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Fostering students' computational thinking: Student worksheets on integer material

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Abstract

Computational thinking (CT) is a critical 21st-century competency, yet its integration into mathematics education remains underdeveloped. At the same time, previous research has focused on identifying CT difficulties. This study aims to address this gap by developing and validating a CT-based worksheet on integer material to improve students' computational thinking abilities. Using a design research method with a development studies approach, the study involved 30 junior high school students in Palembang. Data were collected via pre- and post-tests and analyzed using the N-Gain score to measure enhancement. Results indicate that the CT-based worksheets significantly improved students' CT skills by 66.58%. The structured problem-solving stages within the worksheets effectively guided students through the CT process. Although the quantitative results show substantial gains, the study notes a limitation in qualitative depth regarding student engagement. These findings suggest that integrating CT-based worksheets into mathematics instruction can foster structured thinking and provide a practical foundation for curricular adaptation. This study contributes to the field of mathematics education by offering a validated instructional tool that bridges the gap between CT theory and classroom practice. These findings provide a foundation for further refinement of computational thinking-based learning materials and their broader application in similar educational contexts.

Keywords:
Computational thinking, Education, Integers, Mathematics, Student worksheets

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1. INTRODUCTION

In the 21st century, digital technology plays a significant role in daily life (Maharani et al., 2019). The rapid development of digital technology has impacted the educational system (Ansu-Kyeremeh & Goosen, 2022; Challenor & Ma, 2019; Ghory & Ghafory, 2021; Kiong, 2023). Based on several surveys, it has been found that students in the 21st century must be proficient in technology and possess other skills such as teamwork, research, social interaction, learning, communication, and self-management (Kallia et al., 2021). The International Society for Technology in Education (ISTE) states that 21st-century students must exhibit high-level competencies such as problem-solving, collaboration, creativity, and critical thinking (Junpho et al., 2022).

Computational thinking is one of the skills encompassing problem-solving, critical thinking, and analytical abilities, which have become 21st-century standards (Durak et al., 2019). Computational thinking is a fundamental skill related to logic, analysis, and problem-solving (Junpho et al., 2022). According to Wing (2006), computational thinking is a thought process involving problem-solving, system design, and understanding human behavior using basic computer science concepts. Furthermore, Wu and Yang (2022) describe computational thinking as a "language" used in the thinking process for problem-solving.

Computational thinking has four core components: decomposition, pattern recognition, abstraction, and algorithm (Junpho et al., 2022; Kallia et al., 2021; Wu & Yang, 2022). Decomposition is the ability to break down complex problems or structures into simpler parts. Pattern recognition is the ability to identify similarities or patterns in complex problems. Abstraction involves focusing on essential information while ignoring irrelevant details. Lastly, an algorithm refers to the ability to develop step-by-step solutions or rules for solving problems (Durak et al., 2019; Junpho et al., 2022; Kallia et al., 2021).

Computational thinking is included in the PISA 2021 framework and has been integrated into various fields, including education (Tikva & Tambouris, 2021). In some countries, computational thinking has been incorporated into school curricula, such as Thailand, where it was introduced as part of the national curriculum standards in 2017 (Junpho et al., 2022; Katchapakirin et al., 2022; Yu & Chen, 2018). In education, computational thinking is integrated as an approach that incorporates logical reasoning in formulating and solving problems systematically and structurally (Csizmadia et al., 2015; Kallia et al., 2021). Thus, computational thinking serves as a skill that equips individuals with the ability to develop problem-solving thought processes for complex challenges (Ostian et al., 2023).

In mathematics education, computational thinking is a crucial skill, particularly for solving real-life mathematical problems. Mathematics requires analytical, logical, and systematic thinking processes, which can be cultivated through computational thinking (Nurlaelah et al., 2025; Nurlaelah et al., 2024). Computational thinking trains students to break down large problems into smaller ones, recognize patterns in problem-solving, analyze relevant information, and design step-by-step solutions systematically, logically, and effectively (Jaya, 2025).

Computational thinking skills can be cultivated throughout the learning process using instructional designs that integrate computational thinking principles, including the use of computational thinking-based student worksheets (Mendrofa, 2024). By utilizing these worksheets, students can apply computational thinking stages to solve mathematical problems effectively. Mathematical problems that align well with computational thinking are often related to real-life contexts, such as integer operations.

The worksheet serves as an effective tool for developing students' computational thinking skills, as it can present well-structured problems designed to reinforce key computational thinking components (Saad & Zainudin, 2024). Computational thinking-based worksheets incorporate activities that engage students in decomposition, pattern recognition, abstraction, and algorithmic thinking. Therefore, challenges in students' computational thinking abilities can be addressed by implementing learning activities using computational thinking-based worksheets. Currently, existing worksheets do not fully incorporate computational thinking stages, highlighting the need for specially designed worksheet that aligns with computational thinking principles, particularly for integer concepts.

Integers are fundamental concepts in mathematics, forming the basis for addition, subtraction, and understanding inverses. Integers are not only crucial in advanced mathematics (Chong et al., 2022; Hapizah et al., 2024) but are also used in science (Chen et al., 2021), engineering, and everyday problem-solving (Goossens & Beliën, 2023; Purwasih et al., 2024). Students at various educational levels—elementary, middle school, and even higher education—often face challenges with integer topics. These challenges include difficulties in translating word problems into mathematical representations (Ainia & Amir, 2021), writing problem-solving steps (Ainia & Amir, 2021), calculation errors (Ainia & Amir, 2021; Latif et al., 2024; Nur et al., 2022) and conceptual misunderstandings (Harun et al., 2023; Harun et al., 2024; Khalid & Embong, 2019; Permata et al., 2019; Rosyidah et al., 2021). Moreover, students' problem-solving abilities in integer topics remain low (Zainudin et al., 2022), with learning and teaching hurdles in integer topics for both students and teachers (Lin, 2022; Zainudin et al., 2022). These issues are closely related to computational thinking components, as solving such problems involves decomposition, pattern recognition, abstraction, and algorithms.

Previous studies on students' achievements in solving integer problems connected to real-life contexts have utilized various tools and approaches. For instance, some studies have employed games (Chong et al., 2022; Salsabila et al., 2022), load coins (Deda et al., 2024), Gizmos-based lessons (Ismail et al., 2023), and Geogebra applets (Merdekawati, 2022). Other studies have explored metacognitive aspects and conceptual understanding of integers (Sercenia et al., 2023) or evaluated basic operations of integers (Nurnberger-Haag et al., 2022). However, none of these studies have examined students' achievements in integer topics from the computational thinking perspective, particularly through computational thinking-based worksheets. This research focuses on investigating the growth of students' computational thinking abilities in solving integer problems after implementing learning strategies using computational thinking-based worksheets. One of the key problems faced by students is their difficulty in solving integer-related problems. Students are not yet accustomed to engaging in computational thinking processes, particularly in problem-solving contexts. Moreover, the instructional media currently used in teaching integers do not emphasize computational thinking as part of the solution process. Therefore, there is a need to develop student worksheets that are explicitly based on computational thinking to support the development of these skills. This research aims to enhance students' computational thinking skills through the development of computational thinking-based student worksheets on integer material and focuses on investigating the growth of students' computational thinking abilities in solving integer problems after implementing learning strategies using computational thinking-based worksheets.

2. METHOD

The research method used is design research of the development studies type, consisting of three stages: preliminary research, prototype stage, and summative evaluation (Akker et al., 2007). The instrument used in this study was a set of questions designed to measure students' computational abilities. The data Analysis Process in this study involved analyzing students' computational thingking abilities and determining the N-Gain by comparing ther pretest and posttest answers. In the preliminary research stage, the researcher conducts analyses of the curriculum, material, problem contexts, literature review, and the development of the theoretical framework. The prototype stage involves the development of student worksheets that are iteratively tested. These activities aim to produce worksheets with validated quality. During the prototype stage, formative evaluation is employed, which includes self-evaluation, expert review, one-to-one, small group, and field testing (Tessmer, 2013). The final stage is summative evaluation, which is conducted to assess the effectiveness of learning implementation integrated with computational thinking-based worksheets in fostering students' computational thinking abilities. The stages of the research conducted are presented in Figure 1.

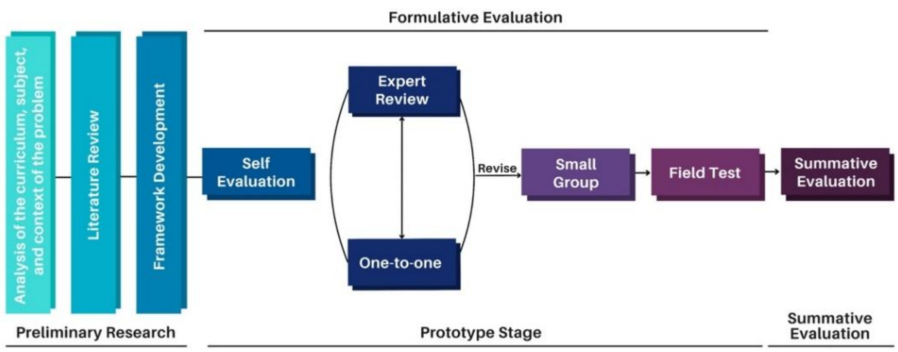


Figure 1. Research stages

Based on the Figure 1, the research process consists of three main stages: Preliminary Research, Prototype Stage (Formative Evaluation), and Summative Evaluation. In the Preliminary Research stage, the researcher begins by conducting an analysis of the curriculum, the subject matter, and the context in which the problem exists. This analysis aims to identify specific needs or issues that require development. The process continues with a comprehensive literature review to gather theoretical foundations and findings from previous studies relevant to the research focus. The insights gained from this review are then used to construct a conceptual framework, which serves as the foundation for developing the prototype.

Following this, the research enters the Prototype Stage, also known as the Formative Evaluation phase. In this stage, the initial prototype undergoes a self-evaluation by the developer to ensure alignment with the predetermined framework and objectives. It is then reviewed by experts and evaluated through one-to-one testing with individual users. These evaluations provide feedback that is used to revise and improve the prototype. Once revised, the prototype is tested with a small group to examine its practicality and usability. After passing this stage, a field test is conducted to observe the effectiveness of the product in a real-world setting.

The final stage is the Summative Evaluation, which aims to measure the overall success and impact of the developed product. This evaluation determines whether the objectives of the research and development process have been achieved and whether the final product is ready for broader implementation.

In the prototype stage, the student worksheets were tested to assess their feasibility, practicality, and effectiveness in the classroom. This process involved expert validation, small-scale trials such as one-to-one and small group testing, as well as implementation. To evaluate the validity of the worksheets, the researchers conducted validation with experts. Once declared valid, the researchers proceeded with one-to-one and small group trials to examine the practicality of the developed worksheets.

The next step was to evaluate the effectiveness of the worksheets through their implementation in field tests, conducted as the final activity in the formative evaluation. The effectiveness of the developed worksheet is measured by the improvement in students' computational thinking achievement. Before implementing the worksheets in the learning process, the researchers conducted a pretest, the results of which were related to summative evaluation. At the end of the stage, the researchers conducted a summative evaluation to determine the impact of the worksheets on students' computational thinking skills. A more detailed explanation of each trial is presented in Table 1.

Table 1. Description of trial activities

Aspects Measured	Type	Form of Assessment Instrument	Subject	Analysis
Validity	Expert review	Questionnaire	Expert with a master's degree	Descriptive
	One-to-one	Questionnaire	18 Seventh-grade students in Palembang	Descriptive
Practicality	Small group	Questionnaire	58 Seventh-grade students in Palembang	Descriptive
Effectiveness	Learning Implementation	One-group pretest-posttest	30 Seventh-grade students in Palembang	Calculation of N-gain score

The effectiveness trial used a one-group pretest-posttest experimental design, as described in Table 2.

Table 2. One-group pretest-posttest experimental design

	Pretest	Treatment	Posttest
Experimental Group	O1	✓	O2

Description:

O1 : The level of students' computational thinking ability in the experimental group before receiving the treatment, which involves the implementation of learning using computational thinking-based worksheets.

O2 : The level of students' computational thinking ability in the experimental group after receiving the treatment, which involves the implementation of learning using computational thinking-based worksheets.

O1-O2 : The change in the level of students' computational thinking ability in the experimental group before and after the implementation of learning using computational thinking-based worksheets.

The lessons conducted with the experimental group consisted of three lessons, namely: 1) a lesson on the arithmetic operations of addition and subtraction of integers; 2) a lesson on the least common multiple of integers; and 3) a lesson on the arithmetic operations of addition, subtraction, multiplication, and division of integers.

The determination of the validity category for the computational thinking-based worksheets developed refers to the criteria shown in Table 3.

Table 3. Validity criteria

Level (%)	Criteria
85.1 – 100	Very valid or can be used without revision
70.1 – 85	Fairly valid or can be used with minor revisions
50.1 – 70	Invalid or should not be used
0.0 – 50	Impractical

The determination of the practicality category for the computational thinking-based worksheets developed refers to the criteria shown in Table 4.

Table 4. Practicality criteria

Achievement (%)	Description
$84 \leq Na \leq 100$	Very Practical
$68 \leq Na < 84$	Practical
$52 \leq Na < 68$	Less Practical
$36 \leq Na < 52$	Impractical
$20 \leq Na < 36$	Very Impractical

The determination of the effectiveness category for the computational thinking-based worksheets developed refers to the criteria shown in Table 5.

Table 5. Effectiveness criteria

Achievement (%)	Description
> 75.1	Effective
55.1 - 75.0	Fairly Effective
40.1 - 55.0	Less Effective
0.0 - 40.0	Ineffective

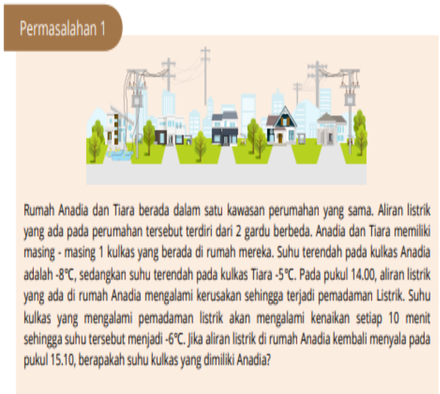
3. RESULTS AND DISCUSSION

3.1. Results

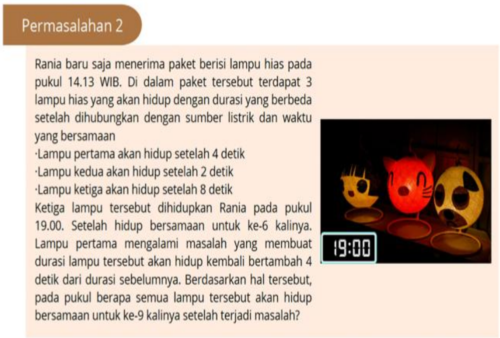
This stage is divided into initial analysis, validity, practicality, and effectiveness of the conducted research.

3.1.1. Initial Analysis

In this initial stage, a curriculum analysis related to the content of quantity was conducted, the research subjects were determined, a pretest was administered, literature was reviewed, problem contexts were selected, and the worksheets were designed. The materials included in the content of quantity for seventh-grade students are integers, fractions, equivalent ratios, linear equations with one variable, and social arithmetic. Based on the literature review and its connection to the material, the chosen problem context is temperature change for the topic of integers. This context was selected because it could be illustrated using a cooling device, which is a concept familiar to students' daily lives. Subsequently, the student worksheets related to the problem were designed, referring to the components of computational thinking. The design of the student worksheets is shown in Figure 2.



Translation:
Problem 1
Anadia and Tiara's houses are located in the same housing complex. The electricity supply in this housing area comes from two different substations. Anadia and Tiara each have a refrigerator in their homes. The lowest temperature in Anadia's refrigerator is -8°C, while the lowest temperature in Tiara's refrigerator is -5°C. At 2:00 PM, the electricity supply in Anadia's house was damaged, causing a power outage. The temperature in the refrigerator, which was affected by the power outage, rises every 10 minutes until it reaches -6°C. If the electricity in Anadia's house is restored at 3:10 PM, what will the temperature of Anadia's refrigerator be?



Translation:
Problem 2
Rania just received a package containing decorative lights at 2:13 PM. Inside the package, 3 decorative lights will turn on after different durations when connected to a power source at the same time:

- The first light will turn on after 4 seconds.
- The second light will turn on after 2 seconds.
- The third light will turn on after 8 seconds.

Rania turned on all three lights at 7:00 PM. After turning on simultaneously for the 6th time, the first light experienced an issue, causing its duration to increase by 4 seconds from its previous duration. Based on this, at what time will all three lights turn on simultaneously for the 9th time after the issue occurs?

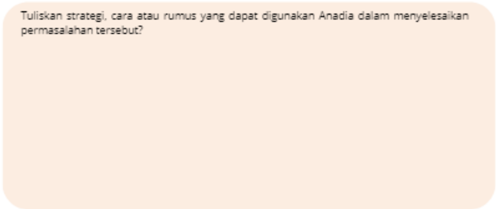
Translation:
Problem 3
This year, Angguna will give hampers (parcels) to her three friends 2 days before Eid. The first two hampers that Anggun bought cost Rp. 55,000 each, and Anggun will buy the third hamper consisting of 3 types of fruits, totaling 13 pieces: 4 apples, 3 pears, and the remaining are oranges. The unit prices for the fruits are as follows: apples Rp. 6,000, pears Rp. 8,000, and oranges Rp. 2,000. Based on this, if Anggun has Rp. 100,000, how many pears can she get from the change she receives after paying for the hampers?

Figure 2. The issues in the worksheet

Figure 2 shows the problem designed in the worksheets. This problem was created to provide students with an opportunity to develop their computational thinking skills through the components of computational thinking, namely decomposition, pattern recognition, abstraction, and algorithm. One of the questions posed to students to stimulate the components of computational thinking is shown in Figure 3.

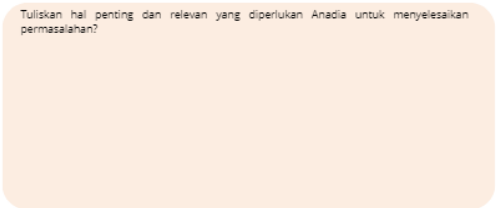
Translation:
What should Anadia do to solve the problem?

(*Decomposition*)



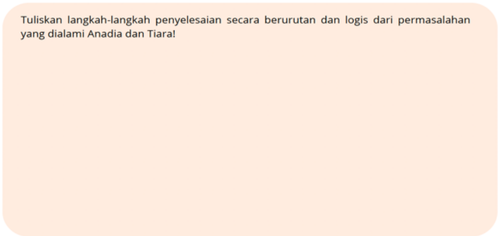
Translation:
Write down the strategy, method, or formula that Anadia can use to solve the problem!

(*Patter Recognition*)



Translation:
Write down the important and relevant information that Anadia needs to solve the problem!

(*Abstraction*)



Translation:
Write down the steps of the solution in a sequential and logical order for the Anadia and Tiara's problem!

(*Algorithm*)

Figure 3. Computational thinking's components in worksheet

Based on the results of the initial analysis and the subsequent design of the worksheets, the next step was to evaluate the validity of the developed learning materials to ensure their alignment with content standards, structure, and computational thinking components.

3.1.2. Validity

The validation of the worksheet design begins with self-evaluation. The result of this stage showed no significant changes, only the need to tidy up the problem presentation and add images. The next stage was to validate the worksheets with experts by assessing aspects of content, structure, and language. The results of the expert validation are shown in Table 6, with the conclusion of being very valid.

Table 6. Validation results

No	Aspect	Percentage
1	Content	91%
2	Structure	81%
3	Language	90%
	Average	87%
	Category	very valid or can be used without revision

The validation process also focused on the computational thinking components, with the validation results shown in Table 7 and the conclusion of being fairly valid.

Table 7. Validation results regarding components of computational thinking

No	Indicator	Percentage
1	Decomposition	75%
2	Pattern Recognition	63%
3	Abstraction	88%
4	Algorithm	88%
	Average	79%
	Category	fairly valid or can be used with minor revisions

In addition to being validated by experts, the worksheet's design was also validated by students through readability responses. The validation with students was carried out through observation, and the results of the observation are shown in Table 8.

Table 8. Observation results

No.	Finding
1.	Students are not accustomed to problems/questions in the form of stories.
2.	On average, students are able to solve the sub-questions related to decomposition and pattern recognition, whereas for the indicators of abstraction and algorithm, students still require a lot of guidance.
3.	Students have difficulty understanding the key terms in the computational thinking indicators.

After confirming the validity of the worksheets through expert review and student responses, the practicality of the materials was examined through small group trials to determine their usability and acceptability in a classroom setting.

3.1.3. Practicality

The small group stage was conducted to assess the practicality of the worksheets that had been designed after undergoing the expert review and one-to-one stages. In this stage, the worksheets were tested on a small group consisting of 3 groups, with each group having 6 to 7 students for each worksheet. All students in the small groups were not part of the research subjects. After each group had conducted the trial, they were asked to complete a questionnaire. The recap of the students' responses to the practicality questionnaire is shown in Table 9.

Table 9. Practicality results

No	Indicator	Percentage
1.	Accuracy and Completeness of Information	76.5%
2.	Convenience	71.8%
3.	Appeal	79.25%
4.	Time Efficiency	72.5%
	Average	75%
	Category	Practical

3.1.4. Implementation

The teaching conducted is based on the components of computational thinking and supported by the computational thinking-based worksheets. The participants were 30 seventh-grade students (15 males and 15 females) selected through random class sampling. During the learning process, students made errors in each computational thinking component. The findings of the mistakes are as follows:

Decomposition

- Students struggled to determine the steps to solve the problem.
- Students found it difficult to break down complex problems into simpler parts.
- Students directly proceeded with calculations.
- There were mistakes in writing the solution steps and patterns for solving the problems.
- Students only wrote down the information from the question.

Pattern Recognition

- Students were unable to identify the concept or material used for calculations.
- Students focused only on the final result of the problem-solving.
- Students experienced misconceptions between the decomposition and pattern recognition indicators.

Abstraction

- Students were unable to write down the important and relevant information from the problem.
- Students only wrote part of the information given in the problem.
- Students still wrote down information that was irrelevant to solving the problem.
- Students directly proceeded with calculations.

Algorithm

- Students only performed calculations without following the correct order of steps.
- Students did not write down the solution steps in a mathematical manner.
- There were calculation errors leading to incorrect answers.

Following the practicality assessment, the focus shifted to evaluating the effectiveness of the worksheets in enhancing students' computational thinking skills, which was measured through a pretest-posttest implementation during classroom instruction.

3.1.5. Effectiveness

The analysis of the effectiveness of the computational thinking-based worksheets were conducted after the learning process. A visualization comparing the pretest and posttest scores of 30 students has been added in Figure 4, which shows a consistent upward trend in students' performance after using the worksheets.

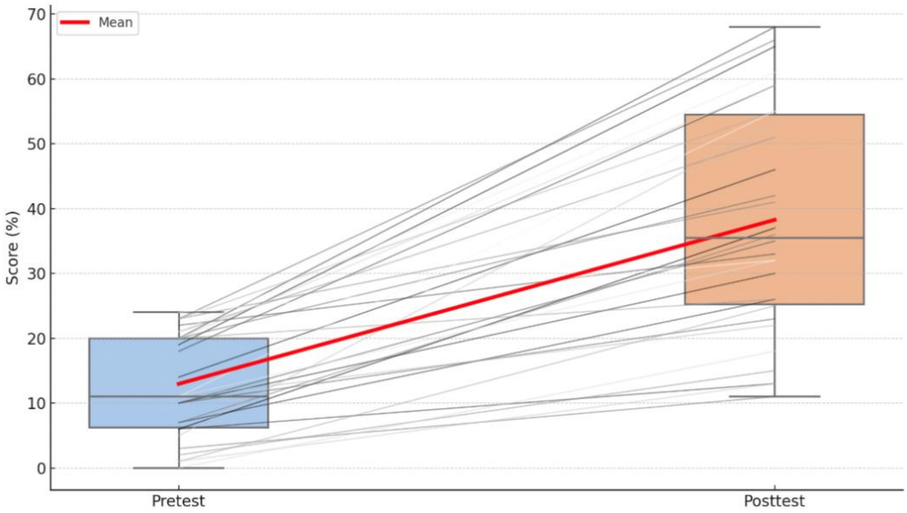


Figure 4. Comparison of pretest and posttest scores

The analysis of each computational thinking component from the pretest and posttest results is shown in Figure 5.

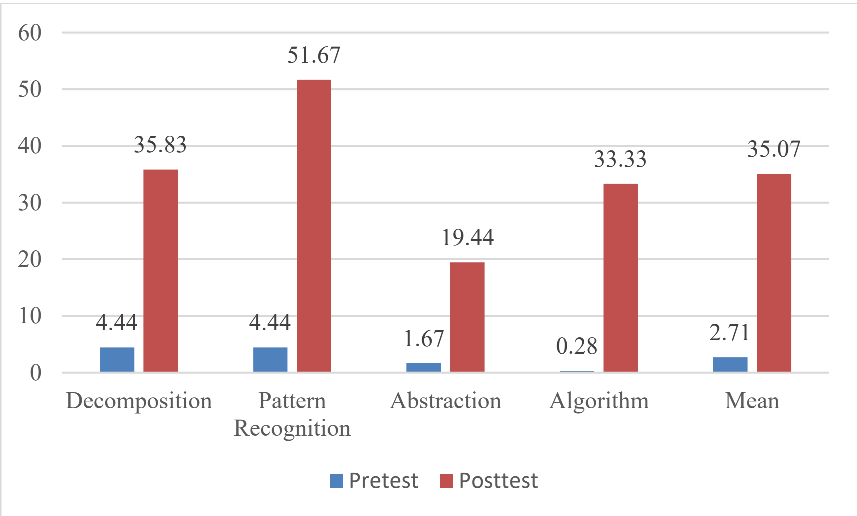


Figure 5. Results of computational thinking components

The improvement achieved by the students is presented in Table 10.

Table 10. N-Gain of computational thinking components

Component	Posttest	Pretest	Posttest-Pretest	Ideal Score Pretest	N-Gain Score	N Gain Score (%)
Decomposition	35.83	4.44	31.39	47.23	0.66	66
Pattern Recognition	51.67	4.44	47.23	47.23	1.00	100
Abstraction	19.44	1.67	17.77	50.00	0.36	36
Algorithm	33.33	0.28	33.05	51.39	0.64	64
Average	**35.07**	**2.71**	**32.36**	**48.96**	**0.67**	**66.58**

To evaluate the statistical significance of the difference between pretest and postest scores, a paired sample t-test was conducted. The analysis showed a t-statistic of 9.47 with a p-value of 2.22×10^{-10}, indicating a statistically significant difference. The effect size, measured using Cohen's *d*, was 1.73, which suggests a large practical impact. These results indicate that the use of a computational thinking-based student worksheet had a strong and meaningful effect on improving student computational thinking skill.

3.2. Discussion

The computational thinking-based worksheets developed in this study were categorized as highly valid, with an average score of 87%. The content aspect received a very high score of 91%, indicating strong alignment with the targeted competencies, namely computational thinking. Similarly, the language and construct aspects scored 90% and 81%, respectively, ensuring clarity, appropriateness, and structural coherence. The components of computational thinking embedded in the worksheets were also considered moderately valid (average 79%), with abstraction and algorithm rated highest (88%), followed by decomposition (75%) and pattern recognition (63%).

In terms of practicality, the worksheets were rated as generally practical based on teacher assessments. Accuracy and completeness reached 76.5%, ease of use 71.8%, attractiveness 79.25%, and time efficiency 72.5%. These findings suggest that the worksheet design can be easily implemented in real classrooms and is predicted to enhance students' computational thinking skills.

To evaluate effectiveness, pretest and posttest results were analyzed. Students' average pretest score was only 2.71%, which increased to 35.07% in the posttest—an indication of notable learning progress, though still in the low category. This improvement was supported by a paired sample t-test, which yielded a t-statistic of 9.47 and a p-value of 2.22×10^{-10}, showing a statistically significant difference. The effect size (Cohen's *d*) was 1.73, indicating a large effect and confirming that the worksheet had a substantial impact on students' computational thinking skills.

Despite the improvement, several difficulties were identified. Many students initially lacked problem-solving strategies and struggled to analyze and understand integer-related problems (Ainia & Amir, 2021; Nur et al., 2022). This was especially evident in the abstraction component, which showed the lowest improvement (pretest: 1.67%, posttest: 19.44%; N-Gain: 36%). Students often failed to filter relevant information or represent problems symbolically, reflecting common challenges reported in earlier studies (Salwadila & Hapizah, 2024; Sun & Yang, 2023; Zhong & Xia, 2020).

In contrast, the pattern recognition component showed an N-Gain of 100% (posttest: 51.67%), with students becoming better at identifying recurring structures and strategies. Decomposition also improved significantly (N-Gain: 66%), helping students break down complex problems into simpler sub-problems (Rijke et al., 2018). Algorithmic thinking saw an increase from 0.28% to 33.33% (N-Gain: 64%), aided by the structured problem-solving steps embedded in the worksheet (Ainia & Amir, 2021; Nur et al., 2022).

The overall N-Gain was 66.58%, categorized as moderate effectiveness. The worksheet successfully scaffolded learning processes, guiding students from problem identification to structured solution, and strengthening their logical reasoning. Compared to previous studies (Ostian et al., 2024), where the majority of students remained at a medium level, this study highlights the benefits of well-designed instructional materials in supporting computational thinking. Nonetheless, abstraction remains a key area for improvement and refinement. As noted by Li et al. (2021), students' unfamiliarity with computational thinking concepts continues to be a barrier, reinforcing the need for repeated exposure and teacher guidance.

4. CONCLUSION

This study concludes that the use of computational thinking-based student worksheets has the potential to enhance students' computational thinking skills in integer material. The developed worksheets are designed with structured problem-solving stages aligned with computational thinking components, guiding students through analyzing problems, identifying relevant strategies, filtering essential information, and systematically solving problems. The results showed a 66.58% improvement in students' computational thinking skills, demonstrating the effectiveness of the developed worksheets.

Although the improvement is not yet optimal, it is significant considering that students initially had very low computational thinking skills. However, this study is limited to assessing effectiveness based solely on test results, without direct classroom observations or qualitative insights from students and teachers. For educators, the findings suggest integrating computational thinking-based worksheets as a regular part of mathematics instruction, particularly for integer concepts. Teachers should familiarize themselves with the four core components of computational thinking (decomposition, pattern recognition, abstraction, and algorithm) and explicitly guide students through these stages when solving problems. Special attention should be given to fostering abstraction skills, perhaps through additional scaffolding, targeted exercises, and explicit discussions on identifying relevant information.

For researchers, a crucial next step involves conducting mixed-methods studies that combine quantitative data (e.g., N-Gain scores) with qualitative data (e.g., classroom observations, student and teacher interviews, focus groups). This would provide a more holistic understanding of how computational thinking-based worksheets influence learning processes, student engagement, and specific learning challenges related to each computational thinking component, especially abstraction. Future research could incorporate observational data, interviews, or longitudinal studies to gain a deeper understanding of how students engage with the worksheets and how these materials can be further refined.

The findings highlight that computational thinking-based student worksheets can serve as a valuable learning tool to support the development of students' problem-solving skills. These results provide a foundation for further refinement of computational thinking-based learning materials and their broader application in similar educational contexts. The success of these worksheets strongly suggests the necessity of integrating computational thinking as a core component of mathematics instruction, advocating for its adoption in national curricula and comprehensive teacher training programs to prepare educators for this evolving pedagogical landscape.

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Declarations

Author Contribution	: H: Conceptualization, Investigation, Methodology, Project administration, Visualization, Writing - original draft, and Writing - review & editing; BM: Formal analysis, Validation, and Writing - review & editing; DC: Formal analysis.
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REFERENCES

Ainia, C., & Amir, M. F. (2021). Analysis of elementary school students difficulties' in solving integer word problems. *MaPan*, *9*(2), 304–319. https://doi.org/10.24252/mapan.2021v9n2a8

Akker, J. v. d., Bannan, B., Kelly, A. E., Nieveen, N., & Plomp, T. (2007). Curriculum design research. In T. Plomp & N. Nieveen (Eds.), *An introduction to educational design research* (Vol. 37, pp. 37–50).

Ansu-Kyeremeh, E. K., & Goosen, L. (2022). Exploring the socioeconomic facet of online inclusive education in Ghana: The effects of technological advancement in academia. In M. B. Garcia (Ed.), *Socioeconomic inclusion during an era of online education* (pp. 47–66). IGI Global Scientific Publishing. https://doi.org/10.4018/978-1-6684-4364-4.ch003

Challenor, J., & Ma, M. (2019). A review of augmented reality applications for history education and heritage visualisation. *Multimodal Technologies and Interaction*, *3*(2), 39. https://doi.org/10.3390/mti3020039

Chen, K., Ren, X.-t., & Yang, G.-l. (2021). A novel approach for assessing academic journals: Application of integer DEA model for management science and operations research field. *Journal of Informetrics*, *15*(3), 101176. https://doi.org/10.1016/j.joi.2021.101176

Chong, W. W. N., Shahrill, M., Asamoah, D., & Latif, S. N. A. (2022). Non-digital card game and year 8 students' performance in integers. *Journal of Mathematics and Science Teacher*, *2*(1), em007. https://doi.org/10.29333/mathsciteacher/11928

Csizmadia, A., Curzon, P., Dorling, M., Humphreys, S., Ng, T., Selby, C., & Woollard, J. (2015). *Computational thinking: A guide for teachers*. Computing At School.

Deda, Y. N., Laja, Y. P. W., & Talan, N. (2024). Effectiveness of using koin muatan teaching aids to improve numeracy skills. *International Journal of Research in Education*, *4*(1), 186–193. https://doi.org/10.26877/ijre.v4i1.16876

Durak, H. Y., Yilmaz, F. G. K., & Yilmaz, R. (2019). Computational thinking, programming self-efficacy, problem solving and experiences in the programming process conducted with robotic activities. *Contemporary Educational Technology*, *10*(2), 173–197. https://doi.org/10.30935/cet.554493

Ghory, S., & Ghafory, H. (2021). The impact of modern technology in the teaching and learning process. *International Journal of Innovative Research and Scientific Studies*, *4*(3), 168–173. https://doi.org/10.53894/ijirss.v4i3.73

Goossens, D., & Beliën, J. (2023). Teaching integer programming by scheduling the Belgian soccer league. *INFORMS Transactions on Education*, *23*(3), 164–172. https://doi.org/10.1287/ited.2022.0269

Hapizah, H., Mariela, A. M., & Mulyono, B. (2024). Assessing seventh-grade students' computational thinking skills through problem-based learning: Focus on integer addition and subtraction. *Journal of Honai Math*, *7*(2), 197–214.

Harun, N. A., Cuevas, K. G., Asakil, O., Alviar, J., & Solon, L. J. (2023). Assessing students' mastery and misconceptions in the fundamental operations on integers. *International Journal of Science, Technology, Engineering and Mathematics*, *3*(3), 36–55. https://doi.org/10.53378/353000

Harun, N. A., Cuevas, K. G., Sagdi, L. J., Sapilin, A., Nasilon, N., Kadil, M., Alviar, J., & Solon, L. J. (2024). Impact of intervention on students' mastery level and analysis of misconceptions in operations on integers. *International Journal of Multidisciplinary: Applied Business and Education Research*, *5*(2), 411–422. https://doi.org/10.11594/ijmaber.05.02.04

Ismail, N. F. H., Shahrill, M., & Asamoah, D. (2023). Learning through virtual manipulatives: Investigating the impact of Gizmos-based lessons on students' performance in integers. *Contemporary Mathematics and Science Education*, *4*(1), ep23009. https://doi.org/10.30935/conmaths/12857

Jaya, S. (2025). Enhancing problem-solving abilities of teachers and students through integrated computational thinking training in the curriculum. *Sebatik*, *29*(1), 96–102. https://doi.org/10.46984/sebatik.v29i1.2606

Junpho, M., Songsriwittaya, A., & Tep, P. (2022). Reliability and construct validity of computational thinking scale for junior high school students: Thai adaptation. *International Journal of Learning, Teaching and Educational Research*, *21*(9), 154–173. https://doi.org/10.26803/ijlter.21.9.9

Kallia, M., van Borkulo, S. P., Drijvers, P., Barendsen, E., & Tolboom, J. (2021). Characterising computational thinking in mathematics education: A literature-informed Delphi study. *Research in Mathematics Education*, *23*(2), 159–187. https://doi.org/10.1080/14794802.2020.1852104

Katchapakirin, K., Anutariya, C., & Supnithi, T. (2022). ScratchThAI: A conversation-based learning support framework for computational thinking development. *Education and*

Information Technologies, *27*(6), 8533–8560. https://doi.org/10.1007/s10639-021-10870-z

Khalid, M., & Embong, Z. (2019). Sources and possible causes of errors and misconceptions in operations of integers. *International Electronic Journal of Mathematics Education*, *15*(2), em0568. https://doi.org/10.29333/iejme/6265

Kiong, J. F. (2023). The impact of technology on education: A case study of schools. *Journal of Education Review Provision*, *2*(2), 43–47. https://doi.org/10.55885/jerp.v2i2.153

Latif, N. H. A., Shahrill, M., & Hidayat, W. (2024). Mastering fractions and innovating with the station rotation model in blended learning. *Infinity Journal*, *13*(2), 501–530. https://doi.org/10.22460/infinity.v13i2.p501-530

Li, X., Zhang, Y., & Huang, J. (2021). Testing a design-based learning approach to enhance elementary students' computational thinking with experience-sampling method. In *The 3rd World Symposium on Software Engineering*, New York (pp. 17–22). https://doi.org/10.1145/3488838.3488842

Lin, X. (2022). Difficulties in learning and teaching numbers: A literature review on the obstacles and misconceptions of learners and instructors. *Journal of Contemporary Educational Research*, *6*(6), 111–118. https://doi.org/10.26689/jcer.v6i6.4073

Maharani, S., Kholid, M. N., Pradana, L. N., & Nusantara, T. (2019). Problem solving in the context of computational thinking. *Infinity Journal*, *8*(2), 109–116. https://doi.org/10.22460/infinity.v8i2.p109-116

Mendrofa, N. K. (2024). Computational thinking skills in 21st century mathematics learning. *JIIP - Jurnal Ilmiah Ilmu Pendidikan*, *7*(1), 792–801. https://doi.org/10.54371/jiip.v7i1.3780

Merdekawati, S. (2022). Enhancing students' understanding of operation in integers through joyful learning with GeoGebra™ Applet. *Southeast Asian Mathematics Education Journal*, *12*(2), 161–170. https://doi.org/10.46517/seamej.v12i2.165

Nur, A. S., Kartono, K., Zaenurİ, Z., & Rochmad, R. (2022). The learning trajectory construction of elementary school students in solving integer word problems. *Participatory Educational Research*, *9*(1), 404–424. https://doi.org/10.17275/per.22.22.9.1

Nurlaelah, E., Pebrianti, A., Taqiyuddin, M., Dahlan, J. A., & Usdiyana, D. (2025). Improving mathematical proof based on computational thinking components for prospective teachers in abstract algebra courses. *Infinity Journal*, *14*(1), 85–108. https://doi.org/10.22460/infinity.v14i1.p85-108

Nurlaelah, E., Usdiyana, D., & Fadilah, N. (2024). The relationship between computational thinking ability and logical mathematical intelligence. *Mosharafa: Jurnal Pendidikan Matematika*, *13*(1), 87–96. https://doi.org/10.31980/mosharafa.v13i1.1978

Nurnberger-Haag, J., Kratky, J., & Karpinski, A. C. (2022). The integer test of primary operations: A practical and validated assessment of middle school students' calculations with negative numbers. *International Electronic Journal of Mathematics Education*, *17*(1), em0667. https://doi.org/10.29333/iejme/11471

Ostian, D., Hapizah, H., & Mulyono, B. (2023). Interactive e-student worksheet based on computational thinking with South Sumatera traditional game context. *Jurnal*

Pendidikan Matematika RAFA, *9*(2), 101–122. https://doi.org/10.19109/jpmrafa.v9i2.20339

Ostian, D., Hapizah, H., & Mulyono, B. (2024). Students' computational thinking ability on learning of integers. *Tarbawi: Jurnal Ilmu Pendidikan*, *20*(1), 88–99.

Permata, D., Wijayanti, P., & Masriyah, M. (2019). Students' misconceptions on the algebraic prerequisites concept: Operation of integer numbers and fractions. *Journal of Physics: Conference Series*, *1188*(1), 012059. https://doi.org/10.1088/1742-6596/1188/1/012059

Purwasih, R., Turmudi, T., Afgani Dahlan, J., Irawan, E., & Minasyan, S. (2024). A semiotic perspective of mathematical activity: The case of integer. *Infinity Journal*, *13*(1), 271–284. https://doi.org/10.22460/infinity.v13i1.p271-284

Rijke, W. J., Bollen, L., Eysink, T. H. S., & Tolboom, J. L. J. (2018). Computational thinking in primary school: An examination of abstraction and decomposition in different age groups. *Informatics in Education*, *17*(1), 77–92. https://doi.org/10.15388/infedu.2018.05

Rosyidah, A. N. K., Maulyda, M. A., Jiwandono, I. S., Oktaviyanti, I., & Gunawan, G. (2021). Misconceptions and errors in integer operations: A study in preservice elementary school teachers (PGSD). *Journal of Physics: Conference Series*, *1779*(1), 012078. https://doi.org/10.1088/1742-6596/1779/1/012078

Saad, A., & Zainudin, S. (2024). A review of teaching and learning approach in implementing project-based learning (PBL) with computational thinking (CT). *Interactive Learning Environments*, *32*(10), 7622–7646. https://doi.org/10.1080/10494820.2024.2328280

Salsabila, I., Amir, M. F., & Wardana, M. D. K. (2022). A learning trajectory of integer addition and subtraction using the kempreng game context. *Jurnal Elemen*, *8*(2), 556–571. https://doi.org/10.29408/jel.v8i2.5541

Salwadila, T., & Hapizah, H. (2024). Computational thinking ability in mathematics learning of exponents in grade IX. *Infinity Journal*, *13*(2), 441–456. https://doi.org/10.22460/infinity.v13i2.p441-456

Sercenia, J. C., Ibañez, E. D., & Pentang, J. T. (2023). Thinking beyond thinking: Junior high school students' metacognitive awareness and conceptual understanding of integers. *Mathematics Teaching Research Journal*, *15*(1), 4–24.

Sun, Q., & Yang, Z. (2023). Research on abstraction ability under the background of mathematics key competencies in junior high school in China. *Asian Journal of Education and Social Studies*, *40*(2), 46–58. https://doi.org/10.9734/ajess/2023/v40i2871

Tessmer, M. (2013). *Planning and Conducting Formative Evaluations*. Routledge. https://doi.org/10.4324/9780203061978

Tikva, C., & Tambouris, E. (2021). Mapping computational thinking through programming in K-12 education: A conceptual model based on a systematic literature Review. *Computers & Education*, *162*, 104083. https://doi.org/10.1016/j.compedu.2020.104083

Wing, J. M. (2006). Computational thinking. *Communications of the ACM*, *49*(3), 33–35. https://doi.org/10.1145/1118178.1118215

Wu, W.-R., & Yang, K.-L. (2022). The relationships between computational and mathematical thinking: A review study on tasks. *Cogent Education*, *9*(1), 2098929. https://doi.org/10.1080/2331186x.2022.2098929

Yu, Y., & Chen, Y. (2018). Design and development of high school artificial intelligence textbook based on computational thinking. *OALib*, *5*(9), 1–15. https://doi.org/10.4236/oalib.1104898

Zainudin, M., Amin, A. K., & Fatah, D. A. (2022). Understanding elementary school students' errors in completing number operations. In *5th International Conference on Education and Social Science Research (ICESRE)*, (Vol. 5, pp. 592–602). https://doi.org/10.18502/kss.v7i19.12478

Zhong, B., & Xia, L. (2020). A systematic review on exploring the potential of educational robotics in mathematics education. *International Journal of Science and Mathematics Education*, *18*(1), 79–101. https://doi.org/10.1007/s10763-018-09939-y