Stimulation of Cognitive and Psychomotor Capability by Game-Based Learning with Computational Thinking Core

Andriyani

Universitas Ahmad Dahlan, Indonesia

andriyani@mpmat.uad.ac.id.

Abstract: Cognitive and psychomotor capabilities are two critical interrelated abilities to improve student learning outcomes. Both abilities play a role in understanding new information and developing fine motor skills. Hence, schools train students these two abilities to equip them with basic skills in solving mathematical problems such as basic arithmetic. However, few previous studies have not much discussed the design of learning strategies which successfully integrate these two capabilities. Moreover, these studies only focus on calculations in arithmetic operations, not the conceptual understanding of operations. Therefore, this study aims to describe the development of learning media designs that accommodate student activities through game-based learning to stimulate cognitive and psychomotor capability in conceptual arithmetic operations, especially multiplication. Core computational thinking integrated with interactive game-based learning was used as the learning framework. The research method was called ADDIE comprising five stages of development with data collection techniques of questionnaires, student responses, and tests. Results show that according to experts and students, game-based learning media are valid and practical correspondingly. From the students' responses, it is known that the development of game-based learning can stimulate cognitive and psychomotor capability to solve contextual problems that were previously becoming obstacles for students.

Keywords: Cognitive, Computational-Thinking, Game-Based Learning, Psychomotor

INTRODUCTION

Cognitive and psychomotor capabilities are essential components in student learning and development which are also challenges for educators and experts in education. According to Begam and Tholappan (2018), a person's cognitive ability refers to his thinking/mental process continuity. This cognitive process involves acquiring, processing, and applying knowledge, including attention, memory, reasoning, understanding, and problem-solving. On the other hand,

according to Simpson (1972), psychomotor capability refers to students' physical movement skills, including coordination, agility, and fine motor skills, that require practice with measurements based on aspects of speed, accuracy, procedures, and implementation techniques. With this psychomotor capability, students explore phenomena, conceptualize the ideas involved, and apply concepts to new situations (Karplus & Butts, 1977). In the context of learning with abstract objects such as mathematics, the processes contained in this psychomotor ability are interpreted by gaining direct experience and providing opportunities for students to manipulate objects and tools. More clearly, Piaget (1929) claims that students' physical experience in learning mathematics could be obtained by giving students opportunities to explore mathematical concepts through the concrete physical experience before moving on to more abstract representations. These experts generally show that cognitive and psychomotor capabilities play a significant role in learning mathematics, especially in active exploration and reflection activities.

In the midst of this significant role, educators have the main challenge of identifying and overcoming differences in individual cognitive and psychomotor capability. Given the unique differences in the nature and characteristics of these two abilities, educators need to provide personalized instruction and support to meet the learning needs of each student. In addition, educators also need to find strategies to help students develop their cognitive and psychomotor capabilities on an ongoing basis. This requires teachers' focus on creating interesting and challenging learning experiences for students to follow. Teachers need to design lessons that can stimulate these two capabilities, especially in solving real-world problems. Stimulus in problem-solving needs to be accompanied by providing opportunities to train students' physical skills in direct practical activities. Moreover, the corona virus pandemic that hit the world last year has an impact on reducing the level of students' active involvement in learning and their study results (Haryani & Hamidah, 2022; Onyema et al., 2020; Orlov et al., 2021).

A decrease in student learning involvement can also be caused by a lack of their intrinsic or extrinsic motivation (Fatimah & Saptandari, 2022) because there is a reasonably close relationship between the two (Saeed & Zyngier, 2012). This involvement affects students' academic outcomes (Finn & Zimmer, 2012). Hence, an effective learning strategy is needed to increase student learning motivation, such as digital game-based learning, which also functions to encourage students' willingness to learn and self-awareness in both formal and informal learning contexts (Owston, 2009; Yang & Chen, 2010; Yien et al., 2011). This positive implication raises a lot of attention given to the relationship between digital games and the education field (Chiang et al., 2011).

The variety of games implemented in learning makes the development of game application models more adaptive and flexible as learning media based on the material presented (Hays, 2005; Papoutsi & Drigas, 2016). Several studies on multiplication-themed educational games have been carried out, including research on Android-based arithmetic games by Amrizal and Kurniati (2016), mobile educational games for multiplication calculations based on the horizontal method

with Html 5 and Phone Gap by Ricky (2013), and designing learning game application for 3rd-grade math calculation operations using unity by Kristina and Talitha (2021). Those studies are related to developing educational games that contain multiplication calculations through fast multiplication counting activities.

In this study, a game-based multiplication concept learning will be designed with the help of digital game applications of which are accessible on Androids. Students are not only trained to count fast but also understand the concept of multiplication, of which the construction is formed from repeated addition. In learning arithmetic, students need adaptive skills, which involve functional academic skills in the basic operations of addition, subtraction, division, and multiplication (Polspoel et al., 2019). These adaptive skills are needed for everyday life because they involve communication, social life, work, and functional academic skills such as reading, writing, and arithmetic (Ainsworth & Baker, 2004; Hodapp, 2002). Thus, learning arithmetic requires both psychomotor and cognitive abilities, especially if arithmetic problems are in the context of students' everyday problems. However in fact, there are still many students who are afraid of learning mathematics because it is considered difficult and complex (Laurens et al., 2018).

The results of an initial study conducted by the researcher in November 2022 in three elementary schools in the Municipality of Yogyakarta and Bantul Regency show that grade III students still do not understand the concept of multiplication operations and often have difficulty solving contextual problems, especially multiplication abstraction which correlates with modeling problems and the procedure for solving it. Meanwhile, the teacher still uses the rote method to teach multiplication. Students' lack of understanding of multiplication often causes boredom, laziness, and a lack of interest in learning multiplication. This is similar to Thai and Yasin (2016) research on multiplication teaching methods. Therefore, we need alternatives in thinking processes and developing problem-solving strategies, including computational thinking (Wing, 2006).

Along with technological advances in recent years, computational thinking has become an important topic in various fields of life (Lindberg et al., 2019). Various countries have attempted to promote computational thinking education in schools, universities, industries, and government sectors (Lin et al., 2020). A large number of researchers attempt to identify students' computational thinking abilities. For example, research by Yadav et al. (2017) and Denning (2017) which investigated the development of computational thinking-based teaching guidelines for students; research by Shute et al. (2017) regarding the design of a model for assessing student computing learning outcomes; as well as research by Sullivan and Bers (2018) and P´erez-Marín et al. (2020) on computational thinking-based learning performance. These studies are clear evidence that computational thinking has become a basic skill needed in learning in this digital era.

Based on the problems experienced by students in learning the concept of multiplication operations above, the researcher considers it necessary and important to design game-based learning with the help of interactive learning media that can stimulate students' cognitive and psychomotor

capabilities. The developed interactive learning medium is a digital game filled with computational thinking core to help students understand the concept of arithmetic operations, especially multiplication. By integrating computational thinking cores, students learn to understand the concept of multiplication operations by solving contextual problems presented in the digital game.

LITERATURE REVIEW

Cognitive and psychomotor capabilities have an important role in the formation of adaptive skills, which are the main elements in the elementary school mathematics curriculum (National Math Panel, 2008) and play a fundamental role in solving more complex mathematical problems (Juliana & Hao, 2018; Prendergast et al., 2017). Therefore, teachers need to train these skills to students for mastery of mathematical concept, including the arithmetic concepts. Knowledge of basic arithmetic operation can be achieved if students understand the concept of operations and the links between operations (Rahman et al., 2017).

Cognitive skill is an ability related to a person's thinking activity in receiving, processing, and transmitting the information obtained (Basri, 2018; Darouich et al., 2017). Cognitive capability is often associated with acquiring information for the short term (Darouich et al., 2017), and the long term is seen as an adaptive function of humans to the cultural, social, and emotional environment (Anderson, 1994). In its development, this cognitive ability is significantly influenced by students' thinking activities (Basri, 2018). In mathematics learning, the completion of mathematical tasks is a basis for starting and practicing various students' mathematical thinking activities, including thinking about solving mathematical problems and understanding mathematical content so that the thinking operations that occur become parts of students' conceptual and procedural understanding (Swanson & Williams, 2014). Developing a person's cognitive abilities is directly related to developing psychomotor, social, affective, and adaptive skills.

Psychomotor skill is the ability to perform motor-physical movements related to learning outcomes in cognitive activity (Murrihy et al., 2017). Yet, the link between motor coordination and learning outcomes is largely neglected in the psycho-educational domain. The results of research related to this have been widely published, with the results of a statistically significant relationship between motor difficulties and academic achievements such as language, reading, spelling, and arithmetic (Archibald, L. & Alloway, 2008; Lopes et al., 2013). This shows that cognitive and psychomotor abilities are closely related to achieving meaningful mathematics learning goals. According to Vallori (2014), meaningful learning is signified by some important principles below:
(a) Open work enables all learners to learn;
(b) Motivation helps to improve the classroom environment, making learners interested in their tasks;
(c) Means must be related to the learners' environment;
(d) Creativity strengthens imagination and intelligence;
(e) Concept mapping helps learners to link and connect concepts;

(f) Educational curricula must be adapted by considering learners with special needs.

These six important principles show the need for teachers to employ fun learning strategies that can accommodate various characteristics of the student's environment so that students can receive complete information by associating new information with relevant concepts in students' previous cognitive structures. One effective and suitable learning strategy to implement is digital game-based learning (Owston, 2009; Yang & Chen, 2010; Yien et al., 2011). The implication of digital educational games is motivating users in a fun learning atmosphere (Kirriemuir & McFarlane, 2004). These educational games tend to arouse curiosity and challenge users to actively explore games until they feel happy when they can finish the game well so that students are motivated and enjoy learning through the games (Chen et al., 2007; Hong et al., 2009; Moon & Baek, 2009).

Games are designed with various systematic, visual, and kinetic activity loads to stimulate students' skills and awareness of specific knowledge (Besgen et al., 2015; Shuqin, 2012). Various student skills are oriented towards achievement by integrating games into learning, including learning basic mathematics. Through games, students are trained to make decisions by controlling objects in the game for a specific purpose designed in a system or program (Jason in Aprilianti et al., 2013).

Regarding the selection of learning strategies that can increase student learning motivation and develop the skills needed, the education system has integrated Information and Communication Technologies (ICT) especially to improve the quality of student learning in schools (Malik et al., 2017). By utilizing ICT, students can become active learners through dynamic and collaborative learning so that the interactivity and communication of learning increase. In addition, students are stimulated to use their ability to think logically, systematically, and skillfully when making the right decisions facing numerous different possibilities (Munir, 2014).

An alternative learning strategy that follows the achievement of this stimulus and has a wide area of application to solve problems is computational thinking approach (Malik et al., 2017). Furthermore, Malik et al. (2017) explain that in a computational thinking approach, instead of thinking like computers, students think about computing which includes the ability to: (1) formulate problems in the form of computational problems; and (2) develop a good computational solution in the form of an algorithm or explain why no suitable solution is found. According to Ioannidou (2011), the computational thinking approach contains the cores of (1) decomposition, or the ability to break down complex tasks into smaller, more detailed tasks; (2) pattern recognition, or the ability to recognize general similarities or differences which will later help in making predictions; (3) generalization of patterns and abstractions, or the ability to filter information to solve problems; (4) algorithm, or the ability to arrange steps to solve a problem; and (5) debugging, or checking and re-checking every step of problem-solving to ensure the process is correct. If it is incorrect, then exploring why the appropriate solution is not found is necessary.

METHOD

This study aims to describe the development of instructional media designs that accommodate student activities through game-based learning to stimulate cognitive and psychomotor capability in conceptual arithmetic operations. The research subjects were ten third-grade students from an elementary school in the District of Yogyakarta for the small class trial and 123 third-grade students from three elementary schools, two from Bantul Regency and one from the District of Yogyakarta, for the large class trial. A total of four classes were involved in the large class trial with the latter school consisting of two study groups. Data collection techniques consisted of test and non-test while data analyses included both quantitative and qualitative. Quantitative data analysis was carried out by calculating the mean score of students' tests, validation questionnaire, and student response. The mean score from the last two instruments were converted into the product validity and practicality category by referring to the criteria guidelines on five Likert scales: 'Not Good' for 1; 'Less Good' for 2; 'Good Enough' for 3; 'Good' for 4; and 'Very Good' for 5 (Widoyoko, 2018). The product was said to reach validity and practicality standards if it reached at least "Good" or score 4.

The procedure in this research consisted of an analysis stage, a design stage, a development stage, an implementation stage, and an evaluation stage, or latter abbreviated as ADDIE (Branch, 2009; Sugiyono, 2019). The researcher chose ADDIE model to develop learning media in digital games because it facilitated the construction of students' knowledge and skills in instructional guided learning plans. In addition, this model was also devoted to solving problems related to gaps due to students' lack of knowledge and skills. Furthermore, the ADDIE model contained generative processes by applying concepts and theories to a particular context.

At the analysis stage, the researcher identified the probable causes of incongruity/differences between learning outcomes and theories, concepts, or other learning problems in the multiplication concept material. Identification is based on experiences, preferences, abilities, and student motivation during learning. In addition, the researcher also identified the resources needed during the development process, including the curriculum, the concept of multiplication, the learning models or methods used, teaching materials, facilities, learning environment, technology, and the characteristics of the students involved during the development process. To determine the characteristics of the students at the research site, the researcher conducted written tests at three elementary schools to measure students' understanding of multiplication concepts presented through contextual problems.

At the design stage, the researcher designed a prospective product based on the analysis results of the previous stage and began by selecting the digital games with core computational thinking to stimulate cognitive and psychomotor capability. Next, the researcher prepared the initial design of the media by making a representation of the interactions between the system and its environment in the form of a diagram until it produces a product blueprint. At this stage, the researcher also formulated specific, measurable, applicable, and realistic learning objectives based on appropriate learning strategies.

At the development stage, the researcher developed an initial prototype according to the initial blueprint, including developing test instruments, validation questionnaires and student responses. Likewise, the initial prototype of the media was also validated by experts in the field of learning media and mathematics learning materials. Furthermore, the researcher revised the prototype by accommodating the validators' suggestion, from six validators in total, so the digital game was declared valid and ready to be implemented in both small and large classes.

At the implementation stage, the researcher formulated concrete steps to implement the previously designed learning system. The researcher initially tested the game product in a small trial to 10 third-grade students at an elementary school in the District of Yogyakarta. The try-out was carried out in three meetings, and then the researcher gave a response questionnaire to students as product users. The student responses served as inputs to revise the product. The researcher tested the product again on third-grade students from four classes at three elementary schools. Of the three elementary schools, two were located in Bantul Regency, and one was from Yogyakarta Municipality with two study group classes. To find out the responses of the large trial classes, the researcher distributed response questionnaires of which the results were used as a basis to determine the practicality of the game products.

At the evaluation stage, the researcher continuously evaluated and revised to reach final product. Evaluation was carried out through qualitative and quantitative data analysis. Based on the need analysis results at the first development stage, the researcher analyzed the quantitative data from the results of the test to find out the characteristics of the students regarding their understanding of the multiplication concept in contextual problems. The validation results at the development stage and field trials at the implementation stage were also analyzed. Qualitative data from input, suggestion, and expert criticism were interpreted as a basis for gradual revisions. Furthermore, a quantitative analysis of the validation and student response questionnaires was carried out to assess validity and practicality of the media. All stages of this evaluation were aimed for the feasibility of the final product in terms of content, design, and user-friendliness.

RESULTS

1.   Analysis Stage

At this stage, the researcher identified the corresponding curriculum as a guideline for developing digital games. Next, the researcher assessed the learning materials related to the concept of multiplication. In this case, the researcher interviewed a mathematics teacher about the implementation of the school curriculum in teaching multiplication. It was revealed that the teacher taught multiplication only limited to calculating two or more integers with time allocation of 4×45 minutes per week distributed in two meetings. To check student understanding, the teacher added one meeting in the form of written test. The limited time allocation turned out to cause problems for students, in which students only memorized multiplication and were oriented towards counting skills only.

The interview also addressed the teacher's teaching method in the expository form. The teacher conveyed the multiplication of two or more numbers directly while teaching the meaning of multiplication as a number multiplied according to the multiplier number. Students who found it difficult to accept the abstraction of the multiplication meaning would eventually choose to memorize the multiplication of integer numbers within the range of 1-10. This was the consequence of the difficulties they experienced in interpreting the teacher's explanation which tended to lead only to calculating numbers. Subsequently, students looked less enthusiastic about participating in learning and were unable to solve contextual problems given by the teacher.

In addition to the learning method, the interview discussed the teacher's teaching materials as well. Books, which are universally textual, served as the main materials. This dissuaded students' interest in learning, which during the Coronavirus pandemic, was often carried out online and utilized more digital learning resources than ever. Therefore, we need interactive digital learning media that can accommodate their learning needs through new post-pandemic habits. Moreover, the initial test result regarding students' understanding of multiplication concept in contextual problems shows that it falls within low category, with a mean score below 50 out of 100. The test result can be seen in Figure 1 below.
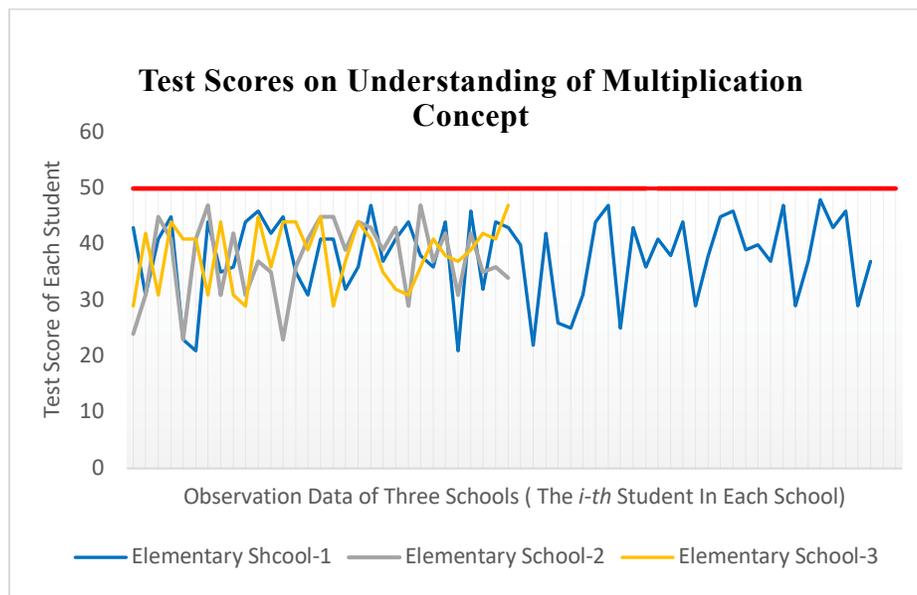
Figure 1. Level of Students' Understanding of Multiplication Concept

From Figure 1 above, we can conclude that students' cognitive and psychomotor capabilities are less than half the maximum score or less than 50. So, on this basis the researcher intends to develop a digital game with core computational thinking to support multiplication concept learning. With this game, it is hoped that students can understand the abstraction of multiplication concepts by solving contextual problems that were previously difficult for students to solve.

2. Design Stage

At this stage, the researcher designed a digital game based on the need analysis result at the previous stage. The researcher then chose digital game media with core computational thinking to stimulate students' cognitive and psychomotor capabilities. Furthermore, at the game design stage, the researcher began creating use case diagrams that describe or represent the interactions between the system and its environment, as shown in Figure 2 (a)-(b) below.

The researcher utilized the use case diagram above to define the functional modeling and operational system requirements by determining the scene method used to build the system from the results of the previous application analysis. At this stage, the researcher decided the name for the game; Monkey Game Arithmetic-CT. In this digital game, there is a monkey character. Monkey is selected since it is a fable main character that sticks in the memories of many children in Indonesia. Children often hear it from their parents during their golden age in reading and listening activities. The fable's monkey character represents an agile animal with a lot of senses and likes to eat fruits, especially bananas and apples. Then the researcher formulated the digital game concept according to the achievement orientation of students' cognitive and psychomotor capability, which were leveled from 1 to 3 on the menu as presented in Figure 3 (a)-(b) below.
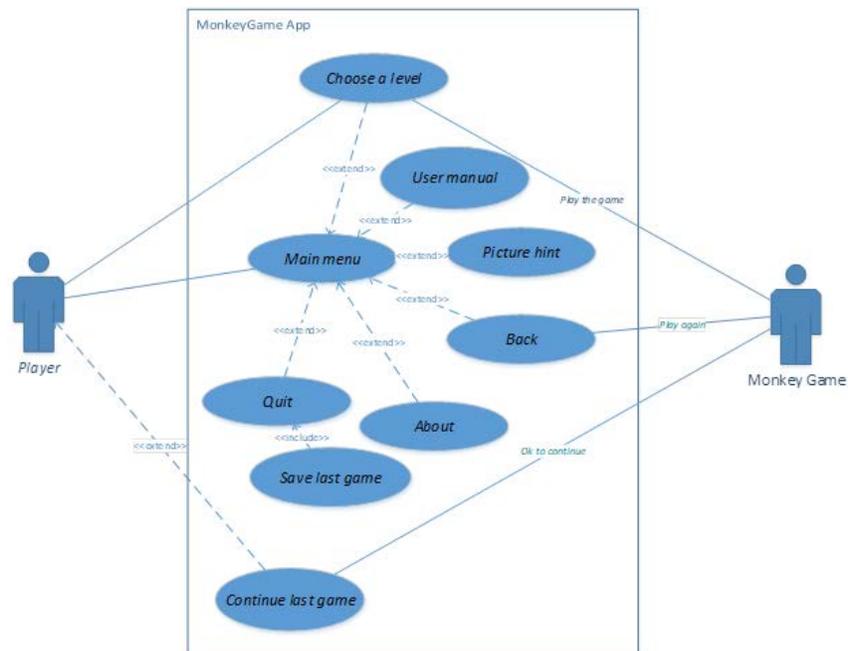
(a) Main Use Case Diagram
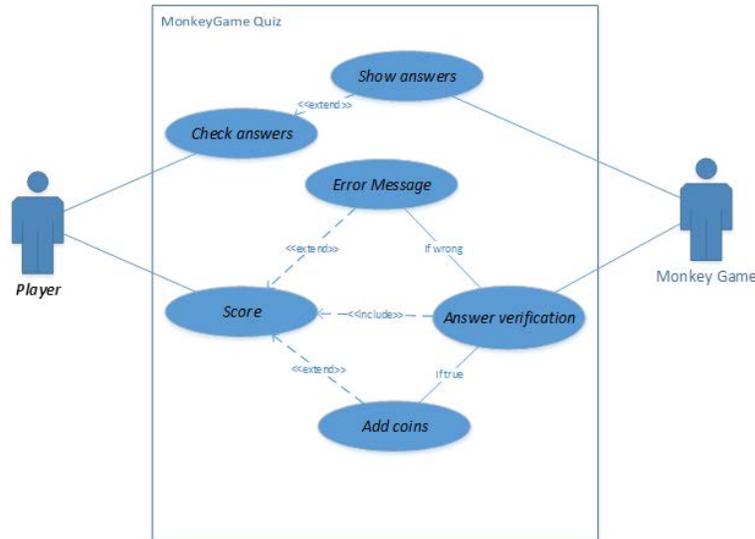
(b) Part Diagram of Main Use Case Containing Checking Answers and Feedback

Figure 2. Digital Game Use Case Diagram

(a) Game Main Menu
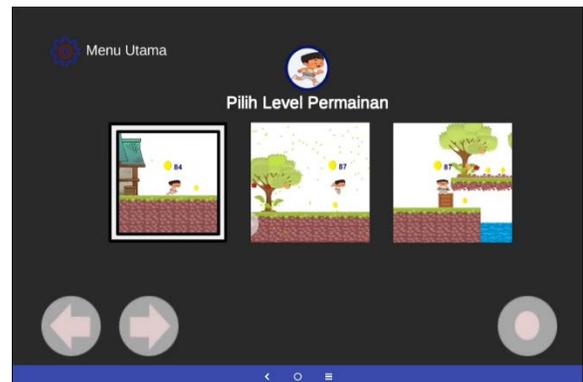
(b) First to Third Level Game

First column translation:

Main Menu
User Manual
Picture Hint
Choose a Level
Back
About
Quit

Second column translation:

Choose a Game Level

Figure 3. Game Leveling on the Main Menu

The game level represents the complexity of the contextual problems as shown in Figure 4 (a)-(c) below.

(a) First Level   (b) Second Level

Translation Column:

(c) Third Level

Translation Column:

There are five 🍎 eating fruits; three 🍎 eating 🍌 and two 🍎 eating 🍎. Of the three 🍎 eating the 🍌, each eats eight 🍌. At the same time, the two 🍎 eating the 🍎, each eats two 🍎. How many 🍌 and 🍎 do the five 🍎 eat?

Express in addition statement

Express in multiplication statement

Check answers   *Score*

Figure 4. Examples of Contextual Problems from First to Third Level

Computational thinking core loads, namely abstraction, algorithm design, pattern recognition, decomposition, and debugging in digital games, are represented in problem-solving activities as presented in Figure 5 below.
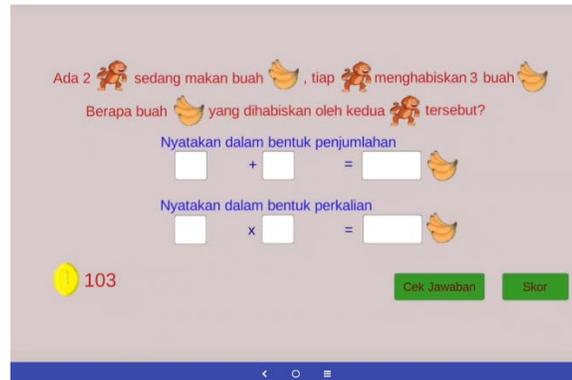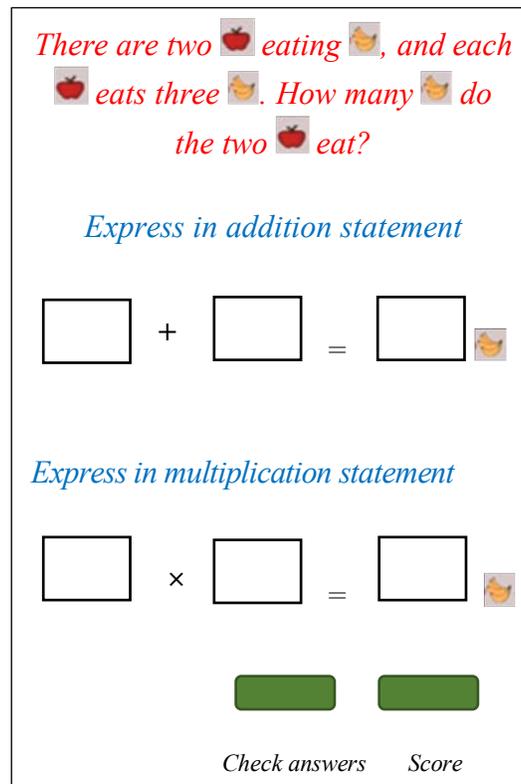

Translation Column:

Figure 5. The Abstraction Core of Computational Thinking

Figure 5 shows that students must generalize and identify common cores by accommodating specific details and necessary patterns and ignoring unrelated data to solve the problem. In this game, students must be able to sort out the number of both the monkeys and fruits to fill in each answer box in the addition and multiplication statements. In the game's display, there are not fruit

picture or instruction hints to fill the answer box. So, students have to filter the details of the data as their abstraction entities. The core loads of the algorithm design are presented in problem-solving steps, as shown in Figure 6 below.

Translation Column:

Figure 6. The Algorithm Design Core of Computational Thinking

Figure 6 shows that students must develop logical and systematic problem-solving instructions to solve problems. In the first step of this game, students must fill in the number of fruits eaten by one monkey in each statement box of the addition model. In the second step, students must fill in the number of monkeys in the first statement box of the multiplication model. Afterwards, students must fill in the number of fruits each monkey eats in the second statement box of the multiplication model. In the final step, students check their answers by clicking the 'check answers' button, followed by pushing the 'score' button to check the achievement of the problem-solving score.

The core load of pattern recognition is presented in the problem-solving steps, as shown in Figure 7 (a)-(b) below.

(a) The First Problem and Its Content on The Digital Game

(b) The Second Problem and Its Content on The Digital Game

Translation Column:

The Second Problem
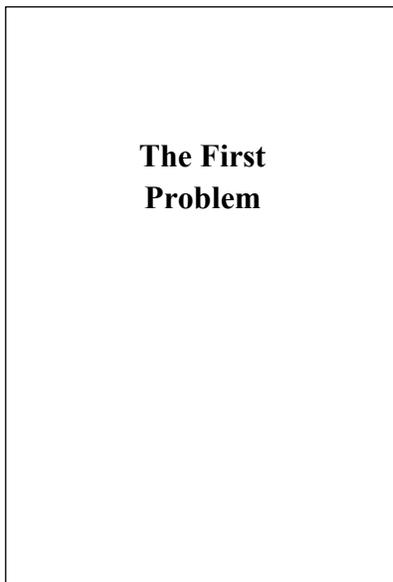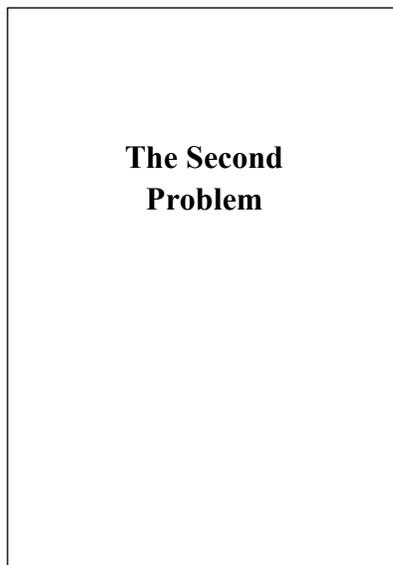
There are three 🍎 eating 🍎, and each 🍎 eats seven 🍎. How many 🍎 do the three 🍎 eat?

Express in addition statement

☐ 🍎 + ☐ 🍎 + ☐ 🍎 = ☐ 🍎

Fill in the number of fruits eaten by one monkey   *Fill in the number of fruits eaten by one monkey*   *Fill in the number of fruits eaten by one monkey*
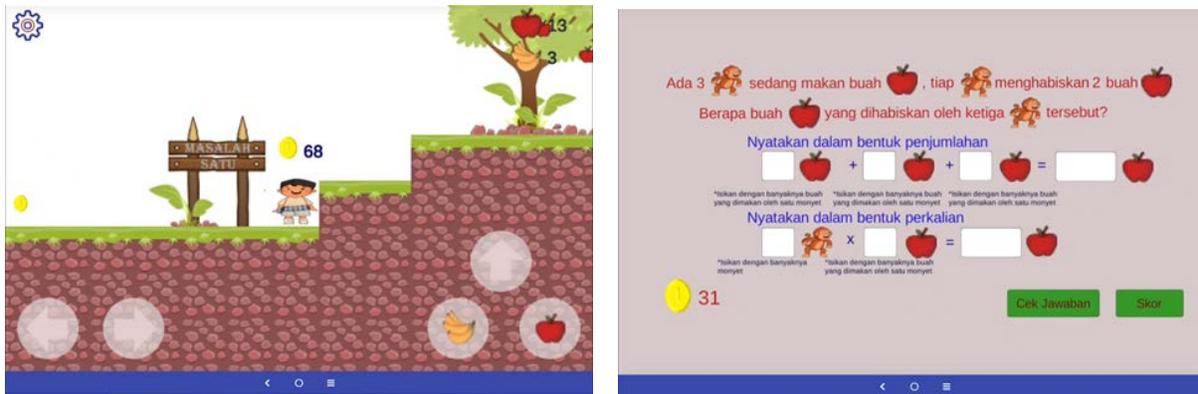
Express in multiplication statement

☐ 🍎 × ☐ 🍎 = ☐ 🍎

Fill in the number of monkeys   *Fill in the number of fruits eaten by one monkey*

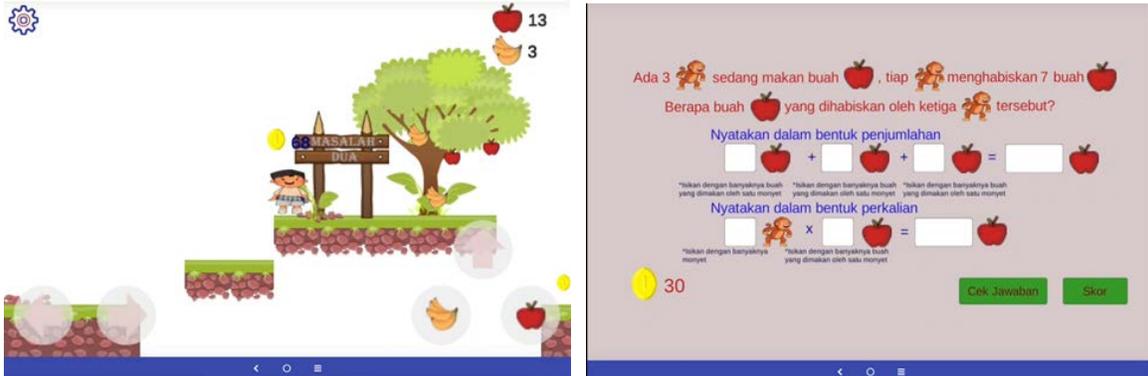*Check answers*   *Score*

Figure 7. The Pattern Recognition Core of Computational Thinking

Figure 7 (a)-(b) shows that students must be able to see similarities or differences in patterns and methods in the data that will be used in predicting and presenting data to classify problems and provide appropriate solutions. This pattern recognition uses previous experience and prior knowledge as the basis for logical thinking. Then, from this logic, students get new experience and knowledge to solve various identical problems according to patterns they already know. In this game, students must be able to see the data pattern and the regularity of solving the first problem,

as shown in Figure 6 (a) above. The first problem presents a data pattern about three monkeys eating apples, and each monkey eats two. Students are asked to determine how many apples the three monkeys eat.

The second problem is presented using an identical multiplication problem. It shows the existence of three monkeys eating apples, and each monkey eats seven. Students are asked to determine how many apples the three monkeys ate. To solve the first problem, students design a solving algorithm that begins with applying the concept of repeated addition. Then, they continue with the solution step by applying the multiplication concept related to the previous repeated addition concept. Using the patterns and regularities of the data in the first problem, students design solutions to the second problem by predicting the same steps for solving the multiplication problems.

The core load of decomposition is presented in the problem-solving steps, as shown in Figure 8 below. Figure 8 shows that students must be able to break down complex data, problems, or processes into smaller and simpler parts. So, if there is a complex problem, it can be more easily solved by breaking it down. In this case, students must be able to separate the number of bananas and apples eaten by the monkeys.

Translation Column:

There are five 🍎 eating fruits. There are three 🍎 eating 🍌 and two 🍎 eating 🍎. Of the three 🍎 eating the 🍌, each eats eight 🍌. At the same time, the two 🍎 eating the 🍎, each eats two 🍎. How many 🍌 and 🍎 do the five 🍎 eat?

Express in addition statement

8 🍌 + 8 🍌 + 8 🍌 = 24 🍌

2 🍎 + 2 🍎 = 4 🍎

Express in multiplication statement

(3 🍎 × 8 🍌) + (2 🍎 × 2 🍎) = 24 🍌 + 4 🍎

Check answers   Score

Figure 8. The Decomposition Core of Computational Thinking

The core load of debugging is presented in the problem-solving steps, as shown in Figure 9 below.

(a) Problem-solving   (b) Result of Rechecking Process

There are two 🍎 eating 🐵, and each 🍎 eats four 🍌. How many 🍌 do the two 🍎 eat?

Express in addition statement

| 4 🍌 | + | 4 🍌 | = | 8 🍌 |

Fill in the number of fruits eaten by one monkey   *Fill in the number of fruits eaten by one monkey*

Express in multiplication statement

| 4 🍎 | × | 2 🍌 | = | 8 🍌 |

Fill in the number of monkeys   *Fill in the number of fruits eaten by one monkey*

Check answers   Score

Your answer is incorrect.

In the multiplication statement, you reversely fill in the number of monkeys and fruits.

Okay

(c) Result of Error Correction from Rechecking Process

Translation Column*:*

Your answer is correct.

Hooray! You get ten gold coins.

Okay

Figure 9. The Debugging Core of Computational Thinking

In Figure 9, it is shown that students must carry out an inspection or process of rechecking each step of problem-solving to ensure the accuracy. If students make mistakes while solving the

problem, the system will provide feedback in the form of notifications, as shown in Figure 9 (b). The picture states that the multiplication form is not accurate as the boxes for the number of fruits and monkeys are switched. Students are also given a chance to improve their problem-solving and recheck their answers. If the answer is correct, the system will pop up a notification saying that ten gold coins are obtained as a prize.

3. Development Stage

This stage began with an instrument feasibility assessment in the form of a product validation questionnaire regarding media and materials and student response questionnaire. The validity test was carried out using expert judgment or reviewing the grid, especially the instrument suitability with the research objectives and questions. Based on the results of expert judgment, the three instruments were declared valid. Furthermore, the material substance and media design of the product were assessed by three validators. The material substance validation is presented in Figure 10 and Table 1 below.
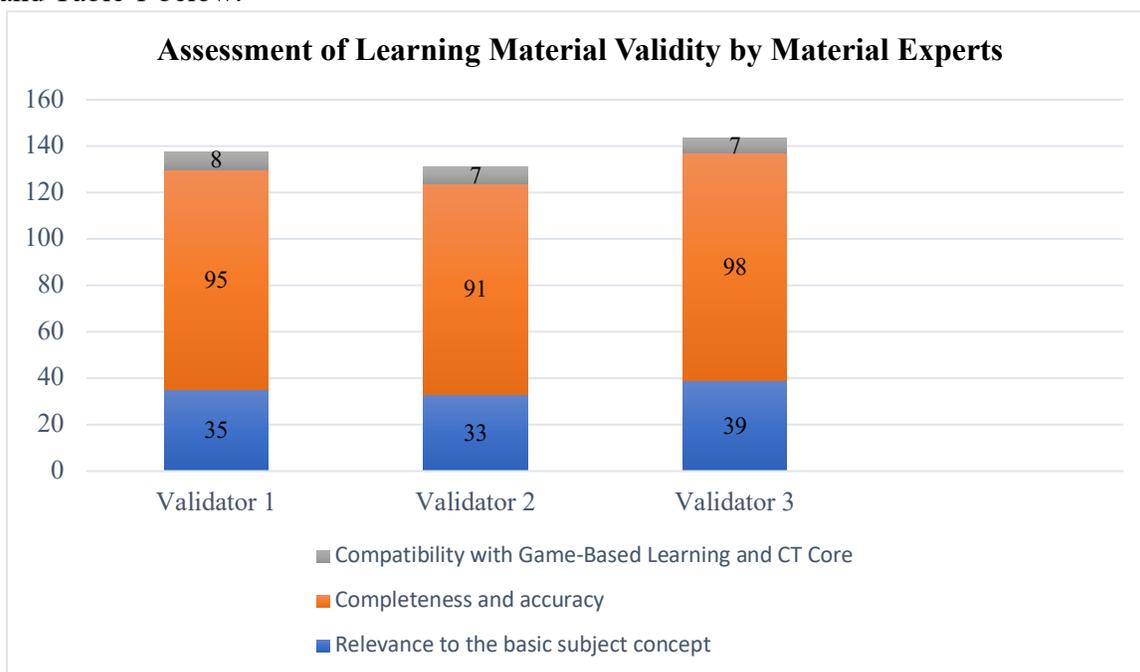
Figure 10. Description of the Assessment Result by Material Experts

Component	Validator-1	Validator-2	Validator-3
Mean	**138**	**135**	**144**
Mean total		**139**	

Table 1: Average assessment of learning material validity by material experts

Based on the material expert validation, it is known that the mean score of validator 1, 2, and 3 correspondingly are 138, 135 and 144 which fall in "Very Good", "Good", and "Very Good" categories. The mean total is 139 belonging to "Very Good" category. Thus, it can be concluded that the material aspect of the learning media is valid. This validity assessment is presented in Figure 11 and Table 2 below.

Assessment of Learning Media Validity by Media Experts
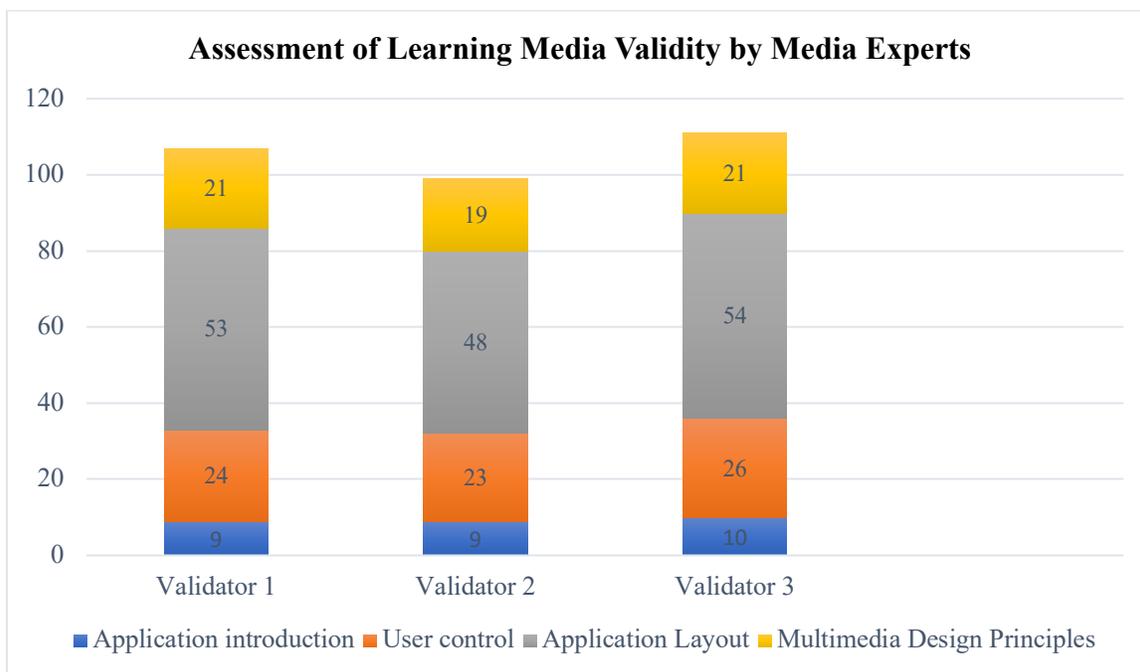
Figure 11. Description of the Assessment Result by Media Experts

Component	Validator-1	Validator-2	Validator-3
Mean	**107**	**99**	**111**
Mean total		**105.67**	

Table 2: Average assessment of learning media validity by media experts

The means obtained from the three validators are 107 (Very Good), 99 (Good), and 111 (Very Good) with the overall mean score of 105.67 (Very Good). Thus, it can be concluded that the media aspect of the learning media is valid. Conclusively, the interactive digital game based on computational thinking developed in this study has achieved the validity criteria of a product development in the aspects of material and media.

4.   Implementation Stage

At the implementation stage, the researcher conducted a small class trial from which was found that the product being developed reached "Very Good" criteria. Next, the researcher conducted a large class trial of four classes of students from three elementary schools. The result of student responses in large classes was 81.9 in "Very Good" criteria. Therefore, we can conclude that students' assessments of the digital game developed in this study reach the practicality principle. 98 out of 123 students showed a very good impression regarding their experience in playing the game.

5.   Evaluation Stage

At this stage, the researcher conducted a continuous evaluation which began with evaluating the test result of students' understanding of the multiplication concept in contextual problems. The mean score of the test was less than half of the maximum score, or more precisely less than 50. The evaluation was also carried out on the validation result at the development stage. The researcher made several revisions to the game, especially in the illustration of contextual problems and the appearance of game characters from a media perspective. Regarding the material perspective, the researcher also revised the legibility of contextual problems. According to students' assessment on the use of the game, researchers did not need to make revisions because more than 90% of students was very appreciative and enthusiastic to welcome the user-friendly game.

DISCUSSION

The use of the digital game integrated into mathematics learning generates a positive impact from students as users. In this game-based multiplication learning, the teacher uses a digital game specially designed to assist students' understanding of multiplication concepts by presenting contextual problems. This educational digital game is called Arithmetic-CT Monkey Game. This game gives students a fun and attractive learning experience with structured game content. Monkey Game Arithmetic-CT trains students' adaptation skills to solve various problems with varied difficulty levels. Even to win the game, students must use their creativity in passing challenges or solving contextual problems. While using this game, students get feedback from the system when they access the answer-checking feature. In this case, students can improve their answers because the game is designed with specific tasks to guide students 'learning by gaming'. Various supporting features are also designed to attract students' attention to this game with a storyline of everyday life. So emotionally, students also encounter meaningful experiences.

Game-based learning supported by the Arithmetic-CT Monkey Game application on the Android platform contains twelve characteristics of digital learning, some of which are enjoyment and fun, rule, control, challenge, stimulant censor, interaction, setting, realism, and victory condition, as stated by Prensky (2003). This learning also refers to two things- education and gameplay-, as well as achieving learning goals and a means of entertainment (Lin et al., 2020). Furthermore, Lin et

al. (2020) state that the use of digital games in learning is designed by integrating the system into the experience of playing games. Because of this, a content design model and game features are often adapted to the behavioral habits of its users, such as rule, target, imagination, mystery, sensory stimulation, and control abilities (Garris et al., 2002). This underlies the conduct of several studies on computer use by children under seven years of age, which is considered to reduce children's important developmental tasks in terms of social and intellectual as well as other types of learning (Healy, 2000).

On the other hand, this game-based learning also loads core computational thinking. There are three levels with different levels of difficulty, namely level one for simple contextual problems that contain one particular variable and involve integers 1-5 as the numbers to be operated on; level two for simple contextual problems that contain one particular variable and involve integers less than ten; and level three for complex contextual problems that contain more than one variable. These problems are posed to assess students' cognitive abilities in sorting concepts into several components (the concept of addition and the concept of multiplication), then linking them together to understand the concept as a whole (the concept of multiplication is constructed from a repeated addition). In this case, core computational thinking abstraction is significant in determining students' success in solving contextual problems in games through analytical activities. The development of logical and systematic problem-solving instructions and the process of rechecking the correctness of each problem-solving step are indicators of students' cognitive capability achievement. Students' cognitive achievement is an implication of the ease of operation, and the continuous interaction between students and games during learning will build students' thinking habits while playing.

The contextual problems of multiplication that students must solve at each level are also used to assess students' psychomotor capability, which can be seen from their attitude or manipulation in the problem-solving process. Students must link various skills based on similarities or differences in patterns to predict or produce appropriate solutions just like core computational thinking pattern recognition. Students should know how to break down complex data or problems in order to effectively solve them, such as decomposition in the core of computational thinking. It is also an indicator of psychomotor abilities that students can achieve. Thus, the experience of 'learning by doing' is obtained by students when playing games, affecting their behavior and psychomotor capability when solving problems. Because with learning game-based mathematics, students transfer the abstractness of mental objects in their cognition into external representations or behaviors that can be observed so that their computational thinking skills increase. This is in line with the research result from Andriyani and Maulana (2019), which shows that a good learning experience is needed to acquire mathematical knowledge with abstract and hierarchical objects. With digital games in learning, students look enthusiastic about using interactive technology. Because technology reduces the abstractness of learning concepts, the students understand a learning situation more quickly (Buliali et al., 2022; Panthi et al., 2021).

CONCLUSION

The current interactive digital game as a support device for game-based learning can be said to meet the validity principle based on the results of the product feasibility test as indicated by the fulfillment of the "Very Good" category in the aspect of material and media. The practicality of learning media is also indicated by the achievement of "Very Good" criteria regarding student responses. Hence, digital games have effectively addressed contextual multiplication problems that previously posed challenges to students due to their limited grasp of multiplication concept. However, the researcher has not measured the overall effectiveness of digital games in game-based learning, so this possibility opens up as material for further research. Digital games can be an alternative to support students' cognitive achievement by facilitating the translation of abstract images of multiplication concepts and training students' psychomotor capability in solving multiplication contextual problems. By incorporating core computational thinking content, digital games have demonstrated their capability to facilitate cognitive development tasks and enhance psychomotor skills, exemplified by progressive level advancements. As a result, students become accustomed to a "learning by gaming" approach. Furthermore, students' feedback has provided evidence that the core of computational thinking heightens their enthusiasm for learning multiplication. With this core loads, students feel assisted in determining the optimal solution strategy through problem formulation activities and appropriate information processing.

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Appendix

ASSESSMENT SHEET OF THE LEARNING MATERIAL VALIDITY BY
MATERIAL EXPERTS

A. PURPOSE

To assess the validity of the Arithmetic-CT Monkey Game of interactive learning media for application compatibility with Game-Based Learning and CT core quality, completeness, accuracy, and relevance to the basic subject concept by material experts.

B. INSTRUCTIONS

1. To Mr./Miss, please assess by giving a tick (√) in the column that has been provided that is appropriate with the following assessment criteria:
   1: Not Good
   2: Less Good
   3: Good Enough
   4: Good
   5: Very Good
2. To Mr./Miss, please advise on improvement by writing in the comment line suggestions that have been provided.

No	Assessment Criteria	Score				
		1	2	3	4	5
Compatibility with Game-Based Learning and CT Core						
1	The game content present problems whose solutions contain the abstraction core of computational thinking					
2	The game content present problems whose solutions contain the algorithm design of computational thinking					
3	The game content present problems whose solutions contain the pattern recognition of computational thinking					
4	The game content present problems whose solutions contain the decomposition of computational thinking					
5	The game content present problems whose solutions contain the debugging of computational thinking					
6	Games contain special learning that helpzs to solve problems related to the concept of multiplication.					
Completeness and accuracy						
7	Coherent in the preparation of material from simple concepts to more complex concepts					
8	Diversity in giving examples related to the concept of multiplication					

9	The accuracy of the problem given with the concept of multiplication					
10	Correctness of the problem-solving feedback					
11	Readability and clarity of information contained in-game issues					
Relevance to the basic subject concept						
12	Suitability of the material with the core competencies and basic competencies in the referenced curriculum					
13	The usefulness of games as learning media needed by students and facilitates the achievement of learning objectives					
14	Conformity of material with the truth of its substance					
15	Examples of clarity in illustrating the abstract concept of multiplication					
16	Coverage (breadth/depth) of the material					
17	Factual material and material actualization					
18	Appropriateness of the language used with the level of the cognitive and intellectual development of students					
19	Interactivity between students and games that attract student learning motivation					
20	Instruction traction					

Comment and Suggestion:

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C. CONCLUSION

In terms of material aspects, the Arithmetic-CT Monkey Game of interactive learning media states:

1. Worth

2. Worth using after revision

3. Not worth

Please give a circle sign of the choice of numbers provided as the assessment result.

............., ……………… 2022
Validator,

…………………………………....