. However, this study stopped at the development stage and has yet to be disseminated.

Data Collection Technique

Researchers collected data through questionnaires and observations. Questionnaires are used to obtain data regarding the feasibility of the products developed during expert validation. In addition, observations were made in this study before and after the product was developed, namely during the initial needs analysis and field trials. In this study, indicators of children's numeracy were limited to counting ability, classifying, and basic statistics.

Data Analysis Technique

The data analysed includes the feasibility of media from material, media, and language experts from the available questionnaires, as well as data on children's numeracy skills. The measuring instrument used in this research is a questionnaire with a Likert scale of 1-4. Scoring rules for media experts, material experts, and linguists with categories: very feasible (4), feasible (3), less feasible (2), and not feasible (1). For analyzing observation data, the researcher used a Likert scale with a score of 1-4. Start from No Develop (ND), Starting to Develop (SD), Developing as Expected (DE), Developing very Well (DW). With the media feasibility category, the data recapitulation of the validation results can be concluded based on the categories determined on each indicator.

RESULT AND DISCUSSION

The research results are described based on the learning media development procedure using the 4-D model, and then the findings are discussed in depth. At the initial problem identification stage, a learning media is needed to improve early childhood numeracy skills that are interactive and fun. Researchers chose to make digital-based games and introduce technology to early childhood. Technology has emerged in education as a tool to make learning more efficient (Chang and Hwang, 2019; Garshi et al., 2020), fun and interesting (Haleem et al., 2022).

This game's initial material design examines the standard level of numeracy achievement of children aged 5-6 years. Then, researchers designed numeracy learning with the theme of 'animals' through PowerPoint to produce a learning product called Numb Game.

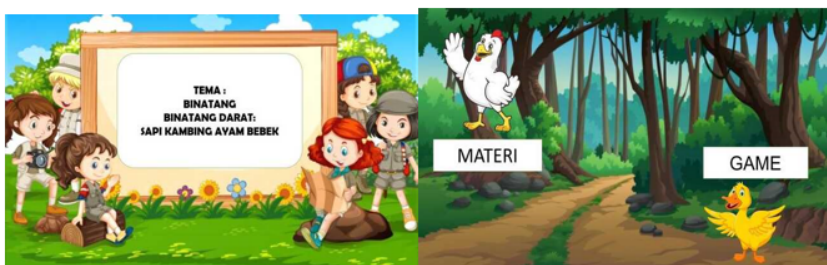


Figure 1. Main page view of 'Numb Game'.

Next, the game went to the validation test. Validators conducted the validation test following their fields of expertise, material, media, and language experts. Based on the validation sheet, the experts also obtained constructive suggestions so that some improvements were made. Researchers changed the colours and backgrounds in Microsoft PowerPoint to be more vivid, added types of animals and per category of the game according to the indicators, and did not bring up the theme and material in the game. The theme and material became the teacher's notes, while the children only played it. The results of the product revision are shown in Figure II .


This game is played using a laptop, and projector is available at school. To play, children press the "play" button and select the menu. There are three menus symbolised by the letters A, B, and C. Menu A is counting, Menu B is grouping, and Menu C is simple statistics. Children can already play the game by clicking on one of the menus. In this concrete period, children like to see objects directly through the images on the learning media (Ananda et al., 2022). By playing the game,



Figure 2. Game screen after revision

children will actively think in a fun way (Putri and Adhe, n.d.). The following details of how to play the game are described in Table 1.

Table 1. How to Play Numb Game

Procedure	Display Screen
Open the first layer of the game, then click "PLAY"	

After clicking "PLAY", the "MENU" page contains A, B and C. Children can choose them.



After clicking "PLAY", the "MENU" page contains A, B and C. Children can choose them. In menu A, children play "Counting". On this screen, children count the chickens by clicking on them individually, and then the chickens go down.



After clicking "PLAY", the "MENU" page contains A, B and C. Children can choose them. In menu A, children play "Counting". On this screen, children count the chickens by clicking on them individually, and then the chickens go down. In menu B, children play "Classify". On this page, children learn to classify animals based on their food, such as tigers, which are carnivores, and elephants, which are herbivores.



Next, on menu C, children will play "simple statistics". In this menu, children will learn to find out the most animals by counting first, namely by clicking on the animals one by one then the animals will go down to their place so that the number of animals that are the most / least and compare them.



The child who plays until the end is the winner!.



Based on the validation sheet, constructive suggestions/comments were obtained from the experts so that several improvements were made. The next expert validation test showed that the learning media 'Numb Game' is appropriate for early childhood numeracy learning. The validator also stated that the game's indicators, content, and learning objectives were the Core Competencies and Basic Competencies of early childhood. Language will be more to the direct use of language by the teacher. Language in interactive media must be considered friendly and communicative (Khomsiyatun, 2019). The results of data analysis show that the average results of validation and trials are in the feasible category with very good predicates according to the table of eligibility criteria and product revisions.

Table 2. Expert Validation Results

Aspect	Skor Rata-rata	Percentage	Category
Media	3,44	92%	Very Good
Content	3,9	98,3%	Very Good
Language	3,64	35% Very Good	

Thus, in terms of media, material, and language, the Numb game can be used by teachers to introduce children's numeracy. After being tested for feasibility, the game is well prepared and packaged to be played by early childhood as an effectiveness test. The learning media effectiveness test is conducted to determine how effective the media is in numeracy recognition (Dini, 2022). Media effectiveness data comes from children's activities using the Numb Game Learning media during the numeracy learning process.

Table 3. Learning Effectiveness Results

Respondent	Aspect			Score	Category
10					
Mean (%)	Counting	Classifying	Statistic		
	39	40	35	114	Effective
	90,9	90,9	88	89,93	

This Numb Game product was developed through product validity and usage trials. Based on the trial results, the product is generally feasible to use as a medium to stimulate early childhood numeracy. Numb games could be effective because they stimulate children's engagement in the numeracy learning process by utilizing visual elements, games, and interactions that stimulate curiosity and the desire to understand mathematical concepts. Through an interactive approach, the development of this interactive digital learning media presents an interesting, adaptive, and effective learning experience according to the needs of children in improving numeracy skills at an early age. Research shows that one of the most effective ways of teaching math in preschool is through goal-oriented games, songs, and free activities (H. Wulandari et al., 2022) so that customized learning materials also follow the stages of children's numeracy development (Ningtyas and Risina, 2018). Learning using media will be more interesting and interactive, cause an attitude of attention, increase the quality of children's learning (Falera, 2021). Effective learning media increases children's ability to number concepts (Gunanti et al., 2021). Therefore, with the right media and methods, stimulation does not damage children's development patterns.

In addition, innovative learning media can increase creative thinking in early childhood (M. Hayati, 2021). By choosing the theme of Animals in Numb Game, children indirectly learn about life science; living things in the form of animals. When classifying animals based on the type of food they eat, children also learn about the knowledge of carnivores and herbivores, which are included in science material for children of this age. Developing comprehensive learning media will help children with cognitive skills (Harliza, Kurniah, et al., 2020). Children will also experience an increased understanding of other concepts that are learned in an integrated manner (M. Hayati, 2021). The concept also easily fits the context of life or daily activities they encounter (Izartin, n.d.). For this reason, it is undeniable that teachers need a simple digital-based method to design and implement. Materials can be added anytime, any number of times, according to the needs of children. Interactive media will make it easier for teachers to convey number concept learning to children and also make it easier for children to understand (Suryana and Hijriani, 2022; Syarfina et al., 2022).

Besides improving numeracy skills, children look enthusiastic about participating in learning activities. Learning involving children can increase motivation (Bin, 2023; S. N. Hayati and Putro, 2021). Children who do this activity have high curiosity, so that they find a feeling of pleasure. When playing this game, children look very happy. It can be seen that when children play this game,

many want to join and practice. Children look enthusiastic in answering the questions displayed in this game.

Numeracy learning using the Numb game is effective because games make children learn numeracy by playing quality games that take a fun approach without realising, their numeracy skills or abilities increase (Handayani and Wulansari, 2021). This digital-based learning medium can be used to introduce numeracy to children after making improvements based on suggestions from validators and observations during the learning process. However, this media has not been disseminated because it does not yet have legal ownership rights. Numb game also needs to develop activities in each menu. Each menu is still limited, but teachers can innovate to add more and can even distinguish games for each child in the same menu. The researcher plan to license it for widely distribution.

CONCLUSION

The digital-based learning media "Numb Game" developed can be an alternative for teachers to introduce the concept of numeracy in early childhood. With the presence of effective and interactive digital media that can be easily designed by ECE teachers in the various area, it is hoped that children in the area will also be technology literate. By playing this game, children will be enthusiastic about learning mathematics in general and numeracy in particular. When they grow up, they will love math because they understand the concepts concretely. Thus, children can achieve academic achievement when continuing to the next level of education. It is necessary to conduct further study on a longitudinal study where students play this game over a semester, with a pre and post-test on a standardized mathematical test, to claim that this benefits students in numeracy skill development and the consequences for their academic success.

AUTHOR CONTRIBUTION STATEMENT

The authors' roles in this study are outlined as follows: S. conceived the research idea and designed the study. S.M. and S.M. formulated the theoretical framework. S. and Y.S. ensured the appropriateness of the analytical methods employed in the research. A.D.P. carried out the data analysis and its interpretation. S. provided guidance and oversight throughout the research process. All authors actively engaged in discussions regarding the results and made substantial contributions to the final manuscript.

DECLARATION

The authors of this study certify that they have No affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

DATA AVAILABILITY

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

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