Development of Computational Thinking Test Instrument for Evaluation of STEM Learning in Elementary School

Mochamad Tubagus Ismail ✉[1], Dedy Setyawan[2], and Wenda Alifulloh[3]

[1] Primary Education, Universitas Pendidikan Indonesia, Bandung, Indonesia

[2] Department of Pshysics, Institut Teknologi Bandung, Bandung, Indonesia

[3] Mathematics Education, Universitas Pendidikan Indonesia, Bandung, Indonesia

✉ mtubagusismail@upi.edu

Abstract. STEM-based learning is one of the efforts in developing 21st century skills today. The characteristic of STEM approach is the strengthening of computational thinking skills that should be able to prepare individuals in facing society 5.0. This research aims to provide an overview of the computational thinking test instrument as an assessment solution in STEM learning. Through the development research method, this thinking test instrument was tested on grade VI elementary school students in the Kertasari District of Bandung Regency. The results showed that the computational thinking skills test instrument based on five indicators has a good level of validity and reliability to be implemented as an element of cognitive assessment assessment in STEM learning in elementary schools on the material components of living things and the surrounding environment.

Keywords: STEM, computational thinking.

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INTRODUCTION

The development of the Industrial Revolution 4.0 not only has an impact on the industrial sector of the economy but also on the implementation of the education system. (Nuraisa et al., 2019). This has changed the development of the teaching and learning process which continues to experience innovation along with the times. Therefore, the current learning process in the field is always adapted to the needs of the times. (Masigno, 2014; Mite, Y, et al., 2015; Wilson, 2016).. In principle, 21st century learning has the characteristics of contextual, community-integrated, learner-centered and collaborative learning. According to Griffin et al. (2012)(2012), there are 4 important skills that should be developed in the 21st century, namely tools of work, ways of thinking, ways of working and life skills (living in the world). Ways of thinking refer to essential skills such as creative, critical thinking, problem solving, decision making, computational thinking, learning to learn, and metacognition. Ways of working consist of communication and collaboration. Tools for working consist of information literacy and ICT literacy. Meanwhile, it is supported by life skills including citizenship, life, career, and responsibility (BSNP, 2011). (BSNP, 2011).

Computational thinking is defined as a set of abstract mental activities with the basic concepts of reasoning processes such as abstraction, pattern drawing, pattern identification, algorithmic thinking, modeling, simulation, evaluation, and experimentation. (Città et al., 2019). According to (Beecher, 2017), computational thinking also has additional concepts such as data representation, critical thinking, computer science, automation, and simulation or visualization. Meanwhile, according to Wing (2008)(2008), computational thinking is an analytical way of thinking that is built to solve a problem mathematically, make a design and evaluation of things that have a big impact technically and the general ability to understand human abilities in the aspects of intelligence, behavior and computing. Computational thinking is one type of Higher Order Thinking Skills (HOTS) that makes it easier for learners to make decisions and facilitate problem solving and can improve achievement in the field of science (Lee et al., 2014; Superman et al., 2014). (Lee et al., 2014; Supiarmo et al., 2021)..

Therefore, it is necessary to introduce computational thinking as early as primary education. The teaching of computational learning systems is currently growing in many formal educational institutions as part of the curriculum. (Sukamto et al., 2019). The application of computational thinking can include STEM-based learning (science, technology, engineering, and mathematics). In STEM, computational thinking is needed to solve complex problems into simpler ones by decomposing data based on patterns to develop algorithms as data simulation materials so that it can make it easier for users to provide representations of the data (Wing, 2006). (Wing, 2006).

The results of research conducted Afriana et al. (2016) showed that the application of the STEM approach for secondary school students can help develop skills to help develop critical thinking skills, curiosity and the ability to solve problems related to STEM. Based on these considerations, relevant assessments should be required to observe the effectiveness of STEM learning as an integral part in developing computational thinking. (Stohlmann et al. (2012).

METHOD

This study applied the development research process (Research and Development). Development research is sought as a solution in solving problems in education. The process of cyclical procedural implementation through repeated testing is sought to produce an educational product that has novelty and is appropriate (B. T Borg & Gall, 1983). This research aims to create a product in the form of a test instrument. This test instrument should be used to measure the ability of computational thinking through trials that continue to be evaluated periodically so as to produce a product that is of good value and feasible. This test instrument is sought as one of the cognitive assessments for STEM learning in elementary schools on the material Components of living things and the surrounding environment. The samples used were grade VI students at SD Negeri Cihalimun 01 and SD Negeri Cihalimun Kertasari in semester 2 of the 2022/2023 school year. B. T Borg & Gall (in Supriyono, 2022) describe the procedural stages carried out in development research in the following chart.

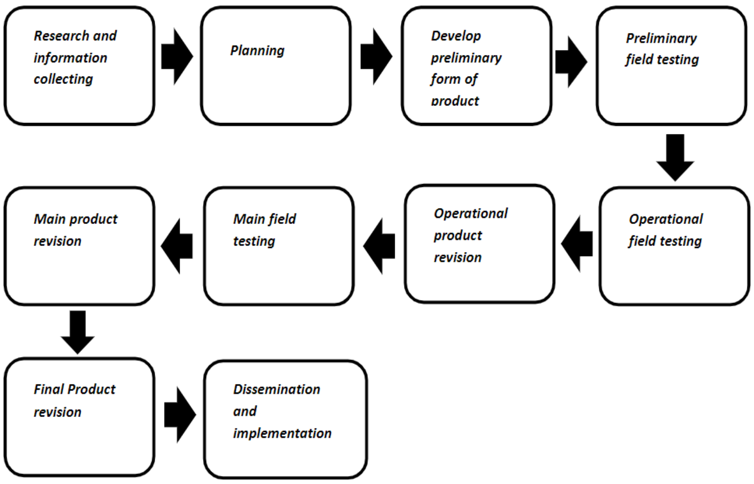

Figure 1: Implementation stage of Development Research

The stages of this development research include: 1) Gathering research information; 2) Planning; 3) Initial product development; 4) Initial product testing; 5) Operational revisions to the product; 6) Operational testing in the field; 7) Operational product revision; 8) Main field testing, 9) Final product revision and 10) Dissemination.

RESULTS AND DISCUSSION

Findings

The initial stage of developing a computational thinking skills instrument begins with research information gathering. This step is the stage of collecting relevant information related to STEM learning and assessment of computational thinking skills that are adapted to the abilities of students at the elementary school level. Based on the pre-research analysis, it is known that the computational thinking ability of students is still relatively low (Sa'diyyah et al., 2021).. In addition, according to Danindra and Masriyah (2020)In addition, according to Danindra and Masriyah (2020), there are differences in the computational thinking process of students in solving problems related to algorithmic patterns. Therefore, the process of developing computational thinking skills in learning can continue to be trained because students are still unable to solve problems by integrating the information obtained. Mufidah (2018).

The next stage is planning. At this stage it is necessary to determine the indicators for instrument development. This is done to provide clarity on the instructions that will be used on the instrument. Therefore, indicators that are relevant to the development of computational thinking skills are needed. The relevance can be explored through existing theory as a basis for determining the construct and content of the instrument. The relevant theories in the development of this instrument include computational thinking skills, the concept of material components of living things and the environment, and STEM learning.

Computational thinking is one type of Higher Order Thinking Skills (HOTS) that makes it easier for students to make decisions and facilitate problem solving and can improve achievement in mathematics (Lee et al., 2014; Supiarmo et al., 2021). (Lee et al., 2014; Supiarmo et al., 2021).. Computational thinking with abstraction and decomposition methods has the following stages, namely:

1. Classify the problem into smaller or easier sub-sub-subjects;
2. Describe the problem;
3. Search and interpret data;
4. Algorithm development;
5. Evaluate the efficiency of the solution.

(Chen et al., 2017)

Then from the five indicators, it is described into indicators of computational thinking skills with information in the following table.

Table. 1 Indicators of Computational Thinking Test Instrument

No.	Computational Thinking Ability Indicator	Indicator Description
1	Classify the problem into smaller or easier sub-sub-subjects	1. Explain problems related to the environment in at least three aspects 2. Classify at least 2 sources of problems related to the environment in the household area.
2	Describing the problem	3. Explain the impact of problems related to the environment and pest vectors in the neighborhood. 4. Classify the types of pest vectors in the surrounding environment.
3	Search and interpret data	5. Develop alternative solutions to problems related to pest control.
4	Algorithm development	6. Develop a chart for making pest control prototypes according to procedures. 7. Make prototypes according to procedures.
5	Evaluate the efficiency of the solution.	8. Create a prototype improvement evaluation list.

The description of the indicators in the table is used as a reference in the preparation of the computational thinking skills instrument. Then from the indicators that have been made, it is necessary to form the instrument items. The number of items of this computational thinking skills instrument consisted of 8 items, each of which measured the indicators of computational thinking skills. This computational thinking skills test instrument was given to students of grade VI elementary school. The instructions on each answer sheet are arranged based on the material about Pest Control on Components of living things and the surrounding environment. Through these instructions, students can demonstrate the expected computational thinking skills.

In the preparation of test instruments, a validation test is needed. Validation testing for the development of this computational thinking instrument was carried out with construct validation involving 3 experts consisting of 1 academic in the field of engineering, 1 academic in the field of science and 1 teacher at the elementary school level. The results of the construct validity test showed that all instrument items were valid enough with a high level of validity. However, to support this validity, content validation was also used involving 20 students at the junior high school level in the Kertasari District area to measure the validity of the instrument. The content validation results also showed a high level of validity for the computational thinking test instrument. The following are the results of the validation test of the computational thinking test instrument on the material Components of living things and the surrounding environment using SPSS version 27 as a test tool.

Table 2. Content Validation Test Results

Item No.	*Pearson Correlation* Score	Validity
1	0,986	High
2	0,969	High
3	0,968	High
4	0,935	High
5	0,946	High
6	0,986	High
7	0,968	High
8	0,935	High

Significance levels: (Retnawati, 2016):
If significance < 0.4, then the assumption is low validity.
If significance is between 0.4 and 0.8, then the assumption is moderate validity.
If significance > 0.8, then the assumption is high validity.

In addition to the validity test, the reliability test of the computational thinking ability instrument was also conducted. Through the use of SPSS 27, the results of the reliability test on the instrument showed a Cronbach's alpha value of 0.806. This value means that the computational thinking skills instrument will show consistency and relatively the same results in each test (Retnawati, 2016). These results indicate that the instrument can be continued at the instrument development stage. The following are the results of the reliability test of the computational thinking instrument.

Table 3. Reliability Test Results

Reliability Statistics	
Cronbach's Alpha	*N of Items*
0.806	9

The next development research process is initial field testing. At this stage, the first instrument trial was carried out at SD Negeri Cihalimun 01 with 30 students. Based on qualitative data, this instrument can be continued for the next stage. The following initial trial results are presented in the diagram below.

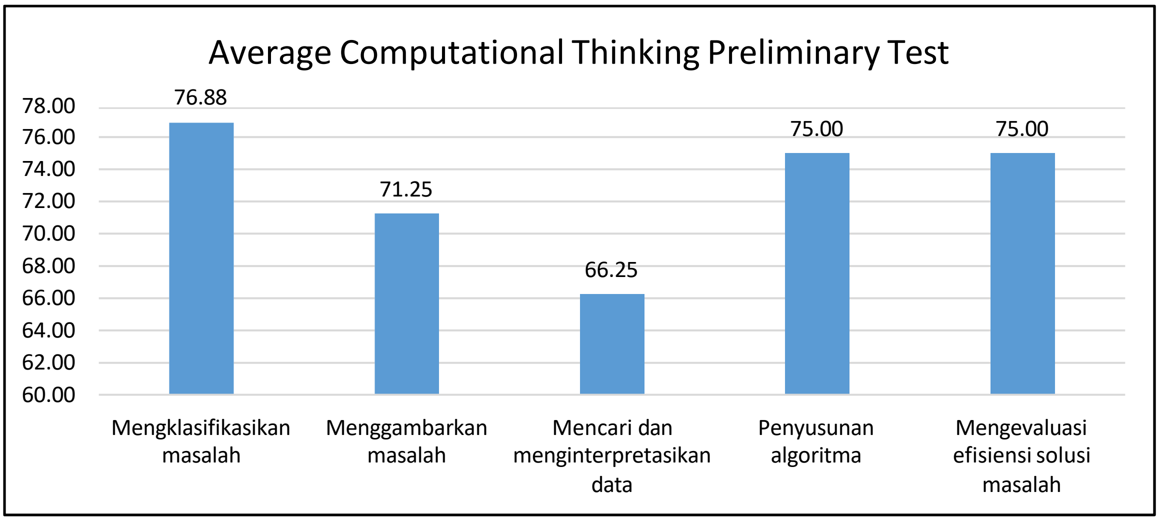

Figure 2: Average Initial Test of Computational Thinking

Based on the results of the graph of the average score of computational thinking skills above, it is obtained that the ability of students in the aspect of classifying problems into smaller or easier sub-subs is higher than the other aspects of computational thinking skills. This aspect has an average of 76.88 with the lowest average score being at the stage of finding, using and interpreting data at 66.25. This shows that students have the ability to decompose problems with additional strengthening exercises in other aspects. Then the next stage is operational field testing. This operational field trial was conducted at SDN Lebaksari and SDN Cihalimun 02 with a total of 30 students From this trial the following results were obtained.

Figure 3: Computational Thinking Operational Field Test Average

The data from the operational trial showed that the highest average score was still in the aspect of classifying problems into smaller or easier sub-subscales with a score of 75.83 while the lowest score was in the data search and interpretation phase with an average of 71.67. The implementation of this instrument trial received some input related to the need for additional clearer instructions in finding references and the need for more space for students to determine prototypes. The improvement stage was carried out in the operational revision phase through FGDs with construct validators. After making improvements, it can be continued to the next stage, namely the main field test involving 30 students of SDN Cibeureum 01 and SDN Sukasari. The following are the results of the main field test related to the computational thinking test instrument.

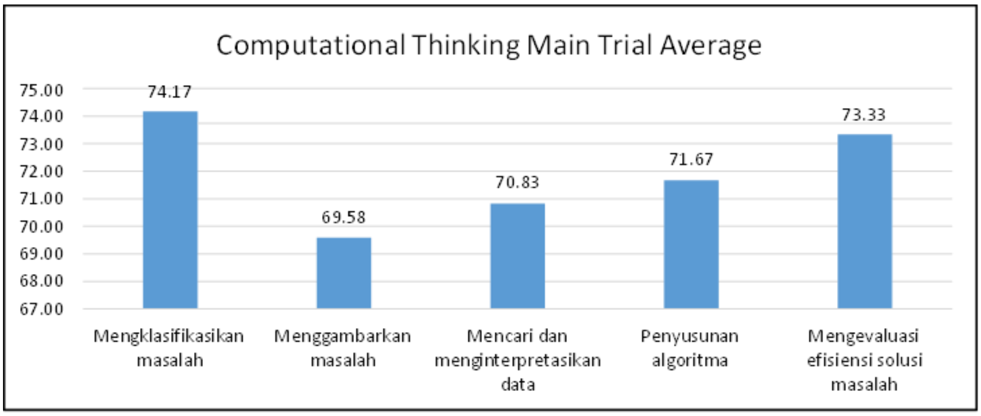

Figure 4: Average of Operational Thinking Computational Main Trial

In the graph, it is found that the stage of classifying the problem into smaller or easier sub-substances still has the highest average score compared to other aspects at 74.17. Then in the next rank evaluating the efficiency of the problem solution has an average of 73.33. Another aspect is compiling algorithms with an average of 71.67 followed by the aspect of finding, using and interpreting data with a score of 70.83. Of all the aspects of computational thinking, the lowest result was found in the aspect of representing or describing the problem with a score of 69.58.

After the results of the main field trial were carried out, there was no further input on the improvement of the instrument. However, to ensure that the tested product is ready for use, dissemination and FGDs are required by reviewing the results of the main trial. The results of the dissemination and FGDs reviewed the final feasibility test on the computational thinking skills instrument.

Discussion

Based on the results of the trials that have been conducted, it can be obtained that the indicators of computational thinking at the basic education level need to be trained and developed since basic education. Although computational thinking is a high-level thinking skill, it does not mean that students are directed to directly strengthen the ability to create programs. In this case, there are often some misconceptions that develop in the community related to computational thinking. Basically, computational thinking is a basic way of thinking fundamentally and is not an ability to memorize or repeat material. (Mulyanto et al, 2020). To provide clarity regarding the results of the instrument trial, the following is a detailed explanation of the results of the computational thinking test instrument graph.

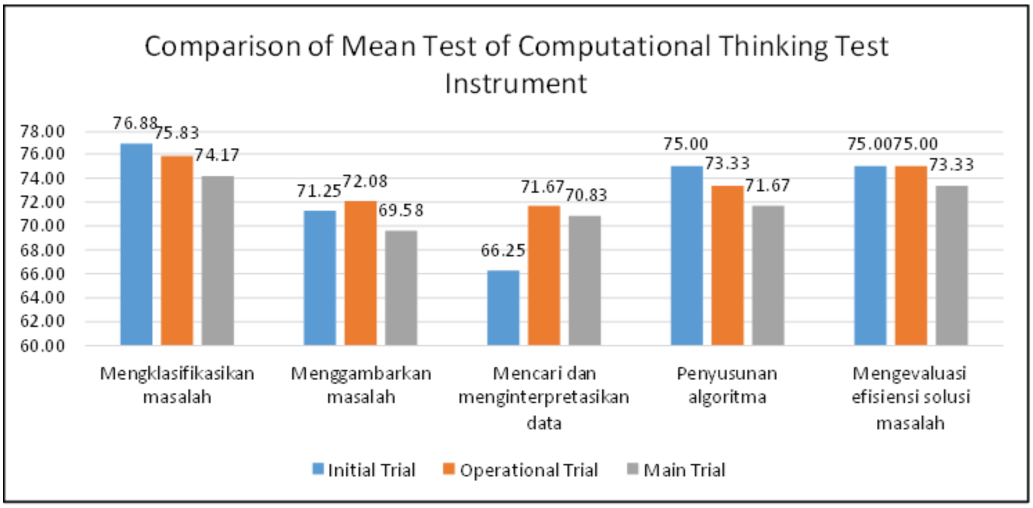

Figure 5: Comparison of the Mean Test of the Computational Thinking Test Instrument

In the indicator aspect of classifying problems into smaller or easier sub-sub- subjects, some test results show fairly constant results in the upper average score compared to other aspects. This shows that the ability to classify problems at the elementary school age level in learning is good enough. However, it also depends on other aspects such as learning support capacity, prerequisite materials and the individual ability of the learners themselves.

Furthermore, in the aspect of representing or describing the problem, there are quite interesting results based on the average score that has been found. In the initial test and operational test, the score of this indicator was on average among the five indicators but when the main field test was conducted, it had a fairly low score compared to other indicators. This shows that the ability to describe problems needs to be improved in computational thinking skills in STEM learning. This condition can be due to the unaccustomed students to be able to think formally, represent or describe the problem at hand to take parameters for solution making. Therefore, simultaneous training and intervention from the teacher is needed on the ability of students to elaborate problems because after all STEM is learning that emphasizes problem-solving-based learning including the ability to solve problems through computational thinking skills (Nadelson et al., 2013). (Nadelson et al., 2013).

The next aspect addresses the ability to find, use and interpret data. The lowest results were obtained during the initial test but there was an increase during the operational test and the main trial. Although there was an increase, the average score of ability in this aspect was still below the other four aspects. Some considerations for this are due to the ability of students to explore the problems offered. In addition, the lack of instructions on the test instrument also affects the ability of students to elaborate on the material. So this is a note so that in making test instruments, the use of effective sentences and procedural steps related to learning activities should be able to be made as well as possible.

Then it continues to the ability to compose algorithms. Talking about the ability to compose algorithms in computational thinking, in teaching this ability teachers need an explicit understanding not only of the technology but also how to teach the right pedagogy related to the material being taught (Guzdial, 2008; Kale et al., 2018). (Guzdial, 2008; Kale et al., 2018).. One of the teaching strategies that can be used is self-regulated learning. This is because self-regulated learning theory can be used as a framework to assess and improve goal-oriented computational thinking (Peters-Burton et al., 2018). (Peters-Burton et al., 2015).. Self-regulated learning includes the process of asking and answering a series of questions about why, where, when, or how the problem is solved so that it is related to the algorithm, this stage requires the ability is the ability to strategize problem solving. (Noroozi et al., 2019).

The results of the pilot test of the algorithm development stage showed a fairly standard average score among other aspects of computational thinking skills. However, the difference in results when the main field trial was conducted, the results of the algorithm development ability test were below the results of the previous two tests. The main difficulty of algorithm development is a continuation of the problems at the stage of finding, using and interpreting data. In this case, the main factor that is desired is that students are not accustomed to exploring the material further due to the lack of learning resources or are not accustomed to learning independently in constructing their own knowledge so that considerable intervention is needed from the teacher in preparing the stages of problem solving. So based on this, project-based learning should be carried out regularly as a form of practice for students to build good problem-solving skills and awaken students' visual- spatial intelligence in providing an overview of the preparation of a work.

As for the final stage tested in computational thinking, it is the ability to evaluate the efficiency of the problem solution. Basically, the evaluation ability in Computational thinking is defined as a series of abstract mental activities with additional concepts such as testing ways of data representation, critical thinking, automation, and simulation or visualization. (Beecher, 2017)In STEM learning, this stage allows students to be able to evaluate the shortcomings of the work that has been made in order to find solutions to improve the work itself. Based on the results of testing the ability to evaluate the efficiency of problem solutions, some test results show fairly constant results in the upper average score compared to other aspects. This is because students simultaneously perform hands on activities that require focus on the work created. But in addition, intervention and input from the teacher are still needed so that the work made remains in accordance with the expectations of the learning objectives.

CONCLUSION

The rapid development of the requirements needed for today's industry and the emergence of new types of work patterns that are closely related to computerization are the basis of urgency to prepare students to enter a world that is very progressive in complexity in digital development and literacy, especially related to computational technology such as robotics, artificial intelligence, robotics, and the internet of things. Therefore, computational thinking is an important basic skill to learn in the 21st century because it focuses not only on solving problems but also on how to solve them. Computational thinking can hone mathematical intelligence, logical and mechanical thinking skills that are aligned with modern knowledge of digitalization, technology, and computerization. In addition, computational thinking can also shape the character of confidence, open-mindedness, tolerance, and sensitivity to the environment.

The carrying capacity of computational thinking learning is often associated with STEM. The STEM approach for students should be able to improve the development of critical thinking skills and students' awareness in understanding the urgency of technology, therefore STEM learning in schools should be well packaged and holistic including matters related to the assessment system on computational thinking ability itself.

The establishment of this computational thinking test instrument was formed with the aim of facilitating assessment in STEM learning, especially the material on the components of living things and the surrounding environment in grade VI Elementary School. The computational thinking indicators used are based on five aspects including: 1) classifying the problem; 2) describing the problem; 3) finding, and interpreting data; 4) developing algorithms and; 5) evaluating the efficiency of the problem solution. The determination of these indicators is outlined in the items of the computational thinking test instrument which is then procedurally tested through a series of development research trials. Based on the results of construct validity, content validity and reliability testing, the computational thinking instrument has a high level of validity and good reliability. This shows that the computational thinking instrument is consistent and relevant to be tested in this development research. The results of testing the test instrument involving grade VI elementary school students were carried out three times through preliminary trials, operational trials to the main trial in the field.

The findings related to the trial results are related to the average ability of students in solving procedural problems of computational thinking. In this case, based on the results of the initial trial, operational trial and main trial on the instrument, the results show fairly consistent results related to students' ability to classify problems and evaluate the efficiency of problem solutions. However, further research is needed to get answers to factors that can influence the results of research related to the use of this computational thinking test instrument in order to add reinforcing points to scientific studies related to computational thinking ability.

It is hoped that future researchers will continue to increase exploration related to computational thinking ability instruments on different subject matter or samples so that the repertoire of knowledge related to computational thinking ability can be increasingly referenced. In addition, it is expected that the development of this computational instrument can be updated and improved with the involvement of computer programs.

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