JPPIPA 10(12) (2024)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Effectiveness of Block Programming and Quarky Robots to Improve Computational Abilities Thinking through the STEMC Approach

Muzakiah[1], Irwandi[1,2*], Elin Yusibani[1] , Intan Mulia Sari[1], Romarzila Omar[3], Rini Oktavia[2,4]

[1] Department of Physics, FMIPA, Universitas Syiah Kuala, Banda Aceh, Indonesia.
[2] STEM Research Center (STEM.id), Universitas Syiah Kuala, Banda Aceh, Indonesia.
[3] Department of Early Childhood Education, Sultan Idris Education University, Perak, Malaysia.
[4] Department of Mathematics, FMIPA, Universitas Syiah Kuala, Banda Aceh, Indonesia.

Received: August 26, 2024
Revised: November 27, 2024
Accepted: December 26, 2024
Published: December 31, 2024

Corresponding Author:
Irwandi
irwandi@usk.ac.id

DOI: 10.29303/jppipa.v10i12.8965

Abstract: The results of PISA 2022 show that Indonesian students are still weak in science literacy, mathematics, and technology-based problem solving, which are the basis for developing computational thinking (CT) skills. CT includes four primary indicators: decomposition to break down significant problems into smaller parts, pattern recognition to find similarities in data, abstraction to filter out irrelevant information, and algorithms to design systematic steps in solving problems. There are many ways to train CT, so this study uses block programming and the Quarky robot. This approach was chosen because it is visual and interactive and makes it easier to apply CT concepts practically, making it suitable for building 21st-century skills. The study was conducted in two high schools in Banda Aceh, involving 20 students from school A and 26 students from school B. Students were divided into two study groups in each school. Learning activities were designed based on STEMC in the form of Student Worksheets (LKPD), which include interactive learning scenarios, block programming challenges, and exploration of the Quarky robot's functions to solve real problems. The activities were arranged in stages, from a basic introduction to applying CT concepts in solving complex problems. The results showed a significant increase in students' CT abilities, especially in the algorithm indicator. Although both schools progressed, school B recorded higher growth, with better pre-test and post-test results than school A. This shows that block programming-based learning and Quarky robots effectively improve CT skills, which is essential in 21st-century education.

Keywords: 21st Century Education; Block Programming; Computational Thinking; Quarky Robot; STEMC

Introduction

Based on the Program for International Student Assessment (PISA) study results, Indonesia is ranked 68th. Although there was an increase in ranking compared to 2018, the mathematics and science literacy scores in PISA 2022 decreased. Indonesia's average mathematics literacy score fell by 13 points, from 379 in 2018 to 366 in 2022, and the average science literacy score also dropped from 396 to 383 (OECD, 2023). Mathematics and science literacy plays an important role in students' computational thinking (CT) development (Lockwood & Mooney, 2018; Weintrop et al., 2016). CT is an essential skill that must be possessed in the 21st century (Ansori, 2020; Masfingatin & Maharani, 2019; Shute et al., 2017) because it can prepare students to adapt to an increasingly digital and technology-based world (Grover, 2021) and offers systematic methods for solving increasingly complex problems (Wang et al., 2022; Yadav et al., 2016).

How to Cite:
Muzakiah, M., Irwandi, I., Yusibani, E., Sari, I. M., Omar, R., & Oktavia, R. (2024). Effectiveness of Block Programming and Quarky Robots to Improve Computational Abilities Thinking through the STEMC Approach. *Jurnal Penelitian Pendidikan IPA*, *10*(12), 10593–10599. https://doi.org/10.29303/jppipa.v10i12.8965

CT is a thinking process involving solving problems using available data to represent the resulting solution logically, efficiently, and effectively (Wing, 2006). Wing in (Azizia et al., 2023) explains four CT indicators: (1) decomposition, the ability to break down complex problems into smaller, more manageable parts; (2) pattern recognition, the ability to find similarities and differences in patterns that are then used to develop solutions to problems; (3) abstraction, the ability to identify important information and ignore irrelevant details when implementing a problem-solving plan; and (4) algorithms, the ability to develop solutions, the steps that must be followed to solve a problem.

Coding or programming is one of the activities that can hone CT skills (Sun et al., 2021).Through programming, students can learn the basics and principles of computer science by breaking down problems into algorithms to find the right solution, thereby helping to understand how computers work and practicing systematic and practical problem-solving skills (Grover & Pea, 2018). One method that makes it easier for students to create programs is block programming, which is visual programming similar to assembling Lego pieces, where students can select the appropriate code blocks and combine them to create puzzle-like programs through drag-and-drop (Pratama, 2018). This programming can be trained with Quarky, a robot that allows users to learn and apply programming intuitively and visually. It is an effective tool for teaching programming and CT, helping students develop technical skills and problem-solving abilities (STEMpedia, 2022). Programming training in robotics can also improve students' skills, creativity, motivation, and fluency in CT (Lye & Koh, 2014).

Robot technology is essential in stimulating innovation and becoming the latest trend in 21st-century education. In addition to being an exciting learning tool, robots also support the development of more holistic and interactive STEM (Science, Technology, Engineering, and Mathematics) learning, especially in solving real problems (Hanik et al., 2021). The STEM approach integrates the concepts and principles of science, technology, engineering, and mathematics to develop products, processes, and systems that are useful for life (Weintrop et al., 2016; Sengupta et al., 2013; Barr & Stephenson, 2011; Council, 2011). The STEM Research Center of Syiah Kuala University has developed STEMC adapted from the STEM approach by adding "C" for Character, which includes six primary skills: Critical Thinking, Creativity, Collaboration, Communication, Computational Thinking, and Character (Irwandi et al., 2022; Sofyan et al., 2021; Stem.id, 2019). Therefore, this study uses block programming and robots to improve students' abilities through the STEMC approach in classroom learning.

This study uses block programming and Quarky robots to improve students' computational thinking skills through the STEMC approach. This is important considering the results of PISA 2022 show the low literacy of Indonesian students in science, mathematics, and technology, which is a challenge in building 21st-century skills. By integrating robotics and block programming, this study aims to improve decomposition, pattern recognition, abstraction, algorithm skills, and character skills such as creativity and collaboration through technology-based learning and real problems.

Method

This research is applied research with the type of case study. The sample in this study were high school students from School A and School B Banda Aceh. Students from school A numbered 20 people, consisting of 4 males and 16 females. Meanwhile, students from school B numbered 26 people, all female genders. This study focuses on the activities carried out by students from two schools in utilizing PictoBlox programming and Quarky robots to improve CT skills, which are essential skills in the 21st Century. This activity is presented in the form of Student Worksheets (LKPD). The robots and LKPD used by students have been validated by experts for various assessment aspects and declared feasible to be applied in learning activities.

The data processing technique used in this study is the results of student responses to learning and student learning outcomes. The data obtained from this study are qualitative and quantitative. Quantitative analysis uses a Likert scale with five alternative answers based on the score weight: 1 (not good), score 2 (less good), score 3 (quite good), score 4 (good), and score 5 (very good), which are converted into percentages.

The robot used in this study is Quarky (Figure 1). Quarky robot is a portable device with solid performance, allowing students to develop complex projects. Figure 2 shows the block diagram of the Quarky robot. This robot has a matrix display with 35 RGB LEDs in a 7×5 box that can be programmed to create animations, write text, and display patterns, and is equipped with high-quality speakers for audio. The robot has three sensors: two IR sensors on the right and left bottom to detect objects and colors and one ultrasonic sensor in front of the robot for navigation and obstacle avoidance. The ultrasonic sensor measures distance by sending ultrasonic waves and their travel time. Data from the sensors are sent to the ESP32-WROOM-32 microcontroller, which controls the entire robot system. The output is in the form of two DC motors that function as the primary actuators, controlled by a motor driver to control the direction and speed of the robot's movement. The robot is connected to a 3.7V Li-Ion battery via a connector that stabilizes the 3.3V voltage and can be controlled via Bluetooth communication with a laptop.

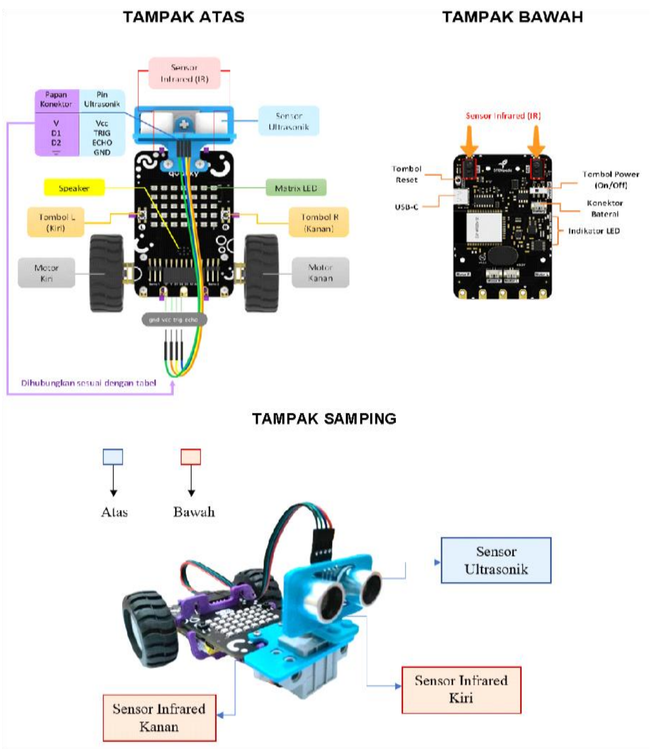

Figure 1. View of Quarky robot from top, bottom, and side

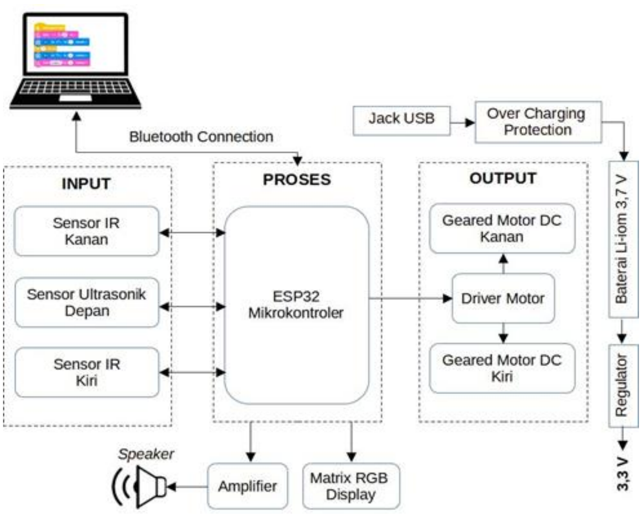

Figure 2. Block Diagram of Quarky Robot

Result and Discussion

The research data is qualitative and quantitative. Qualitative data is obtained from student observation activities during the learning process. This data is assessed to analyze students' CT abilities based on CT indicators, including decomposition, pattern recognition, abstraction, and algorithmic thinking.

Analysis of Learning Activities

In this case study, the researcher divided the students into two study groups, each consisting of 10 people in school A and 13 people in school B. Each group was given one Quarky robot unit, one laptop equipped with PictoBlox programming software, LKPD sheets, and technology guides explaining how to use the robot and the software.

Students began the activity by conducting initial observations of the robot and its components and exploring the features of the PictoBlox program. After that, they continued by working on the activities on the LKPD sheets. Two activities were carried out, namely Activity A, which contained four programs to make the robot move and turn, and Activity B, which contained two programs to detect lines and obstacles or objects in front of the robot. During this activity, students were trained to think systematically in creating programs and were challenged to modify them according to their creativity (See Figures 3 and 4).

Figure 3. CT learning activities using Quarky robots at School A

Figure 4. CT learning activities using Quarky robots at School B

Students demonstrated significant progress in CT skills through a series of programs using the Quarky robot, such as those shown in Figures 5 and 6. In the early programs, students began to understand the basic concept of decomposition, where they break down complex problems, such as moving a robot forward and backward, into smaller steps that can be organized into blocks of code. They learned that simple changes in instructions can directly affect the robot's behavior, strengthening their understanding of how algorithms work in real-world contexts. As the program transitioned to visual aspects, such as matrix displays, students honed their pattern recognition and abstraction skills. They could separate the movement instructions from the display instructions and recognize patterns of change based on different parameters. This strengthened their ability to identify patterns that could be repeated and changed as needed, which is an integral part of generalization skills in CT.

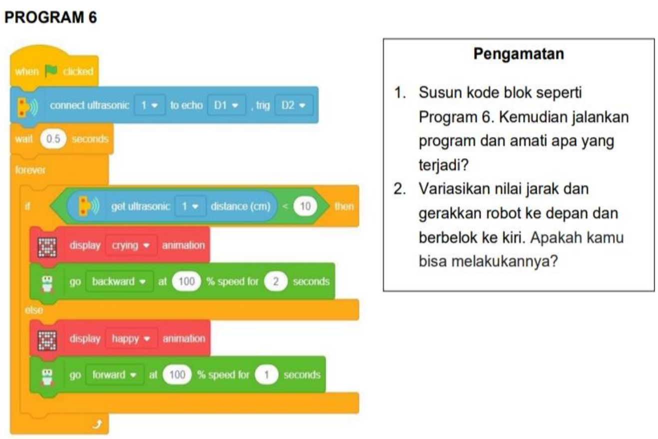

Figure 5. An example of a program contained in the student worksheets

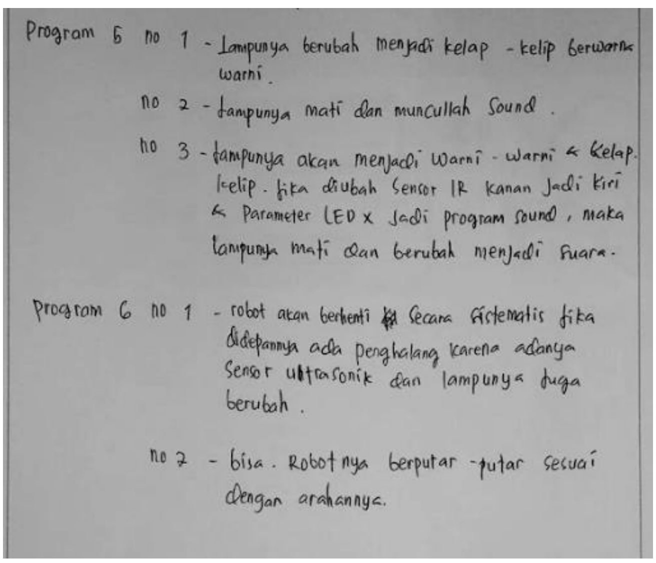

Figure 6. Part of the student observation result

In programs combining robot movement and audio playback, students further developed their skills in integration and iteration. They understood how instruction variations affected the overall output by constructing programs that combined movement and audio in a looping fashion. This helped them design more complex algorithms and demonstrated a deeper understanding of iteration, where a given process is repeated until a specific condition is met. Next, when working with IR and ultrasonic sensors, students strengthen their problem-solving and logic skills. They learn to identify patterns in sensor data and how this data can be translated into instructions that govern the robot's movements. By simplifying and generalizing sensor data into logical decisions, they demonstrate a deeper understanding of how abstraction and decomposition work together to solve complex problems in CT.

Analysis of Student Response Results

The students' responses to CT learning media were very positive, with an average response percentage of 81.38% in school A and 85% in school B. The assessment of the robot showed very good results, with a response of 83.25% in school A and 84.62% in school B, while the evaluation of LKPD was also high, with 79.5% in school A and 85.38% in school B. Using LKPD and robot control based on existing activities can improve students' understanding and CT skills. Overall, technology in CT learning makes learning more enjoyable, memorable, and efficient. The response result diagram can be seen in Figure 7.

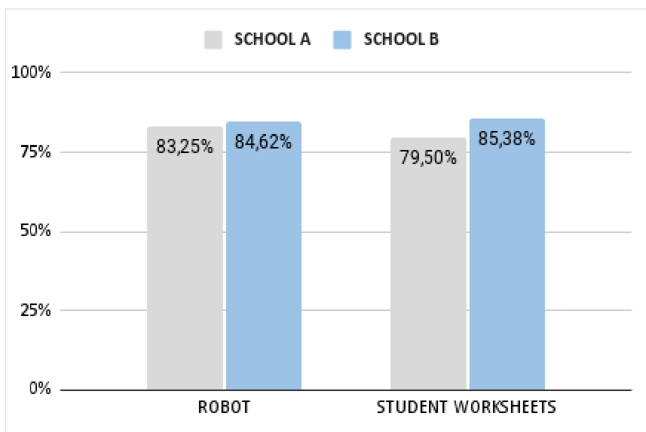

Figure 7. Graph of student response results for robots and student worksheets

Students' responses to the CT learning process in this study were also analyzed based on CT ability indicators and showed excellent results (See Figure 8). The response results show that CT-based learning using Quarky robots and PictoBlox software has improved students' CT abilities in four primary indicators: algorithms, decomposition, pattern recognition, and abstraction. The level of achievement in each indicator varies.

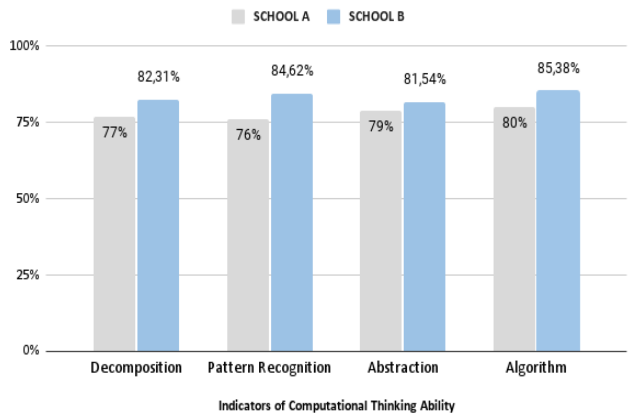

Figure 8. Graph of student responses to CT ability indicators

The algorithm is the indicator with the highest achievement, namely 85.38% in school B and 80% in school A, which reflects students' ability to compile logical steps to solve problems very well. Other indicators, such as decomposition and pattern recognition, are also in the excellent category but require more attention to improve equality of achievement between the two schools. The abstraction aspect, although in the good category, shows that there are still challenges in developing students' ability to filter relevant information and make generalizations.

This finding is in line with the research of (Wang et al., 2022), which states that CT-based learning can improve students' ability to break down problems into smaller parts, recognize patterns, and design logical solutions. In addition, Yadav et al., (2016) study also confirmed that the CT-based approach provides a systematic framework that helps students develop higher-order thinking skills.

However, these results also indicate differences in achievement between indicators, which underscores the importance of more focused learning strategies to improve the abstraction aspect. Similar research by Grover & Pea (2018) emphasized that strengthening abstraction requires exploratory and project-based activities to train students to sort out relevant information.

Improving student learning outcomes

CT learning using Quarky robots and PictoBlox software successfully improved student learning outcomes in both schools despite variations in achievement levels (See Figure 8). The posttest results showed a significant increase, with an achievement level of 25% in school A and 81% in school B. This difference reflects variations in student engagement, educational background, and support for facilities and technology in each school.

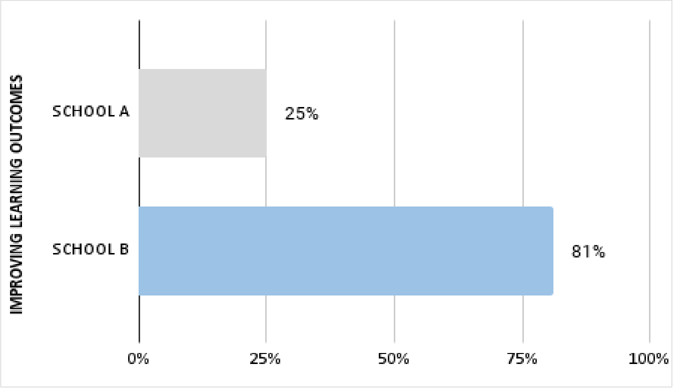

Figure 9. Percentage of increase in student learning outcomes

In school B, active student engagement and prior programming experience supported higher achievement. This is in line with Grover & Pea (2018), who stated that early experience in coding can strengthen understanding of CT-based learning. Adequate facilities and a supportive learning environment are also important factors, in accordance with the findings of (Lye & Koh, 2014).

In contrast, although the level of achievement in school A was lower, an increase in learning outcomes was still seen. This finding supports the research of Wang et al., (2022), which shows that students from less supportive backgrounds can still experience increased CT abilities through appropriate learning design. However, the lack of exposure to technology-based learning and the lack of supporting facilities are obstacles that need to be considered.

These results emphasize the importance of the learning environment, student background, and infrastructure readiness in supporting the success of CT-based learning. This study supports the view of Yadav et al., (2016) that the success of CT development depends on the readiness of infrastructure and adequate learning support. Therefore, improving facilities and training for educators in schools with limited resources is necessary for the equitable distribution of CT learning outcomes.

Conclusion

This study shows that the use of block programming and Quarky robots supported by activities in LKPD has a positive impact on improving students' CT abilities. Through observation and a series of programming activities, students in schools A and B showed significant developments in decomposition, pattern recognition, abstraction, and algorithm skills, with algorithms as the most prominent indicator. Although school A showed appreciable but limited improvement, more significant results were seen in school B. The higher improvement in school B may be due to students' active involvement, previous experience with the basics of programming, and more adequate facility support. School background factors, such as the level of favoritism and facilities, also seem to play a role in the differences in learning outcomes between the two schools. Overall, this CT-based learning has increased students' interest, involvement, and understanding in more exciting and efficient learning.

According to (Omar et al., 2023), it is appropriate to develop a Science Literacy teaching model to help students who have problems in Science Literacy. CT Computational thinking is a thinking skill that students need to master in order to enhance their skills in robotics. The Research findings show that the use of computational thinking (CT) by teachers in STEM teaching and learning has helped them better understand the basic concepts of robotics compared to other thinking methods.

Computational thinking is fundamental to developing 21st-century skills such as creativity, critical thinking, and problem-solving. It empowers students to break down complex problems into manageable parts (decomposition), identify patterns, and design algorithms to solve those problems. These skills are crucial in subjects like mathematics, science, and even humanities, providing a bridge between abstract concepts and practical applications (Grover et al., 2024).

Acknowledgments
The author would like to thank the facilities from the STEM Research Center used during this research in the form of equipment, namely Laptops and Quarky robots. Thanks also to various parties who have helped carry out this research.

Author Contributions
This research group played a crucial role in crafting this scientific paper, including generating ideas, designing the study, gathering and analyzing data, interpreting results, drafting the manuscript, writing the article, undergoing revisions, and securing funding for the research.

Funding
This research receive funding by Unversitas Syiah Kuala, Ministry Education, Culture, Research, and Technology, with contract P3KA STEM Research Center Category A 2023 Number: 600/UN11.2.1/PT.01.03/PNBP/2023 Date 16 May 2023.

Conflicts of Interest
The authors clarify that there is no conflict of interest.

References

Ansori, M. (2020). Pemikiran Komputasi (Computational Thinking) dalam Pemecahan Masalah. *Dirasah : Jurnal Studi Ilmu Dan Manajemen Pendidikan Islam*, *3*(1), 111–126. https://doi.org/10.29062/dirasah.v3i1.83

Azizia, A. J., Kusmaryono, I., Maharani, H. R., & Arifuddin, A. (2023). Students' Computational Thinking Process in Solving PISA Problems of Change and Relationship Content Reviewed from Students' Self Efficacy. *Eduma : Mathematics Education Learning and Teaching*, *12*(1), 112. https://doi.org/10.24235/eduma.v12i1.13132

Barr, V., & Stephenson, C. (2011). Bringing computational thinking to K-12: What is involved and what is the role of the computer science education community? *ACM Inroads*, *2*(1), 48–54. https://doi.org/10.1145/1929887.1929905

Council, N. R. (2011). Report of a Workshop on the Pedagogical Aspects of Computational Thinking. In *Report of a Workshop on the Pedagogical Aspects of Computational Thinking*. https://doi.org/10.17226/13170

Grover, S. (2021). *Toward A Framework for Formative Assessment of Conceptual Learning in K-12 Computer Science Classrooms*. 31–37. https://doi.org/10.1145/3408877.3432460

Grover, S., Fields, D., White, S., & Strickland, C. (2024). *Enduring Lessons from "Computer Science for All" for AI Education in Schools*. 1533–1534. https://doi.org/10.1145/3626253.3631656

Grover, S., & Pea, R. (2018). Computational Thinking: A Competency Whose Time Has Come. In *Computer Science Education* (Issue December). Bloomsbury Academic. https://doi.org/10.5040/9781350057142.ch-003

Hanik, E. U., Ulfa, M., Harfiyani, Z., Septiyani, F., Sabila, N., & Halimah, N. (2021). Pembelajaran berbasis STEM melalui Media Robotika untuk Meningkatkan Keterampilan Siswa Abad 21 Sekolah Indonesia Kuala Lumpur (SIKL). *ICIE: International Conference on Islamic Education*, *1*(1), 83–96.

Irwandi, Sulastri, Artika, W., Oktavia, R., Abdi, J., Yusibani, E., Sari, I., M., & M. (2022). *Pembelajaran STEMC (Science, Technology, Engineering, Mathematics, and Character) Suatu Pendekatan Komprehensif Menghadapi Tantangan Abad 21*. Syiah Kuala University Press.

Lockwood, J., & Mooney, A. (2018). Computational Thinking in Secondary Education: Where does it fit? A systematic literary review. *International Journal of Computer Science Education in Schools*, *2*(1), 41–60. https://doi.org/10.21585/ijcses.v2i1.26

Lye, S., & Koh, J. (2014). Review on teaching and learning of computational thinking through programming: What is next for K-12? *Computers in Human Behavior*, *41*, 51–61. https://doi.org/10.1016/j.chb.2014.09.012

Masfingatin, T., & Maharani, S. (2019). Computational thinking: Students on proving geometry theorem. *International Journal of Scientific and Technology Research*, *8*(9), 2216–2223.

OECD. (2023). PISA 2022 Results (Volume I): The State of Learning and Equity in Education. In *PISA*. OECD Publishing. https://doi.org/10.1787/53f23881-en

Omar, R., Safwan, L. B., Abdullah, R., Ismail, H., Peh, S. S., Farhana Kariuddin, N. A., & Bakar, A. A. (2023). The Development of an Interactive Science Literacy Model Based on Folk Stories for Chinese Children Using Dialogic Reading Techniques. *Journal of Curriculum and Teaching*, *12*(6), 107–121. https://doi.org/10.5430/jct.v12n6p107

Pratama, A. (2018). Pengaruh Pengajaran Pemrogaman Animasi melalui Aplikasi Scratch pada Kemampuan Pemecahan Masalah. *Joined Journal (Journal of Informatics Education)*, *1*(1), 24. https://doi.org/10.31331/joined.v1i1.613

Sengupta, P., Kinnebrew, J. S., Basu, S., Biswas, G., & Clark, D. (2013). Integrating computational thinking with K-12 science education using agent-based computation: A theoretical framework. *Education and Information Technologies*, *18*(2), 351–380. https://doi.org/10.1007/s10639-012-9240-x

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

Sofyan, H., Irwandi, I., Artika, W., Oktavia, R., Lubis, Z. A., & Sari, I. M. (2021). The Integration of STEMC in Indonesia: Current Status and Future Prospects. *Proceedings - 2nd SEA-STEM International Conference, SEA-STEM 2021*, *2239*, 177–180. https://doi.org/10.1109/SEA-STEM53614.2021.9668108

Stem.id. (2019). *Deklarasi STEM+C (Science, Technology, Engineering and Mathematics Plus Character) untuk Pendidikan Aceh*. https://stem.id/deklarasi-stemc-science-technology-engineering-and-mathematics-plus-character-untuk-pendidikan-aceh/.

STEMpedia. (2022). *Quarky – Documentation*. https://thestempedia.com/product/quarky/

Sun, L., Hu, L., Yang, W., Zhou, D., & Wang, X. (2020). STEM learning attitude predicts computational thinking skills among primary school students. *Journal of Computer Assisted Learning*, *37*, 1–13. https://doi.org/10.1111/jcal.12493

Wang, C., Shen, J., & Chao, J. (2022). Integrating Computational Thinking in STEM Education: A Literature Review. In *International Journal of Science and Mathematics Education* (Vol. 20, Issue 8). https://doi.org/10.1007/s10763-021-10227-5

Weintrop, D., Beheshti, E., Horn, M., Orton, K., Jona, K., Trouille, L., & Wilensky, U. (2016). Defining Computational Thinking for Mathematics and Science Classrooms. *Journal of Science Education and Technology*, *25*(1), 127–147. https://doi.org/10.1007/s10956-015-9581-5

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

Yadav, A., Hong, H., & Stephenson, C. (2016). Computational Thinking for All: Pedagogical Approaches to Embedding 21st Century Problem Solving in K-12 Classrooms. *TechTrends*, *60*(6), 565–568. https://doi.org/10.1007/s11528-016-0087-7