Encouraging Students' Critical Thinking Using Problem-Based Book Integrated Daily Problems and Solutions about Environmental Pollution

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Abstract

Using learning books for students related to everyday problems and their solutions is important to support the empowerment of students' thinking. This research aims to encourage students' critical thinking (CT) using a problem-based book integrated with daily problems related to environmental pollution. Quasi-experimental-based research was used to investigate the CT of 103 junior high school students. Forty-nine students were given an intervention using a problem-based book integrated with daily problems about environmental pollution. A total of 54 students were not given intervention (control class). Students' CT was collected using tests validated by experts and empirically and met reliability. CT n-gain was calculated based on pre- and post-CT values. Students' CT priors show differences, so the calculation of the intervention effect uses n-gain data. The t-test calculates CT differences in the intervention and nonintervention classes. Data analysis shows that using a problem-based book integrated with daily problems about environmental pollution affects increasing students' CT, which is significant (Sig. n-gain < 0.05). Students in the experimental class showed a moderate increase, while students in the control class showed a low CT increase. Presenting daily problems related to the environment around students has increased critical discussion during learning. This condition causes CT students to be encouraged to be better during learning.

Keywords: critical thinking, environmental pollution, student book

1. Introduction

Environmental pollution is a problem that occurs along with increasing knowledge and the needs of human life. Environmental pollution is a serious problem for organisms and affects the normal environment (Baroudi et al., 2020). Environmental pollution can be in the form of air pollution (Chatkin et al., 2022), soil pollution (Maxim et al., 2022), noise pollution (Sabe, 2018), and water pollution (Khiri et al., 2023). Environmental pollution can be caused by various factors related to human life. Several researchers have found the causes of a polluted environment, such as traces of toxic metals, wastewater from housing, coliforms, microplastics, agriculture, and other organic and inorganic pollutants (Hasan et al., 2019; Menéndez-Pedriza & Jaumot, 2020); even economic growth contributes to the problem of the environmental pollution (Li et al., 2014; Rao & Yan, 2020). The impact of environmental pollution on organisms can be in the form of cardiovascular disease (Zhang et al., 2023), gastrointestinal cancer (Hasan et al., 2019), kidney (Tsai et al., 2021), decreased animal health (Lu et al., 2019), impact on plant life (Mateos-Cárdenas et al., 2021), and many other effects of environmental pollution.

Environmental problems must be handled properly. Teaching and understanding are necessary solutions to increase peoples' awareness about efforts to prevent pollution. Teaching people about this can start at a young age, for example, through education (Rajapakse, 2023). Young people, like students in middle school, are the next generation who will take care of and protect the environment so that pollution does not occur. Now the problem of environmental pollution has occurred a lot. It takes critical thinking from humans, especially students in middle school, to raise awareness and keep the environment from being polluted. With good critical thinking skills from students, environmental pollution will not worsen.

Critical thinking skills (CT) are essential for learners as they are needed to be more skilful, to identify alternative solutions, to prevent mistakes, and to make the right decisions (Mehrpour et al., 2023). CT is related to achieving students' success in learning while helping them avoid negative life phenomena (Damopolii et al., 2022; Ghanizadeh, 2017). CT is built by placing students in learning conditions that encourage curiosity and creativity, where they can develop problem-solving ideas (Tahirsylaj & Wahlström, 2019). The effect of students' CT development activities is that they can realize the risks and evaluate the negative effects of the information they encounter. CT helps students be better informed and accurate through questioning, evaluating, and seeking the truth of the information they obtain (Orhan & Çeviker Ay, 2023). High CT helps students defend themselves from fake news that occurs in their daily lives by detecting the truth and evaluating the accuracy of the information (Orhan, 2023).

Sinnewe et al. (2023) revealed that decreased student engagement and limited resources lead to an imbalance between the reception of course content and the development of CT. Hillary et al. (2023) investigated the CT of junior high school students and found that they had weak critical thinking. Students were unable to develop ideas based on the presented problem information. Students could not link the information they obtained with the concepts they learned. This happens because there was no habituation activity to think critically in learning. Sun et al. (2023) have researched CT China and found that more than 75% of respondents fell in the low group. They also found that students were low on the truth-seeking scale due to their reading habits. Another study in Tehran, Iran, found more than 65% of students fell into the weak CT category (Mehrpour et al., 2023). Findings from previous studies indicated that it was necessary to strengthen students' Critical Thinking.

CT is an ability that effectively involves multiple cognitive dimensions to analyze and interpret conditions to ultimately create an appropriate solution to action that can be built using active strategies (Kaddoura et al., 2016; Nusantari et al., 2021). When students are posed with a problem, they will apply their critical thinking to analyze arguments related to the problem and build their arguments based on the facts and knowledge obtained (Rath & Rock, 2021). The causes of students' difficulty in having critical thinking skills are influenced by teaching methods, complex learning processes and teachers' ability to develop students with CT skills, as well as the availability of learning resources that support the empowerment of students' critical thinking (Hasbie et al., 2023; Negoro et al., 2023). Teachers should prepare their students to acquire critical thinking skills by encouraging them to engage in active learning and real-world problem-solving with teams (ŽivkoviĿ, 2016); one example is the use of Problem Base Learning (PBL) in the future (Razak et al., 2022).

PBL is learning that presents problems in its teaching. These problems stimulate students' thinking during learning. During PBL classes, students collaborate with each other in their investigation teams to identify the causes of real-world problems (Nicholas & Scribner, 2021). Each phase of PBL interacts with each other, inviting students to build their knowledge with their team members (Tan & Tee, 2021). Leasa et al. (2023) explained that PBL had drawbacks for students who did not understand the problem and identified challenges based on the content they learned, making their CT weak. However, it can be overcome by combining PBL with other types of learning. Siew and Mapeala (2016) students also used PBL with concept maps. Their findings revealed that PBL with concept maps had a better effect on CT than conventional learning.

Heim et al. (2023) found that there was no difference in the CT development of first-year and senior students in terms of what to believe and do. This indicated that there was no teaching that empowered students' CT. Pardamean (2012) examined CT processes among first- to third-year students without a control group. In his study revealed that there was no difference in total CT between the groups studied in a PBL setting. Iwaoka et al. (2010) conducted an eight-year study where students were taught using PBL to improve their CT. Of the eight years, there were only two years that had a significant effect on students' CT. Although the other six years did not show any significant difference, there was a change in scores between pre-CT and post-CT. Fitriani et al. (2020) in their study added another strategy to PBL in order to improve CT. However, they found that PBL with added strategy did not have a significant impact compared to PBL alone, but it was better than conventional learning.

CT towards an issue requires basic knowledge and facts about the issue (Hitchcock, 2022). If these are not present, then students cannot explore the issue. Real-life problems are complex and unstructured (Iwaoka et al., 2010), thus additional information about the solution to the problem is required by presenting various solutions that are closely related to the problem. Critical thinking is naturally present in students, but they need to be trained by providing correct information based on knowledge they have previously known or recognized (Pasquinelli et al., 2021). This kind of knowledge is common in their daily lives. Students are aware of the information, but they do not understand or even recognize the right solution to construct new knowledge based on the knowledge they have. Real cognitive-based activities related to handling daily events in the student environment can train students' critical

thinking (Tunjungsari & Takwin, 2021). Problem-recognition activities through situation analysis and problem-solving processes are daily tasks that require critical thinking (Halpern, 2014). One of the components of CT is being able to analyze and interpret situations that are related to daily problems (Mejía et al., 2019).

Daily problems can be integrated into teaching books. This fits well with PBL learning, which teaches students to solve real-world problems. Yomaki et al. (2023) have designed a PBL-based book that is used to promote students' CT. The findings revealed that during the learning, students discussed the problems with each other, and led to better CT after the learning. However, this research did not use daily problems and solutions that occur in the students' surrounding environment. Another research by Ikegami et al. (2017) sed daily problems and conventional problems in a PBL class. Their findings showed that students obtained better achievement in PBL that was integrated with daily problems. Unfortunately, there was no measurement of students' CT during the learning process.

Negoro et al. (2023) have examined using teaching materials to improve students' CT. This research showed a change in students' critical thinking but needs to be optimized further by creating other teaching materials. Hasbie et al. (2023) have produced valid teaching material to improve student's critical thinking. In this research, there are no real results of implementation in the classroom that show changes in students' critical thinking. Examining the impact of teaching materials on critical thinking must be conducted through implementation in learning activities. Learning resources containing information that originates from the students' immediate context can train students to synthesize important information through critical thinking (Tahirsylaj & Wahlström, 2019). The closest context for students is the daily problems found where they live. It is therefore essential to use learning books for students that are linked to daily problems and solutions to support the empowerment of students' thinking. This research aims to encourage students' CT by using a problem-based book integrated with daily problems and solutions on environmental pollution

2. Method

2.1 Research Design

This research used a quasi-experimental design to accomplish the research objectives. This type of research was selected since students in the school were placed in their respective classes to use intact classes. Quasi-experiments were used because they cannot be used in educational research that uses intact classes, and it is difficult to reorganize students into new classes (Cohen et al., 2017). A pretest-posttest design was used with four classes of students. Two classes received instruction using the daily problem-integrated problem-based student book and were referred to as the experimental class (hereafter, EC). The other two classes received conventional instruction and were referred to as the control class (CC). Students in both classes (EC and CC) received CT measurements at the beginning of learning, referred to as pre-CT, and at the end of the intervention, referred to as post-CT.

2.2 Sample

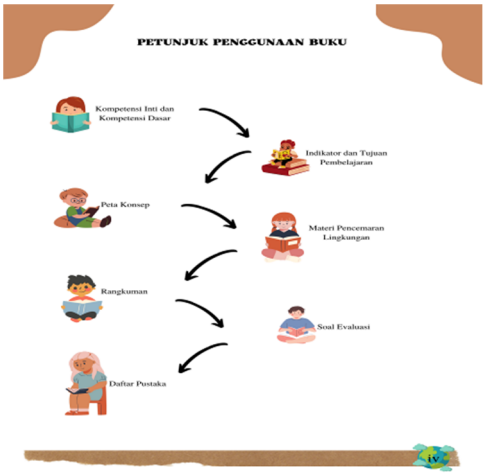
The samples were students in the first year of junior high school. A total of 104 samples comprised 54 students in CC and 49 in EC. The students came from two schools. School A is a private junior high school in Manokwari, with 19 students in EC and 22 in CC. School B is a public junior high school in Manokwari with 30 students in EC and 32 in CC. The sample is first-year students (Grades VII). They are taught environmental pollution material. Two science teachers also participated in the study. Both of them taught environmental pollution material, which consisted of three topics: water, air and soil pollution.

2.3 The Design of The Problem-Based Book Integrated with Daily Problem

The book design process used the Canva application. The book contains the topic of environmental pollution with the topics of air, water and soil pollution. The book consists of a front and back cover, table of contents, book content and bibliography. Figure 1 shows some parts of the book's contents.

Daily problems in the Papua region were presented as learning problems. This is in line with the steps of PBL, where students are oriented to the problem at the beginning of learning. The use of local problems is due to the fact that students are more familiar with the problems that exist in the environment where they live. Thus, they can more easily absorb and understand the information provided. The solution to the problem also used the creative ideas of the local community on how to manage waste. An example is shown in Figure 3. a. This section explains how the local community manages coir waste into products with economic value. It also includes how the local community manages plastic waste and coconut shell waste into economically valuable products. Students also learn about the waste collection by a species of bird, *Amblyornis inornatus*.

a. Cover



b. Guideline for using the book

c. Material

d. Daily problems about garbage

e. Coconut coir waste management by local communities

f. Sample reading about waste collection in the forests of Papua by Amblyornis inornatus

Figure 1. The Design of the Problem-Based Book Integrated with Daily Problems and Solutions

2.4 Instrument and Data Collection

The instrument used to measure students' adaptive critical thinking (CT) is adapted from Mapeala and Siew (2015). The CT test is in a two-tier format, where the first choice is for students to select one correct answer, and the second choice is for them to determine their level of thinking. Each item is scored on a scale of 0-3. Score 0 confirms that the student answered incorrectly in both tiers. Score 1 confirms that the student answered incorrectly in the first tier but correctly in the second tier. Score 2 indicates that the student answered correctly in the first tier but incorrectly in the second tier. Score 3 confirms that the student answered correctly in both the first and second tiers. The instrument was developed and validated by two experts, and the validation results showed that the instrument is valid. The total number of questions is eighteen items. The total test reliability is 0.723, indicating that the test is reliable. The validity and reliability values per item are presented in Table 1.

Data was gathered by administering a CT test to students before they were told to use a problem-based integrated daily problem textbook. Following the intervention, students' CT was assessed once more using the identical instrument utilized before the instruction. The students underwent four 80-minute learning sessions, during which both pre- and post-CT measurements were conducted.

Table 1. Validity and Reliability

No	r	Sig.	Decision	Cronbach's Alpha	Decision
1	0.357	0.000	V	0.723	GR
2	0.498	0.000	V		
3	0.593	0.000	V		
4	0.227	0.000	V		
5	0.490	0.000	V		
6	0.408	0.000	V		
7	0.224	0.000	V		
8	0.594	0.000	V		
9	0.414	0.000	V		
10	0.444	0.000	V		
11	0.362	0.000	V		
12	0.452	0.000	V		
13	0.476	0.000	V		
14	0.410	0.000	V		
15	0.353	0.000	V		
16	0.411	0.000	V		
17	0.287	0.000	V		
18	0.492	0.000	V		

*GR-Good Reliability; V-Valid

2.5 Data Analysis

CT data were calculated using IBM SPSS 20, including the Kolomorov-Smirnov test for normality and the Levene test for homogeneity calculations. The requirements of these two analyses resulted in Sig. > .05, then calculating CT differences in EC and CC using a t-test. Pre-CT, post-CT, and CT n-gain data were calculated. N-gain is the level of improvement in the student's CT as measured by the difference between the pre- and post-CT. The use of n-gain score was based on the prior CT of the students is different. If it is found that the Sig. in the CT n-gain calculation is greater than 0.05, then the CT of students in EC and CC does not indicate a difference, but if it is less than 0.05, it indicates that students in EC and CC have different CTs.

3. Results

In this study, data were collected on students' CT during their participation in a learning process that utilized a problem-based book integrated with daily problems about environmental pollution. A comparison class (control

group) was employed to assess the impact of the intervention, It is noteworthy to highlight that there were initial variations in students' CT levels, which led to the calculation of intervention effects using n-gain data.

Table 2. Normality and Homogeneity Data

Data	Mean ± SD	Normality		Homogeneity	
		df	Sig.	F	Sig.
Pre-CT – CC	37.04 ± 13.18	54	0.186	0.029	0.865
Pre-CT – EC	43.16 ± 13.07	49	0.162		
Post-CT – CC	53.15 ± 11.12	54	0.921	0.855	0.357
Post-CT – EC	66.82 ± 11.25	49	0.453		
N-gain-CT – CC	0.24 ± 0.15	54	0.859	0.289	0.592
N-gain-CT – EC	0.41 ± 0.16	49	0.825		

The data findings in Table 2 indicate that the students' pre-CT, post-CT and n-gain-CT data have indicated normal and homogeneous. The value in the normality column shows that Sig. > 0.05. Data that meets normality standards can then be calculated for homogeneity. In the homogeneity column, the pre-CT data indicates that the data is normal (Sig. = 0.865 > 0.05). Post-CT data indicated the same thing that Sig. 0.357 > 0.05, which means that the data is homogeneous. Test results on n-gain-CT data revealed that the data met the homogeneous criteria (Sig. = 0.592). This table also reveals that the students' CT n-gain in EC is in the medium category (0.41). This value indicates that the increase in student CT is moderate. On CC, the students' n-gain-CT score was 0.24. This value indicates that the increase in students' CT on EC is low. Here, it is revealed the fact that CT students at EC are more informed about better improvement than CT students at CC.

Table 3. T-test Results

Data	t	df	Mean Difference	Sig.
Pre-CT	3.962	101	6.122	0.020
Post-CT	6.528	101	13.663	0.000
N-gain-CT	2.580	101	0.166	0.000

The data findings in Table 3 show that students have shown different initial CT abilities (Sig. = 0.20 < 0.05). Because students' CT skills were different at the start, when testing, the post-CT data showed the same thing: there were differences in CT between students who used the problem-based book integrated daily problems and solutions and those who did not. To determine the magnitude of the increase and influence of the books used on students' CT, an analysis of the n-gain-CT data was carried out. Data from the analysis revealed that using a problem-based book integrated daily problems and solutions about environmental pollution had an effect on increasing students' CT, which was significant (Sig. n-gain < 0.05).

Table 4. CT Categories of Students

Data	Σ Student (%)				
	Very Weak	Weak	Sufficient	Good	Excellent
Pre-CT – CC	1 (1.85%)	36 (66.67%)	14 (25.93%)	3 (5.56%)	0 (0.00%)
Pre-CT – EC	0 (0.00%)	24 (48.98%)	19 (38.78%)	6 ((12.24%)	0 (0.00%)
Post-CT – CC	0 (0.00%)	6 (11.11%)	36 (66.67%)	12 (22.22%)	0 (0.00%)
Post-CT – EC	0 (0.00%)	0 (0.00%)	17 (34.69%)	27 (55.10%)	5 (10.20%)

The data findings in Table 4 indicate an increase in students in each CT category. Students in EC and CC before learning were in the weak category; there were not a few good and excellent ones. After the intervention on EC, it was found that there were no weak students, and 10.20% were found to be excellent. Class CC students showed that 11.11% were still in the weak category, and no students reached the excellent category. The data in Table 4 reveals that traditional learning has caused students' CT to be low, while modified learning using problem-based books integrated with daily problems and solutions does not cause students' CT to weaken. These findings inform that the use of problem-based books integrated with daily problems can even make students' CT excellent.

4. Discussion

The student book provides various essential information for students to facilitate their learning process. Moreover, the student book designed in this research includes information on concepts, everyday problems, and the problem-solving process. This aids students in developing their CT skills. The conceptual information in the student book helps them understand the subject matter concepts, preventing conceptual errors during the learning process. Conceptual errors can lead to confusion in thinking and a decline in their CT (Simonovic et al., 2023), especially when using traditional student books (Liu & Fang, 2023). Prior to the implementation of this book, it was validated by experts to ensure the absence of conceptual errors in the presented material. Students are able to comprehend various concepts within the content, enabling them to connect one concept to another. This approach helps students develop their critical thinking skills as they actively engage with the lesson content and understand the information they acquire (Pulatova, 2023).

This book presents everyday problems to help students better understand their surrounding environment. Many students struggle to comprehend problems when teachers present issues that do not occur in their daily lives. This difficulty arises because they are unfamiliar with the problems that occur. Consequently, they may not seek solutions due to confusion in their thinking process. However, in learning with the integrated student book, this issue is avoided. Students can think critically about the problems that arise and understand why they occur in their environment. They become aware of the mistakes in their lifestyle that contribute to environmental pollution. The instructional material helps students find solutions by providing various problem-solving information (Negoro et al., 2023). Hitchcock (2022) stated that engagement in problems and providing solutions is a component of the thinking process.

CT plays a crucial role in students' problem-solving abilities (Pulatova, 2023). Our research findings indicate that students already possess strong critical thinking skills, which enable them to navigate problem-based learning successfully. Through engaging in problem-solving activities, the learning process has further enhanced their CT abilities. The implementation of PBL has effectively taught students how to think critically. Notably, students with higher levels of critical thinking actively participate in PBL sessions and engage in meaningful discussions. In the context of PBL, students gather information and communicate their ideas through critical discussions (Pu et al., 2019). Providing opportunities for discussion, conditioning students to authentic or situational problems and examples, and guiding them in developing these thinking habits have had a positive impact on their overall CT skills (Abrami et al., 2015).

In classrooms where the integration of a problem-based book with daily problems and solutions to environmental pollution is absent, students' critical thinking (CT) skills remain untrained. Research has shown that Problem-Based Learning (PBL) is more effective in fostering CT skills compared to teacher-centered instruction (Gholami et al., 2016). In traditional classrooms, students engage in discussions without actively participating in problem-solving activities that relate to their daily lives. The limited exposure to various problem-solving approaches is a key factor contributing to students' lack of critical thinking (Mutakinati et al., 2018), as problem-solving and decision-making are closely tied to CT (Özgenel, 2018). Additionally, students in these classrooms sometimes exhibit a lack of engagement in discussions with their peers. They primarily rely on listening to the teacher's explanations of pre-existing problems presented in generic textbooks provided by the school. This limited interaction with classmates hampers their ability to share ideas and impedes their critical thinking skills (Sinnewe et al., 2023). Furthermore, when asked to devise problem-solving solutions, students may experience confusion because the problems presented in the textbooks do not directly relate to their real-life experiences. As a result, the underdevelopment of students' CT skills is exacerbated in such situations.

The book this research uses presents how real problems occur in students' lives. This can be seen in Figure 1.d, where the daily waste problem is raised in the book. Apart from that, there are several local community activities in managing and protecting the environment. For example, in Figure 1. e, it can be seen that there is a solution for managing coconut fibre waste by local communities. The local potential is also integrated, such as reading about garbage collection in the forests of Papua by *Amblyornis inornatus,* which teaches students that even birds can collect garbage, so humans can also think about the same action and carry it out to prevent environmental damage. Local potential is a source of learning that can increase students' understanding because it directly relates to them (Damopolii et al., 2019). Likewise, environmental management by local communities can be a driving factor for students to find solutions to environmental problems (Nusantari et al., 2020).

In the learning process using a problem-based book integrated with daily problems and solutions, there is an interaction between students and their teachers, as well as among students themselves, which creates a sense of

variation in the learning experience. This approach involves problem-solving activities that facilitate the development of students' CT skills, stimulating real-life conditions, acquiring knowledge, and promoting scientific collaboration within teams. Collaborative problem-solving in teams related to everyday issues improves students' CT skills (Rossi et al., 2021). These research findings complement previous studies that found no significant impact of PBL on students' CT (Iwaoka et al., 2010; Pardamean, 2012), even when combined with other strategies (Fitriani et al., 2020). This research highlights that incorporating daily problems into the problem-based book has effectively enhanced students' CT throughout the learning process. Consideration should be given to integrating other strategies to optimize PBL, such as using real-life situations or problems that students encounter. Furthermore, teacher-student interaction is essential for the optimal implementation of the learning process.

5. Conclusion

The research has revealed a significant change in students' CT during the learning process. Students in the experimental group demonstrated a moderate increase in CT, while those in the control group showed only a small improvement. This study indicates that students with weak CT can be pushed towards excellence by using a problem-based book integrated with daily problems and solutions. Presenting daily problems and solutions related to their environment has enhanced critical discussions during learning. This condition has encouraged students' CT to improve throughout the instructional period. Thus, the research objective has been achieved because using a problem-based book integrated with daily problems and solutions can encourage students' CT about environmental pollution. Future research can use this book, which integrates daily problems and solutions and can be combined with other learning to measure CT or other variables related to student performance in learning. Apart from that, considering that in this research, some students (34.69%) were still in the sufficient category. The practical implication of the research is that the books used in this research can be used as learning resources to encourage students' CT to be high. In practice, teachers in the classroom can use this book to overcome their students' weak CT.

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Authors contributions

Nunaki was responsible for research design, data collection, article preparation, and revision. He was a leader in this research. Lettu, Jeni, Sari, Sahertian, Damopolii and Latjompoh have taken part in designing research tools, data collection and analysis, data curation, editing, reviewing the paper and final approval.

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