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Exploring Teacher Activities in Mathematics Problem Solving through Computational Thinking Using Scratch

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Abstract

This article examines the results of Computational Thinking (CT) training using Scratch for high school teachers who are members of the Barito Kuala district mathematics MGMP *(Musyawarah Guru Mata Pelajaran)*, facilitated by Computer Education Study Program of Universitas Lambung Mangkurat. Employing a case study method, the training focused on the experiences of teachers in understanding and applying CT based on the case given. Key CT concepts, such as abstraction, decomposition, pattern recognition, and algorithmic thinking, were introduced, with participants creating visual programs to solve problems or cases in mathematics. Pre- and post-training questionnaires were used to evaluate changes in teachers' perceptions and knowledge across seven aspects. The results show an increase in understanding of CT concepts for 34 participants by 60%, while 63.33% of participants reported improved confidence in using Scratch compared to 53.33% before the training. Additionally, 66.67% of participants assessed the training as effective in enhancing their teaching skills. This activity shows that integrating CT into mathematics education can significantly enhance teachers' problem-solving abilities and contribute to a more technology-driven educational approach to education in high school classrooms.

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INTRODUCTION

Computational Thinking (CT) has become a fundamental skill across various fields, including education. CT helps individuals solve problems through logical, systematic, and structured thinking (Aminah et al., 2023; Ye et al., 2023). For students, this skill is crucial in facing the increasingly complex challenges of the 21st century. Through CT, students not only learn to solve problems but also develop the ability to think abstractly and algorithmically, as well as break down complex issues into simpler parts (Wang et al., 2022).

In Indonesia, integrating technology into the educational curriculum is one way to preparing the younger generation for the future (Ammade et al., 2018). One technology with significant potential for supporting the teaching of CT is Scratch, a visual programming platform designed for users without prior coding experience (Resnick et al.,

2009). Scratch allows both students and teachers to grasp basic programming concepts in a fun and interactive way. However, the use of this technology remains limited in Indonesia (Kafai, Y. B., & Burke, 2014). Although it does not generalize, it can be used as a reference in one of the regions in southern Kalimantan, namely the district of Barito Kuala where this training is conducted.

Discussion with representatives of high school teachers' associations in Barito Kuala revealed that most high school teachers in Barito Kuala are unfamiliar with CT and the application of Scratch. In their daily teaching, many still rely on traditional methods that focus on memorizing formulas and procedures for solving problems without engaging students in deeper thinking processes like decomposition, abstraction, or algorithmic thinking (Midgett & Eddins, 2001). As a result, students' abilities to solve complex problems have not developed as well as they could.

This represents a gap and challenge that must be addressed through collaborative efforts. One potential solution is to introduce CT as a core element of teaching. This training is designed to introduce CT as a foundational skill that can be applied to solving math problems, with the help of the Scratch platform (Ye et al., 2023). The main goal of the training is to provide teachers with a deeper understanding of CT and how to integrate it into math teaching. Through this approach, it is hoped that teachers can improve students' problem-solving skills, not just through traditional methods but in more creative, interactive, and technology-driven ways.

Additionally, this training aims to reduce the digital skills gap among teachers in Barito Kuala. By using Scratch, teachers are expected to apply concepts such as abstraction (the ability to filter important information from irrelevant details), decomposition (breaking down large problems into smaller, more manageable parts), and algorithmic thinking (creating systematic steps to solve problems). The training is also intended to boost teachers' confidence in using technology in their teaching and provide them with new tools and strategies to enhance the quality of math education in schools (Ye et al., 2023).

Through this training, it is hoped that teachers in Barito Kuala would gain a better understanding of the importance of CT and the role of technology like Scratch in math education, helping them better prepare students to become effective problem-solvers in the future.

METHODS

This training employed a case study method during the workshop, focusing on the exploration of teachers experiences who participated in a workshop aimed at enhancing their understanding of CT and its application in mathematics education (Yin, 2023). The subjects of this study are teachers from Kabupaten Barito Kuala who attended the workshop, where they were introduced to key CT concepts: abstraction, decomposition, pattern recognition, and algorithmic thinking (Aminah et al., 2023; Ammade et al., 2018).

During the workshop, teachers first learned to simplify mathematical problems through abstraction, identifying essential elements while filtering out irrelevant details (Aminah et al., 2023; Wing, 2006). They, then, practiced decomposition by breaking complex problems into smaller, manageable parts (Grover & Pea, 2015). The concept of pattern recognition was emphasized to help them identify recurring sequences in problems (Kafai & Burke, 2014). Following these phases, teachers engaged in algorithmic thinking, where they developed step-by-step procedures for solving problems (Barr & Stephenson, 2014).

After mastering algorithmic thinking, teachers implemented their algorithms in Scratch, creating visual programs to solve specific mathematical problems, such as

calculating areas or sequences. This hands-on experience allowed them to translate their algorithmic steps into functional code, reinforcing their understanding of both CT and programming.

A questionnaire was administered before and after the workshop to evaluate the effectiveness of the training. This tool measured teachers' perceptions of CT concepts and their confidence in integrating these concepts into their teaching. Observations and interviews provided additional qualitative insights into the teachers' experiences, challenges faced, and progress made during the training. Overall, this mixed-method approach allowed for a comprehensive understanding of how teachers engaged with and applied CT in their classrooms (Gregar, 2016), as well as the impact of the workshop on their teaching strategies.

Data gained and being analyzed in this activity involved both qualitative and quantitative approaches to comprehensively evaluate the effectiveness of the workshop on teachers' understanding and application of CT. We observed teachers' activities during the workshop, creating detailed notes on their engagement with CT concepts and their implementation of Scratch to solve mathematical problems. Individual assessments of problem-solving abilities were conducted before and after the workshop to gauge the teachers' progress.

Qualitative data analysis began with organizing, annotating, and describing the observations and interview responses (Merriam & Tisdell, 2016), providing insight into the teachers' experiences and challenges in applying CT in their classrooms. For quantitative analysis, data collected from the questionnaires and problem-solving assessments were analyzed to compare pre- and post-workshop scores (Piryani et al., 2018). This allowed for an evaluation of the impact of the training on the teachers' knowledge and confidence in using CT concepts. The research process was structured in three stages: an initial assessment to establish baseline abilities, the intervention during the workshop, and a follow-up analysis of activities and performance. This triangulated approach ensured a robust evaluation of the workshop's effectiveness.

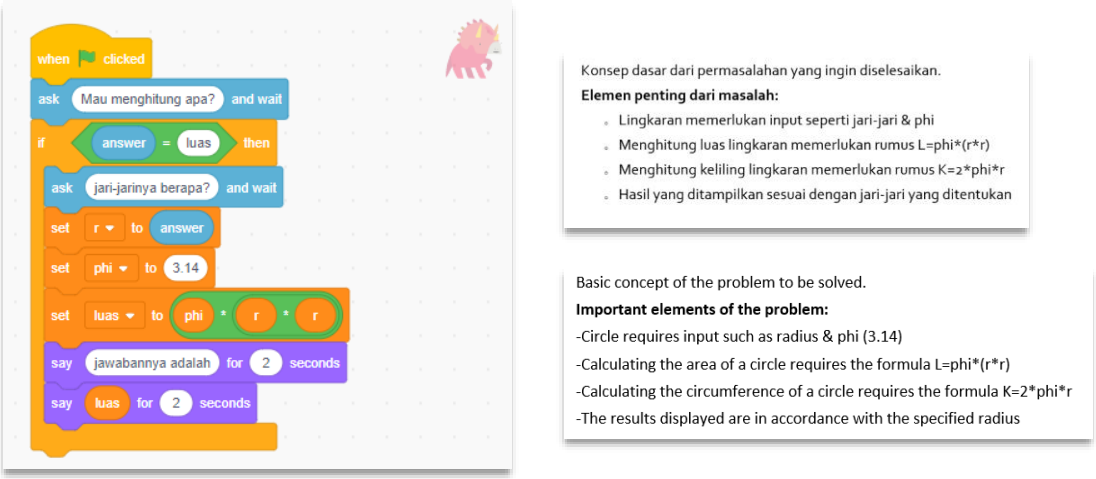
RESULTS AND DISCUSSION

The research process began with an introduction to interactive products that can be made from Scratch so that teachers get an idea of what they can create or develop. In this activity, the teachers are given a briefing on the main features of Scratch. As shown in Figure 1, teachers were introduced and familairized with the features and functions of Scratch that will be used. Teachers are expected to generally be able to understand the functions of the buttons available in the Scratch program before using Scratch directly and the features or buttons in Scratch. Since the first activity, teachers have been enthusiastic about trying what they have just learned.

Figure 1 Teachers are being introduced to Scratch and the features that can be used

In the following session, teachers began practicing the Computational Thinking concepts introduced in the early session. They were assigned a task to solve a mathematical problem related to circles, such as calculating the area or circumference of

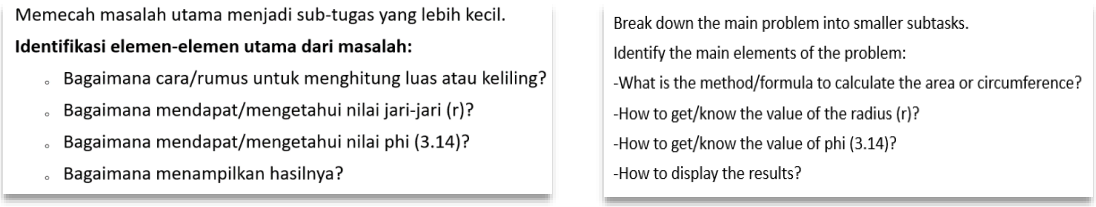
a circle. They were asked to identify the key elements of the problem, such as the radius and the value of pi. This process is referred to as abstraction, where teachers simplify the problem into core concepts like the radius variable (r) and the constant pi ($\pi = 3.14$), and apply the appropriate formulas for either the area ($A = \pi * r^2$) or the circumference ($C = 2 * \pi * r$). Teachers mentally organized these mathematical concepts, transforming the real-world problem into symbols that could later be translated into a program. The process of designing abstractions by teachers to map the essential elements of the problem to be solved is shown in Figure 2.



(a) (b)

Figure 2 (a) Examples of teachers scribbles during abstract thinking and (b) the code they write later

As the activity progressed, teachers moved on to the process of decomposition, where the larger problem—calculating the area or circumference—was broken down into smaller, more manageable tasks. Overview of this activity can be shown in Figure 3, problem solving into simpler problems to facilitate problem solving. Teachers identified sub-tasks, such as determining the radius, deciding whether to compute the area or the circumference, and displaying the calculated results. This stage enabled them to understand how to break a complex problem into simpler, step-by-step solutions that could be tackled one at a time.



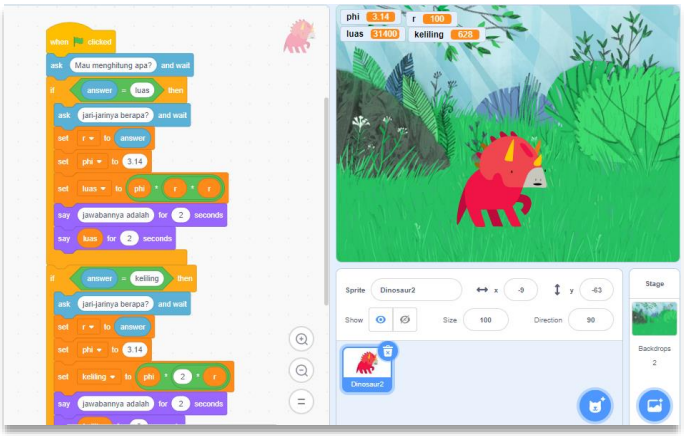
(a) (b)

Figure 3 (a) Examples of teachers breaking down problems into smaller, more essential sub-problems and (b) Translate to English

During the exercise, teachers also had the opportunity to recognize recurring patterns in their programming. At the stage of pattern recognition, teachers identified input-output patterns, where the radius consistently served as the input while the output—either the

area or circumference—changed according to the performed calculations. These mathematical patterns were constant, with the formulas remaining the same, but the input values affected the final output. Recognizing these patterns allowed teachers to more easily grasp how mathematical formulas could be applied to various problem scenarios.

Finally, the teachers entered the stage of algorithmic thinking, where they began to organize the logical steps needed to create the program. They structured the algorithm, starting from defining the radius and pi variables to designing conditional statements to decide whether to calculate the area or circumference. Each step was translated into code (blocked-based) as shown in Figure 4, where teachers first asked the user for input, stored the input value, computed the result using the corresponding formula, and then displayed the output. This process guided teachers to think systematically and methodically, enabling them to build algorithms that effectively and accurately solved the problem.



(a)

Algorithmic Thinking (Berpikir Algoritmik)

Langkah-langkah pembuatan program.:

1. Buat variabel jari-jari (r), phi, luas dan keliling.
2. Buat perintah untuk menyakan kepada pengguna apa yang ingin dihitung: luas atau keliling.
3. Buat perintah untuk menyimpan jawaban pilihan pengguna.
4. Buat perkondisian jika yang dipilih adalah Luas.
5. Buat perintah untuk meminta pengguna memasukkan nilai jari-jari.
6. Buat perintah untuk program menyimpan jari-jari yang diinputkan.
7. Buat perintah untuk menentukan nilai phi (3.14).
8. Buat perintah untuk menggunakan rumus luas lingkaran, phi*r*r
9. Tampilkan hasil perhitungan Luas lingkaran.
10. Lakukan Kembali hal sama dimulai dari tahap no 4, namun yang dipilih adalah Keliling dan rumusnya (no.8) adalah Keliling lingkaran (2phi*r).
11. Tampilkan hasil perhitungan Luas lingkaran
12. Selesai

(b)

Figure 4 Block-based code written by teachers (a) and (b) code writing based on steps from the algorithmic thinking stage

Throughout this process, teachers actively used abstraction skills to simplify the problem and translate it into symbolic forms that could be manipulated by the computer. Iterating through these steps helped them gain a deeper understanding of Computational Thinking as a logical approach that can be applied to everyday mathematical problems.

In addition to conducting an in-depth case study on teachers' activities in solving math problems using Computational Thinking (CT) with Scratch, this research is also supported by a questionnaire that explores participants' perceptions and evaluations

before and after the training. This questionnaire provides a comprehensive overview of initial understanding, experiences, and changes occurring after the training across seven main aspects.

First, regarding understanding of CT before the training, 40% of participants had only a limited understanding, and 30% did not understand it at all. However, after the training, 60% reported an increase in understanding, indicating the effectiveness of the training in introducing this concept. Second, concerning the use of technology in math education, only 30% frequently used technology before the training. After the training, most participants recognized the importance of technology, especially through the CT approach. Third, participants' comfort with new technology before the training showed that 53.33% felt comfortable, which helped them adapt more easily during the training. However, the training successfully boosted participants' confidence in adopting Scratch as a new tool.

Fourth, initial knowledge of Scratch was very limited, with 60% of participants never having used Scratch before. After the training, participants felt more capable of using Scratch for teaching. Fifth, the importance of applying CT in math education was recognized by the majority of participants, with 70% considering CT important and 23.33% deeming it very important, demonstrating awareness of CT's relevance in the educational context. Sixth, 60% of participants reported that the training improved their understanding of CT, with 16.67% feeling their understanding had greatly increased. Seventh, 63.33% of participants felt confident using Scratch to solve math problems after the training, and 66.67% rated the training as effective in providing practical skills. The summary of comparison before and after the training is shown in Table 1.

Table 1 Aspect of training

Aspect	Before Training	After Training
1.Understanding of CT	40% had limited understanding; 30% did not understand it at all.	60% reported an increase in understanding.
2. Use of technology in math education	Only 30% frequently used technology.	Most participants recognized the importance of technology, especially through the CT approach.
3. Comfort with new technology	53.33% felt comfortable.	Training successfully boosted participants' confidence in adopting Scratch as a new tool.
4. Initial knowledge of Scratch	60% had never used Scratch before.	Participants felt more capable of using Scratch for teaching.
5. Importance of applying CT in math education	70% considered CT important; 23.33% considered it very important.	Awareness of CT's relevance in the educational context increased.
6. Improvement in understanding CT	-	60% reported improved understanding; 16.67% felt their understanding greatly increased.
7. Confidence in using Scratch	-	63.33% felt confident using Scratch to solve math problems; 66.67% rated the training as effective in providing skills.

The chart of comparison before and after training is shown in Figure 5 to understand the effect of training easier.

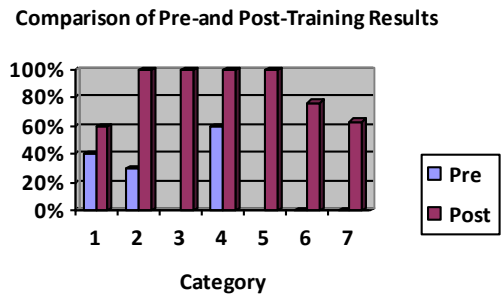


Figure 5 Comparison of pre-and post- training results of seven aspects

The improvement in participants' understanding demonstrates the success of the training method in various aspects. Previously, many participants had little understanding of CT, but after the training, most showed significant improvement. Awareness and use of technology in teaching also increased, from only a few frequently using it to all participants planning to incorporate it more often. Comfort with new technology improved as well, especially in using Scratch, which was initially unfamiliar to many but became a tool that all participants could use after the training. One participant stated, “Before this training, I was unfamiliar with Scratch, but now I feel confident using it to teach math.” Another participant shared, “This training made me realize how important Computational Thinking is in problem-solving, and I will integrate it into my lessons.” Awareness of the importance of CT in mathematics grew, and most participants now feel more confident in teaching these concepts using Scratch, although a few still have some doubts. These results indicate that the hands-on training method effectively enhances participants' understanding, skills, and confidence.

The improvement in participants' understanding in this training aligns with previous research findings emphasizing the effectiveness of CT in mathematics education. For example, a study by Kaswar and Nurjannah found that implementing CT effectively enhances students' mathematical problem-solving abilities (Kaswar & Nurjannah, 2024). Additionally, Mukhibin et al. discovered that integrating CT into STEM education positively impacts students' problem-solving skills. Another study by Karya Murti et al (Murti et al., 2023), showed that incorporating CT in first-grade mathematics learning effectively improves students' Computational Thinking skills (Murti et al., 2023). These findings reinforce that applying CT in mathematics education can enhance students' understanding and problem-solving abilities.

Overall, the questionnaire responses indicate that the training not only reinforced previous research findings on the effectiveness of CT in math education but also enhanced participants' understanding of CT and Scratch, providing them with the confidence and practical skills to apply these concepts in their teaching.

The findings from the case study and questionnaire results highlight significant insights into the implementation of Computational Thinking (CT) with Scratch in math education. The initial understanding of CT among participants was notably limited, as evidenced by the high percentage of teachers who reported minimal or no understanding

before the training. This indicates a crucial need for targeted professional development in CT concepts to equip teachers with the necessary foundational knowledge.

The positive shift in understanding CT after the training, with 60% of participants reporting an increase in comprehension, underscores the effectiveness of the workshop in bridging knowledge gaps. This is further supported by the recognition of the importance of technology in math education, with most participants acknowledging its relevance post-training. The successful adaptation to new technologies, as reflected in the increased confidence levels in using Scratch, illustrates the training's role in empowering teachers to embrace innovative teaching methods.

Moreover, the feedback regarding the practicality of the training is particularly encouraging. The high percentage of participants who felt confident using Scratch indicates that the workshop effectively provided not only theoretical knowledge but also practical skills essential for classroom application. This aligns with the overarching goal of integrating CT into math education—enhancing problem-solving abilities and fostering a more engaging learning environment for students.

The findings also suggest that ongoing support and resources are crucial for sustaining the momentum gained from the training. As teachers implement CT in their classrooms, they may encounter challenges that require further guidance and collaboration. Thus, establishing a community of practice among participants could facilitate continued learning and sharing of best practices.

CONCLUSION

This training has demonstrated the effectiveness of integrating Computational Thinking (CT) with Scratch in enhancing mathematics instruction among high school teachers. The combination of case studies and questionnaire analysis reveals a marked improvement in teachers' understanding and confidence in applying CT principles in their teaching practices. Initially, many participants had limited knowledge of CT and Scratch, but the training significantly bridged these gaps, highlighting the importance of professional development in fostering innovative pedagogical approaches.

The findings indicate that when teachers are equipped with both theoretical knowledge and practical skills, they are more likely to embrace technology in their classrooms, leading to a richer learning experience for students. The acknowledgment of CT's relevance in mathematics education further reinforces the need for its integration into teacher training programs.

This activity itself also has several obstacles and shortcomings. The weaknesses of this activity lie in the limited initial understanding of teachers regarding CT and Scratch or other programming languages, which requires an adjustment period for learning and grasping the fundamentals. Additionally, the limited duration of the training hinders an in-depth exploration of CT applications in various teaching contexts. The lack of access to technology in regions like Barito Kuala also poses a challenge for implementing Scratch in classrooms. Furthermore, the training’s focus on Scratch as a single tool restricts teachers’ exposure to alternative technologies that could support CT-based teaching.

Therefore, for future activities, it is recommended to provide pre-training materials, extend the training duration, and establish a sustainable mentoring program to support more effective implementation in the field. Moreover, it is necessary to maximize post-training mentoring programs or learning communities to help teachers continuously develop their skills independently, as well as introduce other technologies to broaden their knowledge and capabilities.

In light of the results of the activities and the obstacles and shortcomings encountered, in the future it will be important to provide ongoing support for educators as they apply these concepts in their teaching, ensuring continued engagement and continuous improvement in their teaching practices. Overall, this research contributes to the growing body of evidence supporting the incorporation of CT in educational settings, paving the way for more effective and engaging mathematics education.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS STATEMENT

Each author has made a significant contribution to the research and writing of this article. Contributions include the design and implementation of Computational Thinking (CT) training using Scratch, data collection and analysis, as well as manuscript preparation. Additionally, the authors were involved in the interpretation of research findings, as well as the editing and refinement of the article before publication. All authors have read and approved the final version of this manuscript.

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