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Dots of connected numbers as learning instrument computational thinking concept in elementary school

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ABSTRACT

The skill future generations need when computers become more massive and connected is thinking like a computer. Computational thinking is a method of thinking commonly used by programmers when writing program code. There are four principles in computational thinking: (1) Decomposition, (2) Pattern Recognition, (3) Abstraction, and (4) Algorithm Design. The research was conducted in three stages: planning, development, and testing. The results are that the Dots of Connected Numbers can be a simple instrument to teach computational thinking but requires that children have mastered the sum operation. The Dots of Connected Numbers contain the four principles of computational thinking.

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INTRODUCTION

Education in Indonesia is presently facing a crucial momentum. The current development manifests a vast technological enhancement that influences many aspects of human life. Digital gadgets have been an inseparable part of our daily lives. The enacted educational policy is essential in determining the readiness of the upcoming generation, as the nation's development depends on human resources. Therefore, innovations in the educational world are imperative.

The challenge of the 21st century emerges from the abundant information internet users upload. The data keeps accumulating with the possibility of automatically sending information to numerous gadgets through the sensor without the help of human beings. Digital activities and indicators would be valuable when utilized with proper data analysis, and they can be done more swiftly and even in real-time. Several types of monotone, patterned and easy to predict will be replaced with automated systems and machinery.

The skill required by the upcoming generations when computers are becoming more massive and connected is the ability to think like a computer (Román-González et al., 2018). Computational thinking is one of the essential competencies that students must have (Varela et al., 2019) and is considered a critical skill in the 21st century (Yadav et al., 2016). The collaboration between humans and machines will be more intense in the future. The computer will be designed to comprehend human's natural language. In response, PISA in 2021 is projected to be the first to assess computational thinking in the sub-assessment of the mathematics subject. PISA stands for *Program for International Student Assessment,* which is the primary reference in identifying one nation's quality of education. Indonesia still belongs to the lower-rank group.

Computational thinking is the method the programmer commonly uses to write a program's code. Wooster and Papert introduced it in a book titled *Mindstorms: Children, Computers, and Powerful Ideas* (Wooster & Papert, 1982). Since then, computational thinking started to rise in the Computer Science Community in 2006 from an essay written by Jeannette Wing, which proposed that computational thinking is an essential skill of everyone and not only limited to a computer scientist. Jeannette argues that it is essential to integrate computational concepts into other subjects at school (Wing, 2014). Four principles need to be delivered in computational thinking (Anistyasari et al., 2018): (1) *Decomposition*: the ability to deconstruct complex data, process, or problem into smaller parts or works that are more manageable; (2) *Pattern Recognition:* the ability to recognize the similarity and the differences in the patterns, trends, and the regularity in data that will be used in making prediction and data presentation; (3) *Abstraction*: Generalize and identify the general principles that create those patterns, trends, and the regularity. Mainly focus on the critical information and set the irrelevant details aside; (4) Algorithm Design: Develop the instruction of the same problem from step to step to allow other people to solve the same problem.

The role of computational thinking is versatile and implemented within the daily life of human beings (Chen et al., 2017). Every bit of decision-making is inseparable from the activity of thinking in our daily lives. As a kid goes to school, from opening the eyes, the kid faces a problem with one activity to be done the first time and continues with the last activity. Even when on the way and an unusual obstacle occurs during the journey to school, a decision should be taken in response to the problem. Every child is faced with new things every day. The future era they will live in will undoubtedly be different from now. Computational thinking ability will be beneficial for every child in facing new things.

Implementing computational ability in the Education field is not merely learning syntax or programming logic so that the students are directed to become a programmer. Instead, it teaches students the correct way of thinking. Several things can be done in the teaching process without needing technology or are widely known as 'unplugged' (Caeli & Yadav, 2020; del Olmo-Muñoz et al., 2020). The earlier this computational ability is introduced to the students, the better. Informal education is the right choice, especially in Primary School (Tran, 2019). The issue that may not be solved by this generation now using a computational ability may be solved by the next generation.

This study develops a teaching instrument to understand the concept of computational ability. The concept here is the four principles mentioned above. Mathematics Education in Primary Schools of Grade 1 becomes the focus of the scope for this study because computation is seen to be closer to the mathematics subject (Aho, 2012; Hickmott et al., 2018; Rodríguez-Martínez et al., 2019), so that the sub-material here only need to be integrated on the existing lesson, without the need of deconstructing the applied curriculum. However, computational ability can be integrated into various fields of study (Kules, 2016; Tang et al., 2020), even in fields that focus on the right-side brain, such as music (Baratè et al., 2017).

RESEARCH METHOD

This study is a development study that produces a novel product or procedure as the outcome (Bennett et al., 1984). The product referred to here is the instrument for sub-learning material in the Mathematical subject for Grade 1. The process to obtain this product is conducted in three stages: planning, developing, and trying.

The data collection process is carried out during the planning stage to build a thinking construction. Besides, it is also meant to find the cross point of findings, which later can be intercorrelated to become a solution. This stage is done by digging into the relevant previous study and observing the previous products made. This study only searches for those under the topic of computational ability that is done through learning while playing as well as focusing on the visual instrument so that it may become more attractive (Repenning et al., 2010; Zhao & Shute, 2019), the shape may not be abstract and is easy to be understood by the students. The teaching instrument must be made as simple as possible to apply.

The product resulted from the brainstorming sketches on paper and became a final product in the development stage. Various media are used to see how the implementation is used in different conditions. The teaching concept must be delivered in various media, not hindering anything, especially when the available media is minimal.

Then, the direct observation is done on the final stage, the testing stage. The products experiment on grade 1 of the Primary School. The students' skill differences, the clarity of the instructions, and the other findings gained will be the discussion to be shared and, in the future, improving materials for the product.

RESULTS AND DISCUSSION

Based on the objectives of this study, it creates an instrument for the sub-material on the teaching of Mathematics called Dots of Connected Numbers. While the result from each stage is the following:

Planning Stage

In this stage, it gains the main reference for the teaching of computational ability with the use of visuals and games, that is the Code.org (del Olmo-Muñoz et al., 2020;

Kalelioğlu, 2015; Román-González et al., 2018) and Bebras (Manabe et al., 2018). Code.org is a non-profit organization that aims to learn computer science, especially programming. The website has an interactive learning module to train the learning concept as a programmer, such as building the blocks by "drag and drop" to move objects to a dot (Figure 1). At the same time, Bebras is an extracurricular activity that educates problem-solving skills. Inside are concepts of information and computational ability. One of the worksheets is setting the pattern of lights blinking on a board consisting of columns and rows (Figure 2).

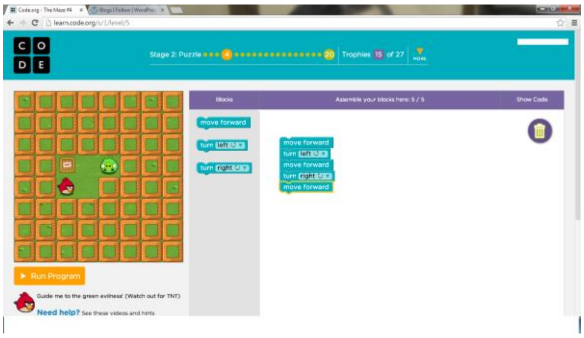


Figure 1. Example of Task on Code.org

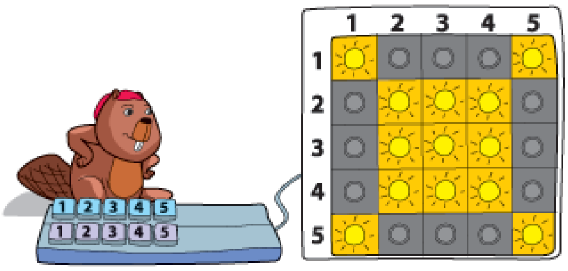


Figure 2. Example of Task on Bebras

The form of the more straightforward worksheet is shown in Figure 3; the students are asked to count how many times the car turns suitable to reach the destination according to the path set to it (Kusnendar & Prabawa, 2018).

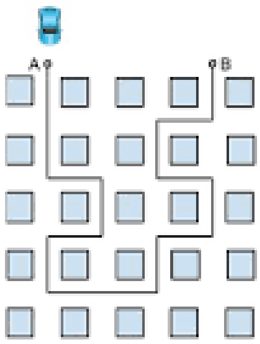


Figure 3. Example of Assignment in the Research of Kusnendar & Prabawa

In the example mentioned above, Decomposition principles can be taught by asking how the path in entirety from dots A and B can be divided into smaller parts by calculating how many times the right turns are needed. Besides counting the right turns, the same patterns also can be made to calculate how many left turns are needed. When the students understand that pattern, they have already learned the principles of Pattern Recognition. Then, it is also learned that in each intersection, the car will choose an option out of three: keep straight, turn right, or leave. This is called Abstraction. Lastly, when these students can make the rule of the game where the three decisions can also be used to create different paths, the students already understand the principle of Algorithm Design.

Based on the results collected on the worksheets above, the last example is simpler to start the fundamental teaching of computational ability. The unit lines and connected object dots can be used to set the more complex steps.

Development Stage

In the teaching of Mathematics, the total is the basic operation that is taught after knowing the concept of numbers. The total is usually formed from two or more numbers. For example 1 + 2 = 3 or 1 + 2 + 3 = 6. In the total that has the constructed format aiming at the result, the final result will have the score of true or false, and there is only one correct answer according to the construct. In computational ability, the principle of Decomposition is a skill in dividing something into smaller parts. The format is reversed, moving from the result to the construct. 7 = 4 + 3. The construct varies; 7 can be built from 1 + 6, 3 + 4, 5 + 2, etc. This means that the answers from the construct will be highly likely to be more than one; in other words, one issue can be solved using more than one path. This mindset is very needed for the skill in solving the issues. (Rodríguez del Rey et al., 2020).

The lines and the dots object found in the planning stage will be combined with the reversed addition (the result of a construct). The form is Dots of Connected Numbers, as seen in Figure 4. The combination will vary according to the numbers total and position and the structures created by the teachers.

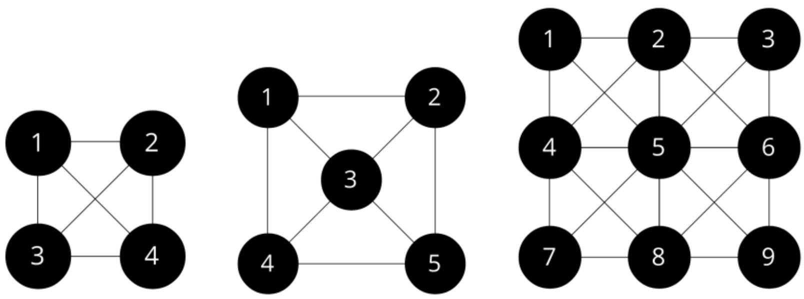


Figure 4. Dots of Connected Numbers

The steps of the teaching done by the teachers to the students are the following:

1. Teachers combine Dots of Connected Numbers, e.g., five dots.
2. The students get a number bigger than the number of the Dots of Connected Numbers, e.g., 7.

3. Students search the alternative answers as many as they can that are the result of the different numbers under the rules of the game of:
   a. No addition should be consecutively done using the dots with the same number.
   b. There should not be any addition that skips a numbered dot with no direct connecting lines.

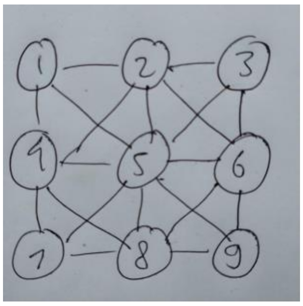
   Alternatives of an answer:
   7 = 3 + 4
   7 = 4 + 3
   7 = 2 + 5
   7 = 5+ 2
   7 = 1 + 2 + 3 + 1

   Examples of answers that violate the rules of the game:

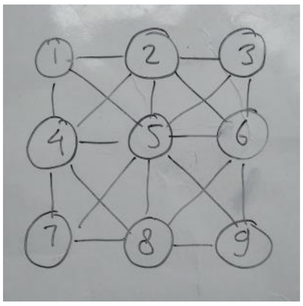
7 = 1 + 2 + 4	(2 is not directly connected to 4)
7 = 3 + 2 + 2	(There should not be any same numbers in a row. In this case, the number 2)

4. The teachers ask the students to fix the mistakes and give the checklist for the revised answer.
5. The students find the same pattern, such as 7 = 3 + 4 and 7 = 4 + 3, have the same patterns in diagonal lines from 3 to 4 or f
6. The teachers give the tasks again to develop the creation of Dots of Connected Numbers to be more complex, e.g., using nine dots.

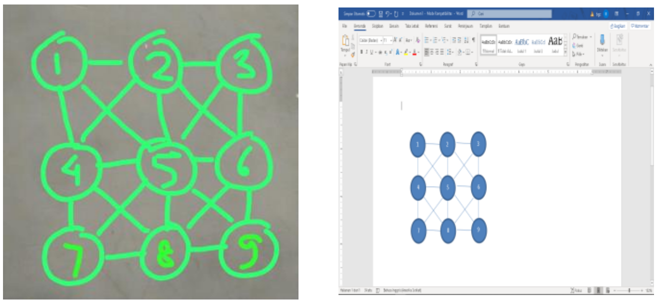
The principles of Pattern Recognition can be taught to the students in step 5 above. The more complex the structure, the more the pattern will be more varied. For example, on the Numbered Dots connected with 9 dots, the result 11 can be arranged into 1 + 2 + 3 + 5 or 1 + 5 + 2 + 3. The same number combination can be shaped into different patterns. The more the students play with the Dots of Connected Numbers, the more their skill in Abstraction and Algorithm Design is sharpened because they are trained to focus only on the connected dots and work on the assignments step by step structurally.



(a)



(b)



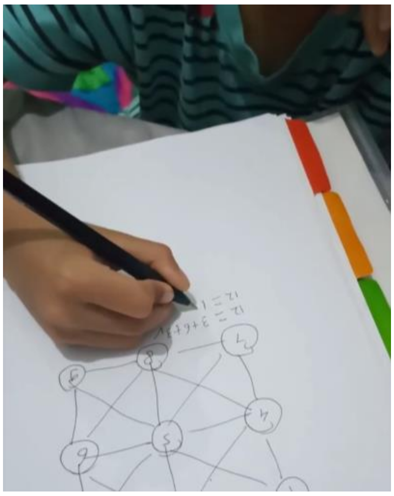
(c) (d)

Figure 5. Implementation of Various Media

Dots of Connected Numbers are applied on various media, as shown in Figure 5. (a) on the paper done in handwriting using a pen, (b) on the whiteboard using a board marker, (c) using a smartphone with a plain background, and (d) editing the text on Microsoft Word. The ease in making the Dots of Connected Numbers to be done in various media enables this learning instrument to be practised personally, in the classroom, in WhatsApp group chat and in printed worksheets. However, making it on paper and whiteboard is more accessible than on a smartphone or laptop. Besides, not all schools allow students to bring their own devices, so pencils and paper are sufficient. (Kim et al., 2013).

Testing Stage

In this final step, the Dots of Connected Numbers are tested on three 1st grade Public Primary School 4 students of Pisang Candi Malang. The three students have high, medium, and low performance, respectively. The Dots of Connected Numbers used are the four dots, then the nine dots.



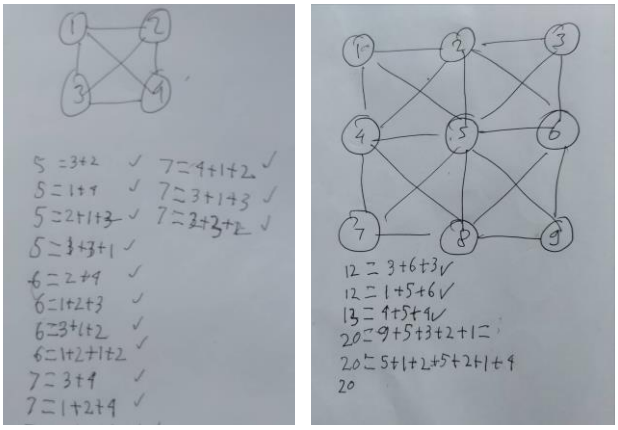


Figure 6. Testing on Student

The instruction is done as the developed teaching steps. Students with high and medium Mathematical skills do not see any difficulties in understanding the instruction and can work on the assignment according to the expectation, although those with medium performance still need to have examples in the beginning and need more time to finish it. However, low-performance students struggled to understand the instructions and work on the assignment. Their skill in adding numbers is still lacking. For the students, the introduction of the pattern still has become something complicated, so the teachers need to guide them to understand it better.

On the next assignment with nine dots, unlike the four dots, there is no example in working the assignment. Only the high-performance students can finish and seem to have no problem working on it. Although the structure is more complex, the students can understand the same concept as those with four dots.

CONCLUSIONS

Dots of Connected Numbers can be a simple instrument to teach the computational ability concept. Simple here means that it can be made more accessible and done in various media available. The structure combination can be developed for the teachers to innovate in improving their teaching skills according to the condition of the students and the lesson topic. However, Dots of Connected Numbers requires the students to master addition to avoid difficulties when performing the Decomposition. Aside from Decomposition, there are three other principles of computational ability: Pattern Recognition, Abstraction, and Algorithm Design, which are also involved in the Dots of Connected Numbers. Extensive training with the guidance of the teachers is needed to habituate and improve the students' skills.

This study is an initial study where the teaching concept of computational ability is trained using the Dots of Connected Numbers instrument so that it is expected that the experts can validate it and can be developed to be a better instrument. In the decomposition process, it also seems the students find the answers not merely because of their intelligence in Mathematics but also because of their creativity in seeing various possibilities. This variable can be measured in future research. This finding is supported by a previous study (Hershkovitz et al., 2019). Then, the opportunity for this instrument to be made into a mobile-based application is also very possible to be done, and it is interesting since the Dots of Connected Numbers is created using the computer program that can randomly generate various structures as well as be able to be adaptive to the skill of the students.

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