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Android-Based Technology: Development of Game-Based Learning Media Based on the Results of Analysis of Arithmetic Learning Difficulties

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ABSTRACT

This research aims to develop educational games and learning media using Android-based technology on arithmetic material for children with barriers to learning mathematics. The research method used in this research is design-based research (DBR) to obtain comprehensive information regarding the analysis of learning difficulties experienced by students and the development of game-based learning media. The subject in this research was a child with learning disabilities in arithmetic material. The result of this research is the development of educational games and learning media using Android-based technology on arithmetic material for children with learning disabilities. The content contained in educational games and learning media has been adapted to the needs of children who have learning obstacles in arithmetic material. Material that is tailored to the needs will be very appropriate for the learning development of children with learning disabilities in arithmetic material. The results of this research showed that educational games media using Android-based technology can increase learning needs for material in arithmetic. Apart from being useful for children with learning disabilities, it is hoped that this educational game learning media can also be used for other children who are studying mathematics using arithmetic material.

1. Introduction

Technological developments in the 21st century have experienced significant changes from year to year [1-6]. Technology is essentially the result of science and is very important for human life [7]. Technology is created to support human life in all aspects. This very rapid technological development occurs especially in advances in the field of information and communication, one of which is smartphones [8]. The Android operating system is the most used on smartphones in Indonesia today [9].

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Current technological developments have an impact on many things, one of which is education. The development of technology in the world of education provides many benefits for educators to carry out learning easily as an educator's way of teaching with currently developing technology. The existence of technological developments that have changed significantly has an impact on the world of education which is required to be more modern. Society and students feel the impact of technology on education in the 21st century, starting from the various types of learning media available to new learning models that utilize advances in technology and information [10]. Equipment and applications that are easy to learn and use as learning media are the result of this very rapid progress in science and technology [11-17]. One of them is that the Android operating system is currently also being used in education. The use of smartphones in learning creates innovation in learning. Technology as a learning tool can make lessons more interesting. Students will learn more interactively, and they can learn anytime and anywhere without having to meet directly with the teacher [18].

According to Al Hakim [19], one of the main problems faced by students in understanding conventional classroom lessons is the repetition of explanations about the material taught by the teacher, problems that arise when students are not ready to understand the lesson, and difficulties to use learning media during the learning process. One of them often occurs in mathematics lessons. Mathematics lessons at school are considered difficult for students because mathematical objects are abstract [20]. According to Dila and Zanthy [21], mathematics is considered one of the difficult subjects in school because it requires extraordinary thinking abilities. As a result, some students consider mathematics to be a boring and difficult subject to learn. In this problem, learning media must apply technology to make the learning process easier. Modern educational games can be used as an alternative to improve students' mathematics learning in a fun way and teach them to think critically [22]. By using games in learning mathematics, it is hoped that it can increase students' enthusiasm for learning mathematics and make it easier for students to understand mathematical concepts.

The development of learning media using game-based learning technology is the aim of this research. Game-based learning media has attracted tremendous attention, as shown by excellent research trends (see Figure 1). Figure 1 shows the improvement of publication numbers in the research on game-based learning media based on the Scopus database taken in June 2024, showing the importance of this study for further uses and applications. Detailed information on how to get this data is explained elsewhere [23-48]. Bibliometric analysis is one of the effective methods for understanding current issues and research trends. Examples of the use of bibliometrics to understand research trends are presented in Table 1.

Game-based learning media is a tool for developing the arithmetic learning process for students with difficulties in learning subjects [49-57], such as mathematics [58]. The novelties in this research include (i) the development of game-based learning media on arithmetic material (place value content and arithmetic operations), (ii) the development of game-based learning media on arithmetic material based on the results of analysis of learning difficulties experienced by students. Table 1. Contains efforts to complete this research. We reviewed several previous studies as study material for developing learning media.

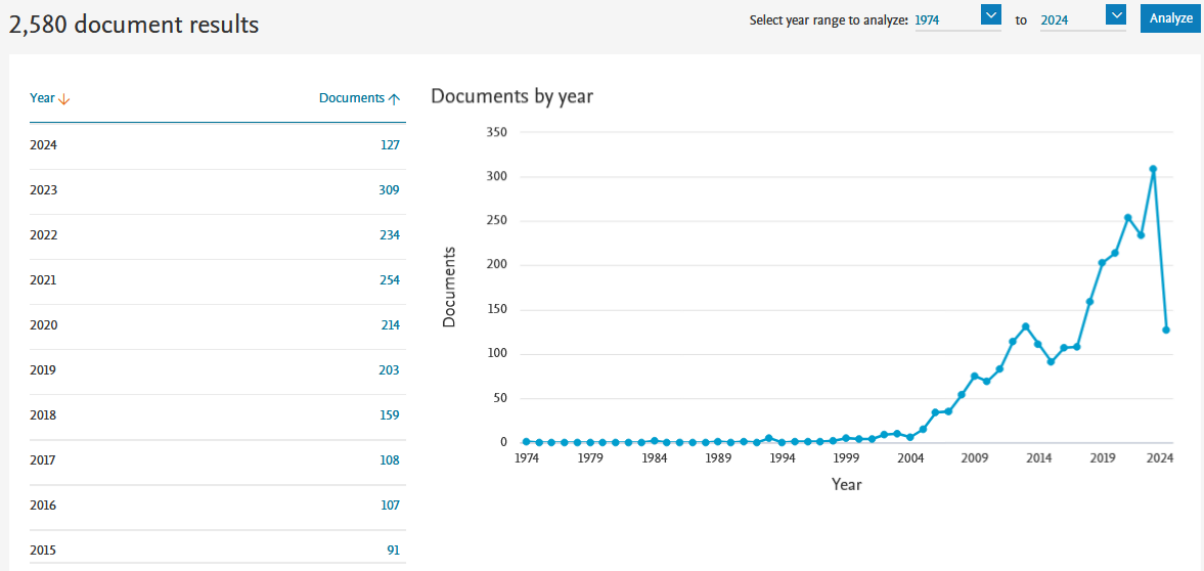


Fig. 1. Bibliometric analysis for obtaining research trend, taken from the Scopus database on June 2024, using the keyword "Game Based Learning Media"

Table 1a
Previous studies on bibliometric analysis

No	Title	Author	Ref.
1	Introducing ASEAN Journal for Science and Engineering in Materials: Bibliometric Analysis	Nandiyanto, A. B. D., Al Husaeni, D. F., & Al Husaeni, D. N.	[24]
2	Involving Particle Technology in Computational Fluid Dynamics Research: A Bibliometric Analysis	Nandiyanto, A. B. D., Ragadhita, R., & Aziz, M.	[25]
3	Particulate Matter Emission from Combustion and Non-Combustion Automotive Engine Process: Review and Computational Bibliometric Analysis on Its Source, Sizes, and Health and Lung Impact	Nandiyanto, A. B. D., Ragadhita, R., Setiyo, M., Al Obaidi, A. S. M., & Hidayat, A.	[26]
4	Social Impact and Internationalization of "Indonesian Journal of Science and Technology" the Best Journal in Indonesia: A Bibliometric Analysis	Nandiyanto, A. B. D., Al Husaeni, D. F., & Al Husaeni, D. N.	[27]
5	Introducing ASEAN Journal of Science and Engineering: A Bibliometric Analysis Study	Nandiyanto, A. B. D., Al Husaeni, D. N., & Al Husaeni, D. F.	[28]
6	Concept of Computational Fluid Dynamics Design and Analysis Tool for Food Industry: A Bibliometric	Muktiarni, M., Rahayu, N. I., Nurhayati, A., Bachari, A. D., & Ismail, A.	[29]
7	Concept of Computational Fluid Dynamics and Its Application in Sport Science: Bibliometric Analysis of Modelling Thermal Comfort in Sport Hall	Rachmat, B., Agust, K., Rahayu, N. I., & Muktiarni, M.	[30]
8	Bibliometric Computational Mapping Analysis of Trend Metaverse in Education using vosviewer	Muktiarni, M., Rahayu, N. I., Ismail, A., & Wardani, A. K.	[31]
9	Phytochemical Profile and Biological Activities of Ethylacetate Extract of Peanut (Arachis hypogaea L.) Stems: In-Vitro and In-Silico Studies with Bibliometric Analysis	Sahidin, I., Nohong, N., Manggau, M.A., Arfan, A., Wahyuni, W., Meylani, I., Malaka, M.H., Rahmatika, N.S., Yodha, A.W., Masrik, N.U.E. and Kamaluddin, A.	[32]
10	Information and communication technology (ict) intervention targeting physical activity and diet behaviors in people with disabilities: vosviewer mapping analysis	Rahayu, N. I., Bachari, A. D., Muktiarni, M., & Maryanti, R.	[33]
11	Computational bibliometric analysis of English research in science education for students with special needs using vosviewer	Sukyadi, D. I. D. I., Maryanti, R., Rahayu, N. I., & Muktiarni, M.	[34]

Table 1 (continue)
Previous studies on bibliometric analysis

No	Title	Author	Ref.
12	Orange and strawberry skins for eco-enzyme: experiment and bibliometric analysis	Muktiarni, M., Rahayu, N., & Maryanti, R.	[35]
13	Counseling guidance in science education: definition, literature review, and bibliometric analysis	Solehuddin, M., Muktiarni, M., Rahayu, N.I. and Maryanti, R.	[36]
14	A bibliometric analysis of management bioenergy research using vosviewer application	Soegoto, H., Soegoto, E.S., Luckyardi, S., and Rafdhi, A.A.	[37]
15	Oil palm empty fruit bunch waste pretreatment with benzotriazolium-based ionic liquids for cellulose conversion to glucose: Experiments with computational bibliometric analysis.	Mudzakir, A., Rizky, K.M., Munawaroh, H.S.H., and Puspitasari, D.	[38]
16	Research mapping in the use of technology for fake news detection: Bibliometric analysis from 2011 to 2021.	Gunawan, B., Ratmono, B.M., Abdullah, A.G., Sadida, N., and Kaprisma, H.	[39]
17	Management information systems: bibliometric analysis and its effect on decision making.	Santoso, B., Hikmawan, T., and Imaniyati, N.	[40]
18	Sustainable Production-inventory model with multi-material, quality degradation, and probabilistic demand: From bibliometric analysis to a robust model.	Utama, D.M., Santoso, I., Hendrawan, Y., and Dania, W.A.P.	[41]
19	Biomass-based supercapacitors electrodes for electrical energy storage systems activated using chemical activation method: A literature review and bibliometric analysis.	Hamidah, I., Ramdhani, R., Wiyono, A., Mulyanti, B., Pawinanto, E.E., Hasanah, L., Diantoro, M., Yuliarto, B., Yunas, J., and Rusydi, A.	[42]
20	Antiangiogenesis activity of Indonesian local black garlic (Allium Sativum 'Solo): Experiments and bibliometric analysis.	Arianingrum, R., Aznam, N., Atun, S., Senam, S., Irwan, A.R., Juhara, N.Q., Anisa, N.F., and Devani, L.K.	[43]
21	Characteristics of tamarind seed biochar at different pyrolysis temperatures as waste management strategy: experiments and bibliometric analysis.	Rahmat, A., Sutiharni, S., Elfina, Y., Yusnaini, Y., Latuponu, H., Minah, F.N., Sulistyowati, Y., and Mutolib, A.	[44]
22	The compleat lextutor application tool for academic and technological lexical learning: Review and bibliometric approach.	Abduh, A., Mulyanah, A., Darmawati, B., Zabadi, F., Sidik, U., Handoko, W., Jayadi, K., and Rosmaladewi, R.	[45]
23	How eyes and brain see color: Definition of color, literature review with bibliometric analysis, and inquiry learning strategy for teaching color changes to student with mild intelligence barriers.	Juhanaini, J., Bela, M.R.W.A.T., and Rizqita, A.J.	[46]
24	Bibliometric analysis of nano metal-organic frameworks synthesis research in medical science using vosviewer.	Shidiq, A.P.A.	[47]
25	Use of blockchain technology for the exchange and secure transmission of medical images in the cloud: Systematic review with bibliometric analysis.	Lizama, M.G., Huesa, J., and Claudio, B.M	[48]

Table 1b
Analysis of previous research

No.	Title	Results	Ref.
1.	Development of Android Based Mathematics Learning Media for Primary School Students	The Android-based learning media developed is very suitable for use.	[59]
2.	Development of Android-Based Mathematics Learning Media	This research uses the development of the ADDIE model and the final result is that mathematics learning media products are suitable for use as alternative learning media for students.	[60]
3.	Effectiveness of Android-Based Mathematics Learning Media Application on Student Learning Achievement	Android-based learning media in basic mathematics subjects is convincingly effective in improving student achievement	[61]

4.	Development of Alternative and Augmentative Mi-Says Communication Systems for Children with Intellectual Disabilities	Android technology for people with disabilities can be used as an alternative and augmentative form of communication	[62]
5.	Multimedia Development of Android Based Mathematics Learning in Elementary School Students	completeness of student learning outcomes after using multimedia Mathematics learning is very good, so its application has a positive impact on student learning outcomes.	[63]

2. Literature Study

2.1 Android Based Technology

The use of mobile devices such as smartphones or tablets is a technology that is very close to students today. One technology that needs to be utilized is creating Android-based media in learning activities [64]. Android-based applications are one of the technological innovations that can be used to assist the learning process [65]. It is hoped that the existence of Android-based learning media will encourage students to learn more independently and according to their abilities.

2.2 Game-based learning

Game-based learning uses digital games as a medium for teaching, so students can better understand what they are learning. According to Ge and Ifenthaler [66], the term game-based learning refers to the use of video games and elements related to game reality, content, subjects, and images in the learning process. Game-based learning uses technology such as computers, cell phones, and online applications [67]. A game-based learning approach refers to the use of games, game interactions, and game design to motivate students to engage in classroom activities [68]. Ebner & Holzinger [69] game-based learning allows students to be involved in solving problems and encourages active learning in the context of games. Game-based learning is one of the learning innovations. Games can be developed in the form of technology such as game-based learning.

2.3 Development of technology-based learning media

Currently, the use of ICT is increasingly widespread in the fields of education, administration, economics, business, and so on. Likewise, in the world of education, the use of ICT is an initiative to facilitate the implementation of learning. At the same time, it is an effort to disseminate or obtain information more widely. Mastering ICT is an effort by educational staff as a form of awareness to optimize the use of technology in assisting the learning process. The progress of ICT is currently having a positive impact on the world of education, teachers, students, and education staff can obtain information related to learning more easily.

Currently, the role of learning media is very urgent and important in increasing the effectiveness of learning. The teaching and learning process in schools always has the aim of achieving certain expectations. To achieve certain expectations the teaching and learning process needs to be meaningful for students. Learning media is anything that is used as an intermediary or liaison from the provider of information, namely the teacher, to the recipient of the information or students to stimulate students to be motivated and able to participate in the learning process completely and meaningfully. This means that there are five components in the definition of learning media, including:

(i) As an intermediary for messages or materials in the learning process

(ii) As a learning resource.
(iii) As a tool to stimulate students' motivation to learn.
(iv) As an effective tool to achieve complete and meaningful learning outcomes.
(v) Tools for acquiring and improving skills.
(vi) These components collaborating well will have implications for the achievement of learning following the expected targets.

Learning media has become a part that can provide meaningful experiences in the learning process. In general, learning media functions as a communication tool in the learning process. It is part of the overall instructional system. Several criteria should be considered in choosing media, according to the objectives to be achieved, appropriate to support lesson content which is facts, concepts, principles or generalizations, practical, flexible and sustainable, the teacher is skilled in using it, and target grouping. According to Winkel in Rahma [70], several general criteria need to be considered when selecting media. However, theoretically, each media has advantages and disadvantages that will influence the effectiveness of the learning program.

Learning Media is a tool used to demonstrate certain facts, concepts, principles, or procedures thus they appear more real/concrete. These tools are intended to provide more concrete experiences and motivate as well as increase students' absorption and memory in learning. Media can foster students' positive attitudes towards the material and learning process. The learning process becomes more interesting if the right media is used thus students are motivated to love the science they are studying. A teacher can be effective and efficient in presenting lesson material if he can use the media well and appropriately [71].

Along with the development of the times, knowledge, and technology, learning media has also experienced development and progress. This means that there are many types and variations of learning media along with the times and advances in knowledge and technology. The use of technology in learning is very necessary in terms of designing, analyzing, evaluating, developing, and dimensionalizing material in the learning process. According to Torrente, game-based learning is the use of games with serious goals (i.e. educational goals), as a tool that supports the learning process significantly. There are several benefits of using games in learning, including [72]:

(i) Motivate and involve all students in learning.
(ii) Train students' abilities such as literacy skills and numeracy skills.
(iii) As a therapeutic medium to overcome cognitive difficulties.
(iv) Playing a certain role or profession before practicing in real life.
(v) Empowering students as producers of multimedia or game-based content [73].

Game-based learning is a game (game) that is deliberately created for educational purposes as a supporting learning medium because it is considered more interesting than conventional teaching and learning processes. Game-based learning is proven to be able to improve student achievement and support the educational process. This relates to the design used in educational games, which consists of animation, appropriate color selection, and interesting illustrations (objects) at each learning stage or each learning topic which is then applied to educational games [74].

2.4 Mathematics

Mathematics is a science that has an important role in human life. This makes mathematics has attracted tremendous attention for researchers, especially in education [75-98].

The ideas range from the most basic to the most sophisticated and are logical, methodical, and hierarchical [99]. Mathematics is a content of interrelated concepts, in its implementation basic concepts in mathematics are a prerequisite for higher mathematical concepts. Mathematics is the

science or knowledge about learning or logical thinking that humans need for life, which underlies the development of modern technology. Mathematics has an important role in various scientific disciplines and advances human thinking. Mathematics is seen as learning material that must be understood as well as a conceptual tool for constructing and reconstructing this material, honing and training the thinking skills needed to solve problems in life. Learning mathematics can improve students' abilities to think logically, analytically, systematically, critically, and creatively. These competencies are needed thus students can obtain, manage, and utilize information to survive in conditions that are always changing, full of uncertainty, and competitive. According to Dali S. Naga [100], arithmetic or counting is a branch of mathematics that deals with the nature of the relationship between real numbers and calculations, especially regarding addition, subtraction, multiplication, and division. In short, arithmetic or counting is the knowledge of numbers. Figure 2. Explaining material in mathematics according to Dali S Naga seen from the content of the material in the form of a spiral which consists of 3 aspects, namely:

(i). Arithmetic/Algebra, consisting of numbers and computing.
(ii). Geometry, consisting of flat planes and space planes.
(iii). Measurements consist of length, circumference, area, contents, weight, and time.

The way of teaching in mathemetics can be divided into two aspects:

(i). Quantitative dimension, consisting of understanding concepts and skills.
(ii). Qualitative dimension, consisting of problem solving.

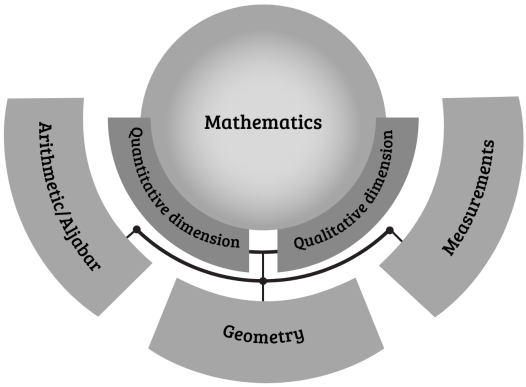


Fig. 2. Mathematics material according to Dali S. Naga [100}

2.5 Components in Mathematics

Mathematics has several components that are studied in elementary school. Figure 3 shows that mathematics has 5 components, including classification, comparing, sorting, symbolizing, place value, and arithmetic operations (addition, subtraction, multiplication, and division).

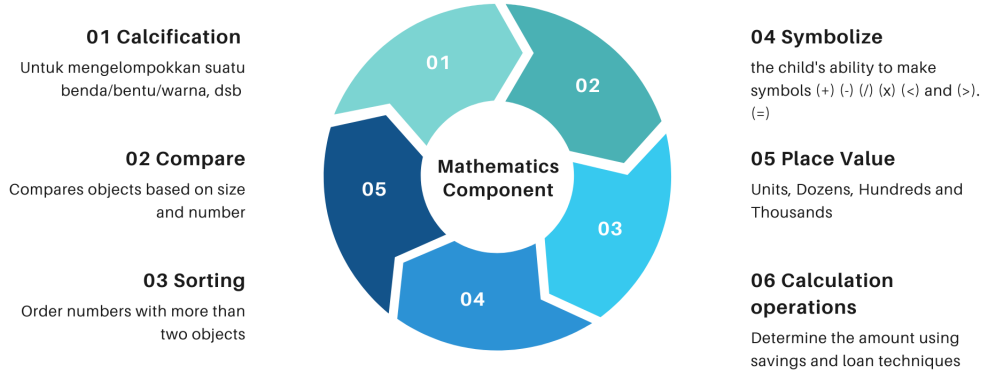


Fig. 3. Mathematical components

(i). Grouping (Classification) is the child's ability to group objects/shapes/colors, etc. Example: grouping based on star and round shapes.
(ii). Comparing (Comparison) is the ability to compare objects based on size or number.
(iii). Sorting (Seriation) is the ability to sort objects from smallest to largest, tallest to shortest, etc.
(iv). Symbolizing (Symbolization) children's ability to create symbols, Table 2. for example; + sign (Addition), – sign (Subtraction), / sign (Division), x sign (Multiplication), < sign (Less than), > sign (more than), = sign (Equal to).

Table 2
Mathematical symbols

Symbol	Symbol name
+	Addition
-	Subtraction
×	Multiplication
÷	Distribution
>	More than
<	Less than
=	Together with

(v). Ability to Determine Place Value. The numbers on the left have a greater value than the numbers on the right. Table 3. Place values relate to the place values of ones, tens, hundreds, and thousands.

Table 3
Place value

Number	Thousand	Hundreds	Dozens	Unit
1473	1	4	7	3

(vi). Ability to Perform Addition and Subtraction Operations. Figure 4. determines the addition operation using saving techniques. Figure 5 shows reduction using borrowing techniques.

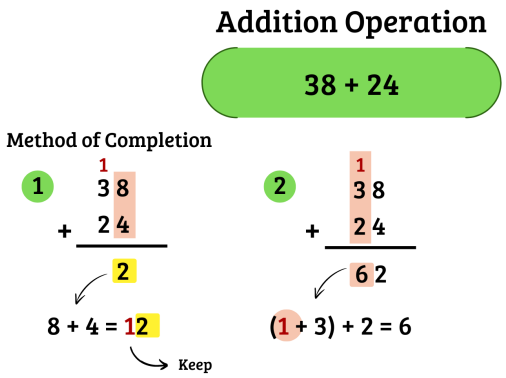


Fig. 4. Addition using saving techniques

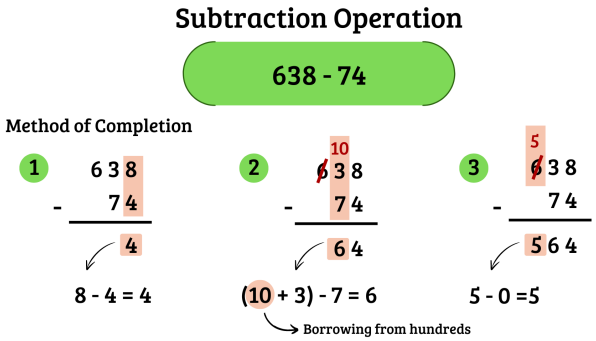


Fig. 5. Reduction using borrowing techniques

(vii). Ability to Understand the Concept of Multiplication and Division. Figure 6. Determines the multiplication calculation operation and Figure 7. Determines the division calculation operation.

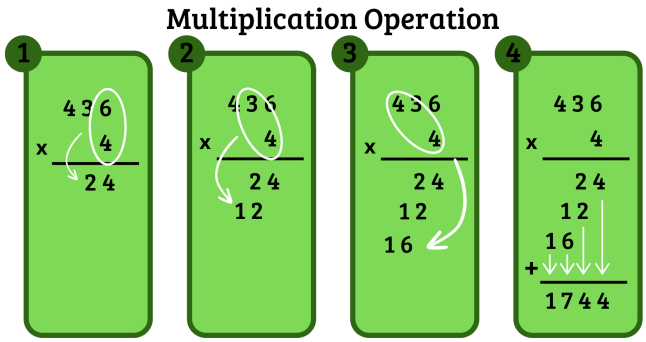


Fig. 6. Multiplication calculation operation

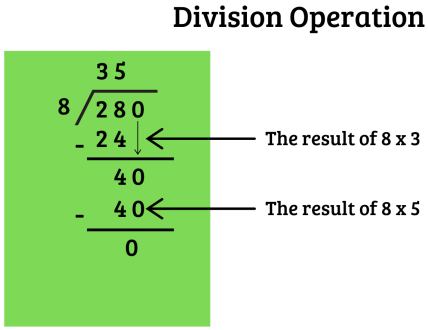


Fig. 7. Division calculation operation

The above mathematics learning abilities are related to each other. Thus, students can understand the concept of multiplication and division, students need the basic ability to group and carry out arithmetic operations of addition and subtraction, this is because each mathematics material is a prerequisite for the next mathematics material [101]. According to the Ministry of Education and Culture (2023) shown in Table 4, mathematics is organized into 4 content elements (at the elementary school level) namely as follows:

Table 4
Mathematics content elements according to the Ministry of Education and Culture

Element	Description
Number	The field of Number studies discusses numbers as number symbols, the concept of numbers, number counting operations, and the relationship between various number counting operations in the sub-elements of visual representation, sequence properties, and operations.
Aljabar	The field of Algebra studies discusses non-formal algebra in the form of picture symbols to formal algebra in the form of letter symbols that represent certain numbers in the sub-elements of equality and inequality, number relations and patterns, as well as ratios and proportions.
Measurement	The field of study of Measurement discusses the magnitude of measurement quantities, how to measure certain quantities, and proving principles or theorems related to certain quantities in the sub-elements of measuring geometric and non-geometric quantities.
Data Analysis and Opportunities	The field of study of Data Analysis and Opportunities discusses the meaning of data, types of data, data processing in various forms of representation, and quantitative data analysis related to the concentration and distribution of data as well as the opportunity for certain data or events to appear in data sub-elements and their representation, as well as uncertainty and opportunity.

The objectives of mathematics learning in elementary schools consist of several components including; (1) Perform arithmetic operations of addition, subtraction, multiplication, division, and mixed operations, including those involving fractions. (2) Determine the properties and elements of various flat shapes and simple geometric shapes, including the use of angles, perimeter, area, and volume. (3) Determine the properties of symmetry, congruence, and coordinate systems. (4) Using measurements: units, unity between units, measurement estimates. (5) Determine and interpret simple data (measure, average, mode, collect it, and present it [102]. Referring to the objectives of mathematics learning in elementary schools, the most basic ability needs to be mastered, namely the ability to do arithmetic operations.

Having skills in arithmetic operations certainly requires more basic abilities, namely the ability to place value as a prerequisite. Place value is an important concept in mathematics that influences various aspects of problem-solving and mathematical achievement. The place value of a number is the value of the ones, tens, hundreds, and so on. Place value starts from units as the smallest number (i.e 1 to 9), tens (i.e 10 to 99), hundreds (i.e 100 to 999), and so on [103]. A strong place value concept should be introduced formally in the first grade of elementary school to help students expand their place value knowledge that the value of a number can be derived in various arithmetic operations in subsequent grade levels. For example, to understand decimal numbers in grade 6 of elementary school requires an understanding of place value that has been mastered in grade 2 of elementary school [104]. Understanding place value in the number system is a modality for students to develop the ability to calculate arithmetic operations on symbolic representation of numbers [105]. Students develop the meaning of place value as they understand positions in numbers. Knowledge of place value is very important for understanding grouping, understanding numbers, and making calculations, for example in arithmetic students need an understanding of the place value system and an understanding of numerical quantities [106]. In line with this opinion, Lambert & Moeller [107] stated that place value is an important initial competency for subsequent arithmetic skills along with other basic numerical competencies.

2.6 Misconceptions of Mathematical Thinking

Mathematics is a subject taught at every level of education, but errors in mathematical concepts are still often experienced. Mathematical concept errors are caused by students' lack of understanding in learning the concept of arithmetic operations and mathematical relations.

Mathematical misconceptions can also take the form of errors in applying a rule or inappropriate generalizations [108]. When students show incorrect reasoning and take shortcuts that hinder the development of mathematical concepts, it is a sign that they have misconceptions [109]. Mathematics has qualitative and quantitative dimensions, conceptual errors can occur in these two dimensions. Mathematical conceptual errors in the qualitative dimension include solving story problems as stated by Ndek *et al*., [110] (shown in Table 5), including conceptual errors, procedural errors, and technical errors.

Table 5
Mathematical conceptual errors in the qualitative dimension

Indicator of Student Error Types	
Conceptual error	Errors in determining the formula to answer the problem Don't write formulas to answer problems
Procedural error	Not writing down the problem-solving procedures correctly Do not write final conclusions
Engineering error	Errors in calculating multiplication, division, subtraction, and addition operations Errors in writing variables and constants

Technical errors in performing the arithmetic operations in point (a) are often found in the arithmetic operations of addition, subtraction, multiplication, and sequential division (see Figures 8 and 9).

Figure 8 shows misconceptions about the arithmetic operation of adding two numbers (tens) and one number (ones) using a one-time storage technique. Students misunderstand how to add using saving techniques. The way students add 4 + 7 = 11 is correct, but students do not understand how to write place value and addition correctly. Students only write the arithmetic operation 4 + 7 = 11 directly without adding the tens and tens units to the ones. The misconceptions experienced by students are caused by students not understanding the place value of tens and ones.

In Figure 9, the student had a misconception regarding the operation of subtracting the number zero, where the student says that 500 – 125 = 425, then he also explains that "In my opinion 0 – 5 = can't, because 0 doesn't exist, sir, keep subtracting 5, if you want to borrow the front it will also be 0, so the answer is 5 sir. Then 0 – 2 = 2, and 5 – 1 = 4". The solutions made by students in arithmetic operations are erroneous due to students' lack of mastery of the concepts of place value of units, tens, fractions, and thousands [111].

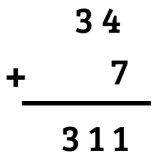


Fig. 8. Error in the addition calculation operation

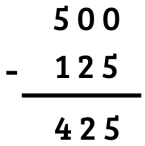


Fig. 9. Error in the subtraction arithmetic operation

Sujarwo *et al*., [108] in their research revealed that conceptual misunderstandings in carrying out whole number addition operations using the one-time saving technique for adding two numbers

with one digit and two numbers with two-digit numbers were found because children did not understand the concept of exact values. Students' misunderstandings in solving problems in arithmetic operations are usually caused by basic arithmetic operations concepts that have not been mastered. This is because the concepts that children have do not match the concepts they should have [112-114].

As indicated by Subanji and Mulyoto in Rahmawati *et al*., [115], Table 6 shows that there are 5 errors in understanding mathematical concepts with several indicators in them.

Table 6
Indicators of errors in understanding mathematical concepts

Error type	Error indicator
Conceptual error	a. Error determining a theorem or formula to answer a problem b. The use of theorems or formulas by students is not following the prerequisite conditions for the application of these formulas or they do not write down the theorems
Data usage errors	a. Not using data that should be used b. Error entering data into a variable c. Adding data that is not needed to answer a problem
Language interpretation errors	a. Errors in expressing everyday language in mathematical language b. Mistakes in interpreting symbols, curves, graphs, and tables into mathematical language.
Technical problem	a. Calculation or computing errors b. Errors in manipulating algebraic operations
Errors in drawing conclusions	a. Melakukan penyimpulan tanpa alasan pendukung yang benar b. Melakukan penyimpulan pernyataan yang tidak sesuai dengan penalaran logis.

Mistakes in mathematical concepts can also be caused by the stages of mathematical development in learning mathematics experiencing problems that cannot be resolved. Problems that are not resolved can cause the development of mathematics learning to not be completed perfectly. Among them, the concrete stage in the learning process uses real objects as a medium for solving mathematical problems in learning. Concrete media has been proven to increase students' motivation and achievement in learning mathematics. The semi-concrete stage is where students' knowledge is built using visual media which can be presented through a set of images to provide information. Figure 10 shows the semi-concrete stage which emphasizes efforts to develop associations between visual models and symbolic processes. The abstract stage of learning mathematics already uses number symbols to solve mathematical problems. Students have the ability in the abstract stage if the concrete and semi-concrete stages can be passed without obstacles.

Fig. 10. Example of a semi-concrete stage in mathematics

3. Method

3.1 Research Subjects and Locations

This research was located at an elementary school providing inclusive education in Bandung Regency, West Java. The subject in this research was a third-grade elementary school student. The subjects in this study had learning obstacles in mathematics regarding place value and arithmetic

operations. The material on place value and arithmetic operations is related to each other because to master arithmetic operations students need to have basic skills in exact values.

3.2 Research design

This research was designed using a Design-Based Research (DBR) approach or research-based design to develop game-based learning media. Figure 11. Contains procedures in this research containing four research stages including problem identification and analysis, designing game-based learning media, developing learning media, and reflection to obtain game-based learning media.

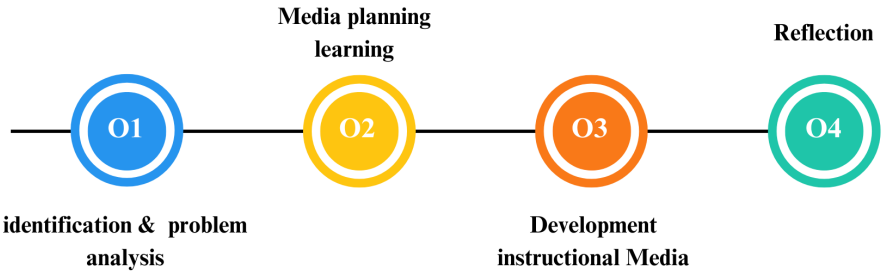


Fig. 11. Research Flow

The first stage contains problem identification and analysis based on the students' objective conditions obtained based on the results of the assessment which contains a profile of the students' abilities, obstacles, and needs. Analysis of the results of interviews and observations of children, parents, and teachers as a complement thus the data obtained is comprehensive. The first stage is equipped with analysis for solutions to overcome children's learning obstacles and analysis of student potential. The second stage contains the design of learning media as a solution to children's learning obstacles and the children's potential. The design of this learning media is based on the results of an analysis of problems and opportunities to overcome obstacles to student learning. The third stage is the stage of developing learning media based on the designs in the second stage. This stage develops the learning media design into a game-based learning media application to overcome learning obstacles for students as the final goal of this research. The fourth stage is the reflection stage to improve game-based learning media which has been designed through discussions with experts in the field of learning and learning media.

4. Results and Discussion

This research was conducted in schools that provide inclusive education in Bandung Regency. The results of the assessment concluded that the subject experienced student barriers to learning mathematics. Indicators of learning difficulties among students are that students are unable to master the lesson material within the allotted time. This is following the assessment results which show that there are many learning outcomes in numeracy in class 3 that the subject has not been able to master. According to Kohli [114], a student with arithmetic disorders may experience difficulty in organizing problems on numbers, following through on multi-step calculations such as long division; and using calculation signs learning difficulties can be divided into two types, caused by internal factors (including IQ, students' attitudes towards learning, learning motivation, physical

health, and sensory abilities) and external factors (including teacher variations in teaching, use of learning media, school infrastructure, and family environment) [116].

4.1 Results of Problem Identification and Analysis

Student characteristics can be explored through the assessment stage. Assessment of Children with Special Needs is a systematic (or regular) as well as comprehensive process for studying problems further to determine problems, obstacles, advantages, and individual needs [117]. The assessment was carried out to obtain a profile of abilities, obstacles, and needs as well as how the intervention service program is for children with hearing impairments thus the program will support children's development optimally [118-119]. Assessment of the subject is carried out on three components of academic learning, namely reading, writing, and arithmetic with material at each level of elementary school education (Class I, II, and III).

The numeracy skills of grade 3 elementary school students ideally fulfill four elements, namely numbers, algebra, measurement, and analysis of data and opportunities. This numeracy development is provided in the curriculum of each level of education [120]. Findings in the field show that the current objective condition of students in grade 3 elementary school is included in the frustration level group with a score of 1% so it is followed up with a numeracy assessment process. Table 7 shows the results of the 2nd grade elementary school numeracy assessment on the subject which is still included in the frustration level group with a score of 39%. Table 8. Further efforts by conducting an assessment in class 1 of elementary school, the subject is included in the independent level group with a score of 96%. The results of the assessment of the subjects found that there was a gap in the numeracy aspect, namely in the 2nd-grade elements of elementary school.

Table 7
Subject assessment results in grade 2 mathematics

No.	Element	Score
1.	Number	39%
2.	Aljabar	50%
3.	Measurement	50%
4.	Geometry	0%
5.	Analyze data and opportunities	60%
Total score		39% (frustration level)

Based on the results of the numeracy assessment in class 1 material, the subject received an overall score of 96%, which means the subject was included in the independent-level group. The details of the quantitative numeracy assessment results are as follows:

Table 8
Subject assessment results in grade 1 mathematics

No.	Element	Score
1.	Number	100%
2.	Aljabar	100%
3.	Measurement	87.5%
4.	Geometry	100%
5.	Analyze data and opportunities	100%
Total score		96% (independent level)

After identifying the material in class 3 which shows that the child is at the instruction level (quantitative value 1%), then an assessment is carried out by reducing the material in class 2 to determine the prerequisite abilities. The results of the quantitative assessment show a score of 33%, which means that many children still have not mastered the material in class 2. With an accumulated score of 17% in the number element, 50% in the algebra element, 50% in the measurement element, 0% in the geometry element, and 60% in data analysis elements. Then a further assessment was carried out with a reduction in material in class 1, which showed that the child had mastered almost all the numeracy material in class 1 with a quantitative score of 96%. Thus, from these results, the assessor decided to further analyze the results of the child's assessment in class 2 and determine the priority scale for the material that the child must master.

Based on the results of the assessment carried out by the assessor team, the subject experienced the most severe difficulties in the academic aspect of numeracy among other academic aspects. One of the indicators of learning difficulties among students is that students are unable to master the lesson material within the allotted time. This is following the assessment results which show that there are many learning outcomes in numeracy in class 3 that the subject has not been able to master. According to Kohli *et al*., [114], a student with arithmetic disorders may have trouble in organizing problems on numbers, following through on multi-step calculations such as long division; and using counting signs. They may also be confused about operations and basic facts. According to [121], students who have difficulty learning numeracy have several characteristics. Students with learning difficulties often make mistakes in learning arithmetic, mistakes in learning geometry, and mistakes in solving word problems. Following the results of the assessment, the subject had difficulty in determining the place value of hundreds and thousands, was not able to perform addition operations using saving techniques and subtraction using borrowing techniques, was unable to perform multiplication and division calculation operations as well as determining the parts of cubes and blocks.

Furthermore, a fundamental problem was discovered, namely that children had difficulty in determining the place value of hundreds and thousands, children were not yet able to carry out addition arithmetic operations using saving techniques and subtraction using borrowing techniques. This is the reason why children are not able to master the material at the next stage, namely in grade 3 of elementary school. The cause of learning barriers that occur in children based on observations during the assessment is that children have a low attention span and often do not complete their assignments. Thus, some material is not mastered by the child. However, in some conditions, children can focus and complete the task well, namely if the problem they are working on looks interesting, such as there are pictures and colors (semi-concrete), if the child doesn't understand he has the initiative to ask so he can solve the problem. In contrast to questions that only consist of numbers and ordinary writing, children will refuse to do them and immediately leave their seats.

The results of the analysis carried out showed that the subject needed a treatment/intervention program to overcome his learning obstacles. The intervention program provided needs to consider the positive potential of the environment and/or the potential of the subject. The potential of the subject includes a connection to the automotive world, especially buses. The interest in this subject is based on the results of very in-depth observations based on the results of interviews, including the subject knowing the aerodynamic function of buses which is related to vehicle airflow which has an impact on fuel efficiency, stability, and noise. Subjects also mentioned other terms and functions of the chassis, chassis, and routes of each bus and even specific accidents for each bus (when, where, and why).

The results of further observation and interview analysis found that the subject had an interest in the world of digital games. Subjects are interested in digital games with various simulation content

(war content, cooking, puzzles, and others). The subject is facilitated by gadgets by parents as a means of communication and entertainment. The results of interviews with students' parents found that giving gadgets to children was not only for communication and entertainment, but the subjects enjoyed learning via YouTube.

Based on the results of the assessment analysis, it was found that the subject had characteristics that required intervention to overcome learning obstacles. Subjects need to learn in-place value, which results in a lack of skills in performing arithmetic operations using savings and loan techniques. The subject has several interests to develop into a solution to overcome barriers to learning, including students having an interest in public transportation (buses), an interest in digital games, parents facilitating gadgets, and liking forms of learning with the help of semi-concrete or pictures. Some of these potentials can be used as a basis for designing learning and game-based learning media as intervention tools.

4.2 Learning Media Design

Learning media needs to be developed and completed according to student's needs with the aim that media as a learning tool will be appropriate. Science and technology-based learning media can be developed through Android-based technology. Learning media using Android-based technology can be used as an alternative to increasing student interest and learning outcomes [122]. Media can foster students' positive attitudes towards the material and learning process. The learning process becomes more interesting if the right media is used thus students are motivated to love the science they are studying. A teacher can be effective and efficient in presenting lesson material if he can use the media well and appropriately [123]. Media is essentially a component of the learning system. As a component, media should be an integral part and must be following the overall learning process. Exercises and simulations through educational games can trigger certain skills, knowledge, and attitudes in students [124]. Vanbecelaere *et al*., [125] assume that digital educational games can have a positive impact and a good impact on student's academic knowledge, for example in reading and mathematics. Interventions using digital learning media in mathematics learning provide positive effects for students with and without disabilities [126].

The development of learning media developed in this research is based on the results of student assessments and analysis of their potential. This learning media is designed using game-based learning technology with procedures for its use as shown in Figure 12. This is a game-based learning media design based on the results of needs analysis and the results of theoretical analysis.

The flow chart in Figure 12 above illustrates the flow of using game-based learning. This application consists of two large contents, namely place value and arithmetic. The formulation of these two contents is based on the results of an assessment of student needs and theoretical analysis that the concept of place value is a prerequisite for arithmetic as stated by Lestari [127] that before students learn number operations, teachers must teach students the concept of place value correctly. Understanding the concept of place value becomes the basis for further mathematical concepts. Place value is an important initial concept in improving basic mathematical understanding [128].

The flow in this game starts with the start button, on the start page material on place value and arithmetic will appear, however, the arithmetic material cannot be accessed by the child before the child completes the final evaluation stage on the place value material. Each level is determined based on Bloom's cognitive theory, namely C1, C2, and C3. In the latest version of Bloom's taxonomy, the cognitive process dimension has six processes from the simplest to the most complex, namely remembering, understanding, applying, analyzing, evaluating, and creating [129].

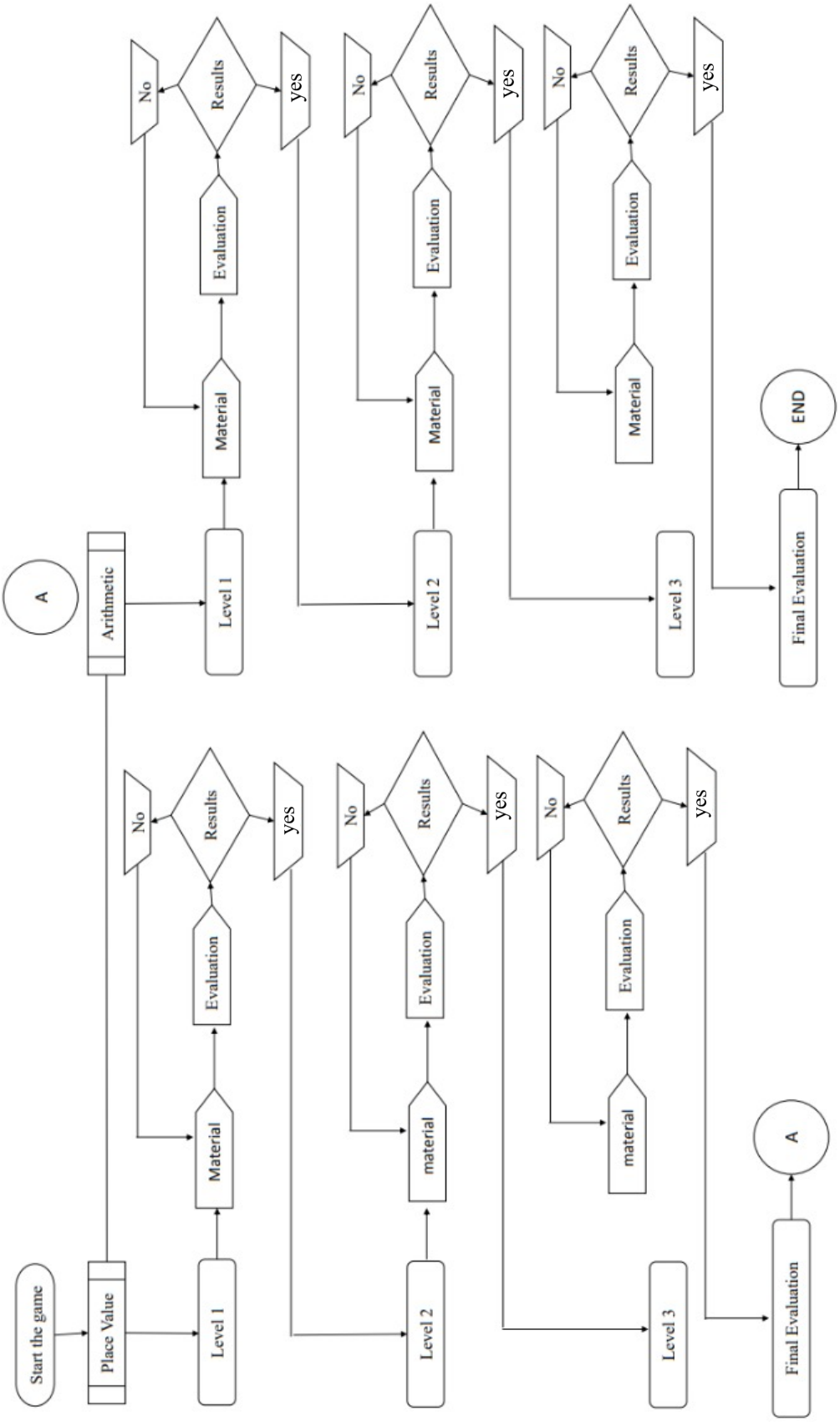


Fig. 12. Flow chart game-based learning

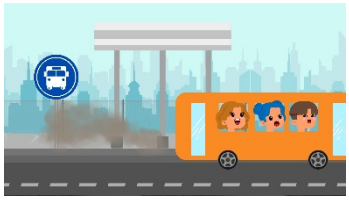
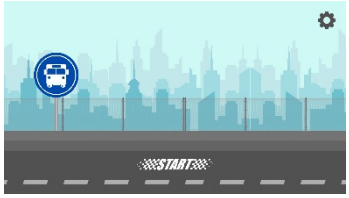
The place value material consists of three levels and one final evaluation. Each level contains an explanation of the material and the evaluation. If the child can complete the evaluation with a score of at least 80, the child can access the next level. If the child's score is less than 80, the child will repeat the learning material and re-do the evaluation. The level 1 game flow is repeated at levels two and three in the final evaluation containing practice questions from levels one to three without explanation of the material to ensure children have skills in the concept of place value. To access material on number operations, children are required to meet the minimum criteria, namely 80.

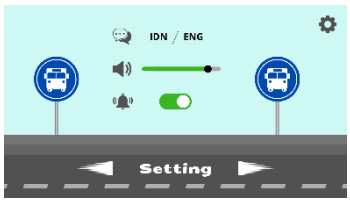
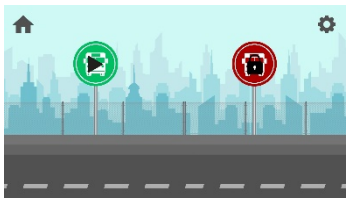
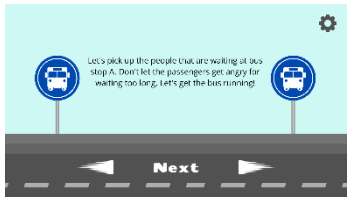
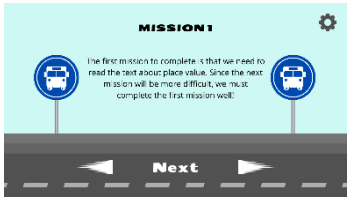
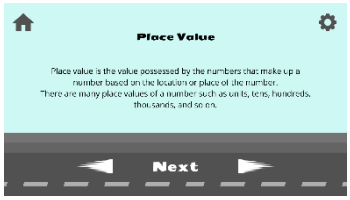
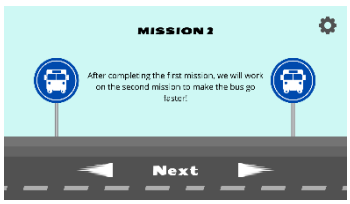
4.3 Development of Learning Media

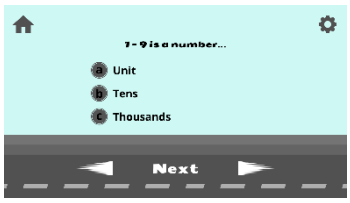
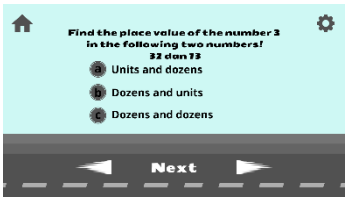
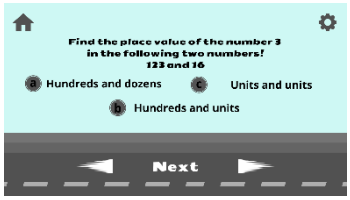
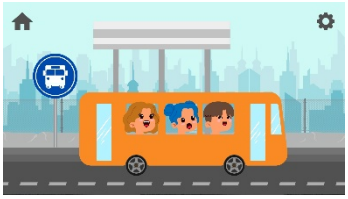
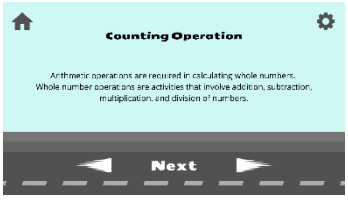
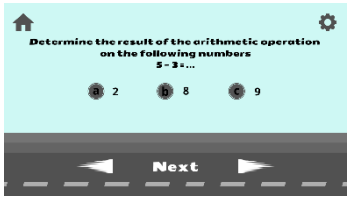
The development of learning media was developed from the results of an analysis of student learning needs. Table 9 explains the learning media on public transportation themes according to student regularity. The media developed consists of two interrelated contents, namely place value content as a basic ability to master arithmetic operation skills. Students need to complete challenges from each level in the value content to access challenges in the arithmetic operations content, this rationale corresponds to the stages of mathematical concepts. students can understand the concept of multiplication and division, students need the basic ability to group and carry out arithmetic operations of addition and subtraction, this is because each mathematics material is a prerequisite for the next mathematics material [101]. This game has a storyline of a bus driver who has problems with the speed of his bus so that bus passengers are often late at their destination. To overcome this problem, the bus driver asked passengers for help to complete the mission (materials and evaluation) so that the bus speed could be faster.

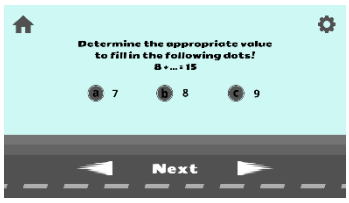
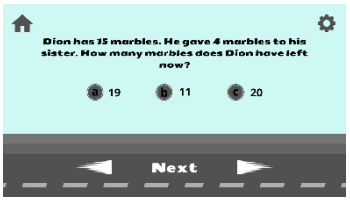
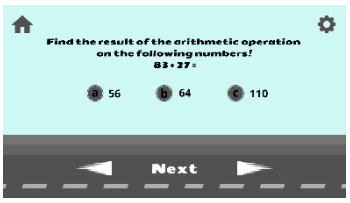
Place value content consists of three levels. Day 1 contains material and evaluation to remember the concept of place value, day 2 contains material and levels to understand the concept of place value, and day 3 contains material and evaluation for applying the concept of place value in daily life. Meanwhile, day 4 only contains a collection of evaluations from day 1 to day 3. After all challenges on place value have been completed, students can access the content of the arithmetic operation. Day 1 contains material and evaluation to remember the concept of arithmetic operations, day 2 contains material and levels to understand the concept of arithmetic operations, and day 3 contains material and evaluation for applying the concept of arithmetic operations in daily life. Meanwhile, day 4 only contains a collection of evaluations from day 1 to day 3.

Table 9
Development of learning media

Game-based learning media application	Description
	The initial display of the learning application when you first open the application.
	The learning application menu page display contains 1 start button and 1 setting button.

	On the settings page, several features are filled the buttons are connected to the destination desired. For example, language, audio, and notification features.
	Click the start button on the menu page to enter the game. On the game page, there are 2 levels. The game starts from level 1 which is symbolized by a green sign.
	On the plan page, 4 levels must be completed.
	Click the green button, and then a narrative about this game will appear.
	There are also conversations between passengers and drivers regarding problems in this game.
	There is a first mission that must be passed to solve the problem.
	The first mission contains material regarding place value.
	After completing the first mission, the second mission will appear, which is about practice questions.

	On the first day, 4 practice questions regarding place value. The question level is at level C1.
	On the second day, 10 practice questions regarding place value. The question level is at level C2.
	On the third day, 10 practice questions regarding place value. The question level is at level C3.
	On the fourth day, 15 practice questions regarding place value. The question levels are at levels C1, C2, and C3. This level is an evaluation.
	After completing the mission, the bus can walk to the bus stop.
	On the floor plan, page 4 levels must be completed.
	The first mission contains material regarding arithmetic operations.
	On the first day, 10 practice questions regarding arithmetic operations. The question level is at level C1.

	On the second day, 10 practice questions regarding arithmetic operations. The question level is at level C2.
	On the third day, 10 practice questions regarding arithmetic operations. The question level is at level C3.
	On the fourth day, 15 practice questions regarding arithmetic operations. The question levels are at levels C1, C2, and C3. This level is an evaluation.

5. Conclusion

The development of educational games and learning media using Android-based technology on arithmetic material for children with barriers to learning mathematics is the aim of this research. This research uses a research design (DBR) to collect comprehensive data regarding the analysis of student learning difficulties and the creation of game-based learning media. A child who has difficulty learning arithmetic material is the subject of this research. This research reveals that Android-based technology can be used to develop game-learning media for children who have difficulty learning arithmetic. The content contained in game-based learning media has been adapted to the needs of children who face difficulties in learning arithmetic material. Material that is tailored to your needs will be very suitable for the learning development of children who face difficulties in learning arithmetic material. The results of this research indicate that teaching game media using Android-based technology can increase students' need to learn about mathematics material. It is hoped that this game-based learning media can also be useful for children who face learning difficulties. They can also be useful for other children learning mathematics and arithmetic material.

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