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Building students' research skills in environmental science courses with research team-based learning

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Abstract

Research skills are required in studying environmental science because many environmental problems require analytical skills to find effective solutions. However, students' research skills remain insufficient and need to be strengthened. This study investigates whether the research team-based learning (RTBL) model effectively develops students' research skills in environmental science courses. This study used a sequential explanatory mixed method approach. A total of 119 students taking environmental science courses spread across 3 experimental classes, namely RTBL, research-based learning (RBL), and team-based learning (TBL) were included in this study. The research data were gathered using research skill questionnaires, research reports, and semi-structured interviews. This study's findings show that the RTBL model is superior compared to the RBL and TBL models in strengthening students' research skills in environmental science courses. The RTBL model can be utilized as an alternative effective learning model that assists students improve their research skills in environmental science courses.

Keywords: research skills, environmental science courses, research team-based learning

INTRODUCTION

Environmental science is the scientific and systematic study of the environment of living creatures. Environmental science is the study of physical phenomena in the environment, including the sources, reactions, effects, and biological species found in air, water, and soil, as well as the impact of human activities on the environment, environmental issues, and management (Fang et al., 2023). Environmental learning frequently focuses on real-world problems and stresses students' ability to detect, analyze, and solve environmental challenges (Svensson et al., 2022). Studying environmental science is crucial because of the growing number of environmental issues of today, particularly those about sustainable development and future human welfare solutions (Kågström et al., 2023). Sustainable environmental education is needed to develop responsible human citizens who are able to act in ensuring environmental sustainability (Ying et al., 2024). The most widely reported goal of environmental science teaching is to educate students to conserve and protect the environment (Mongar, 2022). The learning process in environmental science includes submitting hypotheses, planning, experimenting, evaluating, and solving existing issues with the environment (Ramanujan et al., 2019).

One of the most crucial skills to have when studying environmental science is research. Research skills are required to validate and improve environmental knowledge through a systematic investigation process that involves collecting and understanding facts based on investigations, experiments, and factual verification methods. Scientific methods are used to analyze environmental issues and find effective solutions to environmental problems (Fang et al., 2023). Most environmental problems are complex problems whose solutions require people who can analyze and find solutions to environmental problems (Fang et al., 2023; Kågström et al., 2023) and can support strategies that have long-term impacts (Fang et al., 2023). Accordingly, there is an urgent need for environmental science education that can develop skills in problem-solving, navigating scientific literature, critical thinking,

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Contribution to the literature

- The findings of this study indicate that the research team-based learning (RTBL) model supports the collaborative learning theory, which highlights the relevance of social interaction in environmental science learning.
- Students actively participate in solving real-world environmental concerns through teamwork and group discussions, supporting Vygotsky's social constructivism theory, which emphasizes the role of social interaction in knowledge acquisition.
- RTBL blends research-based learning (RBL) approaches with team-based learning (TBL), reinforcing the theoretical foundation for real research-based learning and reflection to increase students' research skills.

scientific inquiry, effective communication, and critical reflection (Svensson et al., 2022).

Previous research findings indicate that first-year students at the faculty of biology have poor research skills as a result of their lack of participation in research activities during the learning process (Whittle, 2020). Primary science students at the lower levels still lack a thorough comprehension of scientific concepts and research skills (Fornsaglio et al., 2021). Biology students believe they need more research skills, such as the ability to design research questions or select the appropriate experimental techniques to answer research questions, due to a lack of student experimental experience (Canniffe et al., 2024). According to Hughes (2019), the usual learning process still does not emphasize research skills. Students' research skills are still low and need to be improved (Alabdulaziz et al., 2022).

Initial search data on the research skills of students who have taken environmental science courses at several universities in Riau, Indonesia, which was conducted in January-February 2024, showed that students' research skills were still in the low category. The initial data that has been obtained shows that students' research skills in environmental science courses need to be improved. The results of a survey conducted on lecturers teaching environmental science courses at several universities in Riau, Indonesia, show that it is necessary to develop students' research skills in environmental science courses. The current learning and assessment process does not emphasize empowering students' research skills.

Low student research skills can result from learning that does not train research skills (Hughes, 2019). As a result, it is vital to design learning in environmental science courses to address the issue of poor student research skills. Learning experiences that allow students to do research or investigations can improve research skills (Abbott, 2019; Carberry et al., 2021; Lee et al., 2020). RBL requires group discussion and team collaboration (Tajuria et al., 2024). The RBL methodology also necessitates feedback and reflection. Reflection is used to align data findings with research efforts and student skill achievements (Brew & Saunders, 2020).

The RTBL model is one solution for dealing with students' lack of research skills. The RTBL model, which was designed as an innovative learning approach in research learning, is based on constructivism, cognitivism, behaviorism, transformative learning, and experiential learning theories. Students who take classes with a constructivist science teaching approach tend to view their learning experiences in a more positive way (Holley & Park, 2020). The stages of the RTBL model consist of

(1) preparing, where students are prepared with a basic understanding;

(2) assessing readiness, assessing students' understanding of starting research;

(3) researching in a team, where students work collaboratively in research teams, and

(4) reflecting, encouraging students to reflect on the results and processes of research that has been carried out (Daryanes et al., 2024).

The RTBL model is a learning model required for the environmental science learning process. The learning process in environmental science includes submitting hypotheses, planning, experimenting, assessing, and developing solutions to current environmental problems (Ramanujan et al., 2019). Analyzing environmental challenges and developing solutions necessitates collaborative learning (De-Abreu et al., 2022). Researchers play a role in providing knowledge, critical voices, and solutions to existing environmental problems; in addition, environmental learning also requires reflection (Kågström et al., 2023). Additionally, environmental learning necessitates reflection. This is supported by Fang et al. (2023), who believe that in addition to detailed observation, analysis, discussion, and constant self-criticism, it is also critical to seek feedback or reflection to modify the initial theoretical prototype better so that environmental education is structured around a mutually coordinated framework to achieve sustainable development goals.

Improving research skills takes work (Hughes, 2019). Previous research findings have examined how to improve research skills, including through RBL (Hegde & Karunasagar, 2021; Khumraksa & Burachat, 2022; Marcella & Samofalova, 2022; Noguez & Neri, 2019; Solovieva et al., 2022; Thiem et al., 2023; Walkington & Ommering, 2022), through the supporting the

Table 1. Research design plan

Group	Pre-test	Treatment	Post-test
Experimental class 1 (learning using the RTBL model)	Pre-test	X1	Post-test
Experimental class 2 (learning using the RBL model)	Pre-test	X2	Post-test
Experimental class 3 (learning using the TBL model)	Pre-test	X3	Post-test

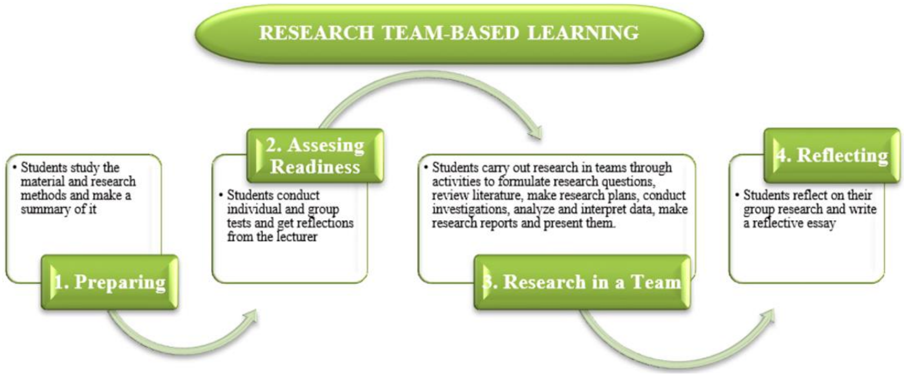


Figure 1. Stages and activities of the RTBL model (Daryanes et al., 2024)

advancement of research skills program (Tajuria et al., 2024), student research programs (Asghar et al., 2023; Galvez et al., 2024; Kaur et al., 2023), through learning experiences mediated by Education 4.0 application technology (George-Reyes et al., 2023), using the systematic literature review method (Ryan et al., 2023). However, no studies have been found related to the application of RBL model stages combined with TBL stages to empower students' research skills.

Several previous studies have discussed the role of RBL in the subjects of chemistry (Nogales-Delgado et al., 2022; Pernaa et al., 2022), mathematics (Suntusia et al., 2019), medicine (Kaur et al., 2023; Walkington & Ommering, 2022), social sciences (Wessels et al., 2021), natural sciences (Khumraksa & Burachat, 2022), biotechnology (Alvarez et al., 2022), physics (states of matter and change), political science (Anson, 2020), Geografi (Ryan et al., 2023), biology (Hegde & Karunasagar, 2021), microbiology and virology (Veses et al., 2020; Zhang & Ranadheera, 2023), health (Galvez et al., 2024; Tajuria et al., 2024), engineering (Martín-Garin et al., 2021; Siddiquee et al., 2023). However, research using the stages of the learning model with the essence of integrating RBL with collaborative learning in improving students' research skills in environmental science is quite limited. This is supported by the opinion of Hasebe et al. (2023) that education for undergraduate and postgraduate students based on environmental studies is still limited, especially in RBL. The overall objective of this study is to improve students' research skills. The purpose of this study is to determine whether the RTBL model effectively empowers students' research skills in environmental science courses. The research questions of this study are, as follows:

1. Is there an influence of the RTBL model on students' research skills in environmental science courses?
2. How do students' experiences in learning environmental science using the RTBL model affect students' research skills?

The theoretical benefits of this study's findings contribute to the advancement of science and provide references for environmental science learning activities using the RTBL model to empower students' research skills. The practical benefits of this study include improved research skills, direct experience for students conducting research throughout the learning process, and alternative innovations in learning models that can be used to strengthen students' research skills.

METHOD

Research Design

This is a mixed-method study using a sequential explanatory design. The explanatory sequential design is a mixed method design in which researchers start with a quantitative phase and then use a qualitative phase to assist in explaining the quantitative results (Creswell & Clark, 2017). This study examines the effectiveness of the RTBL learning model in empowering students' research skills, as evidenced by the research skills questionnaire and student research reports. Then, the findings are explained in detail using qualitative data. The quantitative data design in this study used a pre-test-post-test three-treatment design (modified from Cohen et al., 2018). Tests on research skills were administered at the start and completion of the learning process to three groups (**Table 1**). Qualitative data were collected through semi-structured interviews after collecting quantitative data.

This study used 3 experimental classes, namely classes using the RTBL model (**Figure 1**), RBL (**Figure 2**), and TBL (**Figure 3**).

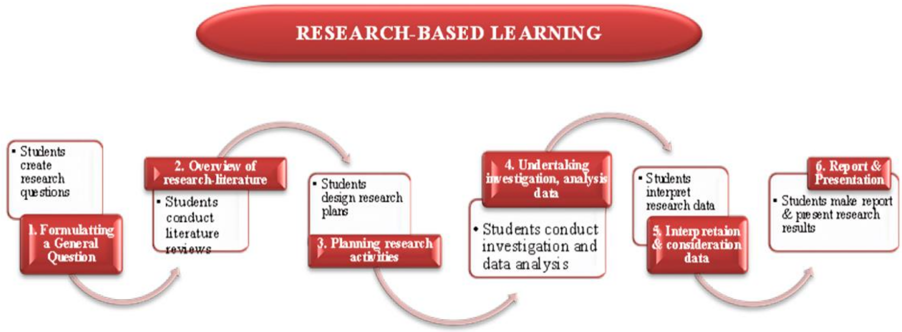


Figure 2. Stages and activities of the RBL model (Tremp & Hildbrand, 2012)

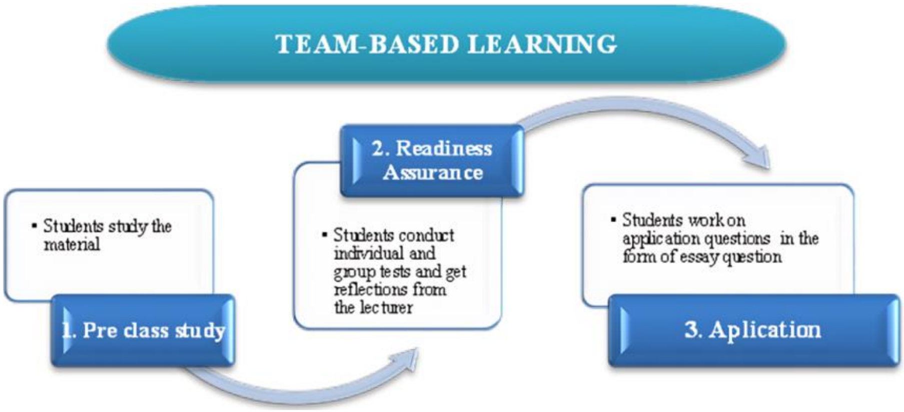


Figure 3. Stages and activities of the TBL model (Michaelsen et al., 2008)

The RTBL, RBL, and TBL models are learning models in active learning. Active learning is student-centered learning that stimulates thinking and makes students more actively involved in meaningful activities (Lombardi et al., 2021). Active learning provides opportunities for students to summarize, analyze, synthesize, and communicate through reading, writing, discussing, and solving existing problems (Kitchens et al., 2018).

The three models are also based on constructivist learning theory. Cognitive constructivism theory (Jean Piaget) emphasizes learning as the construction of knowledge by individuals. Students are given the responsibility to build their understanding through independent preparation and activity (Dong et al., 2021). Social constructivism theory (Vygotsky) states that when students actively form their understanding through social engagement with peers, learning outcomes can be effective. They are encouraged to contribute responses and test new theories (Do et al., 2023). The RTBL model combines the RBL and TBL models, and the two models are compared to determine the success of the RTBL model in empowering research skills.

Learning Procedures in RTBL, RBL, and TBL Models

This research was conducted on environmental science courses taken by first-year students. This study ran for 16 weeks, including one week for pre-testing, 14 weeks for intervention implementation, and one week for post-testing. Each group was assigned to conduct a study on environmental challenges such as garbage accumulation and flood disasters. Each group chose its research title, however they all focused on the same issue of garbage accumulation and flood disasters.

Table 2 describes the learning process in each model, which is schematically depicted in **Figure 1**, **Figure 2**, and **Figure 3**.

Table 2. Learning process in RTBL, RBL and TBL classes

No	Class	Learning process
1	RTBL (Daryanes et al., 2024)	1. Preparing a. Students read material related to environmental science, ecosystems, environmental issues and research methods and then make a summary of the material they have read. 2. Assessing readiness a. Students take individual tests consisting of 15 multiple-choice questions related to environmental science material and research methods, followed by group tests. b. Lecturers provide feedback on the results obtained

Table 2 (Continued). Learning process in RTBL, RBL and TBL classes

No	Class	Learning process
1	RTBL (Daryanes et al., 2024)	3. Researching in a team a. Lecturers explain the problem of piling up garbage b. Students create research questions in groups c. Students conduct literature reviews in groups d. Students create research plans that will be carried out in groups e. Students conduct investigations in groups related to the problem of piling up garbage in various places (markets, streets and rivers) f. Students analyze data obtained from investigative activities in groups g. Students interpret data and research results in groups h. Students create written reports and present their research results in groups 4. Reflecting a. Students reflect on their group's research process, facilitated by the lecturer. b. Students create reflective essays on the research activities that have been carried out. Activity stages 1 to 4 are repeated for issues related to flood disasters
2	RBL (Tremp & Hildbrand, 2012)	1. Formulating a general question a. Lecturers provide problems related to waste accumulation b. Students create research questions 2. Overview of research-literature a. Students conduct a literature review 3. Planning research activities a. Students make research activity plans related to the problem of waste accumulation. 4. Undertaking investigation, analyzing data a. Students conduct investigations at various waste disposal sites and analyze data from the research results obtained. 5. Interpretation and consideration of results a. Students interpret data and research results 6. Report and presentation of results a. Students make research reports and present research results Activity stages 1 to 6 are repeated for issues related to flood disasters
3	TBL (Michaelsen et al., 2008)	1. Pre-class study a. Students study material related to environmental science concepts, ecosystems, environmental issues 2. Readiness Assurance a. Students take individual tests consisting of 15 multiple-choice questions b. Students take group tests c. Provide feedback to students regarding the results obtained 3. Application a. Students work on application questions that are essay questions related to environmental science concepts, ecosystems, and issues. Activity stages 1 to 3 are repeated to discuss the concept of research plans, research on environmental problems, research results reports, disaster mitigation strategies, environmental management systems, disaster program research plans, disaster mitigation program research, and disaster mitigation program research reports.

Research Sample

The quantitative data sample include 119 students enrolled in environmental science courses separated into three classes (RTBL, RBL, and TBL). Qualitative data were collected from 9 students chosen to be interviewed, with 3 representing the upper group, 3 representing the middle, and 3 representing the lower group based on their questionnaire scores. Qualitative data were utilized to investigate quantitative data findings.

Research Instrument

Research skills were measured through a questionnaire developed according to Willison & Pijlman (2016), consisting of 25 items and using a 5-point Likert scale, point 1 = never to point 5 = always. The lowest possible score is 25, and the highest possible score is 125. The questionnaire consists of six indicators of research skills (**Figure 4**), namely embark and clarify (items 1-5), find and generate (items 6-11), evaluate and reflect (items 12-15), organize and manage (items 16-18), analyze and synthesize (items 19-22), and communicate and apply (items 23-25). The research skills questionnaire aims to assess the research skills of each student. The research skills questionnaire was first tested before being used and given to 212 respondents, and then validity and reliability tests were carried out. The correlation coefficient (Pearson) and significance value

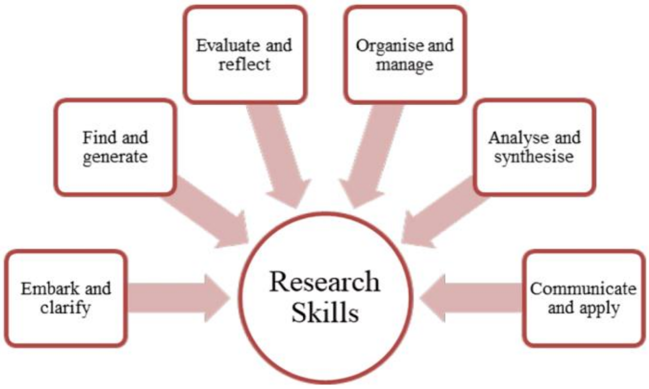


Figure 4. Research skills indicators (Willison & Pijlman, 2016)

Table 3. Results of the validity test of the research skills questionnaire (r table = 0.134)

No	Statement items	R coefficient	Significance	Category
1	Item _1	0.636	0.000	Valid
2	Item_2	0.672	0.000	Valid
3	Item_3	0.730	0.000	Valid
4	Item_4	0.698	0.000	Valid
5	Item_5	0.724	0.000	Valid
6	Item_6	0.651	0.000	Valid
7	Item_7	0.706	0.000	Valid
8	Item_8	0.709	0.000	Valid
9	Item_9	0.721	0.000	Valid
10	Item_10	0.747	0.000	Valid
11	Item_11	0.761	0.000	Valid
12	Item_12	0.715	0.000	Valid
13	Item_13	0.754	0.000	Valid
14	Item_14	0.688	0.000	Valid
15	Item_15	0.767	0.000	Valid
16	Item_16	0.723	0.000	Valid
17	Item_17	0.785	0.000	Valid
18	Item_18	0.723	0.000	Valid
19	Item_19	0.794	0.000	Valid
20	Item_20	0.797	0.000	Valid
21	Item_21	0.815	0.000	Valid
22	Item_22	0.803	0.000	Valid
23	Item_23	0.784	0.000	Valid
24	Item_24	0.723	0.000	Valid
25	Item_25	0.750	0.000	Valid

demonstrate the instrument's validity. The instrument's validity analysis is conducted using SPSS software.

The results of the validity test analysis of the research skills questionnaire (**Table 3**) show that all items have a Pearson correlation coefficient value (Pearson) greater than r table (0.134) and a significance value of less than 0.05, indicating that all items in the research skills questionnaire are internally consistent. Cronbach's alpha is used to evaluate the instrument's dependability. The reliability test analysis of the research skills questionnaire reveals that it has a high-reliability value of 0.964.

The researcher prepared an interview list that included six questions. Furthermore, the research report assessment sheet developed by Anderson (2015) was employed as a data collection instrument.

Data Analysis

Questionnaire data were analyzed using analysis of covariance (ANCOVA) at a 5% significant level, while research report data were examined using analysis of variance (ANOVA). If the ANCOVA and ANOVA results indicate significance, the LSD test is repeated. Prerequisite tests, including normality and homogeneity tests, come before the ANCOVA and ANOVA analyses. MAXQDA 2024 software was used to examine qualitative data using content analysis. Participant names are coded to protect publication ethics.

RESULTS

The Influence of RTBL Model on Students' Research Skills in Environmental Science Courses

Student research skills based on questionnaires

The findings of the hypothesis test on the research skills questionnaire show how the RTBL model affects students' research skills. The hypothesis test was preceded by a prerequisite test, which included a normality test and a homogeneity test. The results of the normality test on the pre-test and post-test values of research skills showed a normally distributed distribution with a sign value. 0.200 (p. > 0.05), and the results of the homogeneity test on the pre-test and post-test values showed a homogeneous distribution with a sign value. 0.701 (p. > 0.05) on the pre-test value and a sign value. 0.526 (p. > 0.05) on the posttest value. After that, to find out the differences in research skills in the RTBL, RBL, and TBL classes, a hypothesis test was carried out using ANCOVA.

The results of the ANCOVA test (**Table 4**) show that the calculated F value of the treatment of differences in learning models is 24,090 with a p-value of 0.000 (< 0.05). The results obtained indicate that the research hypothesis is accepted and that the RTBL learning model influences students' research skills. Furthermore, a further LSD test was carried out.

The results of the further LSD test (**Table 5**) show a comparison of the research skill values of each learning model treatment given. Comparison of the research skill

Table 4. Summary of ANCOVA test results on research skills variables

Source	Type III sum of squares	df	Mean square	F	Significance	Partial eta squared
Learning model	1384.953	2	692.477	24.090	.000	.295

Note. [a]R squared = .586 (adjusted R squared = .575)

Table 5. Summary of LSD advanced test results for research skills

(I) Class	(J) Class	Mean difference (I-J)	Standard error	Significance[b]	95% confidence interval for difference[b]	
					Lower bound	Upper bound
RTBL	RBL	3.564*	1.199	.004	1.189	5.940
	TBL	8.368*	1.209	.000	5.973	10.763
RBL	RTBL	-3.564*	1.199	.004	-5.940	-1.189
	TBL	4.803*	1.208	.000	2.411	7.196
TBL	RTBL	-8.368*	1.209	.000	-10.763	-5.973
	RBL	-4.803*	1.208	.000	-7.196	-2.411

Note. Based on estimated marginal means; *The mean difference is significant at the .05 level; & [b]Adjustment for multiple comparisons: LSD (equivalent to no adjustments)

Table 6. Summary of results of pre-test, post-test, post-test/pre-test difference, corrected mean, percentage improvement, and LSD advanced test notation research skills

Class	Initial research skills	Final research skills	Difference	Corrected mean	Percentage increase (%)	Notation
1: RTBL	65.2	82.2	17.0	82.4	26.0	a
2: RBL	64.5	78.7	14.2	78.8	22.2	b
3: TBL	64.0	73.5	9.5	74.0	14.9	c

Table 7. Results of ANOVA test of research report

	Sum of squares	df	Mean square	F	Significance
Between groups	1,666.334	2	833.167	17.912	.000

Table 8. Summary of LSD advanced test results for research skills

(I) Class	(J) Class	Mean difference (I-J)	Standard error	Significance	95% confidence interval	
					Lower bound	Upper bound
RTBL	RBL	11.46250*	3.41004	.003	4.3252	18.5998
	TBL	21.90000*	3.68327	.000	14.1908	29.6092
RBL	RTBL	-11.46250*	3.41004	.003	-18.5998	-4.3252
	TBL	10.43750*	3.68327	.011	2.7283	18.1467
TBL	RTBL	-21.90000*	3.68327	.000	-29.6092	-14.1908
	RBL	-10.43750*	3.68327	.011	-18.1467	-2.7283

Note. *The mean difference is significant at the .05 level

values of the RTBL and RBL models with a p-value of 0.004 (< 0.05), meaning that by considering the covariates, the research skill values of students with the RTBL and RBL models are significantly different. The p-value of 0.000 (< 0.05) indicates a significant difference in research skill values between students with the RTBL and TBL models, considering confounders. The (+) number in the mean difference indicates that students who use the RTBL model perform better in research than those who use the RBL and TBL models.

The corrected mean results (**Table 6**) demonstrate that the RTBL model has the greatest mean (82.4), indicating that it is the most effective in strengthening students' research skills.

Student research skills based on research reports

The normality and homogeneity tests on the research report values revealed a normally distributed distribution with a p-value of 0.086 (> 0.05) and homogeneity with a p-value of 0.132 (> 0.05). A hypothesis test was then performed using ANOVA to determine the variations in research skills observed in the research reports of the RTBL, RBL, and TBL classes.

The ANOVA test (**Table 7**) yielded a computed F value of 17.912 for the treatment of differences in learning models, with a p-value of 0.000 (< 0.05). The findings confirmed the research hypothesis, indicating that the RTBL learning model had an impact on students' research skills. Furthermore, a further LSD test was carried out.

The LSD test findings (**Table 8**) compared research report values for each treatment of the learning model. A p-value of 0.003 (< 0.05) indicates a significant difference in the values of student research reports between the RTBL and RBL models. Comparison of the value of the RTBL and TBL model research reports with a p-value of 0.000 (< 0.05), meaning that the value of the student research report with the RTBL and TBL models is significantly different. The (+) value in the mean difference shows that students who study using the RTBL model have better research skills than those with the RBL and TBL models. The mean results for each class (**Table 9**) show that the RTBL model has the highest

Table 9. Summary of mean values and LSD advanced test notation

Class	Group report average	Notation
1: RTBL	82.3	a
2: RBL	70.8	b
3: TBL	60.4	c

mean, 82.3. This shows that the RTBL model is the most superior in empowering students' research skills.

Improving research skills in each indicator

The RTBL class showed the greatest gain in pre-test and post-test scores for each research skill indicator when compared to the RBL and TBL classes (**Figure 5**). This demonstrates that the RTBL class is the most superior in empowering all indicators (embark and clarify, find and generate, evaluate and reflect, organize and manage, analyze and synthesize, communicate and apply) of research skills.

Student Experiences in RTBL Learning That Can Improve Research Skills

Data from interviews about student attitudes about RTBL learning in environmental science were examined by developing themes, categories, and codes (**Figure 6**).

The theme "research team-based learning" was included in the analysis, which is divided into the following categories: contribution, challenges, embark and identify, find and generate, assess and reflect, organize and manage analysis and synthesis, communication and application. Interview data attempts to delve deeper into how RTBL learning might improve students' research skills based on their experiences using the model.

Contribution category

The 'contribution' category includes the following codes: research skills, real problems, concept understanding, problem-solving, and effective collaboration. Students feel that RTBL learning improves their research skills by acting as researchers. In addition, students feel that their conceptual understanding of the problem of waste accumulation in the city and flood disasters increases because RTBL learning provides real problems. Research activities carried out in groups also encourage students to collaborate effectively, and together, they can solve existing environmental problems.

> R (1): "RTBL learning helps me understand how to conduct structured research starting from identifying problems, making observations, collecting and analyzing data to making research reports."

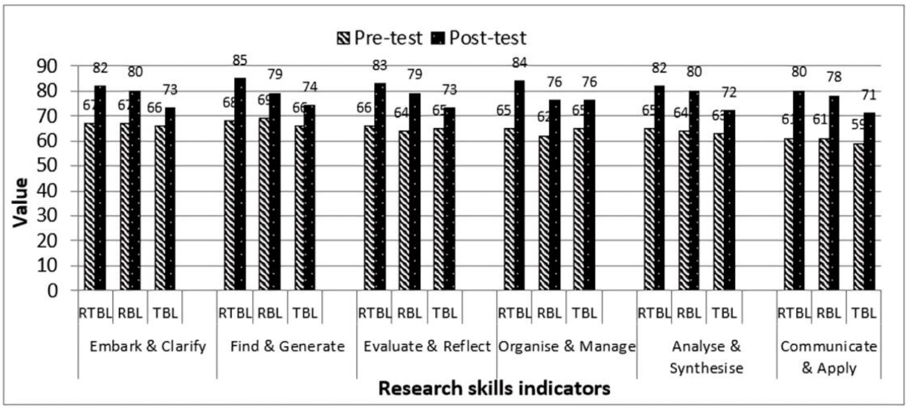


Figure 5. Graph of pre- and post-test values for each research skills indicator in the RTBL, RBL and TBL classes (Source: Authors' own elaboration)

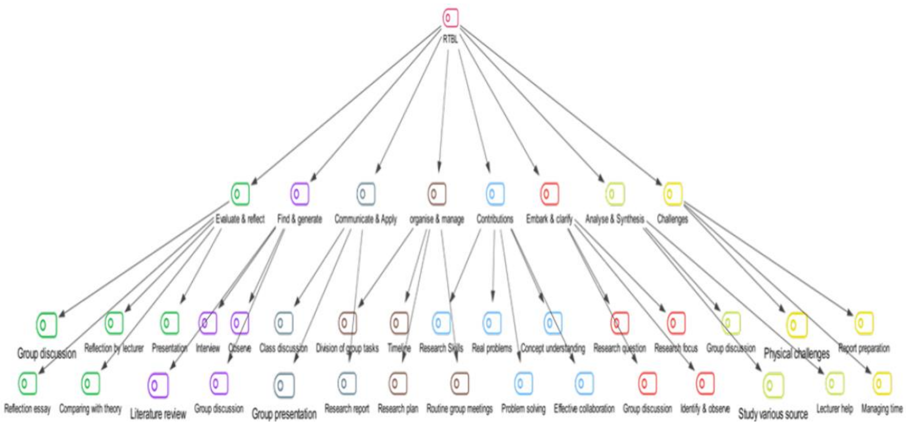


Figure 6. Hierarchical code-subcodes model for RTBL (Source: Authors' own elaboration)

R (2): "I understand the concept of material related to waste management and flood disaster mitigation better."

R (5): "I feel that this learning encourages more effective collaboration with teammates so that we can work together to solve the problem of waste accumulation and flood disasters well."

Challenge category

The 'challenge' category contains the following codes: physical challenges, report preparation, and time management. According to students, RTBL learning has challenges, such as when students conduct research in the field, it is difficult to find sources or respondents willing to be interviewed; additionally, the research location is quite far away, and extreme weather makes it difficult for students to travel to the field. Students are also said to struggle with report compilation and time management.

R (1), R (5), and R (8): "Not many informants are willing to be interviewed and it takes courage and confidence to interview sources."

R (3): "It is difficult to reach the research area because the location is quite far."

R (9): "Managing time to complete individual tasks and group research simultaneously is sometimes difficult, especially with other lecture schedules."

Embark and clarify category

The codes in the 'embark and clarify' category are research questions, research focus, group discussion, and identification and observation. Students can begin and clarify a research problem by developing research questions, focusing on the research location plan, holding discussions with groups about the focus of the research to be conducted, identifying problems, and making preliminary observations of areas with high garbage accumulation and flooding risk.

R (1): "I first identify by observing directly in the field, see how the accumulation of garbage and flooding affects the community, then define the problem based on the findings."

R (2): "We conduct group discussions first to clarify the research problem to be studied, then create research questions so that the research to be conducted can be known."

Find and generate category

The 'find and generate' category includes codes for literature review, group discussion, interview, and observation. Students can gather information and generate data or ideas using suitable methodology by reviewing literature from various sources, such as scientific journals, books, and so on. They might also collect research data through interviews and firsthand observation at the study site.

R (1): "I get information by searching Google Scholar based on what the lecturer taught me. Then, read related articles. For study data information, we conduct group interviews."

R (8): "I read and review various research articles and read research methodology books so that I know the right method to conduct research, besides that, the data obtained from direct observation and interviews with sources."

Evaluate and reflect category

The 'evaluate and reflect' category contains codes such as group discussion, reflective essay, lecturer reflection, presentation, and theory comparison. Students can assess and reflect on data and research efforts collected through group discussions before presenting them. They can also reflect on the process and outcomes of their research by writing reflective essays and reflections, which lecturers encourage. Students also compare the data collected to existing theories.

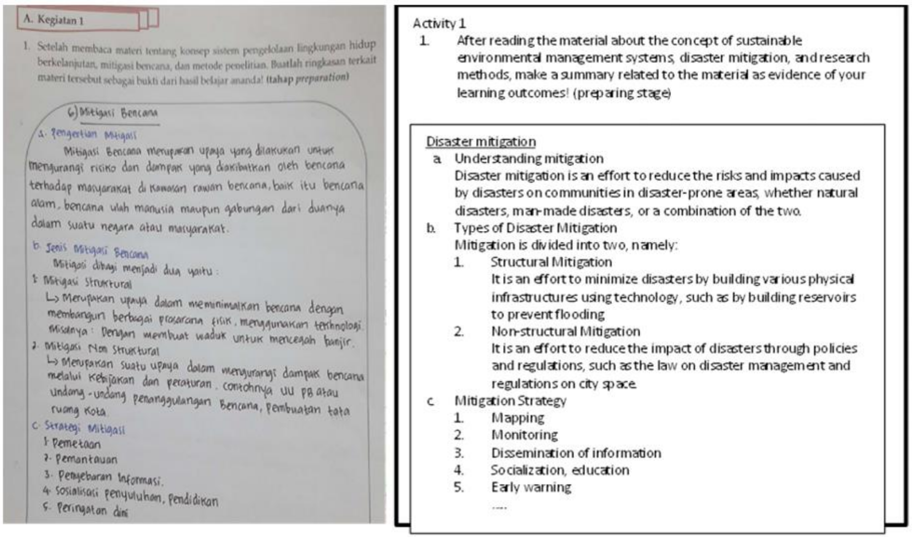
R (1): "I evaluate the data obtained through group discussions and class discussions so that it can be known whether the research activities carried out are correct and the data obtained is sufficient or not."

R (3) and R (6): "When I hear feedback given by lecturers and other friends during group presentations and through making reflective essays, I can evaluate the results of the group's research."

R (9): "I will evaluate the data collected by comparing the theory and the results of previous research to ensure whether there is a match or difference."

Organise and manage category

The 'organize & manage' category comprises codes such as research plan, routine group meetings, timeline, and group work divisions. Students can control and organize the research process by developing a research plan and a timeline outlining the goals to be attained. Furthermore, several students stated that clearly defining duties and responsibilities among group members can assist students in completing their projects on time. Students also plan routine meetings to help them manage and coordinate their activities.



A. Kegiatan 1

1. Setelah membaca materi tentang konsep sistem pengelolaan lingkungan hidup berkelanjutan, mitigasi bencana, dan metode penelitian. Buatlah ringkasan terkait materi tersebut sebagai bukti dari hasil belajar ananda! (tahap *preparation*)

6) Mitigasi Bencana

a. Pengertian Mitigasi

Mitigasi Bencana merupakan upaya yang dilakukan untuk mengurangi risiko dan dampak yang diakibatkan oleh bencana terhadap masyarakat di kawasan rawan bencana, baik itu bencana alam, bencana ulah manusia maupun gabungan dari duanya dalam suatu negara atau masyarakat.

b. Jenis Mitigasi Bencana

Mitigasi dibagi menjadi dua yaitu:

1. Mitigasi Struktural

↳ Merupakan upaya dalam meminimalkan bencana dengan membangun berbagai prasarana fisik, menggunakan teknologi. Misalnya: Dengan membuat waduk untuk mencegah banjir.

2. Mitigasi Non Struktural

↳ Merupakan suatu upaya dalam mengurangi dampak bencana melalui kebijakan dan peraturan. contohnya UU PB atau undang-undang penanggulangan Bencana, Pembuatan tata ruang kota.

c. Strategi Mitigasi

1. Pemetaan
2. Pemantauan
3. Penyebaran Informasi.
4. Sosialisasi penyuluhan, Pendidikan
5. Peringatan dini

Activity 1

1. After reading the material about the concept of sustainable environmental management systems, disaster mitigation, and research methods, make a summary related to the material as evidence of your learning outcomes! (preparing stage)

Disaster mitigation

a. Understanding mitigation
Disaster mitigation is an effort to reduce the risks and impacts caused by disasters on communities in disaster-prone areas, whether natural disasters, man-made disasters, or a combination of the two.

b. Types of Disaster Mitigation
Mitigation is divided into two, namely:
1. Structural Mitigation
It is an effort to minimize disasters by building various physical infrastructures using technology, such as by building reservoirs to prevent flooding
2. Non-structural Mitigation
It is an effort to reduce the impact of disasters through policies and regulations, such as the law on disaster management and regulations on city space

c. Mitigation Strategy
1. Mapping
2. Monitoring
3. Dissemination of information
4. Socialization, education
5. Early warning
....

Figure 7. At the preparing stage, an example of a summary of the material made by students (left = original in Indonesian, right translated into English) (Source: Authors' own elaboration)

R (1): "Making a research plan and targets to be achieved allows me to manage and organize the research process."

R (2): "To organize the research process, I will create a clear timeline for each stage starting from data collection, and analysis, to report preparation so that all team members know when each task must be completed."

R (5): "I will organize regular meetings to evaluate research progress, discuss interim findings, and ensure that each team member is working on the tasks that have been given."

Analyse and synthesise category

The following codes are included in the "analyze & synthesize" category: group discussion, research of various sources, and lecture assistance. Students claimed that group discussions, mutual support, and reading from a variety of sources, such as technique books, pertinent articles, and YouTube videos, could help them develop their capacity to analyze and synthesize data. Additionally, students were able to examine and understand data with the assistance of lecturers who guided each group.

R (4): "I will discuss with team members to share perspectives on the data we get, which will help me see the data from different perspectives and enrich my analysis."

R (7): "I can process data by studying how to analyze data in research methodology books, relevant articles, and YouTube and I can practice it directly."

Communicate and apply category

The category 'communicate and apply' includes codes: group presentation, group report, and class discussion. Through presentation activities and class discussions, students can communicate their research results and apply their understanding. Making research reports also helps students learn to communicate their research results and apply their understanding scientifically. Students admit that they have gained much new knowledge, especially in compiling research reports.

R (2): "The research results that we have done in groups are then discussed and presented so that we can communicate our research data and apply the knowledge we have gained."

R (3): "I put together a well-structured research report that covers the background, methodology, results, and conclusions so that the research data is easy for readers to understand."

DISCUSSION

The Influence of the RTBL Model on Students' Research Skills in Environmental Science Courses

The study's findings suggest that applying the RTBL model significantly improves students' research skills. Students using the RTBL model had stronger average research skills than those using the RBL or TBL models. Each stage of the RTBL model helps to empower students' research skills.

Preparing stage

During the preparation stage, students examine material regarding key ideas in environmental science, environmental problems, disaster mitigation techniques,

a b

Figure 8. At the assessing readiness stage: (a) students take individual tests & (b) team tests (Source: Field study)

a b

Figure 9. At the research in a team stage: (a) students observe the accumulation of rubbish around the market & (b) on the side of the highway (Source: Field study)

and research methodology before writing a summary of what they have read (**Figure 7**). The significance of this level is in providing students with sufficient knowledge to do research. Research skills can be developed by reading numerous related books and supplying adequate knowledge for the research process (Afdal & Spernes, 2018). The process of reading materials at home will provide students with several concepts to be discussed together (Zubaidah et al., 2018b) and actively participate in solving problems (Faezi et al., 2018). Reading is a valuable practice for obtaining information (Mahanal et al., 2022). The initial concept that students have regarding the concept to be learned is very important to help students instill new knowledge from material and solve a problem (Zhao, 2023).

Assessing readiness stage

The assessing preparedness stage involves analyzing individual student readiness and improving collaboration among group members to execute research tasks via individual assessments, team testing, and reflection (**Figure 8**). Individual and group assessments help students work better in groups and increase their understanding (Burgess et al., 2018; Faezi et al., 2018). The provision of readiness assurance assessments for individuals and groups increases student motivation to study and fosters a dynamic learning environment (Burgess et al., 2018; Christensen et al., 2019).

Researching in a team stage

Researching in a team stage involves students working together as a team to research and solve challenges encountered during scientific activities. Students' investigations focus on garbage accumulation (**Figure 9**) and flood disasters. Conducting investigations and research projects to solve problems cooperatively will improve student participation. Many effective things are made for students through integration and direct involvement (Solovieva et al., 2022; Supratman et al., 2021). Research activities also train students in collecting, processing, and extracting information from extensive databases (Marcella & Samofalova, 2022; Noguez & Neri, 2019). Group discussions and communication help students develop appropriate environmental attitudes and values (Fang et al., 2023). Students can learn to create teamwork through

Figure 10. At the researching in a team stage: (a) students interviewed the village head & (b) members of the Regional Disaster Management Agency (Source: Field study)

the group learning process, in addition to dealing with environmental challenges more effectively and having more in-depth conversations (Fang et al., 2023).

Reflecting stage

The reflecting stage allows students to reflect on their research activities. Reflection activities are used to confirm data findings with research activities and student skill achievements (Afdal & Spernes, 2018; Brew & Saunders, 2020). Research skills relate to the activities of evaluating methods and data and reflecting on each process used in research activities (Ain et al., 2019). Through self-reflection, critical thinking, and collective evaluation, the environment can be improved. Through introspection, we can better our preconceptions and thoughts while also strengthening the responsibility of earth citizens' acts (Fang et al., 2023).

Research Skills Improvement in Each Indicator

Embark and clarify

The data analysis results demonstrate that the RTBL class outperforms the RBL and TBL classes in terms of enabling all research skill indicators. Students require a great deal of clarity before beginning an investigation or experiment. Providing scaffolding in the form of materials can be related to students' embark and clarify abilities (Abbott, 2019; Torres, 2018). Furthermore, when students develop inquiries and study strategies for waste accumulation and flood disasters, they will practice 'embark and clarify' skills (Torres, 2018). Forming research questions increases students' familiarity with environmental issues (Sukaesih et al., 2022). Reading and asking questions can spark pupils' curiosity and improve their ability to construct knowledge (Angraini et al., 2023). The concept of environmental education has evolved into critical and creative clarification related to research questions and value clarification (Fang et al., 2023). The interview results back up this finding. Students stated that through talks with the team, they were able to develop research questions and plans for the research that will be conducted.

Find and generate

Student involvement in literature reviews might help them build finding and generation skills. All information discovered by students is helpful in generating information utilized in organizing research tasks such as creating instruments, interpreting data, and finding the best answer. Reading books or articles increases students' opinions and grasp of the content while also broadening their knowledge of conceptual studies required for research (Pernaa et al., 2022; Veses et al., 2020). In addition, study data was gathered through investigative activities such as direct observation in areas of rubbish accumulation and flood disasters, as well as interviews with sources (**Figure 10**). The find and generate indicator refers to the activities of gathering information, using scientific instruments, or producing data as part of the experimental procedure (Torres, 2018). The interview results also confirm this finding; students stated that by conducting literature reviews on books, journals, and other relevant sources, as well as travelling straight to the field to conduct observations and interviews, they obtain relevant information and generate the research data required.

Evaluate and reflect

Student activities in group discussions might help them strengthen their evaluation and reflection skills. Collaborative group projects help students identify faults, appraise themselves, and demonstrate learning progress (Hegde & Karunasagar, 2021; Marín, 2020). The ability to analyze and reflect can be developed by reviewing team structures, responsibilities, and effectiveness (Torres, 2018). Furthermore, during the reflection stage, students reflect on the research process assisted by the lecturer and write a reflective essay that encourages the development of their abilities to assess and reflect. The lecturer's feedback positively promotes student learning and the reflection of knowledge on the learner (Faezi et al., 2018). The results of the interview also support this finding. Students said that through the discussion stage, reflection, and reflective essays from the research activities that have been carried out, they can evaluate and reflect on their research activities.

Organize and manage

Student activities in developing research plans before beginning research, as well as effective collaboration skills among group members while doing research, play a vital role in building organizational and management abilities. To improve ownership of research initiatives, new data-gathering methods, as well as their selection or design, are required (Smith et al., 2023). Planning cards provide students with additional ideas for executing their study (Abbott, 2019). Students assign duties to each group member, which include interviewing residents in garbage buildup regions, distributing questionnaires, and visiting the city sanitation office. The organize and manage indicator refers to how students can work together based on their various tasks and efficiently manage their time to finish assignments on time (Torres, 2018). The interview results also support this finding. Students said that by making a research plan, creating a timeline, and dividing tasks, they can organize and manage their research process.

Analyze and synthesize

Student activities such as analyzing interview results through data collection, reduction, presentation, and verification, as well as reading research methodology books, reviewing relevant articles, and studying data processing through YouTube, can develop students' analysis and synthesis skills. Analysis and synthesis skills occur through the process of comparing data and information (Torres, 2018). The activity of analyzing relevant facts related to environmental problems will develop students' analysis skills (Krawczyk & Showalter, 2020). The interview results back up this finding; students stated that data processing and synthesis were done by examining diverse material, including methodology books, articles, and YouTube videos. Group conversations also help to strengthen analytical and synthesis abilities. Seeking accuracy through the process of asking questions and comparing outcomes across peers provides an opportunity to exercise analysis and synthesis skills (Abbott, 2019; Torres, 2018).

Communicate and apply

Student activities such as composing research reports and presenting research findings on environmental issues such as waste accumulation and conveying alternative solutions so that the environment becomes cleaner, waste-free, and flood-free, as well as group discussions and providing suggestions, can all help students develop communication and application skills. Students can share information through conversations, presentations, and questions and answers. Furthermore, students grab the audience's attention, especially using graphics such as PowerPoint presentations, photos, and so on (Shivni et al., 2021). Presenting research results in class is important for improving communication skills (Smith et al., 2023). Learning that allows students to debate experimental results and articulate conclusions in writing is essential for developing communication and application skills (Torres, 2018). The interview results confirm this finding, as students stated that they can express and apply their learning by writing research reports, giving presentations, and participating in class discussions.

Students' Experiences in Learning Environmental Science Using RTBL

The first

According to the findings of the content analysis, students claim that RTBL learning, in addition to strengthening research skills, helps them better understand the concept of waste management and flood catastrophe prevention measures. Students get in-depth knowledge from the interviews they conduct. Collecting data about environmental issues through interviews allows students to obtain an in-depth understanding (Fang et al., 2023). Conceptual understanding will aid in the mastery of scientific concepts that promote research skills (Fornsaglio et al., 2021). Students believe they have a greater understanding of real-world challenges. Direct observation helps students understand challenges that are contextual and relevant to their lives (Fang et al., 2023). RTBL learning requires students to think critically when examining the challenges of garbage accumulation and floods and developing acceptable solutions. Inquiry activities encourage students to study, look for, and solve problems, which improves critical thinking abilities (Zubaidah et al., 2018a). Furthermore, students believe that this learning fosters more effective team collaboration to solve research problems. Collaboration fosters long-term innovation and creativity, shaping individual talents in collaborative critical thinking to address challenges together (Wilkerson & Trellevik, 2021).

The second

Exciting findings regarding several challenges faced by students in RTBL learning, including the difficulty of finding sources to be interviewed, physical challenges related to distant research locations and extreme weather, and challenges in writing research reports. Students also stated that they required courage and confidence to dig up information and interview sources. Students receive both difficulties and great experiences. As part of environmental education, developing students' self-confidence is critical for promoting environmental literacy (Deveci & Karteri, 2022). Working with a community to execute outdoor learning can boost self-confidence (Kalungwizi et al., 2020). Other findings emphasize the necessity of time management and regular group meetings for assessing research progress. Regular one-semester meetings help students arrange their work routines and provide opportunities for reflection and improvement (Fornsaglio et al., 2021).

The third

Students in the lower group acknowledged a need for lecturer support in analyzing and synthesizing data to understand it as scientific evidence. Low-achieving students require additional academic support to develop scientific ideas, attitudes, and perceptions comparable to those of professionals in the field (Fornsaglio et al., 2021). Lecturers play a role in helping students develop their research skills. Understanding the function of lecturers in research might enhance students' research skills (Bueno, 2017; Perez et al., 2017; Rodríguez et al., 2019). Scaffolding provides learning support to students, allowing them to finish assignments and develop independence (Antonio, 2020; Procter, 2020). Students are encouraged to try based on the relationship between "stimulus and response", and educators can correct mistakes through the guidance process (Fang et al., 2023). Students in the higher group demonstrate greater independence in learning; they take the initiative to learn data analysis using multiple references. Students with high academic talents do better in reacting to and understanding lessons than students with low academic abilities (Mahanal et al., 2019).

Practical Implications

The RTBL model allows students to reflect deeply on their research processes and outcomes. This can help students not only enhance their research skills but also their understanding of the content being studied and their reflective thinking skills, both of which are essential for lifelong learning. Students with stronger research and collaborative abilities are better equipped for the workforce, particularly in fields that need complex issue analysis and data-driven solutions.

Research Limitations

This study is still being undertaken at one university with a small sample. To strengthen the validity of the study's findings, it should be replicated at more universities and with a larger sample size. More specifically, this study was evaluated on a single course: environmental science.

Recommendations

It is recommended that the RTBL model be formalized and included in the college curriculum. The RTBL model can be utilized as an alternative effective learning strategy to help students develop their research skills. Lecturers should extend the RTBL approach to other courses that require students to build their research skills. This study emphasizes the relevance of teamwork and reflection in the learning process. Lecturers should provide additional opportunities for students to work collaboratively in groups and reflect on their research experiences.

CONCLUSION

The study found that the RTBL model is much more successful at enhancing students' research skills than the RBL and TBL learning models. RTBL offers well-structured learning experiences that include collaboration, hands-on research, and in-depth reflection. Students benefit significantly from RTBL in each of the following research skill indicators: embark and clarify, locate and generate, assess and reflect, organize and manage, analyze and synthesize, communicate and apply. This model has been successful in enhancing students' ability to solve complicated problems, particularly those related to the environment.

Another finding from this study is that, in addition to boosting research skills, RTBL helps students understand the material's concept, understand real-world difficulties, and solve problems. Physical obstacles, report writing, and time management are all challenges associated with RTBL learning. Students requested professor assistance in analyzing and synthesizing data. RTBL, which is used to address environmental challenges like garbage accumulation and flood disasters, gives pupils a more relevant learning experience. They not only learn theory but also get hands-on experience tackling real-world situations, making learning more contextual and applicable.

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