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Effectiveness of Creative Problem Solving (CPS) - STEM Learning Model on Students' Computational Thinking and Digital Literacy Skills in Biotechnology Material

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Abstract

Computational Thinking (CT) and digital literacy are skills students must possess to adapt and survive amidst the current technological advancements. One way to enhance students' CT and digital literacy skills is through innovative learning models that align with the material being taught. Biotechnology is one of the subjects that students need to master in Phase E of the Merdeka Curriculum. This study aims to determine the effectiveness of the CPS-STEM learning model on students' CT and digital literacy skills in biotechnology material. This research was conducted from April to May in the 2023/2024 academic year at three high schools in the Kayen, with a total population of 891 students. The sample used in this study was calculated using the Slovin formula, its 8 classes consisting of 2 control groups (72 students) and 2 experimental groups (217 students). This study is a quasi-experimental design with a pre-test and post-test group design. The STEM approach is integrated with CPS syntax outlined in the teaching module and assisted with student worksheets. CT skills were measured using post-test instruments, while digital literacy skills were measured using questionnaire. Data analysis was conducted to determine the effectiveness of the CPS-STEM learning model on CT skills, calculated using the N Gain test, while digital literacy skills were measured using a Likert scale. The results showed that the CPS-STEM was effective to improve CT skills in the medium category (0.40), whereas the direct instructional learning model was not effective in enhancing CT skills. This study also showed that the CPS-STEM learning model was effective in enhancing digital literacy skills with a percentage increase of 15.25%

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INTRODUCTION

The provision of quality education is one of the mandates in the 1945 Constitution of the Republic of Indonesia. The National Education System Law of 2003 also stipulates that the government is obliged to provide proper, equitable, quality, and relevant education in line with the times (Law Number 20 of 2003). The relevance of education in current times can be measured, among other things, through students' ability to master 21st-century skills.

21st-century skills are fundamental for students to become quality, superior, and competitive individuals who can thrive amid rapid technological advancements (A. Putri et al., 2023). These skills, commonly known as the 4Cs, include creative thinking, critical thinking and problem-solving, communication, and collaboration. Other studies mention that life planning, flexibility, adaptability, initiative, self-management, entrepreneurship, social and cultural interaction, productivity and accountability, leadership, lifelong learning, computational thinking, and digital literacy are additional skills that students need today (Ansori, 2020; Muliantara, 2023). Weak competency in mastering 21st-century skills among students will impact their competitiveness and employment opportunities (Zubaidah, 2017). Therefore, competencies such as computational thinking and digital literacy need continuous enhancement to meet contemporary demands.

Creative Problem Solving (CPS) is a learning model that emphasizes students' creativity and skills in solving problems. This model helps students develop higher-order thinking skills to transform complex problems into simple solutions. CPS focuses on developing students' ability to think creatively and innovatively in facing challenges (Waluyo, 2023).

Biotechnology is one of the learning materials/achievements that students in phase E (Grade X) of the Independent Curriculum need to master. In this subject, students are taught to skillfully provide solutions to problems occurring in their environment by applying biotechnology concepts. This subject not only aims to enhance students' understanding of biotechnology but also to develop their problem-solving skills, critical thinking, and the ability to apply scientific knowledge to real-world issues.

By engaging with biotechnology, students learn about various applications such as genetic engineering, cloning, fermentation, and the development of bioproducts. These applications are explored within the context of solving contemporary challenges, such as environmental sustainability, health care, and agricultural productivity. Through this approach, students are expected to gain a deeper appreciation for the role of biotechnology in society and to develop the skills necessary to innovate and address complex problems using biotechnological methods.

Several learning models that have been widely used to support the achievement of biotechnology learning outcomes include Problem-Based Learning (PBL) (Batukh et al., 2023; Helmi, 2023; Pratiwi et al., 2023; N. H. S. Putri, 2023) and Project-Based Learning (PjBL) (Alamsyah et al., 2021; Avivi et al., 2023; Khairani Astri et al., 2022; Ma'wa et al., 2022; Ramadhani, 2020). The application of PBL in biotechnology material is known to have drawbacks, such as: students need to have the same foundational knowledge about a problem, and the issues selected by teachers are sometimes not engaging, resulting in low student interest (Hermansyah, 2020). On the other hand, the application of the PjBL model in biotechnology material also has shortcomings, including the long time required for students to prepare biotechnology projects/products within the limited available learning time.

Given these drawbacks, there is a need for another innovative learning model that can enhance problem-solving skills within a short learning period, one of which is the Creative Problem Solving (CPS) model. Creative Problem Solving (CPS) is a learning model that focuses on students' creativity and skills in solving problems (Edy Waluyo, 2023). This learning model teaches students to develop high-level thinking skills in transforming complex problems into simple solutions. Research has shown that CPS is effective in improving high-level thinking skills (Edy Waluyo, 2023), creative thinking (Ekawati, 2023; Khasanah, 2020; Ningsih et al., 2021), and problem-solving (Fitriana Rahmawati, 2023; Lucky & Julyanti, 2023).

The application of CPS-STEM learning to enhance CT skills and digital literacy has not been widely studied. Therefore, this study aims to analyze the effectiveness of the CPS-STEM learning model in improving CT skills and digital literacy in biotechnology material. This research is expected to help students adapt, survive, and compete in the 21st century by improving these essential skills.

METHOD

This research was quasi-experimental study conducted on Grade X Biotechnology ma-

terial under the Merdeka Curriculum for the 2023/2024 academic year. The sample for this study consists of 276 students divided into 8 classes: 2 control classes (72 students) and 6 experimental classes (216 students) (Sugiyono, 2009).

The variables in this study include the independent variable (CPS-STEM Learning Model) and the dependent variables (CT Skills & Digital Literacy). The research utilizes primary data sources derived from pre-test and post-test questions, as well as questionnaires.

The CT indicators in this study include decomposition, algorithms, generalization, and pattern recognition. Meanwhile, the digital literacy skills indicators encompass information, communication, content creation, safety, and problem-solving (Nuvitalia et al.,2022). Data analysis in this study involves:

- Pre-test and post-test to asses CT skills
- Classical assumption tests (normality and homogeneity)
- Hypothesis testing (N Gain and t-test)
- Likert scale to assess digital literacy skills.

Through these methods, the study aims to evaluate the effectiveness of the CPS-STEM learning model in enhancing students' CT skills and digital literacy within the context of biotechnology education.

RESULT AND DISCUSSION

Results

The Analysis on the Effectiveness of Applying the CPS-STEM Learning Model in Enhancing Students' Computational Thinking Skills in Biotechnology Material

Table 1. The Results of Average Critical Thinking Skills Analysis in the Control Group and Experimental Group on Biotechnology Material

No	Perbedaan	Controll group		Experiment group	
		Pretes	Postest	Pretest	Postest
1	Number of student	72		216	
2	x̄	39,44	42,22	38,66	65,52
3	Lowest score	0	0	0	20
4	Highest Score	80	80	80	100
5	Minimum Score criteria (60)	26,34%	30,56%	21,34%	68,62%

Research data on the application of the CPS-STEM learning model in enhancing students' Computational Thinking skills in Biotechnology material can be detailed in the following tables:Table 1 shows that CT skills in the control group and the experimental group differ. The average CT skill score of students in the control group increased by 4.22% after being treated with the direct instructional learning model. In contrast, the average CT skill score of students in the experimental group increased by 47.18% with the CPS-STEM learning model. Classically, it is evident that the direct instructional learning model resulted in 30.56% of students passing the minimum competency criteria (KKM), whereas the CPS-STEM learning model resulted in 68.62% of students passing the KKM. This indicates that the CPS-STEM learning model is more effective in improving students' CT skills in bbiotechnology material.

The N-Gain analysis in Table 2 was conducted to determine the effectiveness of the CPS-STEM learning model on CT skills.

Tabel 2. Analysis of N-Gain Test Scores of Critical Thinking Skills in The Control Group and Experimental Group on Biotechnology Material

	Control Group	Experiment Group
N gain	0,03	0,40
Criteria	Low	Middle

Based on the table, it can be seen that the direct instructional learning model is effective in improving CT skills at a low level (0.03). The CPS-STEM learning model, however, can enhance CT skills at a moderate level (0.40). The t-test analysis in Table 3 was performed to determine whether there is a significant difference in the effectiveness of the CPS-STEM learning model in improving students' CT skills in biotechnology material.

Table 3. Analysis of t-Test for Critical Thinking Skills between Control and Experimental Groups on Biotechnology Material

No	Difference	Control Group		Experiment Group	
		Pretest	Postest	Pretest	Postest
1	x̄	39,44	42,22	40	65,52
2	T-test for pretest control group vs. experimental group	0.760	-	0.780	-
3	"T-test for post-test control group vs. experimental group"	-	0.000	-	0.000

Table 3 shows that the significance value for the average CT skills in the control and experimental groups is greater than 0.05, indicating no difference in pre-test scores between the control and experimental groups. However, after applying the CPS-STEM learning model, the significance value for the average CT skills in the control and experimental groups is 0.00 (< 0.05). This indicates that there is a significant difference in CT skills between the control and experimental groups in the post-test phase.

In this study, CT skills are formulated with 4 indicators: Decomposition, Algorithms, Generalization, and Pattern Recognition. The impact

of the direct instructional and CPS-STEM learning models on each CT indicator can be presented in Table 4.

Table 4. Results of N-Gain Test for Each Indicator of Students' Critical Thinking Skills on Biotechnology Material

No	CT Indicator	N gain			
		Control group		Experiment group	
		N gain	Category	N gain	Category
1	Decomposition	0.109	Low	0.585	Middle
2	Algoritm	-0.014	Low	0.397	Middle
3	Generalitation	-0.164	Low	0.288	Low
4	Patern recognition	0.208	Low	0.583	Middle

Table 4 shows that the direct instructional learning model affects CT skills at a low level across all indicators. In contrast, the CPS-STEM learning model impacts CT skills at a moderate level for decomposition, algorithms, and pattern recognition indicators, and at a low level for the generalization indicator.

The t-test analysis in indicates that the post-test scores for each CT indicator in the control and experimental groups have a significance value of <0.05. This demonstrates that the CPS-STEM learning model significantly affects CT skills across all indicators. The average CT skill scores of students in the control and experimental classes are presented in Figure 1.

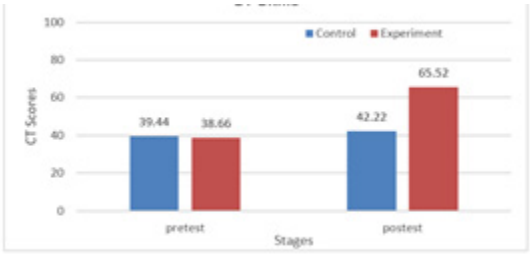

Figure 1. Average CT Skill Score of Control and Experimental Groups

The results in Figure 1 show that the average pre-test CT skill score for the control group is 39.44, while the experimental group is 38.66. This indicates that high school students in the Kayen area have low initial CT skills in biotechnology material. The post-test results for the control group, which received direct instructional learning, show an average CT skill increase of 2.78 points. In contrast, the experimental group, which received the CPS-STEM learning model, shows an average CT skill increase of 26.86 points. This demonstrates that the use of the CPS-STEM learning model is more effective in improving students' average CT skill scores.

The Analysis on the Effectiveness of Applying the CPS-STEM Learning Model in Enhancing Students' Digital Literacy Skills in Biotechnology Material

The level of digital literacy analyzed in this study is based on 5 indicators: information, communication, content creation, safety, and problem-solving. The application of the CPS-STEM learning model is expected to enhance students' digital literacy skills, enabling them to use digital technology wisely to support critical and creative thinking in both learning and daily life. The research results on the effectiveness of the CPS-STEM learning model in the control group are presented in Figure 2.

Figure 2. Average Pretest and Posttest Percentages of Digital Literacy Skills in the Control Group

The digital literacy skills of the control group in both the pre-test and post-test phases show differences. The average digital literacy skills of students in the pre-test indicate the highest score in content creation at 63.18% and the lowest in safety at 46.39%. Figure 2 also indicates that the direct instructional learning model can improve digital literacy skills: information by 0.15%, communication by 2.12%, content creation by 1.3%, safety by 1.39%, and problem-solving by 6.34%. Based on this data, it is evident that the direct instructional learning model can enhance students' digital literacy skills from an initial score of 54.71% (moderate category) to 56.91% (moderate category).

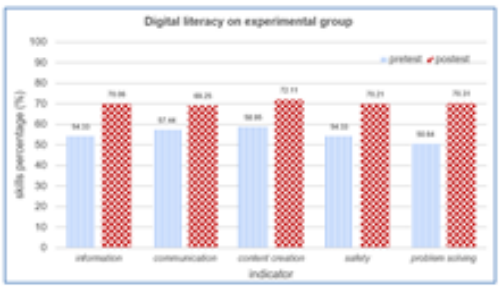

Figure 3. Average Pretest and Posttest Percentages of Digital Literacy Skills in the Experimental Group

Figure 3 shows that the CPS-STEM learning model can enhance students' digital literacy skills in the experimental group. The CPS-STEM learning model improves digital literacy skills in the following indicators: information by 15.73%, communication by 11.81%, content creation by 13.16%, safety by 15.88%, and problem-solving by 19.67%. The digital literacy skills of students in the experimental group indicate the lowest score in the communication indicator (69.25%) and the highest score in the content creation indicator (72.11%).

Based on this data, it can be observed that that the average percentage of digital literacy skills in the experimental group, initially at 55.138% (moderate), increased to 70.388% (high). The comparison of post-test scores between the control and experimental groups is presented in Figure 4.

Figure 4. Comparison of Digital Literacy Skills Percentage Between Control and Experimental Groups at Posttest Stage

Figure 4 shows that there is a difference in the percentage of digital literacy skills in the post-test phase between the control group and the experimental group. Based on the figure, it can be observed that the CPS-STEM learning model enhances students' digital literacy skills more effectively compared to the direct instructional learning model.

Discussion

Based on the results of the research and statistical data analysis conducted, it can be concluded that the CPS-STEM learning model is effective in enhancing students' CT skills in the subject of Biotechnology. CT skills are crucial for 21st-century development as they teach students to think critically, creatively, communicate effectively, and collaborate in solving problems (Ansori, 2020). In the application of the CPS-STEM learning model in this research, students are guided to solve problems creatively by utilizing a STEM approach, guided by activities in the Student Worksheet (LKPD).

Based on the results of the research, it is known that the CPS-STEM learning model is more effective in improving CT skills compared to the direct instructional learning model. The CPS-STEM learning model has an N Gain effectiveness value of 0.40 (moderate) compared to the direct instructional model, which is only 0.03 (low). When viewed based on each CT indicator, the CPS-STEM learning model has a moderate level of effectiveness in all CT indicators (Decomposition, Algorithm, and Pattern Recognition) except for Generalization.

Decomposition is the ability to break down complex problems into simpler ones (Nuvitalia et al., 2022). This aligns with previous research that explains that the CPS learning model can improve problem-solving skills (Fitriana Rahmawati, 2023; Lucky & Julyanti, 2023). The Algorithm is the ability to design steps to solve a problem (Nuvitalia et al., 2022). At this stage, students can not only simplify the problem but also formulate steps to solve it. Besides these skills, in the Pattern Recognition stage, students can also help provide solutions to similar problems (Nuvitalia et al., 2022).

Based on the research results, it is known that the CPS-STEM learning model has low N Gain effectiveness (0.288) on the Generalization indicator. Generalization is the ability to formulate solutions in general terms so that they can be applied to different problems. In the application of the CPS-STEM learning model, the generalization process takes place at the solution-finding stage, where students are expected to provide solutions to the given biotechnology problems. The low effectiveness of CPS-STEM in improving the generalization indicator is due to students needing considerable time to obtain solutions to the problems, thus lacking the time to generalize the solutions they have found into simpler terms.

The results of the analysis of the impact of the CPS-STEM learning model on students' digital literacy skills in biotechnology material show differences between the control group and the experimental group. The CPS-STEM learning model has been proven to improve digital literacy skills in all observed indicators, with the highest indicator being problem solving (70.31%) and the lowest indicator being communication (69.25%). This shows that the group of students who were given biotechnology learning with the CPS-STEM model had better digital literacy skills compared to the group of students who were taught with the direct instructional learning model.

CONCLUSION

The application of the CPS-STEM learning model is effective in improving students' CT skills in Biotechnology material, with a low N-Gain score in the control group (0.03) and a moderate N-Gain score in the experimental group (0.40). The CPS-STEM learning model is also effective in enhancing students' digital literacy skills, showing an improvement of 15.25% in the experimental group.

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