



## Pedagogical Transformation of Biology Teacher Candidates: Integration of Computational Thinking into STEM Learning

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**ABSTRACT**

*This study analyzed the effectiveness of integrating Computational Thinking (CT)-based STEM learning in prospective biology teachers at PGRI Pontianak University, exploring students' perceptions, attitudes, challenges, and opportunities. This integration aims to improve critical thinking, creativity, collaboration, and communication skills to address the challenges of the 21st century. Using Sequential Exploratory Design, data were collected qualitatively through interviews and observations, followed by quantitative descriptive analysis based on student questionnaires. This research involved 100 Biology Education students in the 2023/2024 Academic Year. The results showed that STEM-CT integration effectively improved the thinking skills of prospective Biology teachers with positive student perceptions despite technical challenges.*

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### INTRODUCTION

Education is one of the important pillars in the development of quality human resources. In today's digital era, education is faced with the challenge of adapting to the rapid development of technology and science (Sakiinah et al., 2022). One approach that is considered relevant in this context is STEM (Science, Technology, Engineering, and Mathematics) learning. STEM learning is very important for teachers to be implemented in the teaching and learning process, where it is an agent of change. In line with Viviyanti (2023), teachers had a vital role in preparing the younger generation to face the increasingly complex challenges of the future. STEM learning offers a holistic approach that can develop critical thinking skills (Rahayu et al., 2023), creativeness (Nurfajariyah & Kusumawati, 2023), collaboration (Suranti & Wahyuningsih, 2023), and student communication (Lestari, 2021). From these various opinions, it can be seen that it is very important for students to master STEM concepts in Biology learning. These opinions are in line with Hanik et al. (2021) where STEM learning through robotics media could create an interesting and meaningful learning experience, encourage students' curiosity, and equip them with the skills needed to compete in the digital era. In addition, STEM learning can also help students understand the connections between various disciplines so that they can apply knowledge practically in their daily lives (Mu'minah, 2021). Therefore, mastery of STEM learning is a competency that must be possessed by every teacher to ensure that students are ready to face future challenges.

STEM is an interdisciplinary approach where STEM-based learning can connect various disciplines to solve real-world problems (Erlinawati et al., 2019). Through STEM learning, students are trained to

develop critical thinking, creativity, collaboration, and communication skills. Meanwhile, Computational Thinking is a skill that involves critical thinking and problem-solving through computational concepts, such as abstraction, patterns, and algorithms (Maulidiyah & Anistiyasari, 2020; Satria et al., 2022). The integration of these two approaches is expected to increase students' competence in solving problems innovatively and effectively.

Several recent studies have shown the potential of integrating STEM learning and Computational Thinking. A study published by Mardiany & Rusmawati (2024) concluded that the Computer Science Unplugged (CSU) and Computer Science Plugged learning methods (CSP) have different influences on students' computational thinking skills. Meanwhile, the results of the research by Ishartono et al. (2023) showed that Computational Thinking-based STEM learning can increase students' motivation and learning outcomes.

IKIP PGRI Pontianak, especially the Biology Education Study Program, has a strategic role in preparing prospective biology teachers who can meet the demands of the 21st century. One of the approaches that is considered relevant in this context is the integration of STEM learning with Computational Thinking. Through this approach, it is hoped that prospective biology teacher students can gain the competencies needed to teach and solve problems innovatively and effectively.

Several recent studies have shown the potential of integrating STEM learning and Computational Thinking in education. A published study by Markandan et al. (2022) concluded the development of the Metacognitive Empowerment by Computational Thinking (ME-CoT) learning module by developing computational thinking through programming skills to increase metacognitive awareness in Biology students. Swaid (2015) mentioned that Computational Thinking-based strategies can be adopted to encourage computational thinking in STEM subjects.

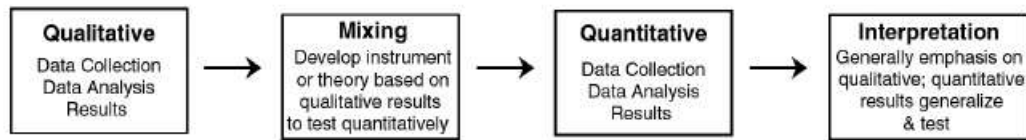
The objectives of this research are (1) analyzing the effectiveness of integrating STEM learning with Computational Thinking in prospective biology teacher students at IKIP PGRI Pontianak; and (2) knowing students' perceptions and attitudes towards STEM learning that is integrated with Computational Thinking. It is hoped that future studies can explore the right strategy to integrate the two approaches, as well as analyze their impact on the competence of prospective biology teachers in facing the challenges of the 21st century. The results of these studies can be the basis for the development of more innovative curriculum and learning practices in the Biology Education Study Program of IKIP PGRI Pontianak.

## **RESEARCH METHOD**

This study used a Mixed Methods approach with the type of Sequential Exploratory Design. The research was conducted in the Even Semester of the 2023/2024 Academic Year at the Biology Education Study Program of IKIP PGRI Pontianak, with research subjects of 100 prospective Biology teachers. The data collection technique was carried out through two stages. At the qualitative stage, data was obtained through semi-structured interviews to explore students' perceptions, attitudes, challenges, and opportunities towards STEM learning integrated with Computational Thinking, as well as observation of student activities in the learning process and STEM-CT projects to assess engagement, creativity, collaboration, and communication. Meanwhile, at the quantitative stage, data was collected using a questionnaire that measures Computational Thinking skills based on indicators such as decomposition, pattern recognition, abstraction, algorithms, automation, repetition, data manipulation, modelling, generalization, debugging, and simulation. Qualitative analysis was used to broaden the understanding of the research problem and then continued with hypothesis testing through quantitative analysis (Aladağ et al., 2021).

The data analysis technique in this study was also carried out gradually. Qualitative data were analyzed using thematic analysis, with stages of data reduction, categorization, interpretation of meaning, and conclusions drawn. Meanwhile, quantitative data was analyzed descriptively and

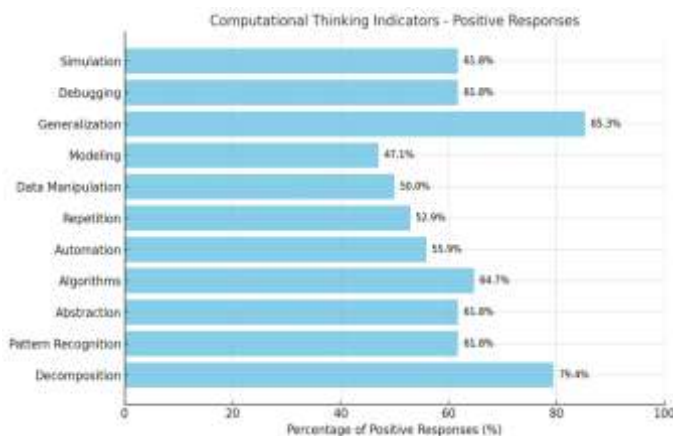
quantitatively, by calculating the percentage of achievement of each Computational Thinking indicator. The results of these two analyses were then integrated to provide a more comprehensive understanding of the effectiveness of STEM-CT learning integration as well as students' perceptions and attitudes towards learning. The research design drawings can be seen in Fig. 1.



*Fig. 1. Sequential Exploratory Design Method*

## RESULTS AND DISCUSSION

Based on the results of the computational thinking questionnaire obtained from several main indicators in computational thinking that were tested on students after attending STEM lectures. The results of the analysis of students' computational thinking questionnaire showed that there were variations in abilities in the main indicators of computational thinking (see Fig. 2). In the Decomposition indicator, as many as 79% of students were able to break down the problem into smaller parts. For Pattern Recognition, 62% of students were able to recognize patterns in a given problem. Meanwhile, in Abstraction, 62% of students were able to simplify problems by ignoring irrelevant details, while 65% of students were able to design systematic steps to solve problems on Algorithm indicators. Meanwhile, the Automation indicator shows that 56% of students can understand and apply automation in problem-solving. However, in the Repetition indicator, only 53% of students were able to use the repetitive process well, and for Data Manipulation, the percentage was even lower, namely only 50% of students managed to do it well. Students' ability in Modelling is also relatively low, with only 47% of students able to use computational models in solving problems. In contrast, the Generalization indicator obtained the highest results, with 85% of students able to apply solutions to similar problems. In the Debugging and Simulation indicators, 62% of students each successfully detected errors and conducted simulations for problem-solving. These results show that the generalization aspect has the best achievement, while data manipulation and computational modelling need special attention in learning.



*Fig 2. Computational Thinking Biology Education Students*

In the research that has been conducted, the researcher asked students to create various projects to make STEM-based learning media, the products made by students include; A simple robot from plastic glass waste called Waste-Bot abbreviated as W-Bot and Augmented Reality (AR) learning media of biology materials can be seen in Fig. 3.



*Fig. 3. Results of STEM-based Biology Teacher candidate student projects*

Based on the results of the questionnaire analysis, students' computational thinking skills showed significant variations among various indicators. The Generalization aspect stands out with the highest achievement of 85%. This shows that most students can apply the solutions they have learned to similar problems, which is in line with Thorndike's theory of transfer of learning (Ang & Van Dyne, 2015), where skills learned in one context can be applied to another. Meanwhile, Thorndike stated that reading ability is an indicator of a person's ability to think and reason (Zubaidah et al., 2018). Generalization ability is one of the important indicators in computational thinking because it supports students in solving complex problems efficiently.

However, aspects such as Data Manipulation and Modelling showed the lowest results, at only 50% and 47%, respectively. This low ability is due to a lack of learning that emphasizes data analysis and the application of computational models, which often requires intensive experience and practice. The findings of this study are in line with Papert's (1980) argument that children should "program computers" rather than the other way around, which means they should have control over their learning process through interaction with computers (Caeli & Yadav, 2020). Experiential learning that involves simulations or direct experiments with data can improve the ability of prospective Biology teacher students in data manipulation and modelling. A low score on this indicator indicates the need to integrate technology or software that supports data exploration in the learning process.

Meanwhile, the Decomposition aspect showed quite good results, with 79% of students able to break down the problem into smaller parts. This shows that students have a basic understanding of problem analysis, which is in line with the problem-solving theory by Polya (1945) states that the first step in solving a problem is to understand and break it down into simpler parts (Hardiani, 2022). However, indicators related to processing such as Automation and Repetition still show moderate results (56% and 53%, respectively). This signals the need to reinforce algorithm-based learning, such as the use of coding or simple programming, to improve students' understanding of the automation and repetition process.

Overall, this study reflects that although prospective teacher students show good potential in generalization and problem-solving, they still need more systematic practice-based learning to improve their abilities in more technical indicators, such as data manipulation and computational modelling. Integration of innovative learning strategies, such as the Project-based learning (PjBL) approach can be done using simple materials and integrating technology, it can be an effective solution to improve the ability to think comprehensively computation (Arianto et al., 2023).

The results of the study show several challenges in the application of STEM and Computational Thinking. The main challenges include a low understanding of concepts such as generalization and data manipulation (50% each), which indicates the difficulty of students in applying programming and data analysis. In addition, the limitations of facilities, such as the lack of technological devices and

weak internet access, are significant obstacles to supporting technology-based learning. The complexity and duration of STEM projects are also felt as a burden for students, considering the tasks that require time and a high level of understanding.

However, there is a great opportunity in the application of this approach, especially in the development of 21st-century skills, such as critical thinking and analytical, as evidenced by the high results in the indicators of decomposition (78%) and debugging (84%). The STEM approach is also relevant to the needs of the world of work, especially for prospective biology teachers who need technological literacy to face the challenges of the industrial era 4.0. In addition, STEM-based learning encourages collaboration in groups, improves communication and teamwork skills, and encourages innovation in biology teaching, such as the use of technology simulations to explain scientific concepts in an interdisciplinary manner.

## CONCLUSION

Based on the results of the questionnaire and the resulting projects (such as Waste-Bot, AR Biology), STEM-CT integration had been proven to be effective in improving critical thinking indicators (decomposition 79%, generalization 85%), although aspects such as modelling (47%) and data manipulation (50%) still need to be strengthened. This showed that STEM-CT integration was generally effective in improving the critical thinking and problem-solving skills of Biology teacher candidates. The results of interviews and questionnaires showed that most students positively welcome STEM-CT learning. They felt that this learning increases creativity and cooperation skills. However, some students found it difficult to understand the concepts of data manipulation and automation, especially due to limited facilities (internet, devices).

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