Designing Model of Mathematics Instruction Based on Computational Thinking and Mathematical Thinking for Elementary School Student

Rina Dyah Rahmawati[1,2,3], Sugiman[1], Muhammad Nur Wangid[1], Yoppy Wahyu Purnomo[1,3]

[1]Universitas Negeri Yogyakarta, Indonesia, [2]Universitas PGRI Yogyakarta, Indonesia, [3]PULITNUM, Indonesia

rinadyah.2020@student.uny.ac.id*, sugiman@uny.ac.id, nurwangid@uny.ac.id, yoppy.wahyu@uny.ac.id

Abstract: In this new era, computational thinking is becoming increasingly intriguing for in-depth study. The 2022 PISA framework illustrates that computational thinking can play a significant role in solving real-world mathematical problems, both in formulating problems and in mathematical reasoning processes. Many countries have integrated computational thinking into their curricula, starting as early as elementary education. The 2022 PISA framework marks the first time that substantial attention has been given to the intersection between computational thinking and mathematical thinking. Consequently, research was conducted to analyze the validation process, practicality, and effectiveness of using integrated computational thinking and mathematical practical design thinking to enhance students' computational thinking skills. The research results demonstrate that the integrated computational thinking and mathematical thinking learning design are highly suitable for implementation. According to expert judgment, its validity rate is 95.5%, with a practicality score of 93.75%. The instructional design applied in this study has proven to be effective in enhancing the computational thinking skills of elementary school students. It's important to note that this research is limited to elementary school students, and further studies are needed to explore this topic at higher education levels.

Keywords: learning mathematics, computational thinking, mathematical thinking, elementary school

INTRODUCTION

One of the skills needed in the global era is mathematical literacy (Habibi & Suparman, 2020; OECD, 2018). Even learning mathematics starting from elementary school requires mathematical literacy skills (Lange, 2003), namely the ability to analyze, reason, convey ideas, and solve problems in various situations. Mathematical literacy is an important ability to support students' mathematical abilities (Lengnink, 2005; Yore et al., 2007). However, in reality, students' mathematical literacy in Indonesia is still low (Fatwa et al., 2019). The learning of elementary school (SD) mathematics applied in Indonesia has adapted the achievement of learning objectives in Indonesia, namely emphasizing modern pedagogic dimensions, so that the learning model used utilizes a scientific approach. This is also shown by the curriculum that has been prepared with attention to aspects of developing mathematical literacy, namely formulating, using, and interpreting mathematics in various contexts of everyday life (Afriansyah, 2016; Buyung, 2017). In order to prevent pupils from studying and interpreting mathematical concepts themselves, problems from real life are solely used as a source of inspiration for inventions or concept formulation. (Jeheman et al., 2019; Warmi, 2019). This causes the form of mathematics to tend to be rigid and far from the origins of the mathematical concepts construction, so that learning mathematics is only limited to the transfer of knowledge (Risdiyanti & Prahmana, 2021). Therefore a learning model is needed that integrates mathematical literacy, especially in learning in elementary school. Students in the age range in elementary school are in the concrete operational stage where the child's cognitive aspects will develop rapidly, especially those related to logical reasoning. The hope is that since the beginning of elementary school, learning activity programs in schools can stimulate and facilitate this aspect of logical reasoning (Rita Eka et al., 2017). This is relevant to mathematical literacy skills as an important skill (AACTE & P21, 2013).

Solutions to overcome low mathematical literacy have been carried out, but the results have not been maximized because they have not thought about the importance of a synergistic approach between computational thinking and mathematical thinking. The series of thought processes is still a new thing in the realm of learning development in Indonesia. This is due, in part, to the teacher's mindset which still leads to the development of learning materials that students must master. The implication is that learning tends to be associated with how students master the targeted material content, so that the target of achievement is limited to pursuing material achievements without regard to the competencies students acquire (Fajri et al., 2019). These unresolved problems show that teaching to cultivate mathematical thinking tends not to occur. Many teachers continue to deliver explicit mathematics knowledge using traditional approaches without connecting it to student life or daily activities (Risdiyanti & Prahmana, 2021). The first reason is that teachers do not appreciate the value of mathematical reasoning. Teachers cannot instruct something they do not comprehend, which is the second reason (Katagiri, 2004). Even though mathematics learning will be maximized if the teacher focuses on mathematical thinking and reasoning (Allen et al., 2020). Another study adds that teachers misunderstand computational thinking skills and lack knowledge of how to teach computational thinking skills in class (Sands et al., 2018). Teachers often neglect daily problem-based content to enhance computational thinking abilities, resulting in students' low computational thinking skills in math lessons (Munawarah et al., 2021).

Conceptually, solving long-term literacy problems is carried out by building a synergistic relationship between computational thinking and mathematical thinking, which is related to technology which is important in students' lives (OECD, 2018). This explanation is relevant to the PISA assessment which makes adjustments to the challenges of the times. It is in the PISA 2022 framework that, for the first time, more attention has been shown to the intersection between computational thinking and mathematical thinking, which gives rise to the same set of viewpoints, thought patterns, and mental models that pupils need to flourish in a world that is becoming more technical (OECD, 2019). Additionally, these advances give students a more accurate understanding of how mathematics is used in the real world and practiced in the professional sector, which better prepares students to pursue professions in related subjects.(Muhammad Zuhair, 2020). Therefore, this research will develop a mathematics learning design that integrates computational thinking and mathematical thinking in elementary schools and examine its effect on the computational thinking skills of elementary students.

LITERATURE REVIEW

Computational Thinking

Computational Thinking has become one of the most important abilities to be honed from an early age because in the information age, industrial era 4.0 or society 5.0. Humans live in the real world, and at the same time in the digital world surrounded by IoT (Internet of Things), Big Data, and Artificial Intelligence (ITB, 2020). One opinion even says that computational thinking is an ability worthy of being the "fifth C" in 21st Century Skills; the 4 C's include critical thinking, creativity, collaboration, and communication (Sung et al., 2017). Computational thinking is a critical component of problem-solving techniques (Al Farra et al., 2022). Computational thinking is important in learning in schools because it allows students to think in different ways, express themselves through various media, solve real-world problems, and analyze everyday problems from different perspectives (Bocconi et al., 2016). Computational thinking is a paradigm for changing patterns of access to knowledge (Ho et al., 2019), which includes high-level thinking processes involved in algorithmic thinking, creative thinking, solving problems, forming innovative solutions, and understanding human behavior based on the foundations of computer science (Barr et al., 2011; Kalelioglu et al., 2016).

Computational thinking, which describes fundamental computing ideas, functions as a strategy for problem-solving, system design, and understanding human behavior (Atmatzidou & Demetriadis, 2016; Maharani et al., 2020; Sneider et al., 2014; Zaharin et al., 2018). According to a study (Kalelioglu et al., 2016), computational thinking is a process for addressing problems that includes the following steps: problem identification, data collection, representation, and analysis, solution invention, selection, and planning, solution implementation, and solution evaluation. These stages of action are types of cognitive actions (Wing, 2008).

In this study, the components of computational thinking that will be used will adapt to learning in elementary school. The steps in this learning model are a combination of the opinions of two researchers and refer to the 2022 PISA (Ho et al., 2019; Shute et al., 2017) so that computational thinking aspects are obtained in this study, namely: abstraction, decomposition, algorithms, debugging, iteration, and generalization. The explanation of the aspects contained in computational thinking includes:

1) Decomposition: breaking the problem down into smaller bits and getting to the core of a problem, in order to address the problem one at a time and discover each component of where the problem originated.
2) Abstraction: Identify the broad principles that give rise to these regularities, trends, and patterns. Usually by examining the overall traits as well as modeling a remedy.
3) Algorithm: creating detailed instructions for resolving the same issue so that others may utilize the knowledge to resolve an identical issue.
4) Debugging: detect and identify errors, then fix errors, when the solution doesn't work.
5) Iterations: repeating the design process to refine the solution, until the ideal result is achieved.
6) Generalizations: formulate solutions in general so that they can be applied to different problems (Selby, 2013)

These aspects are used in complex tasks, when choosing the right representation of a problem, and when modeling the relevant aspects of a problem to make the problem easier to trace.

Mathematical Thinking

An important aim of education is to develop one's capacity for mathematical thought and the application of mathematics to problem-solving. In this situation, mathematical reasoning will assist science, technology, economic life, and economic development (R. Bybee et al., 2009). Mathematical thinking means a characteristic of thinking when carrying out activities or thinking mathematically related to content and solving mathematics (Vittayaboon et al., 2018).

Mathematical thinking is the knowledge and skills needed to solve every problem (Katagiri, 2004). Katagiri (2004) also added that mathematical thinking is an understanding of the importance of using mathematical knowledge and skills, learning how to learn independently, and achieving the abilities needed for independent learning, so mathematics is a complex activity. Mathematical thinking is very important to equip students with mathematical skills (Stacey, 2006).

Mathematical thinking can be demonstrated through two processes, namely: (1) Specialization and Generalization; and (2) Conjecturing and Convincing (Stacey, 2006). These two things are used by students to think and solve mathematical problems. Specialization ability is intended as the ability to solve various problems by looking at examples. Generalization ability is the ability to identify an issue, phenomenon, problem, or study based on patterns and connections. The conjecturing is intended as a form of ability to predict relationships and results. Meanwhile, the ability to convince is the ability of students to find and communicate the rationale for an issue, phenomenon, object, or problem that is considered true (Fajri et al., 2019). Students do mathematical thinking to achieve new knowledge or concepts (Sa et al., 2023). Mathematical thinking is a complex activity so it is important to equip students with these abilities since elementary education.

Stacey (2006) states in more detail that mathematical thinking includes mathematical knowledge, reasoning skills, the ability to use strategies, beliefs and attitudes, personal skills, and skills to communicate solutions. During math activities, mathematical thinking is applied and is strongly tied to content, arithmetic techniques, and mathematics. In order to be more exact, many techniques are utilised when arithmetic or mathematics is used to carry out mathematical operations and to provide various kinds of mathematical content. The substance of mathematical thinking influences the success of students' school mathematics learning.

Synergistic Relationship between Computational Thinking and Mathematical Thinking

The synergistic relationship between computational thinking and mathematical thinking was formed because of the shift in the PISA framework. The 2022 PISA framework when compared to the 2003 PISA and 2012 PISA framework, experienced several shifts in the assessment of mathematical literacy, according to what was conveyed by the PISA Governing Board (OECD, 2018, 2019). Of course, by not abandoning the basic ideas of mathematical literacy that were developed previously, this definition provides information about the meaning of mathematical literacy which indicates three main things. First, mathematical literacy refers to an individual's ability to reason mathematically when formulating, using, and interpreting mathematics in the real world. Second, the ability to describe, explain, and predict real-world phenomena using mathematical concepts, procedures, facts, and tools. Third, mathematical literacy helps individuals understand the active role of mathematics in the real world.

The process of interpretation of the 2022 PISA definition referred to (OECD, 2018) is applying and evaluating mathematical results by using computational thinking and mathematical thinking to make predictions, provide evidence for arguments, test, and compare proposed solutions. The trend is that the need to adapt to a rapidly changing world is driven by technology, where humans are more creative and involved, and make judgments for themselves and the communities in which they live (OECD, 2019). This explains why there is a recognition of the junction between computational thinking and mathematical thinking for the first time in the PISA 2022 framework (OECD, 2019).

The long-term trajectory of mathematical literacy includes a synergistic and reciprocal relationship between computational thinking and mathematical thinking (OECD, 2018). Computational thinking and mathematical thinking work well together to help students develop their conceptual understanding of the field of mathematics as well as their concepts and computational thinking abilities. This helps students develop a more realistic understanding of how mathematics is used and applied in the real world. Ultimately, this will improve students' readiness to pursue professions in relevant industries (Muhammad Zuhair, 2020). The process of computational thinking intersects with the ability to solve mathematical problems, where both have the same significant steps (Neneng Aminah, 2022). Computational thinking that is taught well is proven to foster a critical attitude of students (Surahman et al., 2020; Yadav et al., 2014, 2017), so that students will also be accustomed to thinking creatively and practically by looking for the most effective way to solve a problem (Ashish Aggarwal,Gardner-mccune & Touretzky, 2017; García-Peñalvo, F. J., & Mendes, 2018).

METHOD

The test subjects in this study consisted of 3 teachers and 82 fifth grade students at a private school favorite in Yogyakarta. The subjects were described as subjects for limited trials of 17 students, 31 students for the control class, and 34 students for the experimental class. Eight boys and nine girls made up the research participants in the limited trial class; sixteen boys and fifteen girls made up the control class; and twenty-one boys and thirteen girls made up the experimental class. The study participants, who ranged in age from nine to ten, had a variety of traits and varied origins in terms of culture and economic. The research sample used a purposive sampling technique by considering that 5th-grade elementary school students already can read, write, and count, which is considered sufficient to implement the development of mathematical literacy learning (Simarmata et al., 2020). The determination of the test subjects also took into account the heterogeneous backgrounds of the schools used so that the test was more comprehensive and representative of the research subjects. This study uses part of the steps in the ADDIE development model, with the steps illustrated in Figure 1 below.

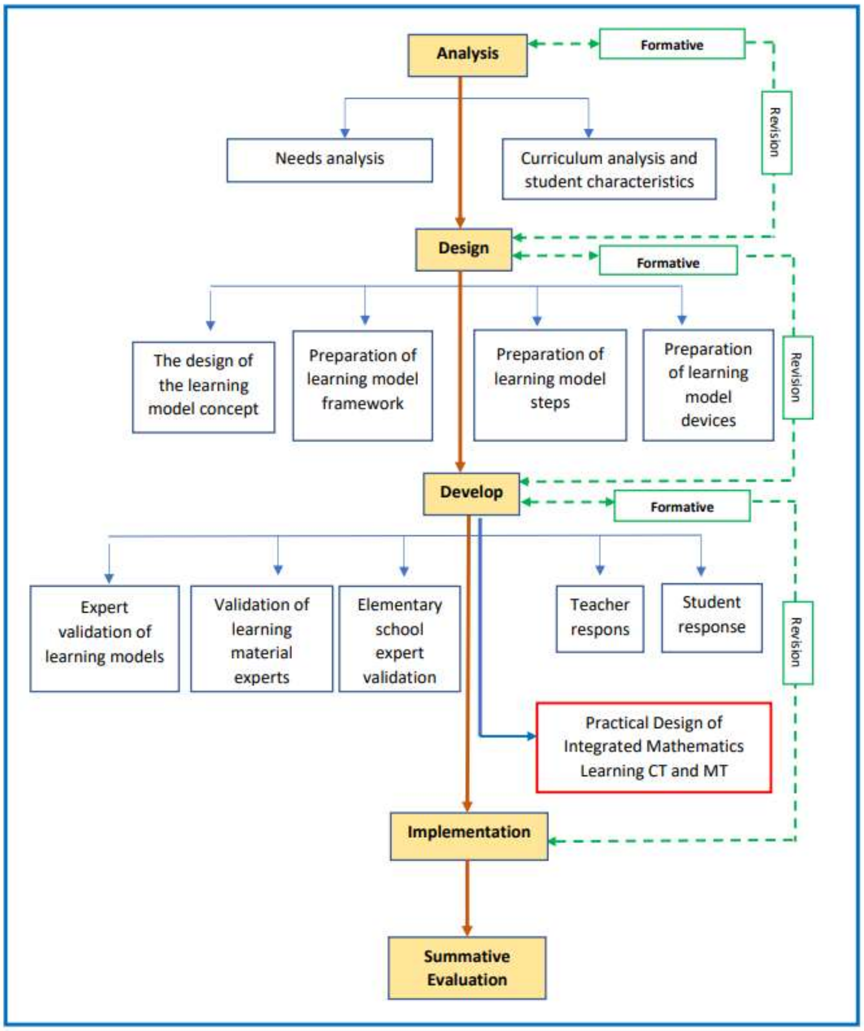


Figure 1: Adaptation of the ADDIE model development procedure (Branch, 2010)

The processes of creating this learning model start with the analysis stage, which includes analyzing the requirement to see existing circumstances, analyzing the appropriate curriculum, and analyzing student characteristics (Istikomah et al., 2020). In the initial identification process to obtain data on student needs, we observe learning in schools that have integrated aspects of computational thinking. Through interviews and field observations at schools, we generate data to identify learning models that are following the targets and ideas for practical learning models that are suitable for development. Interviews were conducted with the Principal and Teachers to explore information related to mathematics learning that has been implemented so far. The initial observation was carried out to see and record the integrated learning process of computational thinking that has been applied at school, so that the strengths and weaknesses were found as material for the initial analysis in this study. After conducting an analysis related to needs and performance, the researcher reflects on the results of the analysis which is part of the formative evaluation stage, before continuing the design process.

The next step is called the design stage, namely designing the concept of a practical learning model to be developed, compiling a learning model framework, compiling the learning model steps, and preparing learning tools. After carrying out the design related to the learning model concept, the researcher reflects on the results of the analysis which is part of the formative evaluation stage, before continuing the development process. The development stage, which is the process of turning the design into a product, comes after creating the concept model. Products that have been made will go through the next step, which is to implement test the products offered. For this reason, it is necessary to test its feasibility through the evaluation experts. Aside from that, rated practicality through analysis results, teacher responses, and student responses.

At the implementation stage, the teacher's teaching observation data was obtained in the form of written notes, recordings of interviews with researchers, and documentation in the form of photos and videos during learning. The research tool is a computational thinking test for students that has been validated through prior research (Angeli et al., 2016) and has been updated for the present environment. The interview guide is used to investigate the process, which calls for clarity from the outcomes of observations, and all instruments have been validated and approved as valid. The computational thinking skills test is given to students in the form of a test that integrates computational thinking. This test measures computational thinking with the aspects in it. This test is a high order thinking skills question that is suitable for grade 5 elementary school students and consists of a pretest and postest. Currently, not many have been found that can contain measurements of all aspects of computational thinking skills so that it becomes a note for further research to develop tests that measure computational thinking skills in other grades and materials in elementary school.

The evaluation phase includes formative and summative evaluations. According to Branson et al. (1975), the formative evaluation stage manifests itself in the form of expert validation and applicability at each point in this study. The activity concludes with the summative evaluation phase.

RESULTS

Preliminary Analysis. The development of integrated computational thinking learning design is limited to computational thinking oriented. The study begins with the **analysis stage**. By examining the circumstances that make learning primary mathematics necessary, examining the relevant curriculum, namely the 2013 curriculum, and examining student characteristics, the analysis's findings are presented as a needs analysis. We use the results of the analysis as a reference in preparing the design of this learning practice.

Needs Analysis. Based on the observations and interviews conducted, it can be concluded that there is a need for activities where students or teachers explain directly and in real terms the completion of a process using concrete media. In this case, it is needed because students need to see directly how the process, stages and sequences of solving a problem are real. It was also found that there was a presentation of search results by students from a given case, but there was no intense discussion between students, so only the collection of solutions from a given case was found. Another analysis obtained information that learning has not shown how the scheme has a clear causal relationship and mutual influence, and there are still many students who cannot understand how the process or sequence of problem-solving from start to finish is structured.

Analysis curriculum. In the analysis of the curriculum, information was obtained that in learning, namely still using the K-13 national curriculum as the main guideline for mathematics learning activities in class. The 2013 curriculum is the curriculum that applies in the Indonesian education system and aims to build students who are ready to face the future.

Analysis of student characteristics. Based on the analysis of student characteristics, information is obtained that 1) students are heterogeneous both in gender and background, 2) most students can operate computers. 3) students consist of various levels of cognitive abilities. 4) There are students with special needs who need teacher assistance.

The design stage is carried out to design a mathematics learning design integrated with computational thinking and mathematical thinking. The focus of model development is on the model of instruction approach. The model of instruction expresses an emphasis on the construction and application of a physical conceptual model of phenomena as an important aspect of learning and its implementation (Jackson et al., 2005). The model of instruction produces students who are intelligently involved in classroom discourse and scientific debate (Jackson et al., 2005). Modeling Instruction is an approach to inquiry-based learning. There are several interesting student activities in each stage of the Model of Instruction, namely small group discussions, class discussions (board meetings), and the use of whiteboards (whiteboarding) as a means of communicating the results of the learning process in the form of writing/pictures. This approach has the potential and flexibility to teach students 21st-century skills (Wicaksono, 2019). The design principles of the model of instruction are that one or more 21st-century skills must have explicit learning outcomes for the learning model (R. W. Bybee, 2009). The learning sequence of the model of instruction includes focused instruction, guided instruction, collaboratory learning, and independent learning

(Fisher & Frey, 2008) (Kylsyit, 2019). The following is a mapping of the model of instruction learning sequence and aspects of the computational thinking and mathematical thinking approaches.

Stages of problem-solving in CT	Aspect CT and MT	Stages of the Model of Instruction			
		Core Learning			output
		Focused Instruction	*Guided Instructions*	*Collaborative Instruction*	*Independent Learning*
Identification of problems	**Specialization**	1. Deliver learning objectives and learning scenarios 2. Split groups	Conduct discussions and ask questions about the material		
	Decomposition		Divide the problem into smaller parts		
	Abstraction		1. Analyze activity tasks and plan problem solving 2. Collect, organize, and analyze problems and interpret information from various sources		1. Analyze activity tasks and plan problem solving 2. Collect, organize, and analyze problems and interpret information from various sources
Solution creation, selection, planning	**Algorithm**			1. Exchange ideas to discuss finding solutions in the context of solving activity tasks 2. Make a series of sequential steps to solve a problem	Make a series of sequential steps to solve a problem
Assess solutions and achieve improvements	**Debugging**			Identify errors, then fix errors when solutions don't work as intended	Identify errors, then fix errors when solutions don't work as intended
	Conjecturing			Predict relationships and outcomes	
	Convincing			Finding and communicating the rationale for something that is considered true	
	Iteration			If there is an error, repeat the design process to refine the solution, until the ideal result is achieved	If there is an error, repeat the design process to refine the solution, until the ideal result is achieved
	Generalization			Presenting the results of completing the activity task	Formulate solutions so that they can be applied to different activity tasks

Table 1: The stages of solving CT problems adjust the model of instruction

The syntax in learning design refers to the overall flow or sequence of learning activities. Joyce et al. (Joyce et al., 2015) explained that "The syntax or phasing of the model describes the model in action". This shows that scenarios will be very useful for carrying out the learning process successively because each learning activity consists of several stages that become one in the learning process. Next, design this learning combines procedures for computational thinking and mathematical thinking so that the intersection is found, which then becomes a structured procedural framework that describes learning objectives and management.

Results of the development stage

Stage develop in this study were developed through several validation processes assessed by learning model experts, learning material experts, and elementary school experts, so that a revision process was carried out based on expert input. This stage applies the formative evaluation stage, namely the expert validation and practicality stages. Specific validation results can be seen in Table 2 below.

Aspect	**Validators**			**Information**
	1	**2**	**3**	
Completeness of Learning Design Structure	4	4	3	0 - 0.80 not feasible 0.81 - 1.60 less feasible 1.61 - 2.40 quite feasible 2.41 - 3.20 feasible 3.21 - 4.00 very feasible
Appropriateness of Supporting Theory	3	4	3,5	
Learning Design Focus	3,5	3,5	4	
Learning Design Syntactic	4	4	4	
Clarity of Learning Design Reaction Principles	4	4	4	
Clarity of Social Systems Learning Model	4	4	4	
Clarity of Instructional Impact and Accompanying Impact	3,5	3,5	4	
Clarity of Learning Design Tools	3,8	3,8	4	
Clarity of Learning Design Application Context	4	4	4	
Total	**33,8**	**34,8**	**34.5**	
Score average	**3.82 / very decent**			
Identified as	**95.5%/ very feasible**			

Table 2 : Results of validation by experts

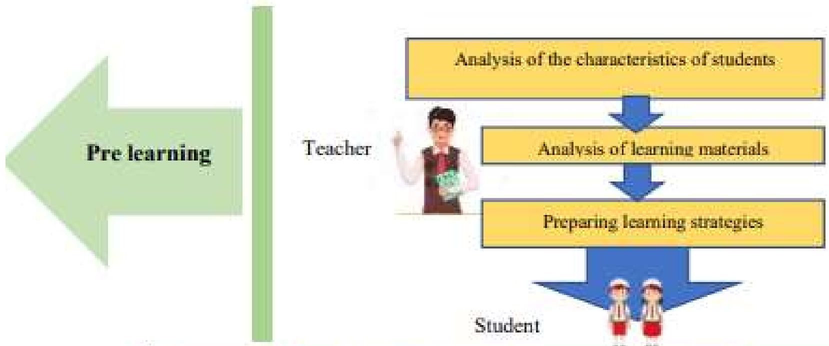
According to the experts' evaluation, the learning design falls into the 95.5% category. This claim demonstrates that the quality of the created learning design is regarded as valid and that the learning model can be further expanded through updates made in accordance with recommendations and advice from experts. Repairs are made in accordance with professional recommendations.

Expert advice. This information was gathered from specialists who were thought to be qualified to offer opinions and recommendations on the teaching practice model that was being created. suggestions or advice during the teaching expert validation phase to improve the learning design. Suggestions given by design and learning material experts can be seen in Table 3.

No	Aspect	Suggestion
1.	Learning stages	It is better to give an example of integrated learning of computational thinking and mathematical thinking in one learning material
2.	Details of activities	Arranged more specifically at each stage of the introduction, core activities, and closing
3.	Technology utilization	On worksheets, students are given a project that is directly related to computer operations in demonstrating broader CT integration
4	Learning design support	Revision and editing of learning design support devices so that they are more suitable for use in learning

Table 3 : Expert advice

The following figure illustrates how the researcher enhanced the learning design under the guidance of the learning expert validator (shown in Figure 2).



Core Learning

output

Model of Instruction	Teaching Activity	steps Learning model	Integration aspects of CT and MT	Tool
Focused Instruction	Submission of material	Deliver learning objectives and learning scenarios	Specialization	Teacher information and instructions
		Split groups		
		Conduct discussions and ask and answer questions regarding the material and solving story problems		
Guided Instructions	Analyze Activities Task and identify problems	Divide the problem into smaller parts	Decomposition	• *E-module* • *Concrete Media* • *Mathematics Activity Task Worksheet (MATW)*
		Analyze activity task and plan effective problem solving	Abstraction	
		Collect, organize, and analyze problems and interpret information from various sources		
Collaborative Learning	Guide the solution discovery process	Exchange ideas to discuss finding solutions in the context of solving activity tasks	At this stage apply aspects Algorithm debugging *Conjecturing* *Convincing* Iteration on an ongoing basis with the sequence of aspects that adjust to the needs	
		Make a series of sequential steps to solve a problem		
		Predict relationships and outcomes		
		Identify errors, then fix errors when solutions don't work as intended		
		find and communicate the rationale for something that is considered true		
		If there is an error, repeat the design process to refine the solution, until the ideal result is achieved		
	Review the completion of the activity task	Presenting the results of completing the activity task	At this stage the aspects of generalization, convincing, and debugging apply, continuous iteration according to needs	
		find and communicate the rationale for something that is considered true		
		Identify errors, then fix errors when solutions don't work as intended		
Independent Learning	Analyze other activity tasks as implementation of independent solutions	Formulate solutions so that they can be applied to different activity tasks	At this stage, aspects of decomposition, abstraction, algorithms, debugging, iteration, and generalization apply continuously according to needs.	Evaluation Tool (Test)

Mathematical Creative Self Efficacy and Computational Thinking Skills

Figure 2: Computational Thinking and Mathematical Thinking Integrated Learning Design Framework

The practicality of teaching practice models. Questionnaires were used in this study to state that the integrated learning design of computational thinking and mathematical thinking is practical to use. Data were taken from three teachers as practitioners. Apart from that, to see the practicality of our learning design, we also involved 17 students through a questionnaire. After designing, mathematics learning practices integrated with computational thinking and mathematical thinking are developed to obtain valid and practical results. Furthermore, the learning design is implemented to see its effectiveness, following the expectations of researchers. Based on the teacher's assessment, a value of 3.75, or 93.75%, is obtained, as shown in table 4, so that it can be declared feasible for the learning design.

Aspect	Subject Score			Information
	1	2	3	
The practicality of the instructional model guide book	3.75	3	4	0 - 0.80 is not feasible 0.81 - 1.60 is not feasible 1.61 - 2.40 is quite decent 2.41 - 3.20 decent 3.21 - 4.00 very decent
Lesson plan practicality	3.75	4	4	
The practicality of the learning model syntax	3.75	3.75	3.75	
Math Activities Task Worksheet practicality	4	4	3.75	
The practicality of the e-module	3.75	3.75	3.75	
Total	19	18.5	19.25	
Average	3,8	3,7	3.85	
score average	3.75/very practical			
Identified as	93.75/very practical			

Table 4: Practicality Based on Teacher Response

While practicality according to students, obtained an average total value of 3.79 with a percentage of 94.5%, which is included in the very practical category.

Results of Implementation Stage

The implementation stage is carried out after the design of this learning design has obtained valid and practical final results. Then the learning design was implemented in 5th grade elementary school in February - March 2023.

Figure 3: Process Computational Thinking and Mathematical Thinking Integrated

Students in the control and experimental classes took the initial and final learning tests. The intervention in the experimental class was carried out five times, with each lesson taught at each meeting. Students receive different treatment according to the project that has been prepared at each meeting.

Meeting	Learning objectives	Integration of CT and MT
Meeting 1	Describe the volume of geometric shapes of cuboids and cubes	At this stage, CT and MT aspects have been involved with the integration of the model of instruction, especially on the aspects of focused instruction and guided instruction
	Determine the volume of cubical and cuboidal shapes	
Meeting 2	make nets of cubes and blocks according to their creativity.	At this stage, CT and MT aspects have been involved with the integration of the model of instruction, especially in the aspects of focused instruction, guided instruction, and collaborative learning
	solve problems related to nets of cubes and blocks.	
Meeting 3	solve problems about cubes in everyday life.	
	solve problems about blocks in everyday life.	
Meeting 4	solve a problem about cubes in everyday life.	
	solve a problem about blocks in everyday life.	
Meeting 5	learning evaluation related to blocks and cubes	At this stage, the evaluation given involves CT and MT aspects with the integration of the model of instruction, especially on the independent learning aspect

Table 5: Details of activities in each meeting

The project takes measurement and geometry content, with material on the volume of blocks and cubes and their nets, following the material that grade 5 students should acquire in that semester. Examples of tasks completed by students to explore their computational thinking skills are shown in figure 4 below.

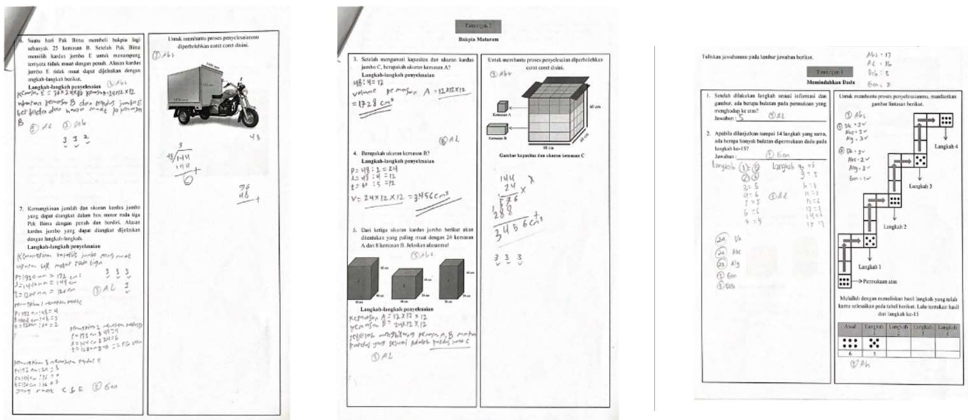


Figure 4: Examples of students' mathematical task completion results

After the intervention was carried out, the data was obtained, which was then processed. Analysis of the difference test data is carried out after the prerequisite tests, namely the normality test and homogeneity test. Based on the results of the analysis, it can be concluded that the data are normally distributed and homogeneous, then it can be continued with the parametric statistical method of the independent t-test.

Once it is established that the data are homogenous and normally distributed, the independent t-test is used to determine whether there is a difference between the means of the two groups. Following are the results of testing the effectiveness of computational thinking skills using independent samples t-test :

	Levene's test for equality of variances		**t-test for equality of means**					**95% confidence interval of the difference**	
	F	***Sig.***	***t***	***df***	***Sig (2-tailed)***	***Mean Differences***	***std. Error Difference***	***Lower***	***Upper***
Equal variances assumed	2,289	.135	9,367	63	.000	18.28264	1.95185	14.3822	22.18310
Equal variances not assumed			9,450	62,417	.000	18.28264	1.93463	14.4159	22.14939

Table 6: Test the effectiveness of computational thinking skills

The test was given to the experimental class to see the effectiveness of the learning design on computational thinking skills. The results of the difference test to determine differences in computational thinking skills that received direct learning and integrated learning of computational thinking and mathematical thinking obtained a significance of p value = 0.135 (p 0.05). Based on p=0.000, $p < 0.05$ we can be concluded that the skills of control and experimental class students have significant differences.

Results of Evaluation Stage

The numerous processes stated above, starting with the analysis stage and ending with the execution stage, have all been merged to carry out the evaluation stage. The evaluation conducted at the end of this activity is a summative evaluation.

The results of the research show that evaluations have been carried out by learning design experts, satisfaction from the practical use of computational thinking and mathematical thinking integrated learning models, and increased student competency mastery after implementation. Based on these results, an integrated learning model of computational thinking and mathematical thinking has been successfully designed for elementary school students.

DISCUSSION AND CONCLUSION

The integrated learning design of computational thinking and mathematical thinking can be used as an alternative to learning mathematics for elementary students in class. As stated in the PISA 2022 framework (OECD, 2019), more attention should be paid to the intersection between computational thinking and mathematical thinking. These advancements give students a more accurate understanding of how mathematics is used and practiced in the real world, thereby improving their readiness to pursue jobs in related subjects (Muhammad Zuhair, 2020). The integrated learning design of computational thinking and mathematical thinking in this study has a valid category, as indicated by the percentage score of 94.5% of SD learning design experts. This learning design is also stated to be practical based on the percentage of teacher responsesof 93.75% and student responses of 94.5%. Therefore, the integrated learning design of computational thinking and mathematical thinking can be declared valid and practical, so it is suitable for use as an alternative to elementary mathematics learning models. It is now commonly acknowledged that incorporating computational thinking into many topic areas of K–12 education will enhance student learning (Güven & Gulbahar, 2020). The integration of computational thinking into learning has been carried out in several countries, such as the UK, the European Union, America, Malaysia, and Thailand (Bocconi et al., 2016; Chongo et al., 2021; Threekunprapa & Yasri, 2020), also the Indonesian government in 2022 has made it a policy that computational thinking is integrated into several subjects, including mathematics, starting in elementary school (Kemendikbud, 2020). The things that need to be considered are that if the teacher wants to encourage mathematical thinking in students, then they need to be involved in mathematical thinking throughout the lesson (Stacey, 2006). Teachers should also allow students to gain more insight into mathematics. This is in line with the opinion (Isoda & Katagiri, 2012) that mathematical thinking can improve understanding, skills, and independent learning. As stated (Henderson et al., 2002) that mathematical thinking is a mathematical technique, concept, and method that is used directly or indirectly in the process of solving problems, so mathematical thinking is needed in learning mathematics.

It is appropriate that the reciprocal relationship between mathematical and computational thinking in math learning is a long-term trajectory in mathematical literacy, which in turn generates a similar set of perspectives, thought processes, and mental models that students need to succeed in a world that is becoming more technological (OECD, 2018). Of course, the teacher still has to know an effective way of motivating learners to represent and relate prior knowledge and understanding and effectively use them in depth and breadth during problem-solving (Ashish Aggarwal,Gardner-mccune & Touretzky, 2017).

Based on data analysis, the integrated learning design of computational thinking and mathematical thinking shows significant effectiveness in students' computational thinking skills. A study has been conducted by researchers on computational thinking skills, which states that computational thinking must be included as a mandatory skill in the 21st century (ITB, 2020; Wing, 2008). Computational thinking is a thinking process for formulating problems and strategies in determining effective, efficient, optimal solutions to be carried out by the information processing agent (solution) (Nurohman et al., 2022). Early instruction in computational thinking should equip kids with the abilities to: (i) prepare for the workforce and fill ICT job openings; and (ii) think creatively, express themselves through new media, and solve problems in the real world (OECD, 2019). Computational thinking also hones logical, mathematical, and mechanical knowledge, which is combined with modern knowledge regarding technology, digitalization, and computerization and even forms confident, open-minded, tolerant, and sensitive characters to the environment (Marifah et al., 2022).

Based on the research conducted on the integrated computational thinking and mathematical thinking learning design, it can be concluded that the design is suitable for use as an alternative model for learning mathematics for elementary school students in the classroom. This research is still limited to the elementary school level in grade 5. As a recommendation, this research can be extended to other mathematical contexts and content as well as to other classes both in elementary schools and schools above.

ACKNOWLEDGMENTS

I would like to thank the principal, teachers, and students at one of the schools in Yogyakarta who actively participated in this research.

References

[1] AACTE & P21. (2013). Teachers for the 21st Century. *Education*, *September*, 22–29. http://www.oecd-ilibrary.org/education/teachers-for-the-21st-century_9789264193864-en

[2] Afriansyah, E. A. (2016). Makna Realistic dalam RME dan PMRI. *Lemma*, *II*(2), 96–104. Pendidikan Matematika Realistik Indonesia (PMRI), Realistic Mathematics Education (RME),HansFreudenthal

[3] Al Farra, N. K., Al Owais, N. S., & Belbase, S. (2022). Computational, Logical, Argumentative, and Representational Thinking in the United Arab Emirates Schools: Fifth Grade Students' Skills in Mathematical Problem Solving. *Mathematics Teaching-Research Journal*, *14*(1), 215–252.

[4] Allen, C. E., Froustet, M. E., LeBlanc, J. F., Payne, J. N., Priest, A., Reed, J. F., Worth, J. E., Thomason, G. M., Robinson, B., & Payne, J. N. (2020). National Council of Teachers of Mathematics. *The Arithmetic Teacher*, *29*(5), 59. https://doi.org/10.5951/at.29.5.0059

[5] Angeli, C., Voogt, J., Fluck, A., Webb, M., Cox, M., Malyn-Smith, J., & Zagami, J. (2016). A K-6 computational thinking curriculum framework: Implications for teacher knowledge. *Educational Technology and Society*, *19*(3), 47–57.

[6] Ashish Aggarwal,Gardner-mccune, C., & Touretzky, D. S. (2017). Evaluating the Effect of Using Physical Manipulatives to Foster Computational Thinking in Elementary School. *SIGCSE '17: Proceedings of the 2017 ACM SIGCSE Technical Symposium on Computer Science Education*, 9–14.

[7] Atmatzidou, S., & Demetriadis, S. (2016). Advancing students' computational thinking skills through educational robotics: A study on age and gender relevant differences. *Robotics and Autonomous Systems*, *75*, 661–670. https://doi.org/10.1016/j.robot.2015.10.008

[8] Barr, D., Harrison, J., & Conery, L. (2011). Computational Thinking: A Digital Age Skill for Everyone. *Learning and Leading with Technology*, *38*(6), 20–23. http://quijote.biblio.iteso.mx/wardjan/proxy.aspx?url=https://search.ebscohost.com/login.aspx?direct=true&db=ehh&AN=59256559&lang=es&site=eds-live%5Cnhttps://content.ebscohost.com/ContentServer.asp?T=P&P=AN&K=59256559&S=R&D=ehh&EbscoContent=dGJyMMTo50Sep6

[9] Bocconi, S., Chioccariello, A., Dettori, G., Ferrari, A., Engelhardt, K., Kampylis, P., & Punie, Y. (2016). Developing Computational Thinking in Compulsory Education - Implications for policy and practice. In *Joint Research Centre (JRC)* (Issue June). https://doi.org/10.2791/792158

[10] Branch, R. M. (2010). Instructional design: The ADDIE approach. *Instructional Design: The ADDIE Approach*, 1–203. https://doi.org/10.1007/978-0-387-09506-6
[11] Buyung, D. (2017). Analisis Kemampuan Literasi Matematis melalui Pembelajaran Inkuiri dengan Strategi Scaffolding. *Unnes Journal of Mathematics Education Research*, *6*(1), 112–119.
[12] Bybee, R., McCrae, B., & Laurie, R. (2009). PISA 2006: An assessment of scientific literacy. *Journal of Research in Science Teaching*, *46*(8), 865–883. https://doi.org/10.1002/tea.20333
[13] Bybee, R. W. (2009). The BSCS 5E Instructional Model and 21st Century Skills. *A Workshop on Exploring the Intersection of Science Education and the Development of 21St Century Skills*, *26*(2001), 1–21.
[14] Chongo, S., Osman, K., & Nayan, N. A. (2021). Impact of the Plugged-in and Unplugged Chemistry Computational Thinking Modules on Achievement in Chemistry. *Eurasia Journal of Mathematics, Science and Technology Education*, *17*(4), 1–21. https://doi.org/10.29333/ejmste/10789
[15] Fajri, M., Yurniawati, & Utomo, E. (2019). Computational Thinking , Mathematical Thinking Berorientasi Gaya Kognitif Pada Pembelajaran Matematika Di Sekolah Dasar. *Dinamika Matematika Sekolah Dasar*, *1*(1), 1–18.
[16] Fatwa, V. C., Septian, A., & Inayah, S. (2019). Kemampuan Literasi Matematis Siswa melalui Model Pembelajaran Problem Based Instruction. *Mosharafa*, *8*(3), 389–398.
[17] Fisher, D., & Frey, N. (2008). *Better Learning Through Structured Teaching A Framework for the Gradual Release of Responsibility*. https://books.google.com/books?hl=en&lr=&id=0BFRBAAAQBAJ&oi=fnd&pg=PP1&dq=leadership+through+instructional+design+in+higher&ots=Nxnq7ZB5-Y&sig=D7k-VYFSLaediIBbD_bP1j6YJ-Y
[18] García-Peñalvo, F. J., & Mendes, A. J. (2018). Computers in Human Behavior Exploring the computational thinking effects in pre-university education. *Computers in Human Behavior*, 1–5. https://doi.org/10.1016/j.chb.2017.12.005
[19] Güven, I., & Gulbahar, Y. (2020). Integrating Computational Thinking into Social Studies. *The Social Studies*, *111*(5), 234–248. https://doi.org/10.1080/00377996.2020.1749017
[20] Habibi, & Suparman. (2020). Literasi matematika dalam menyambut PISA 2021 berdasarkan kecakapan abad 21 [Mathematical literacy in welcoming PISA 2021 based on 21st century skills]. *JKPM: Jurnal Kajian Pendidikan Matematika*, *6*(1), 57–64. https://journal.lppmunindra.ac.id/index.php/jkpm/article/view/8177
[21] Henderson, P. B., Fritz, J., Hamer, J., Hitchner, L., Marion, B., Riedesel, C., & Scharff, C. (2002). Materials development in support of mathematical thinking. *Proceedings of the Conference on Integrating Technology into Computer Science Education, ITiCSE*, 185–190. https://doi.org/10.1145/960568.783001
[22] Ho, W. K., Looi, C. K., Huang, W., Seow, P., & Wu, L. (2019). Realizing Computational Thinking in the Mathematics Classroom: Bridging the Theory-Practice Grap. *Proceedings of the 24th Asian Technology Conference in Mathematics*, 35–49.
[23] Isoda, M., & Katagiri, S. (2012). Mathematical Thinking. In *Mathematical Thinking*. https://doi.org/10.1142/8163

[24] Istikomah, Purwoko, R. Y., & Nugraheni, P. (2020). Pengembangan E-Modul Matematika Berbasis Realistik Untuk Meningkatkan Kemampuan Berpikir Kreatif Siswa. *Jurnal Ilmiah Pendidikan Matematika*, *7*(2), 63–71. https://ejournal.stkipbbm.ac.id/index.php/mtk/article/view/490

[25] ITB. (2020). Pembelajaran Computational Thinking pada Pendidikan Dasar dan Menengah. *Intitut Tekhnologi Bandung*, *December*. https://www.researchgate.net/profile/Ginar-Niwanputri/publication/350383897_Computational_Thinking_Learning_and_Teaching_Guide_for_Primary_and_Secondary_Schools_in_Indonesia/links/605cc073458515e8346fdb11/Computational-Thinking-Learning-and-Teaching-Guide

[26] Jackson, J., Dukerich, L., & Hestenes, D. (2005). Modeling Instruction : An Effective Model for Science Education. *Science Educator*, *17*(1), 10–17.

[27] Jeheman, A. A., Gunur, B., & Jelatu, S. (2019). Pengaruh Pendekatan Matematika Realistik terhadap Pemahaman Konsep Matematika Siswa. *Mosharafa: Jurnal Pendidikan Matematika*, *8*(2), 191–202. https://doi.org/10.31980/mosharafa.v8i2.454

[28] Joyce, B., Weil, M., & Calhoun, E. (2015). *Models of teaching*. Pearson.

[29] Kalelioglu, F., Gulbahar, Y., & Kukul, V. (2016). A Framework for Computational Thinking Based on a Systematic Research Review. *Baltic Journal of Modern Computing*, *4*(3), 583.

[30] Katagiri, S. (2004). Mathematical Thinking and How to Teach It. *Criced, University of Tsukuba*, 1–53.

[31] Kemendikbud. (2020). Penyesuaian Kebijakan Pembelajaran di Masa Pandemi Covid 19. *Kemendikbud*, 26. https://www.kemdikbud.go.id/main/blog/2020/08/kemendikbud-terbitkan-kurikulum-darurat-pada-satuan-pendidikan-dalam-kondisi-khusus

[32] Kylsyit. (2019). *We Teach Together*. http://kilsythps.vic.edu.au/wp-content/uploads/2019/11/We-TEACH-together-DRAFT-an-instructional-model.pdf

[33] Lange, J. de. (2003). Mathematics for Literacy. *Quantitative Literacy: Why Numeracy Matters for Schools and Colleges*, *February*, 75–90.

[34] Lengnink, K. (2005). Reflecting mathematics: An approach to achieve mathematical literacy. *ZDM - International Journal on Mathematics Education*, *37*(3), 246–249. https://doi.org/10.1007/s11858-005-0016-2

[35] Maharani, S., Nusantara, T., Asari, A. R., Malang, U. N., & Timur, J. (2020). *Computational thinking pemecahan masalah di abad ke-21* (Issue January 2021).

[36] Marifah, S. N., Mu'iz L, D. A., & Wahid M, M. R. (2022). Systematic Literatur Review: Integrasi Conputational Thinking dalam Kurikulum Sekolah Dasar di Indonesia. *Creative OfLearning Students Elementary Education*, *5*(5), 928–938. https://www.journal.ikipsiliwangi.ac.id/index.php/collase/article/view/12148

[37] Muhammad Zuhair, Z. (2020). Telaah kerangka kerja PISA 2021 : Era Integrasi Computational Thinking dalam Bidang Matematika. *Prosiding Seminar Nasional Matematika*, *3*(2020), 706–713. https://journal.unnes.ac.id/sju/index.php/prisma/

[38] Munawarah, Thalhah, S. Z., Angriani, A. D., Nur, F., & Kusumayanti, A. (2021). Development of Instrument Test Computational Thinking Skills IJHS/JHS Based RME Approach. *Mathematics Teaching-Research Journal*, *13*(4), 202–220.

[39] Neneng Aminah, et. a. (2022). Computational Thinking Process of Prospective Mathematics

Teacher in Solving Diophantine Linear Equation Problems. *European Journal of Educational Research*, *11*(1), 1–16. https://www.researchgate.net/profile/Suntonrapot-Damrongpanit/publication/356662582_Effects_of_Mindset_Democratic_Parenting_Teaching_and_School_Environment_on_Global_Citizenship_of_Ninth-grade_Students/links/61a6dda685c5ea51abc0f7b6/Effects-of-Mindset-Dem

[40] Nurohman, S., Purnomo, Y. W., Muznil, Prabawa, H. W., Wardani, R., & Utomo, B. (2022). *Computational Thinking dalam Pembelajaran* (Issue December). Direktorat Pendidikan Profesi Guru.

[41] OECD. (2018). *Pisa 2022 Mathematics Framework (Draft). November 2018*.

[42] OECD. (2019). Pisa 2021 Mathematics Framework (Second Draft). *Directorate for Education and Skills Programme for International Student Assessment*, *11*(19), 2–4. https://pubs.acs.org/doi/10.1021/acsami.9b03822

[43] Risdiyanti, I., & Prahmana, R. C. I. (2021). Designing Learning Trajectory of Set Through the Indonesian Shadow Puppets and Mahabharata Stories. *Infinity Journal*, *10*(2), 331. https://doi.org/10.22460/infinity.v10i2.p331-348

[44] Rita Eka, I., Yulia, A., Farida Agus, S., & Rizki Nor, Amalia. (2017). Prediktor Prestasi Belajar Siswa Kelas 1 Sekolah Dasar. *Jurnal Psikologi*, *44*(2), 153. https://doi.org/10.22146/jpsi.27454

[45] Sa, N., Faizah, S., Sa, C., Khabibah, S., & Kurniati, D. (2023). Students' Mathematical Thinking Process in Algebraic Verification Based on Crystalline Concept. *Mathematics Teaching Research Journal*, *15*(1).

[46] Sands, P., Yadav, A., & Good, J. (2018). Computational thinking in K-12: In-service teacher perceptions of computational thinking. *Computational Thinking in the STEM Disciplines: Foundations and Research Highlights*, 151–164. https://doi.org/10.1007/978-3-319-93566-9_8

[47] Selby, C. (2013). Computational Thinking : The Developing Definition. *ITiCSE Conference 2013*, 5–8.

[48] Shute, V. J., Sun, C., & Asbell-Clarke, J. (2017). Demystifying computational thinking. *Educational Research Review*, *22*(September), 142–158. https://doi.org/10.1016/j.edurev.2017.09.003

[49] Simarmata, Y., Wedyawati, N., & Hutagaol, A. S. R. (2020). Penyelesaian Soal Cerita Siswa Kelas V Sekolah Dasar. *Jurnal Pendidik Mat*, *2*(1), 100–105.

[50] Sneider, C., Stephenson, C., Schafer, B., & Flick, L. (2014). Computational Thinking in High School Science Classrooms. *The Science Teacher*, *081*(05), 2014. https://doi.org/10.2505/4/tst14_081_05_53

[51] Stacey, K. (2006). What is Mathematical Thinking and Why Is It Important? In *Review of Educational Research*. University of Melbourne.

[52] Sung, W., Ahn, J., & Black, J. B. (2017). Introducing Computational Thinking to Young Learners: Practicing Computational Perspectives Through Embodiment in Mathematics Education. *Technology, Knowledge and Learning*, *22*(3), 443–463. https://doi.org/10.1007/s10758-017-9328-x

[53] Surahman, E., Ulfa, S., Pendidikan, T., & Malang, U. N. (2020). Pelatihan Perancangan

Pembelajaran Thinking untuk Guru Sekolah Dasar Berbasis Computational. *JURPIKAT (Jurnal Pengabdian Kepada Masyarakat)*, *1*(2), 60–74.

[54] Threekunprapa, A., & Yasri, P. (2020). Unplugged coding using flowblocks for promoting computational thinking and programming among secondary school students. *International Journal of Instruction*, *13*(3), 207–222. https://doi.org/10.29333/iji.2020.13314a

[55] Vittayaboon, N., Changsri, N., Staff, M. I.-E., & 2018, U. (2018). Students' Integrative Thinking in Mathematics Classroom Using Lesson Study and Open Approach. In *Proceeding of APEC-ICER*. https://www.researchgate.net/profile/Achaporn_Kwangsawad/publication/327828853_Satisfaction_of_Website_Visitors_about_Mushrooms_Products_Website_in_Community_Enterprise_at_Prachaupkirikhan_Province/links/5ba7227d299bf13e6045fa7d/Satisfaction-of-Website-Vi

[56] Warmi, A. (2019). Pemahaman Konsep Matematis Siswa Kelas VIII pada Materi Lingkaran. *Mosharafa: Jurnal Pendidikan Matematika*, *8*(2), 297–306. https://doi.org/10.31980/mosharafa.v8i2.384

[57] Wicaksono, I. (2019). *Elemen Kunci dari Siklus Pembelajaran Modeling Instruction dalam Proses Pembelajaran Keterampilan Abad 21 The Key Element of Modeling Instruction ' s Learning Cycle in 21th Century Skills Learning Process*. *4*(1).

[58] Wing, J. M. (2008). Computational thinking and thinking about computing. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *366*(1881), 3717–3725. https://doi.org/10.1098/rsta.2008.0118

[59] Yadav, A., Gretter, S., Good, J., & Mclean, T. (2017). *Emerging Research, Practice, and Policy on Computational Thinking*. Springer. https://doi.org/10.1007/978-3-319-52691-1

[60] Yadav, A., Mayfield, C., Zhou, N., & Hambrusch, S. (2014). *Computational Thinking in Elementary and Secondary Teacher Education*. *14*(1). https://doi.org/https://doi.org/10.1145/2576872

[61] Yore, L. D., Pimm, D., & Tuan, H. L. (2007). The literacy component of mathematical and scientific literacy. *International Journal of Science and Mathematics Education*, *5*(4), 559–589. https://doi.org/10.1007/s10763-007-9089-4

[62] Zaharin, N. L., Sharif, S., & Mariappan, M. (2018). *Computational Thinking : A Strategy for Developing Problem Solving Skills and Higher Order Thinking Skills (HOTS) Computational Thinking : A Strategy for Developing Problem Solving Skills and Higher Order Thinking Skills (HOTS)*. *8*(10), 1265–1278. https://doi.org/10.6007/IJARBSS/v8-i10/5297