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Enhancing critical thinking dispositions and skills: A constructivist project-based learning approach for environmental geography

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ABSTRACT

Environmental Geography in higher education faces challenges in empowering students to navigate complex ecological issues, a problem often exacerbated by traditional textbooks lacking real-world context. This hinders the development of essential critical thinking skills (CTS) and dispositions (CTD). Addressing this gap, this study developed and validated a constructivist-based textbook integrated with the project-based learning (PjBL) model. Employing an Educational Research and Development (R&D) design, the study encompassed expert validation, progressive preliminary trials, and a main operational field test involving 31 geography education students in Indonesia. Effectiveness was evaluated using a one-group pre-test-post-test design, utilizing the California Critical Thinking Disposition Inventory (CCTDI) and a rubric-based essay test. Results indicated that the textbook was highly valid across language, design, and content dimensions. Following implementation, students' CTD significantly improved from the "fair" to "good" category (n-Gain = 0.12), and CTS advanced from the "poor" to "good" category (n-Gain = 0.37). Paired sample t-tests confirmed statistically significant enhancements for both variables ($p < .001$). Furthermore, student responses were overwhelmingly positive (82.19%), reflecting high pedagogical engagement. These findings demonstrate that integrating constructivist PjBL syntax into textbooks successfully bridges the gap between abstract theoretical knowledge and practical critical reasoning. This study advocates for the wider adoption of such interactive instructional materials to foster higher-order thinking in global geography curricula.

Keywords: critical thinking disposition, critical thinking skills, constructivist, project-based learning, environmental geography

INTRODUCTION

The challenges of 21st-century learning encompass various complex and dynamic aspects that are influenced by technological advances and rapid social change. In this context, critical thinking has become one of the essential competencies that students must possess, especially in 21st-century higher education (Kocak et al., 2021; Putra et al., 2018; Santos-Meneses & Drugova, 2023; ŽivkoviL, 2016). Critical thinking consists of two main dimensions, namely the cognitive dimension and the affective dimension (Facione, 2013). The cognitive dimension is known as critical thinking skills, while the affective dimension is referred to as critical thinking disposition. The cognitive dimension relates to the ability to solve problems and analyze information, while the affective dimension reflects an individual's readiness to apply critical thinking skills in various real-life situations (Álvarez-Huerta et al., 2024).

In the context of strengthening 21st-century competencies, critical thinking dispositions (CTD) are a fundamental aspect that determines the extent to which students are willing and consistent in using their critical thinking skills (CTS) in various academic and real-life situations. Empowering critical thinking dispositions enables students to become better critical thinkers than individuals who only possess critical thinking skills without strong dispositions (Aizikovitsh-Udi & Cheng, 2015). A disposition for critical thinking is an internal motivation that consistently encourages students to use critical thinking skills, especially when involved in decision-making processes (Barta et al., 2022; Fitriani et al., 2018; Liu & Pásztor, 2023). The experts' views emphasize that critical thinking is a fundamental dimension of consciousness and needs to be systematically

empowered through the learning process (Abrami et al., 2008; Hadad, 2025; Yin et al., 2023).

In addition to disposition, critical thinking skills also play a very significant role in learning. Critical thinking skills are the process of seeking, producing, evaluating, analyzing, and synthesizing information, as well as constructing concepts as a basis for developing one's thinking abilities consciously and reflectively (Demirhan & Köklükaya, 2014; Irwanto, 2023; Shaw et al., 2020; Zubaidah et al., 2017). This skill provides long-term benefits because it helps students solve academic problems and apply them in their daily lives outside of formal learning contexts (Alismaiel, 2022; Kaddoura, 2011). Critical thinking encompasses high-level cognitive skills that enable students to engage in reflective, independent, and responsible thinking (Barta et al., 2022; Loes & Pascarella, 2017). Therefore, critical thinking skills are not innate, but rather skills that can and must be developed through a planned and continuous learning process (Irwanto et al., 2019). Both skills need to be empowered in the Environmental Geography learning process.

Environmental Geography is a discipline inherently characterized by complex, multidimensional issues such as climate change, resource depletion, and socio-spatial inequalities. Addressing these contemporary ecological crises requires more than theoretical comprehension; it demands robust critical reasoning to evaluate spatial data, synthesize multiperspective information, and propose sustainable solutions. Consequently, geography education students, as future educators and environmental problem solvers, must be equipped with both high-level CTS and strong CTD to navigate and eventually teach these complexities effectively. However, despite this pedagogical urgency, a disconnect often persists in higher education where traditional, theory-heavy instructional approaches still dominate, leaving a significant gap between the required critical competencies and actual student performance.

Furthermore, the cultivation of these critical competencies aligns seamlessly with the global mandate for Education for Sustainable Development (ESD). Specifically, Sustainable Development Goal (SDG) 4.7 emphasizes the necessity of equipping all learners with the knowledge and skills needed to promote sustainable development, sustainable lifestyles, and global citizenship. Recent discourse within the sustainability education community heavily emphasizes that pedagogical innovations are vital for operationalizing these ESD goals in higher education (Gaanya et al., 2025; Nouri & Bouzaabia, 2025). In the context of Environmental Geography, critical thinking is not merely an academic exercise; it is the cognitive and affective foundation required for students to analyze complex socio-ecological systems, challenge unsustainable practices, and innovate resilient solutions. Therefore, developing instructional materials that effectively foster these traits is a direct contribution to the broader global sustainability agenda.

This specific gap is highly evident in the Environmental Geography learning context at Muhammadiyah University Mataram. Based on observations of students in the geography education program at the university, several major problems were found, including: (a) students' critical thinking skills and dispositions are still relatively low, as evidenced by their passive attitude in class discussions, lack of questions, and superficial answers; (b) students are not yet able to present detailed logical and argumentative reasoning on the issues presented; and (c) students' problem-solving skills are still low, as reflected in the learning evaluation results that have not met the expected criteria. These problems are fundamentally rooted in the limitations of the existing instructional materials, which tend to be heavily theoretical and lack authentic, real-world environmental contexts. Consequently, students are rarely exposed to innovative, constructivist-based learning models that systematically train their critical reasoning.

Based on these issues, there is a need for teaching materials in the form of constructivist-based Environmental Geography textbooks that can systematically encourage the development of students' critical thinking skills and dispositions. Well-structured, specific, systematic textbooks that are aligned with the applicable curriculum are believed to support a more effective learning process (Abdelmohsen, 2020). In addition, textbooks need to be designed with consideration for the principle of multiperspectivity and an effective combination of images and text in order to improve learning effectiveness (Behnke, 2021; Dörfel et al., 2023). The existence of textbooks in learning has a significant influence on improving student learning outcomes (Radić-Bojanić & Topalov, 2016). Teaching facilitated by textbooks also plays an important role in developing critical, evaluative, and synthesis skills (Putra et al., 2023). Researchers emphasize the importance of textbooks presenting scientific characteristics that include descriptions of the scientific process and the work of scientists (Vojíř & Rusek, 2019; Vojíř & Svobodová, 2024).

Active student involvement in learning is a key factor in developing critical thinking skills and dispositions. One effective learning model for increasing active student involvement is project-based learning (PjBL). The PjBL model is student-oriented and has been proven to significantly improve problem-solving skills (Kong et al., 2024). PjBL is a learning approach that emphasizes active student involvement in projects related to real-world problems (Kong et al., 2024; Loyens et al., 2023; Marnewick, 2023; Santos et al., 2023). The PjBL model is rooted in constructivist learning theory, which views knowledge as being actively constructed by students through meaningful learning experiences (Marnewick, 2023).

While traditional textbooks often promote passive reading, a constructivist-based textbook functions fundamentally differently. Rather than serving merely as a static repository of theoretical concepts, it acts as an interactive instructional module that provides scaffolding for active learning. By explicitly integrating the PjBL syntax into its design, the textbook systematically guides students through identifying real-world environmental problems, designing collaborative projects, and evaluating sustainable solutions. This strategic integration transforms the textbook from a one-way information source into a practical framework that contextualizes ecological theories, thereby driving the active engagement necessary to develop both critical thinking skills and dispositions.

While previous studies have highlighted the positive impact of project-based learning (PjBL) on active student

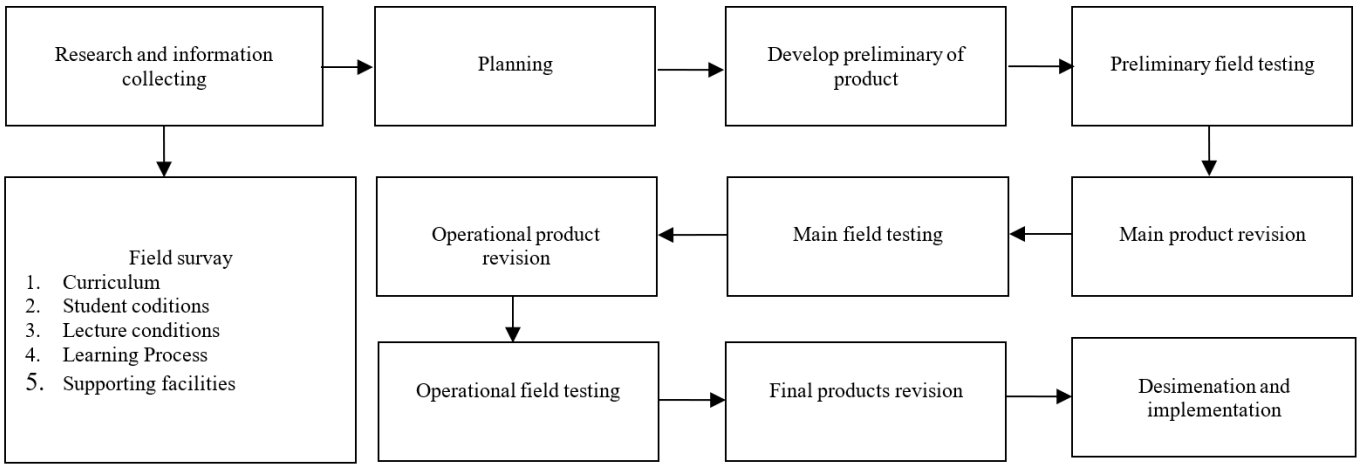

Figure 1. Research flow diagram (Adapted from Borg & Gall, 1989)

engagement and problem-solving (Kong et al., 2024; Marnewick, 2023), its successful implementation in complex subjects like Environmental Geography often struggles due to a lack of structured, constructivist-based instructional materials to scaffold the learning syntax. Conversely, recent developments in geography textbooks largely focus on multiperspectivity and visual design (Behnke, 2021; Dörfel et al., 2023) or remain heavily theoretical, failing to provide the practical framework necessary to drive independent, project-based inquiry. Furthermore, most existing literature evaluates critical thinking either solely as a cognitive skill (CTS) or an affective disposition (CTD), rarely examining them simultaneously within a single pedagogical intervention. Therefore, a critical gap exists in the literature regarding the development and empirical validation of a constructivist-based Environmental Geography textbook that seamlessly integrates PjBL to simultaneously empower both students' critical thinking dispositions and skills.

While an extensive body of literature has established the general positive correlation between Project-Based Learning (PjBL) and critical thinking across various disciplines, there remains a notable scarcity of research contextualizing this relationship specifically within higher education Environmental Geography. Furthermore, previous studies predominantly evaluate PjBL as an instructor-led pedagogical intervention. They rarely explore the systematic embedding of PjBL syntax directly into foundational instructional materials. Therefore, the primary novelty and contribution of this article lie in bridging this specific literature gap: it explicitly investigates how integrating a constructivist PjBL framework into a tangible textbook uniquely influences both the cognitive dimension (Critical Thinking Skills) and the often-overlooked affective dimension (Critical Thinking Dispositions) of geography education students.

Based on the above description, this study aims to: (1) develop and validate a constructivist-based Environmental Geography textbook through a project-based learning model; (2) test the effectiveness of constructivist-based Environmental Geography textbooks through the project-based learning model on students' critical thinking dispositions; (3) test the effectiveness of constructivist-based Environmental Geography textbooks through the project-based learning model on students' critical thinking skills, and (4) analyze the implementation of learning and student responses to Environmental Geography learning.

METHOD

Research Design

The present study employed an Educational Research and Development (R&D) design, adapting the widely recognized model proposed by Borg and Gall (1989). This design was selected because it systematically guides the process of developing, validating, and testing the effectiveness of a novel educational product, in this case, a constructivist-based Environmental Geography textbook integrated with the Project-Based Learning (PjBL) syntax.

While the original Borg and Gall model consists of ten comprehensive steps, for the context of this study, the procedural framework was systematically operationalized into three primary phases to ensure logical progression and feasibility: (1) Preliminary Study Phase (encompassing research and information collecting, and planning), (2) Development and Validation Phase (involving preliminary product development, expert validation, and main product revision), and (3) Field Testing and Finalization Phase (comprising preliminary field testing, operational field testing using a pre-test and post-test design, and final product revision). The detailed progression of these developmental stages is visually depicted in the research flow diagram **(Figure 1**).

Research Location and Time

To ensure the comprehensive evaluation and broad applicability of the developed textbook across diverse student demographics, this research was systematically carried out at three distinct higher education institutions in Indonesia. The testing phases were structured chronologically: first, a limited preliminary trial was conducted at Kanjuruhan University in Malang on August 20, 2025. Following initial refinements, a more extensive trial was implemented at Hamzanwadi University on September 11, 2025. Finally, the main operational field trial, focusing on implementation and effectiveness validation, took place at Muhammadiyah

Table 1. Average validity and reliability scores of learning instruments

No	Component	Validity	Category	Reliability	Category
1	Semester program plan	3.70	Good	93.25%	Reliable
2	Lecture units	3.71	Good	92.9%	Reliable
3	Student worksheets	3.50	Good	97.5%	Reliable

Table 2. Average validity and reliability scores of assessment instruments

No	Component	Validity	Category	Reliability	Category
1	Critical thinking disposition questionnaire	3.30	Good	92.00%	Reliable
2	Critical thinking skills test	3.50	Good	91.75%	Reliable

University in Mataram over a six-week period, from October 27 to December 8, 2025.

Research Sample

The participants for this development study were selected using a purposive sampling technique. The primary selection criterion was the students' prior enrollment status in the Environmental Geography course, ensuring each group was specifically suited for the distinct phases of product development and testing. The total sample comprised three distinct groups.

Limited trial group

11 geography education students from Kanjuruhan University in Malang. Because these students had previously completed the Environmental Geography course, they were selected to evaluate the initial suitability and readability of the textbook draft.

Extensive trial group

25 geography education students from Hamzanwadi University who had also previously taken the course. This larger cohort provided broader, more comprehensive feedback to evaluate the feasibility and guide the structural refinement of the constructivist-based PjBL textbook.

Main field test group

31 geography education students at Muhammadiyah University in Mataram. Crucially, this group had not yet taken the Environmental Geography course. Therefore, they served as the primary experimental subjects to empirically analyze the effectiveness of the textbook intervention on their critical thinking skills and dispositions.

Research Instruments

The instruments utilized in this study were categorized into two main groups: learning instruments and assessment instruments.

Learning instruments

The learning instruments comprised the semester program plan, classroom lecture units, and student worksheets. These documents were rigorously structured to include essential instructional components, ranging from learning outcomes and study materials to time allocation and assessment rubrics. Prior to implementation, these instruments underwent construct validation. As shown in **Table 1,** all learning instruments achieved a "Good" validity category and were deemed highly reliable.

Table 3. Criteria for categorizing critical thinking dispositions (Adapted from Fitriani et al., 2018)

No	Score Range	Category
1	1.00–2.25	Poor
2	2.26–3.51	Fair
3	3.52–4.50	Good
4	4.51–5.00	Very good

Assessment instruments

The assessment instruments were specifically designed to measure the two primary dependent variables: critical thinking disposition (CTD) and critical thinking skills (CTS). The construct validity and reliability scores for both instruments are presented in **Table 2**.

Critical Thinking Disposition (CTD): The affective dimension was measured using the California Critical Thinking Disposition Inventory (CCTDI). The CCTDI consists of seven core indicators: curiosity, self-confidence, truth-seeking, open-mindedness, analyticity, systematicity, and cognitive maturity. To ensure cultural and linguistic appropriateness for Indonesian geography education students, the original English version of the CCTDI underwent a systematic adaptation process prior to deployment. This process involved a forward-backward translation procedure, followed by a thorough review from an expert panel, comprising language specialists and pedagogical experts, to establish content validity and eliminate potential cultural biases in the item statements. Because existing Indonesian adaptations were not specifically contextualized for higher education geography students, this independent translation and rigorous validation process represents a distinct methodological contribution of the present study. Following this cultural adaptation, the translated instrument was subjected to empirical construct validation for this specific sample using SPSS v.23.0. The instrument demonstrated excellent internal consistency with a Cronbach's Alpha coefficient of 0.886. The scoring categorization for CTD is detailed in **Table 3**.

Meanwhile, the main instrument for measuring critical thinking skills is an essay test developed from five components of critical thinking skills, namely: apply, evaluation, use data to develop critical insight, analyze, and synthesize (Greenstein, 2012). Each component is developed into one essay question, resulting in a total of five test questions. The answer criteria for each component consist of exemplary (score of 20), proficient (score of 15), basic (score of 10), and novice (score of 5).

Types and Sources of Data

This study gathered a comprehensive set of empirical data to evaluate the feasibility, validity, and effectiveness of the developed textbook. The quantitative data primarily comprised the students' pre-test and post-test scores from the critical thinking skills essay, the CCTDI questionnaire results, and the scaled responses from the implementation surveys. To provide deeper contextual insights, qualitative data were systematically collected through direct classroom observations assessing the PjBL implementation syntax, in-depth interviews with geography lecturers and students during the preliminary needs analysis, and documentation reviews of existing instructional materials.

Data Collection

The data collection procedures were systematically aligned with the R&D phases to ensure a robust evaluation of the developed textbook. The specific techniques employed included:

Tests and questionnaires

To empirically measure the textbook's effectiveness, essay tests (assessing CTS) and the CCTDI questionnaires (assessing CTD) were administered simultaneously as pre-tests before the learning intervention and as post-tests upon completion of the main field trial.

Observations

Direct classroom observations were conducted continuously across the limited, broader, and operational field trials. This technique was crucial for monitoring student engagement and evaluating the implementation fidelity of the PjBL learning syntax.

Surveys and interviews

These formative techniques were deployed during the preliminary needs analysis, as well as the limited and broader product testing phases. They provided essential qualitative feedback from both lecturers and students regarding the textbook's feasibility, design, and usability.

Document analysis

Performed during the initial preliminary study, this involved reviewing existing syllabi, lesson plans, and instructional materials to establish the baseline pedagogical context and corroborate the existing research gap.

Research Procedures

The systematic progression of this R&D study is visually summarized in the research flow diagram (**Figure 2**). The procedure was executed sequentially across the three predefined phases. It commenced with a comprehensive preliminary study, encompassing literature reviews, field observations, and needs analyses, to establish the foundational design of the constructivist-based PjBL textbook. This was followed by an iterative development and validation phase, where the initial product draft was rigorously evaluated by experts and refined through preliminary trials. The final phase involved operational field testing to empirically assess the textbook's effectiveness on the target variables, culminating in the final product revision and dissemination.

Data Analysis

The data obtained in this study were analyzed using both descriptive and inferential statistics to comprehensively evaluate the textbook's effectiveness. First, normalized gain (n-Gain) scores were calculated to determine the magnitude of improvement in students' critical thinking dispositions (CTD) and critical thinking skills (CTS) from the pre-test to the post-test.

For the inferential analysis, a Paired Samples t-test was employed to ascertain whether the mean differences between the pre-test and post-test scores were statistically significant. Prior to conducting the t-test, data normality was verified. Both Kolmogorov-Smirnov and Shapiro-Wilk tests were computed; however, the Shapiro-Wilk test was primarily relied upon due to its robust suitability for the specific sample size (N = 31). Because the study utilized a One-Group Pre-test–Post-test Design without a control group, a homogeneity of variance test was not required. All statistical computations were performed at a significance level of 0.05.

The operational field testing utilized a one-group pre-test-post-test design. While the absence of a control group limits strict causal inference, this design was deliberately selected as appropriate for the preliminary testing phase of an R&D framework. The primary objective at this developmental stage was to establish the baseline functionality, practical feasibility, and initial pedagogical impact of the newly developed textbook in a naturalistic classroom setting, rather than to conduct a comparative experimental trial. Furthermore, logistical constraints, specifically the limited number of students enrolled in the Environmental Geography course during the research period, precluded the formation of a separate, statistically equivalent control group.

Furthermore, to evaluate the practical magnitude of the instructional intervention, the effect size was calculated. Given the one-group pre-test-post-test design, this study utilized Cohen's d_z, which is specifically designed for within-subject comparisons. Cohen's d_z was calculated by dividing the mean difference by the standard deviation of the differences ($d_z = M_{diff} / SD_{diff}$) (Lakens, 2013). While d_z values can appear substantially larger than standard pooled Cohen's d values when the correlation between measures is high, it accurately reflects the standardized difference within the specific sample.

Conceptual Framework

To understand the efficacy of the developed Environmental Geography textbook, it is essential to delineate the specific pedagogical mechanisms that bridge the constructivist PjBL activities with the targeted learning outcomes. The conceptual framework (**Figure 3**) of this study extends beyond a simple input-output relationship by illustrating how the textbook acts as a structured cognitive and affective scaffold. Specifically, the embedded PjBL syntax drives the parallel development of Critical Thinking Skills (CTS) and Critical Thinking Dispositions (CTD) through three interconnected mechanisms: Cognitive dissonance and exploration, Guided investigation, and Reflective Synthesis.

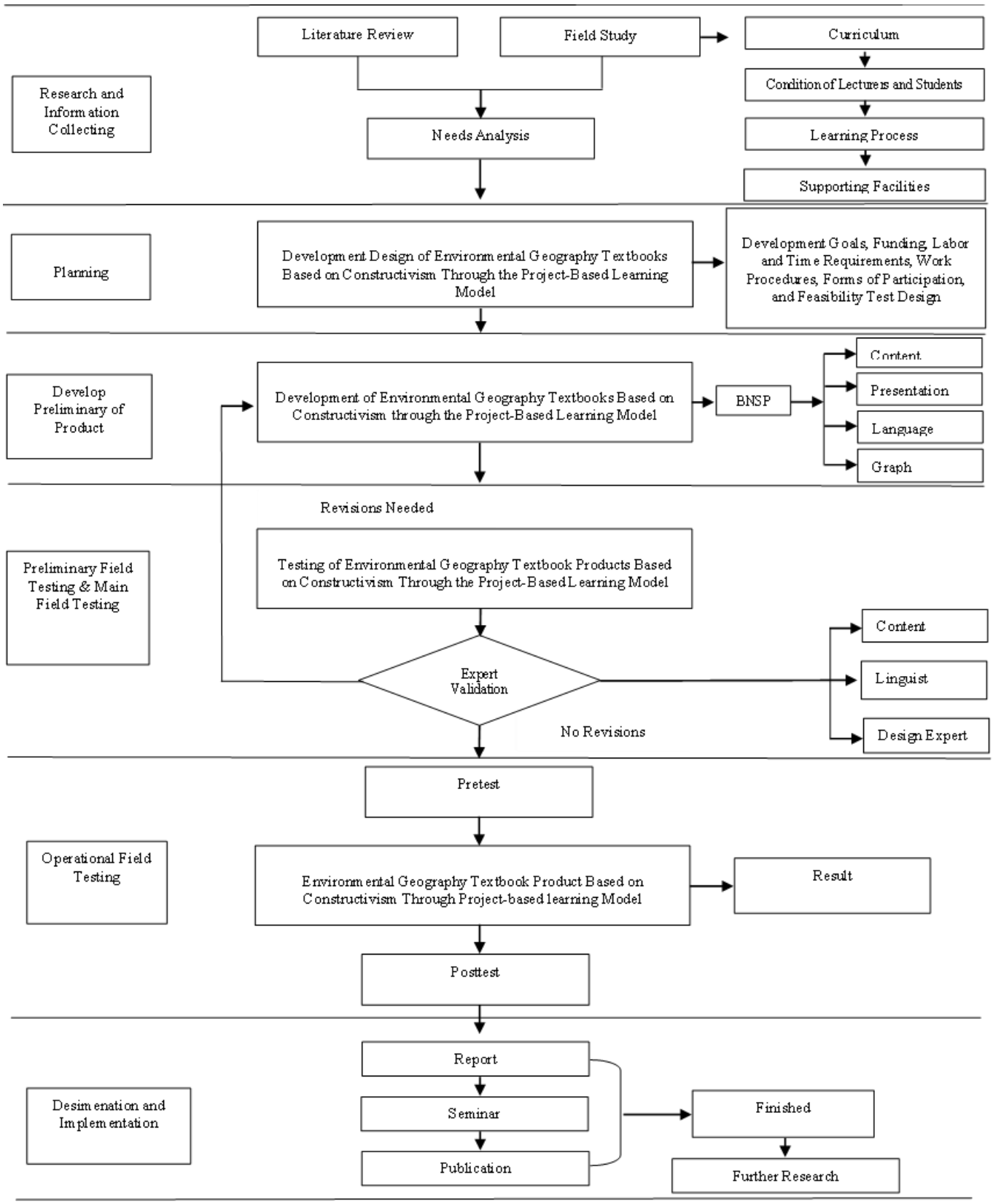

Figure 2. Research and development flow chart (Source: Authors' own elaboration)

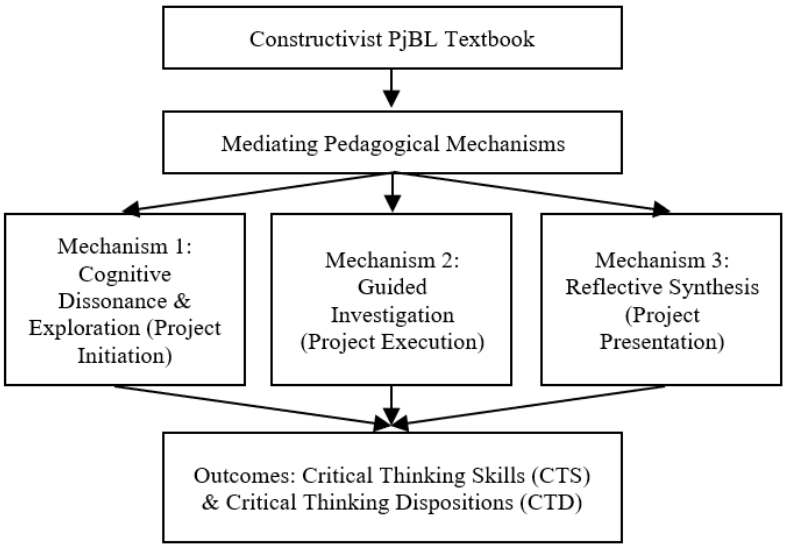

Figure 3. Conceptual framework (Source: Authors' own elaboration)

Cognitive dissonance and exploration: Project initiation

By presenting authentic local environmental crises (e.g., the ecological impacts of rock mining in Lombok), the textbook triggers cognitive dissonance. The process of formulating project questions actively stimulates affective dispositions, specifically curiosity, open-mindedness, and self-confidence (CTD).

Guided investigation: Project Execution

As students collaboratively gather and process spatial and ecological data, the textbook provides constructivist scaffolding rather than direct answers. This active data-handling mechanism directly trains cognitive skills such as analyzing and using data to develop critical insight (CTS), while simultaneously habituating truth-seeking and systematicity (CTD).

Reflective synthesis: Project presentation and evaluation

The final PjBL phase requires students to present solutions and critique peer projects. This mechanism forces the application of higher-order cognitive skills, namely evaluation, synthesis, and application (CTS), while nurturing cognitive maturity and analytical traits (CTD).

Ultimately, the constructivist textbook functions not merely as an informational repository, but as an interactive environment where critical inquiry and sustainable problem-solving are systematically habituated.

Research Hypothesis

Based on the formulated theoretical framework and research objectives, this study posits the following directional hypotheses (**Figure 4**):

H1: The implementation of the constructivist-based Environmental Geography textbook integrated with the Project-Based Learning (PjBL) model significantly improves students' critical thinking dispositions.

H2: The implementation of the constructivist-based Environmental Geography textbook integrated with the Project-Based Learning (PjBL) model significantly improves students' critical thinking skills.

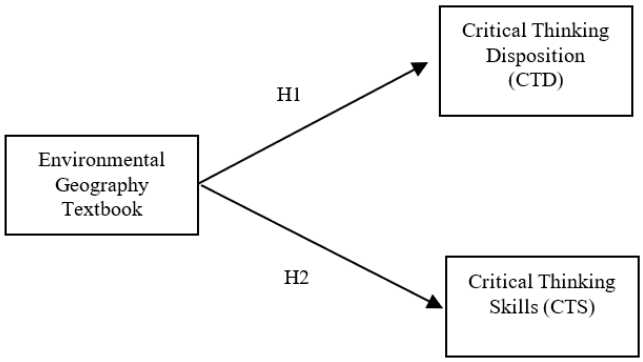

Figure 4. Research hypothesis (Source: Authors' own elaboration)

RESULTS

Development and Validation of Constructivist-Based Environmental Geography Textbooks Through the PjBL Model

Preliminary study results concluded that students and lecturers assessed that Environmental Geography lectures had a high level of urgency and relevance, but their implementation was not yet optimal, especially in dealing with the complexity of the learning material. Lecturers saw the need for the development of systematic and contextual textbooks, while students felt the need for learning resources that were more structured, easy to understand, and relevant to real environmental issues. Lecturers and students assessed that the development of project-based learning textbooks was considered capable of encouraging active student involvement in learning. The development of active learning-based Environmental Geography textbooks is a real and urgent need in supporting learning. In the next stage, detailed planning of learning activities, the formation of a development team, a list of tasks, a schedule of activities, the determination of

Table 4. Average expert assessment scores

No	Expert Rating	Score	Percentage	Category
1	Language expert	4.95	99.00%	Excellent
2	Design expert	4.26	85.29%	Good
3	Content expert	4.28	85.71%	Good

Table 5. Average trial assessment scores

No	Trial	Score	Average	Percentage	Category
1	Limited trial	57.18	4.08	81.68%	Good
2	More extensive trial	56.12	4.00	80.17%	Good

Table 6. Average pre-test and post-test scores for critical thinking disposition

Variable	Average						n-Gain
	Pre-test	Percentage	Category	Post-test	Percentage	Category	
Critical Thinking Disposition	3.35	70.59%	Fair	3.72	74.33%	Good	0.12

Table 7. The results of the normality test based on critical thinking disposition

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pre-test	0.112	31	0.200	0.967	31	0.432
Post-test	0.094	31	0.200	0.979	31	0.774

performance objectives, and the formulation of assessment strategies were carried out. This stage ended with evaluation and revision.

This is followed by the expert development and validation stage, which focuses on the preparation, adoption, and intensive consultation with supervisors and experts regarding the design of the textbook and its tools. Language experts are tasked with ensuring that the Environmental Geography textbook complies with the rules of proper and correct Indonesian language. Design experts are responsible for reviewing the visual aspects of the Environmental Geography textbook, including layout, typography, color selection, illustrations, spacing, and cover design, while content experts are responsible for assessing the accuracy, depth, breadth, and accuracy of the material in the Environmental Geography textbook. The average expert assessment scores can be seen in **Table 4**.

A limited trial was conducted on 11 students majoring in geography education at Kanjuruhan University Malang who had different academic levels, followed by revisions before a wider trial. A wider trial was conducted involving 25 students majoring in geography education at Hamzanwadi University who also had varying academic abilities. This trial aimed to obtain a more representative response from a larger number of users so as to provide a comprehensive picture of the quality of the Environmental Geography textbook that had been developed and followed by revisions prior to field testing. The average results of the limited trial and wider trial can be seen in **Table 5**.

The Effectiveness of Constructivist-Based Environmental Geography Learning Through the PjBL Model on Critical Thinking Disposition

The critical thinking disposition of geography education students was identified using a critical thinking disposition questionnaire administered before the field trial began (pre-test) and after the field trial was completed (post-test). The pre-test and post-test data were analyzed to determine the students' critical thinking disposition. The average pre-test and post-test scores for critical thinking disposition can be seen in **Table 6**.

Based on **Table 6**, the average critical thinking disposition increased. This can be seen from the difference or gap between the pre-test and post-test scores and is reinforced by the n-Gain score. Critical thinking disposition had a pre-test score of 3.35 (70.59%) and a post-test score of 3.72 (74.33%), while the n-Gain score was 0.12, which is in the low category.

Next, a t-test was conducted to examine the effectiveness of constructivist-based Environmental Geography learning on students' critical thinking dispositions. The data used in this study were the results of pre-tests and post-tests of Environmental Geography learning. Data analysis began with a normality test, the results of which are presented in **Table 7**.

As shown in **Table 7**, the Shapiro-Wilk normality test results indicate that the p-value for the pre-test data is 0.432, while for the post-test it is 0.774, both of which are greater than 0.05. This indicates that the pre-test and post-test data are normally distributed, because the probability value is greater than or equal to the 5% significance level. Specifically, the data from the t-test on students' critical thinking dispositions can be seen in **Table 8**.

The paired sample t-test confirmed a statistically significant increase in students' critical thinking dispositions ($t(30) = -15.80$, $p < .001$, $d = 2.84$). In addition to comparing the overall pre-test and post-test scores, a detailed mean comparison was conducted across the seven specific CCTDI indicators: curiosity, self-confidence, truth-seeking, open-mindedness, analyticity, systematicity, and cognitive maturity. As illustrated in **Figure 5**, these comparative data were derived directly from the students' aggregated post-test questionnaire responses (N=31). This indicator-level analysis was performed to isolate and identify which specific affective traits experienced the most substantial growth following the PjBL intervention.

Table 8. The results of the t-test based on critical thinking disposition

		Paired Differences					t	df	Sig. (2-tailed)	Cohen's d_z
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference					
					Lower	Upper				
CTD	Pre-test Post-test	-13.09677	4.61414	.82872	-14.78926	-11.40429	-15.804	30	<.001	2.84

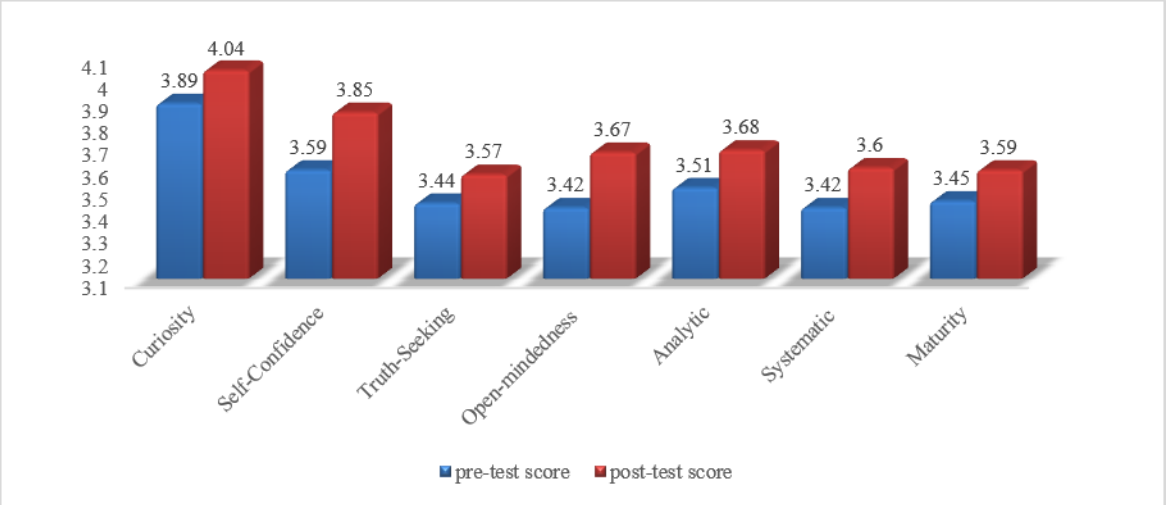

Figure 5. Comparison of the average critical thinking disposition indicators (Source: Authors' own elaboration)

Table 9. Average pre-test and post-test scores for critical thinking skills

Variable	Average				n-Gain
	Pre-test	Category	Post-test	Category	
Critical Thinking Skills	66.00	Poor	78.83	Good	0.37

Table 10. The results of the normality test based on critical thinking skills

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pre-test	0.145	31	0.096	0.969	31	0.498
Post-test	0.154	31	0.059	0.957	31	0.244

The Effectiveness of Constructivist-Based Environmental Geography Learning Through the PjBL Model on Critical Thinking Skills

The critical thinking skills of geography education students were measured using a critical thinking skills test administered before the field trial began (pre-test) and after the field trial was completed (post-test). The pre-test and post-test data were analyzed to determine the students' critical thinking skills. The average pre-test and post-test scores for critical thinking skills can be seen in **Table 9**.

Based on **Table 9**, the average value of critical thinking skills increased. This can be seen from the difference between the pre-test and post-test scores and reinforced by the n-Gain value. Critical thinking skills had a pre-test score of 66.00 and a post-test score of 78.83, while the n-Gain value reached 0.37 with a moderate category. A t-test was conducted to determine the difference in the average critical thinking skills of geography education students after undergoing learning activities.

Next, a t-test was conducted to examine the effectiveness of constructivist-based Environmental Geography learning on students' critical thinking skills. The data used in this study were the results of pre-tests and post-tests of constructivist-based Environmental Geography learning through the PjBL model. Data analysis began with a normality test, the results of which are presented in **Table 10**.

As shown in **Table 10**, the Shapiro-Wilk normality test results indicate that the p-value for the pre-test data is 0.498, while for the post-test it is 0.244, both of which are greater than 0.05. This indicates that the pre-test and post-test data are normally distributed, because the probability value is greater than or equal to the 5% significance level. Specifically, the data from the t-test on students' critical thinking skills can be seen in **Table 11**. The paired sample t-test confirmed a statistically significant improvement in students' critical thinking skills ($t(30) = -53.19$, $p < .001$, $d = 9.55$).

Implementation and Student Response to Environmental Geography Learning

The implementation of learning during the field trial was observed using a learning implementation observation sheet for each meeting. Learning implementation observations were conducted from the first meeting to the seventh meeting. Each

Table 11. The results of the t-test based on critical thinking skills

		Paired Differences					t	df	Sig. (2-tailed)	Cohen's d_z
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference					
					Lower	Upper				
CTS	Pre-test Post-test	-12.83871	1.34404	0.24140	-13.33171	-12.34571	-53.185	30	<.001	9.57

topic was covered in two sessions, except for the fifth session, which was covered in one session. The average implementation of learning for each topic reached 97.71%, which is categorized as very good. Student responses to this learning activity were based on their responses to the implementation of learning that had been carried out during the field trial stage. The average student response to the learning activity was 3.28 or 82.19%.

DISCUSSION

Development and Validation of Constructivist-Based Environmental Geography Textbooks Through the PjBL Model

The development of this constructivist-based Environmental Geography textbook directly addresses the critical gap identified in previous studies, wherein existing instructional materials tend to be heavily theoretical and lack contextual relevance. By systematically integrating the PjBL syntax, the developed textbook transforms passive reading into an active, student-centered experience. For instance, by incorporating localized and contemporary environmental issues, such as the specific dynamics of the rock mining industry on Lombok Island, the textbook provides an authentic real-world anchor for students. This contextualization aligns seamlessly with findings by Kong and Hou (2025), and Saad and Zainudin (2022), who assert that authentic, project-based experiences significantly elevate student motivation, collaboration, and problem-solving capabilities.

Furthermore, the textbook's structured projects require students to actively investigate environmental ethics, ecological concepts, and conduct field observations. This practical scaffolding bridges cognitive understanding with behavioral shifts. As demonstrated by previous environmental education research (Genc, 2015; Roberts et al., 2010; Yolcu, 2023) immersive PjBL environments are highly effective in fostering positive attitudes toward environmental stewardship and sustainable practices.

The rigorous validation process confirmed that the textbook is not only theoretically sound but also practically highly feasible. Evaluated across language, design, and content dimensions (Amalia et al., 2022). The product achieved excellent ratings. Notably, the exceptionally high language validation score indicates that the constructivist instructions and project guidelines are highly comprehensible for geography education students. This clarity is paramount; as highlighted by Quinto (2022), valid and clear instructional instruments are critical for preventing student disorientation during independent project execution. Ultimately, this validated product successfully bridges the gap between abstract ecological theory and practical environmental problem-solving.

The Effectiveness of Constructivist-Based Environmental Geography Learning Through the PjBL Model on Students' Critical Thinking Disposition

The results indicate a significant improvement in students' critical thinking dispositions (CTD) from the "fair" to "good" category following the implementation of the constructivist-based PjBL textbook. The Paired Samples t-test confirmed a statistically significant difference, leading to the acceptance of Hypothesis 1 (H1). Consistent with Allison and Pan (2011), this affective enhancement occurs because the PjBL model inherently demands active engagement. Crucially, the integration of PjBL within a structured textbook provides students with the autonomy and scaffolding needed to navigate complex environmental projects (Hosman & Jacobs, 2018; Miranda et al., 2020). This guided experience nurtures essential affective traits, such as self-confidence, open-mindedness, and cognitive maturity. by habituating students to collaborative problem-solving environments, ultimately strengthening their disposition to think critically (Doğantan, 2025; Morgan, 2025; Wiyono et al., 2025).

While the statistical analysis confirmed a significant difference between pre-test and post-test scores, it is important to objectively interpret the practical magnitude of this improvement. The normalized gain (n-Gain) score for CTD was 0.12, which falls into the low improvement category. This relatively modest magnitude does not negate the textbook's efficacy but rather reflects the complex nature of affective psychological constructs. Unlike cognitive skills, critical thinking dispositions, such as truth-seeking and open-mindedness, are deeply ingrained internal habits that require extended periods to substantially alter. Given that the instructional intervention lasted for approximately six weeks, this duration was sufficient to trigger initial positive behavioral shifts, but understandably too short to produce massive dispositional transformations. Consequently, realizing stronger and more enduring improvements in CTD will likely necessitate prolonged, continuous exposure to the PjBL constructivist environment across multiple semesters.

A detailed indicator analysis revealed that "Curiosity" achieved the highest post-test score (4.04). This high tendency to explore and question new information reflects the effectiveness of the textbook's constructivist prompts, supplemented by active lecturer facilitation. This aligns with Chen et al. (2024) and Nurdiana et al. (2023), who emphasize curiosity as a foundational critical disposition. Furthermore, as Xu and Yang (2024) note, cultivating high curiosity is instrumental in driving students' innovative behaviors during project execution.

Conversely, the "Truth-seeking" indicator recorded the lowest post-test score (3.57). Despite the overall CTD improvement, this indicates a persistent student tendency to accept information without rigorously validating its source or underlying evidence. İskifoğlu et al. (2022) identify this lack of truth-seeking as a prevalent weakness in modern critical thinking, often exacerbated by the rapid influx of unverified digital information (David et al., 2024). To mitigate this in future geographical pedagogy, it is imperative to explicitly integrate information literacy and source-validation exercises directly into the PjBL textbook modules.

The Effectiveness of Constructivist-Based Environmental Geography Learning Through the PjBL Model on Students' Critical Thinking Skills

The implementation of the constructivist-based PjBL textbook significantly improved students' critical thinking skills (CTS), as evidenced by the substantial difference between pre-test and post-test scores. Consequently, Hypothesis 2 (H2) is accepted. This cognitive advancement aligns with Kek and Huijser (2011), who posit that integrating PjBL provides an effective pedagogical approach characterized by repetitive and reflective learning cycles. Through this model, students not only acquire domain-specific environmental knowledge but simultaneously engage in rigorous, independent analytical processes.

Crucially, the developed textbook operationalizes the PjBL syntax, granting students the structured autonomy to design and execute their own environmental projects. This delegation of responsibility fosters greater participation, making the learning process more engaging and interactive (Maros et al., 2023). As students collaborate and discuss solutions guided by the textbook, their attention, cooperation, and intrinsic motivation escalate, which directly and positively impacts their critical thinking capabilities (Awamleh, 2024; Song et al., 2025; Tanaka, 2023).

Furthermore, the textbook facilitates essential scaffolding during project consultations and peer presentations. As Sherin et al. (2018) observe, structured discussions surrounding project outputs enable skilled peers and lecturers to guide students in refining their tasks. While lecturers traditionally act as the sole facilitators exploring concepts and guiding conclusions Wiyono et al. (2025), the textbook acts as a tangible surrogate guide that systematically prompts this active, collaborative problem-solving (de Pedro et al., 2025; Morgan, 2025; Nielsen, 2024; Pan et al., 2023; Sutiani et al., 2021). Ultimately, the synergy between the textbook's constructivist scaffolding and the lecturer's facilitation provides continuous opportunities for students to practice, refine, and master high-level critical thinking skills.

Furthermore, while the quantitative results strongly validate the textbook's efficacy, it is crucial to acknowledge the inherent "instructor effect" in interpreting these outcomes. In PjBL environments, the textbook does not operate in a vacuum. The instructor's specific facilitation style, quality of real-time guidance, and interactive engagement serve as significant catalysts for student performance. Therefore, the observed enhancements in students' cognitive and affective domains should be interpreted as the synergistic product of both the well-structured constructivist textbook and the dynamic pedagogical facilitation provided by the instructor.

Implementation and Student Response in Constructivist-Based Environmental Geography Learning Through PjBL

The observational data from the field trials demonstrated an excellent overall learning implementation rate of 97.71%. Notably, the implementation trajectory exhibited a distinct and rapid adaptation curve: starting at a commendable 92% during the introductory meeting, progressing to 96% in subsequent sessions, and culminating in a flawless 100% execution rate from sessions IV through VII . This upward trend signifies that both the lecturer and the students quickly acclimatized to the new constructivist PjBL syntax. The seamless operationalization of all introductory, core, and closing activities, without the need for structural revisions, proves that the textbook successfully functioned as a highly effective pedagogical intermediary, directly bridging the theoretical curriculum with practical classroom dynamics (Bester, 2026; Maruyama & Kurosaki, 2024).

Correspondingly, the student feedback was overwhelmingly positive, averaging an 82.19% satisfaction rate across all metrics. The textbook proved exceptionally adept at cognitive facilitation, with students reporting that it significantly enhanced their overall learning experience (87.10%) and simplified the comprehension of complex Environmental Geography materials (88.70%). This aligns with Fukuda and Manalo (2024) assertion that well-structured, comprehensible textbooks fundamentally shift students' perceptions, transforming reading from a passive chore into an engaging pathway for deeper understanding.

Furthermore, the PjBL integration successfully fostered crucial academic and collaborative competencies. Students reported substantial benefits in applying scientific methodologies (84.7%) and developing teamwork skills (85.5%). Although the metric for "encouraging the development of new ideas" scored comparatively lower at 77.4%, it still reflects robust engagement in fostering creativity. Collectively, these positive responses validate that the constructivist textbook not only delivers geographical content but actively cultivates the collaborative, creative, and analytical dispositions essential for modern geographical education.

Theoretical Contributions and Pedagogical Implications

This study advances the existing literature by providing empirical evidence at the intersection of constructivist learning theory, project-based learning (PjBL), and environmental education. From a theoretical standpoint, the findings enrich constructivist learning theory by demonstrating that instructional materials, traditionally viewed as passive repositories of information, can be effectively engineered as dynamic cognitive scaffolds. Furthermore, by embedding PjBL syntax directly into the textbook, this research contributes to the discourse on higher education pedagogy, proving that structured autonomy and collaborative problem-solving can be systematically facilitated through course literature. Finally, within the specific context of environmental education, this study illustrates that fostering critical thinking cannot rely solely on theoretical

exposure. Instead, developing both critical thinking skills (CTS) and dispositions (CTD) requires anchoring academic concepts to authentic ecological issues, thereby answering the global call for more transformative Education for Sustainable Development (ESD) practices.

Transitioning from theory to practice, the findings offer actionable pedagogical implications for higher education instructors. Among the PjBL phases integrated into the textbook, the "collaborative project design" and "peer-reviewed presentation" emerged as the most influential components in driving critical thinking. In practice, the textbook operationalized these components by prompting students to map authentic local environmental crises, such as regional waste management issues or the ecological impacts of local extractive industries. Guided by the textbook's constructivist rubrics, students actively designed field observation instruments, gathered spatial data, and collaboratively synthesized actionable solutions.

For instructors seeking to apply this approach in similar environmental or spatial science courses, the following step-by-step actionable guidance is proposed to effectively implement the PjBL components using the constructivist textbook:

Step 1: Role transition and project initiation

Instructors must consciously shift their role from primary information dispensers to project facilitators. Instead of using the textbook as a traditional reading script, instructors should introduce it as a dynamic project roadmap. Begin by guiding students to identify authentic local environmental crises (e.g., regional waste management or local extractive industries) using the textbook's introductory prompts.

Step 2: Scaffolded investigation and data gathering

During the project-planning and execution stages, educators should heavily leverage the scaffolding rubrics embedded within the textbook. Instructors should actively guide students in designing field observation instruments and gathering spatial data, ensuring the cognitive load is managed effectively while students collaboratively synthesize actionable solutions.

Step 3: Peer-reviewed presentation and reflective evaluation

In the final project evaluation phase, instructors should facilitate a structured session where students present their findings. Instructors are highly advised to utilize the textbook's peer-assessment rubrics to cultivate a culture of constructive criticism, open-mindedness, and deep reflective synthesis among students.

LIMITATIONS

While this study demonstrates the significant pedagogical value of the constructivist-based PjBL textbook, certain methodological boundaries should be acknowledged. Primarily, the empirical evaluation was constrained by a relatively small sample size, which is an inherent consequence of the limited student enrollment in the Geography Education program within West Nusa Tenggara. Consequently, these findings are deeply contextualized within this specific regional and institutional demographic. This localized focus inherently restricts the immediate generalizability (external validity) of the results, as student characteristics and learning environments may differ significantly across broader geographical or educational contexts. To build upon these foundational findings, future research should prioritize cross-regional and multi-institutional replications involving larger, more diverse cohorts. Additionally, executing longitudinal studies is highly recommended to determine whether the observed enhancements in students' critical thinking skills and dispositions are sustained over extended periods. Such methodological expansions will rigorously test the external validity of the constructivist-PjBL textbook model and provide a more holistic understanding of its long-term educational impact.

A significant methodological limitation of this study is the reliance on a one-group pre-test-post-test design without a control group. Consequently, definitive causal relationships between the textbook intervention and the observed improvements in critical thinking cannot be strictly established. The documented gains in CTS and CTD may have been partially influenced by confounding variables, such as the specific facilitation style and guidance of the instructor during PjBL activities, the students' natural cognitive development over the intervention period, or their concurrent exposure to other academic courses. Therefore, the findings should be interpreted as preliminary correlational evidence of the textbook's efficacy rather than a definitive causal conclusion. To mitigate these inherent biases, future empirical evaluations must transition to more rigorous designs, such as quasi-experimental approaches utilizing matched control groups to better isolate the textbook's true pedagogical impact. Furthermore, implementing longitudinal tracking across multiple semesters is highly recommended to ascertain whether the observed enhancements in students' critical thinking skills and dispositions are enduring and immune to short-term instructional novelty.

CONCLUSION

This study successfully developed and validated a constructivist-based Environmental Geography textbook seamlessly integrated with the Project-Based Learning (PjBL) model. Rigorous expert appraisals and multi-stage empirical trials confirmed that the product is highly feasible, meeting excellent pedagogical standards in language, design, and content. Furthermore, the field implementation proved highly effective; the textbook significantly enhanced both the critical thinking skills (CTS) and critical thinking dispositions (CTD) of geography education students, as evidenced by substantial gains in the pre- and post-test analyses.

Beyond the statistical improvements, the textbook's implementation was exceptionally well-received by students. By operationalizing the PjBL syntax within the text, the learning environment transformed into a collaborative, contextual, and student-centered space that actively encouraged responsibility and analytical inquiry. These findings strongly reinforce the theoretical premise that

embedding active learning frameworks directly into instructional materials effectively bridges the gap between passive theoretical reading and practical ecological problem-solving.

To maximize these pedagogical benefits, educators must ensure the PjBL syntax is executed consistently, from initial project planning through to final evaluation. Moving forward, the widespread adoption of such constructivist-PjBL textbooks holds significant potential to modernize higher education geography curricula. By moving beyond traditional rote learning, this approach equips future educators with the robust critical reasoning necessary to navigate and address increasingly complex global environmental challenges.

By successfully enhancing both the cognitive skills and affective dispositions of future geography educators, this constructivist PjBL textbook serves as a tangible tool for advancing Education for Sustainable Development (ESD). It practically operationalizes the objectives of SDG 4.7 by transforming students from passive recipients of geographical facts into active, critically-minded global citizens capable of championing sustainability initiatives in their future classrooms.

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AI statement: The authors stated that they used AI for language transition from Indonesian to English.

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