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Empowering Computational Thinking through PBL-SSI: Tackling Conservation Threats Effectively

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Abstract: Computational thinking is one of the skills needed to support 21st-century skills, especially in science education, such as conservation biology. This study aims to analyze the increase in CT in conservation biology lectures, especially the topic of conservation threats. The lectures given are based on PBL-SSI. This study is a quantitative study with a quasi-experimental method. The research design used is a one-group pretest and posttest. The instrument used is a multiple-choice test with 15 questions containing indicators of computational thinking. The thinking indicators used consist of algorithms, decomposition, abstraction, and pattern recognition. The results show that PBL-SSI can significantly improve computational thinking skills with the decomposition indicator as the indicator that shows the most improvement.

Keywords: Computational Thinking; Conservation Biology; PBL; SSI.

Introduction

In the modern era full of complex data challenges, Computational Thinking (CT) is a key skill that students must have to face the dynamics of the world that increasingly requires a systematic approach (Lyon & J. Magana, 2020; Shute et al., 2017; Tang et al., 2020). Universities have a strategic responsibility to equip students with these skills, especially in the science disciplines (Arik & Tapcu, 2021; Ogegbo & Ramnarain, 2022). Computational thinking is a problem-solving approach that uses computational logic to understand human behavior (Wing, 2006, 2017). According to Shute et al. (2017) computational thinking involves solving problems efficiently through algorithms with solutions that can be reused across contexts (Abidi et al., 2023) Define this skill as the ability to understand, sort, and organize information in patterns to define solutions. Computational thinking emphasizes structured and data-driven problem-solving, involving skills such as problem-solving, abstraction, algorithms, and critical analysis (Caeli & Yadav, 2020; Lodi & Martini, 2021; Wing, 2017; Zapata-Ros & Palacios, 2021). Although originally used in computer science (Ansori, 2020). This skill is now widespread across disciplines, including education.

CT enables students to analyze and solve problems through four main components: decomposition, pattern recognition, abstraction, and algorithm design (Wing, 2006, 2017). Through decomposition, complex environmental problems such as climate change or biodiversity loss can be broken down into smaller, more manageable elements (Fagerlund et al., 2021; Grover & Pea, 2021; Hsu et al., 2018; Selby & Woollard, 2014; Shute et al., 2017). Pattern recognition helps students recognize environmental degradation patterns from scientific data (Ehsan et al., 2021; Fagerlund et al., 2021; Grover & Pea, 2021; Hikam et al., 2023; Hsu et al., 2018; Lee et al., 2013, 2008; Moore et al., 2020; Shute et al., 2017). Abstraction allows them to simplify complex information to focus on important elements (Ehsan et al., 2021; Fagerlund et al., 2021; Hsu et al., 2018; Selby & Woollard, 2014; Wing, 2006, 2017). Finally, algorithm design trains them to create solutions based on systematic, measurable steps (Ehsan et al., 2021; Fagerlund et al., 2021; Grover & Pea, 2021; Hooshyar et al., 2021; Hsu et al., 2018; Riley & Hunt, n.d.; Selby & Woollard, 2014; Shute et al., 2017; Wing, 2017).

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In the context of conservation biology, CT is crucial to build in-depth analytical skills towards conservation threats, such as climate change, deforestation, invasive species, overexploitation, and habitat loss (Hadi et al., 2023; Niesenbaum, 2019; Virtanen et al., 2022). These threats are not only ecologically relevant but also involve complex social and economic dimensions (Bonebrake et al., 2019; Ridley et al., 2020). By integrating CT into lectures, students can understand the relationships between variables that cause ecosystem damage and design interventions based on scientific evidence (Fonseca et al., 2021; Surbakti et al., 2023). Unfortunately, gaps are still found in current conservation education, where traditional approaches that are only informative have not provided adequate practical skills.

Therefore, PBL-SSI was chosen as a learning model that is relevant to the characteristics of conservation biology lectures. PBL and SSI are a combination of approaches that offer a dynamic learning framework for developing CT. PBL engages students in a complex, real-world problem-solving process (Ali, 2019; Caramay & Cruz, 2023; Widodo, 2021), while SSI places conservation issues in realistic social and cultural contexts (Arthamena et al., 2024; Chen & Xiao, 2021; Hanifah et al., 2021; Hovardas, 2015; Levinson, 2006; Sadler, 2004; Schenk et al., 2021; Yoon et al., 2023). For example, students can analyze global deforestation data and relate it to local policies, then design an algorithm to map forest restoration priorities. With the context of SSI, students are invited to understand how environmental threats impact not only biodiversity but also human well-being and the economic sustainability of local communities. PBL-SSI integration enables learning of scientific contexts that are relevant to real life (Alpianti & Amelia, 2024; Permatasari & Aji, 2024; Ramos et al., 2021).

By providing CT through the PBL-SSI approach in conservation biology lectures, students can analyze environmental data, predict the impact of policies or human actions on the environment, and design effective solutions to maintain sustainability (Candrawati et al., 2022; Kanaki et al., 2022). Therefore, this study focuses on seeing the increase in CT through conservation threat lectures that apply the PBL-SSI approach.

Method

This research is quantitative research using experimental methods. The research design used is one-group pretest-posttest (Creswell, 2019). The selection of one experimental class is based on the purpose of the research itself, namely, to focus on analyzing the improvement of computational thinking skills. The research instrument used was a multiple-choice test consisting of 15 items. The questions have gone through validity and reliability tests. The question indicators refer to the computational thinking skill indicators according to (Wing, 2017). These indicators consist of decomposition, abstraction, pattern recognition, and algorithms. The following is a grid of test question indicators used:

Table 1. Grid of CT Test Questions

CT indicator	Question Indicator	Items
Decomposition	Analyze and identify SSI accuracy	2
	Describe SSI information that is relevant to environmental problems in the literature review	2
Algorithms	Carrying out systematic investigations into the roots of environmental problems	1
	Organize the results of the literature review appropriately	1
	Plan appropriate conservation efforts for the given environmental problems	1
Pattern Recognition (Generalization)	Understand and formulate the causes of environmental problems	1
	Identifying patterns of causes of environmental problems through literature studies	1
	Formulate solutions to solve environmental problems in general	1
	Formulate appropriate conservation efforts for the given environmental problems	1
Abstraction	Interpreting data on the causes of environmental problems	2
	Generate ideas for conservation efforts as appropriate solutions	1
	Describe appropriate conservation efforts	1
Total question items		15

The test was given twice, namely before the PBL-SSI-based conservation threat lecture was given, and after. The PBL used in this study is the result of thinking Wing (2017), which is combined with the SSI (socio-scientific issue) approach. The following is a display of CT indicators in the PBL syntax used (Table 2).

The SSI used is the result of adjustments to the topic of conservation threats, which include habitat loss, deforestation, overexploitation, invasive species, global warming, and climate change. Data analysis was assisted using SPSS by looking at the differences in CT test gain values in initial conditions and conditions after treatment.

Table 2. Mapping of PBL syntax to CT indicators

PBL syntax	Indicator Computational Thinking
Identification of problems	Decomposition and Pattern Recognition
Formulate the problem	Pattern Recognition and Abstraction
Planning an Investigation	Decomposition and Algorithms
Conduct Research	Algorithms and Pattern Recognition
Analyze data	Abstraction
Interpreting Conclusion	Algorithms, Pattern Recognition, and Abstraction
Implementation and Evaluation	Abstraction

Result and Discussion

Computational thinking skills are a way to solve problems by thinking systematically, involving computer logic. (Wing, 2017). Furthermore Shute et al. (2017), it states that computational thinking is the ability to solve problems effectively and efficiently using algorithmic logic. While the opinion Abidi et al. (2023), Computational thinking is more specifically defined as the ability to understand information thoroughly. The following is the average value of the computational thinking skills test results:

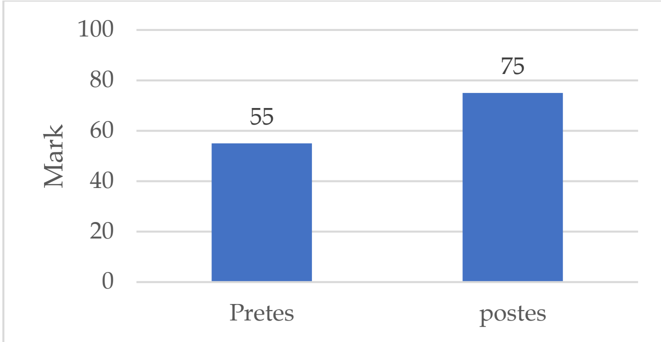

Figure 1. Average Results of Computational Thinking Skills Test Scores

Based on Figure 1, computational thinking skills show an increase from a value of 55 in the pretest to 75 in the posttest. These results indicate an increase in the average results of the computational thinking skills test after being given treatment. However, to better understand the conditions of the differences before and after treatment, a statistical test was conducted. The following are the results of the statistical test of the computational thinking skills test:

Table 3. Statistical Testing of Computational Thinking Skills.

Data	N	Sig	Decision	Z	Asym. Sig	Decision
Pre-test	36	0.00	Abnormally distributed	-2.451	0.014	There is a significant difference
Post-test	36	0.16	Abnormally distributed			

Based on the data in Table 3, the pretest and posttest values each have N = 36, with a significance level (*sig*) of 0.00 for the pretest and 0.16 for the posttest. Both of these values indicate that the data is not normally distributed. Therefore, a non-parametric test was conducted, which produced a value of Z = -2.451 and Asym. Sig = 0.014, indicating that there is a significant difference between the pretest and posttest. These results support the data on the increase in scores from 55 in the pretest to 75 in the posttest, indicating that the conservation threat lecture intervention has a real impact on the development of students' computational thinking skills. Furthermore, to find out how big the level of difference in computational thinking skills is before and after the application of the treatment, an n-gain calculation is carried out. The following are the results of the n-gain calculation on computational thinking skills:

Table 4. N-Gain Calculation of Computational Thinking Skills

N-gain	Difference Level Description
0.4	Currently

Based on Table 4, it can be seen that the increase in computational thinking skills is at a moderate level. (Cohen et al., 2018). With the significant difference in this moderate level, PBL-SSI-based conservation threat lectures have proven to be quite effective in improving students' analytical and problem-solving abilities systematically in computational thinking skills. To better understand the increase in computational thinking skills, more specifically, here are the achievements of computational thinking skills for each indicator:

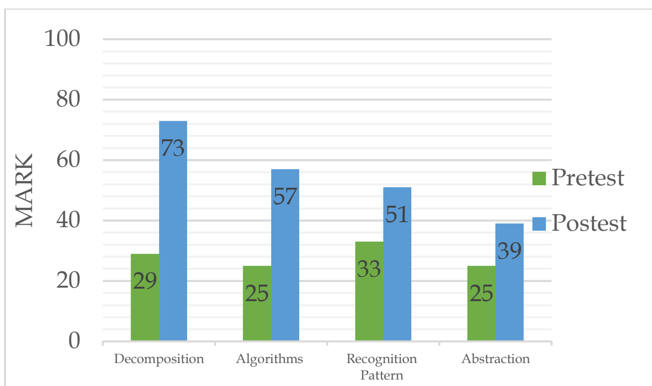

Figure 2. Achievement of Computational Thinking Skills Results Based on Indicators

Based on Figure 2, it can be concluded that each indicator of computational thinking skills experienced an increase that as seen in the difference in values that appeared before and after treatment. The difference in the increase in the decomposition indicator (44), algorithm (32), pattern recognition (18), and abstraction (14). Based on these data, the n-gain can be calculated for each indicator. The n-gain value for each indicator consists of the decomposition indicator (0.6), algorithm (0.4), pattern recognition (0.3), and abstraction (0.2). The intervention carried out in the conservation threat lecture was effective in increasing the decomposition indicator, quite effective in increasing the algorithm and pattern recognition indicators, and less effective in increasing the abstraction indicator. Thus, the indicator with the highest increase value is decomposition. While the indicator with the lowest increase is abstraction. The calculation of n-gain on the results of the computational thinking skills test obtained a gain value of 0.4, in a moderate category. (Cohen et al., 2018). This shows that the PBL-SSI-based conservation threat lecture has proven to be quite effective in improving computational thinking skills. These results support several studies that state that the PBL model can provide computational thinking skills (Bai et al., 2021; Huda & Rohaeti, 2024; Milenia et al., 2024; Oktaviani & Satanti, 2024). These results also support research Yanti et al. (2024), which states that SSI can provide computational thinking skills. There has been no research that specifically states that PBL-SSI integration can improve computational thinking skills. Therefore, this study is an initial step to prove that PBL-SSI implementation can improve computational thinking skills.

Based on these results, several findings can be understood that indicate the reasons why PBL-SSI integration can improve computational thinking skills in general. *The first finding* is based on complex problem-solving skills. Computational thinking skills are the ability to break down complex problems into simpler and easier-to-understand parts (Arik & Tapcu, 2021; Wing, 2017). In PBL, real and complex problem-solving skills are provided (Lenkauskaitė et al., 2021; Meilasari et al., 2020; Scholkmann et al., 2023; Widodo, 2021). The problems solved in PBL are real problems and need to be solved (Widodo, 2021). As SSI also views that the process of solving a problem can involve integration in various multidisciplinary fields (Suparman et al., 2022; Viehmann et al., 2024). Furthermore, several studies also mention that PBL-SSI can provide problem-solving skills (Alpianti & Amelia, 2024; Ramos et al., 2021). Given that this problem-solving ability is a basic competency in computational thinking (Shute et al., 2017; Wing, 2017)PBL-SSI has relevant characteristics in providing computational thinking skills.

The second finding, based on systematic problem-solving procedures and concrete steps. Computational thinking skills are the ability to compile the most efficient steps in solving a problem (Shute et al., 2017). However, critical and analytical thinking skills are needed in compiling problem-solving solutions appropriately and efficiently. Based on several studies, it is stated that PBL can train analytical thinking skills (Maulidya et al., 2021) and critical thinking skills (Irawati & Sulisworo, 2023; Lenkauskaitė et al., 2021; Miterianifa et al., 2019; Wong et al., 2021). SSI also plays a role in training critical thinking skills because the nature of the problems is related to various fields (Hanifah et al., 2021; Schenk et al., 2021), and raises opportunities for discussion (Levinson, 2006; Owens et al., 2019; Stolz et al., 2013). Furthermore, several studies show that PBL-SSI can improve critical thinking skills (Aisy et al., 2024; Fajarianingtyas et al., 2023; Fita et al., 2021), where these skills are the basis for computational thinking skills.

The third finding, PBL-SSI, which is applied, can provide problem-solving based on data and information patterns. Computational thinking is the ability to understand information comprehensively, to arrange information framework patterns to make it easier to understand (Abidi et al., 2023; Wing, 2017). Meanwhile, SSI is a problem that involves various fields. (Hanifah et al., 2021; Schenk et al., 2021), so that information search is the first step in SSI (Alpianti & Amelia, 2024; Owens et al., 2019). However, PBL-SSI is relevant to the characteristics of computational thinking skills that are to be provided.

Conclusion

Based on the results of the study, it can be concluded that there is an increase in computational thinking skills in PBL-SSI-based conservation threat lectures. The intervention carried out in the conservation threat lecture is quite effective in improving decomposition, algorithm, and pattern recognition indicators, and is less effective in improving abstraction indicators. Thus, PBL-SSI is effective in improving computational thinking skills.

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Author Contributions
Overall writing was done by Nisa Sholehah Pangsuma. While conceptualization and design of the idea were done simultaneously by all authors.

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Conflicts of Interest
The authors declare no conflict of interest.

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