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Critical Thinking Skills in High School Biology: Examining the Impact of the Mind Mapping-Assisted RICOSRE Model in an Intact Class Setting

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Abstract
This study aimed to examine the effect of the Reading, Identifying, Constructing, Solving, Reviewing, and Extending (RICOSRE) learning model assisted by Mind Mapping on the critical thinking skills of Grade 10 Biology students. A quantitative quasi-experimental design featuring a non-equivalent pretest-posttest control group design with intact classes was implemented. The study population comprised 112 Grade 10 Science students across four classes at SMAN Bhakti Mulya Bunga Mayang during the 2026/2027 academic year. Using cluster random sampling, two intact classes were selected: Class X.3 (n = 28) served as the experimental group (taught via Mind Mapping-assisted RICOSRE), while Class X.2 (n = 28) served as the control group (taught via conventional Discovery Learning). Data were collected using a validated 10-item essay test measuring five critical thinking indicators adapted from Ennis. Analysis of normalized gain (N-Gain) scores revealed that the experimental group achieved a mean posttest score of 81.21 ± 8.42 with a high average N-Gain of 0.70, whereas the control group obtained a mean posttest score of 62.64 ± 9.15 with a moderate N-Gain of 0.43. Because the posttest data violated normality and homogeneity assumptions, hypothesis testing was performed using the non-parametric Mann-Whitney U test on posttest scores. The test yielded U = 0.50, z = -6.45, p < .001, indicating a statistically significant difference between the two groups. These findings suggest that integrating Mind Mapping specifically during the Constructing syntax of RICOSRE offers a structured visual scaffolding that facilitates students' analytical and evaluative skills in ecosystem topics.

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INTRODUCTION

The rapid development of 21st-century education and the implementation of the Kurikulum Merdeka in Indonesia necessitate a fundamental shift from traditional content-memorization paradigms toward the mastery of core higher-order thinking competencies (Nurmalia et al. al, 2025). Within science and Biology education, critical thinking represents an indispensable cognitive foundation (Sari et al., 2025). It empowers learners to navigate complex ecological phenomena, evaluate scientific evidence objectively, and formulate evidence-based solutions to non-routine socio-scientific issues (Orhan,2023). Despite these curriculum imperatives, empirical preliminary investigations at SMAN Bhakti Mulya Bunga Mayang revealed a pervasive deficiency in students' critical thinking abilities within Biology. Preliminary diagnostic tests administered to 56 Grade 10 students using Ennis-aligned essay instruments yielded an overall mean critical thinking score of only 44.00\% (SD = 6.12), placing students

firmly in the low critical thinking category. Classroom observations and teacher interviews confirmed that instructional practices relied heavily on textbook memorization and passive reception of factual content (Sari et al., 2025). Students experienced pronounced difficulties in interpreting biological terminology, synthesizing cause-and-effect relationships within food webs, and constructing logical scientific arguments during group presentations. Furthermore, although the school had implemented the Discovery Learning model, its effectiveness was hindered by students' insufficient initial domain knowledge, leading to cognitive overload, conceptual confusion, and superficial task execution. (Orhan,2023)

To address these empirical limitations, structured instructional frameworks that combine explicit problem-solving syntax with visual cognitive scaffolding are needed (Sumah et al., 2024). The RICOSRE model—comprising Reading, Identifying, Constructing, Solving, Reviewing, and Extending—presents an integrated, problem-based instructional model (Irdalisa et al., 2024). Theoretically grounded in schema theory and metacognitive instruction, the initial Reading phase explicitly provides students with foundational cognitive schemas, mitigating initial conceptual gaps before they engage in complex problem solving. However, executing problem solving in complex biological systems such as ecosystem dynamics often imposes heavy demands on working memory. To alleviate cognitive load and facilitate structural knowledge organization, incorporating Mind Mapping based on Buzan's cognitive mapping principles serves as a visual scaffold. While prior studies have examined standalone RICOSRE, RICOSRE combined with digital media, or RICOSRE integrated with Collaborative Mind Mapping (CMM), a specific research gap remains regarding how individual student-generated Mind Mapping, embedded specifically within the Constructing syntax of RICOSRE, supports individual reasoning across Ennis's critical thinking dimensions in high school Biology. Distinguishing standard individual Mind Mapping from collaborative variants is crucial, as individual mapping requires each learner to internalize, organize, and synthesize cognitive structures independently. Therefore, this study aimed to examine the effect of the Mind Mapping-assisted RICOSRE model on Grade 10 students' critical thinking skills on ecosystem topics, comparing its performance against a standard Discovery Learning control group within an intact class quasi-experimental framework.

METODS

Research Design and Setting

This study was conducted during the even semester of the 2026/2027 academic year at SMAN Bhakti Mulya Bunga Mayang, Lampung Utara, Indonesia. The intervention focused on the biology topic "Ecosystem Components and Their Interactions" across four structured 90-minute instructional sessions following the Curriculum Merdeka framework. Given that school administrative structures prevented the random assignment of individual students to treatment conditions, a quantitative quasi-experimental approach utilizing a non-equivalent pretest-post test control group design with intact classes was employed. The formal design structure is presented in Table 1. Table 1. Non-Equivalent Pretest-Posttest Control Group Design

Table 1. Pretest-Posttest Control Group Design Research Design

Group	Pretest	Treatment (4Meetings)	Posttest
Experimental(O-1)	Y-1	Mind Mapping assisted(X-1)	Y-2
Control (O-2)	Y-1	Discovery Learning(X-2)	Y-2

Note: Y-1 = Critical Thinking Pretest; Y-2 = Critical Thinking Posttest.

Population and Sampling

The study population comprised all 112 Grade 10 Science students distributed across four intact classes (X.1 to X.4) at SMAN Bhakti Mulya Bunga Mayang. Sampling was executed using Cluster Random Sampling, where intact classes were treated as sampling units. Class X.3 (n =

28) was randomly assigned as the experimental group, while Class X.2 (n = 28) was assigned as the control group. Both classes demonstrated statistically equivalent baseline critical thinking skills prior to intervention (t = 0.112, p = .911).

Instructional Intervention

Both groups were taught by the same biology teacher using identical core learning objectives covering ecosystem components, food chains/webs, energy flow, and biogeochemical cycles. 1. Experimental Group (RICOSRE + Mind Mapping): Implemented six sequential syntaxes:

a. Reading: Students analyzed contextual articles on ecosystem disruptions.
b. Identifying: Students articulated problem statements regarding ecosystem imbalances.
c. Constructing (Core Scaffold): Students constructed individual Mind Maps using keywords, visual branches, and color codes to map causal ecological relationships.
d. Solving: Groups executed solution plans using their visual maps.
e. Reviewing: Students evaluated and peer-reviewed their proposed ecosystem management solutions.
f. Extending: Students applied acquired concepts to novel ecological scenarios. 2. Control Group (Discovery Learning): Followed six standard phases: Stimulation, Problem Statement, Data Collection, Data Processing, Verification, and Generalization without Mind Mapping scaffolding.

Research Instrument and Validation

Critical thinking skills were measured using a 10-item subjective essay test developed according to Ennis's five critical thinking categories: 1. Elementary Clarification (Items 1 & 2) 2. Basic Support (Items 3 & 4) 3. Inference (Items 5 & 6) 4. Advanced Clarification (Items 7 & 8) 5. Strategy and Tactics (Items 9 & 10). Content validity was established by three expert validators in Biology Education (yielding a Content Validity Index CVI = 0.92). Empirical item analysis with 30 non-sample students confirmed that all 10 essay items were statistically valid ($r_{calc} > r_{table}$)= 0.361, range 0.482 - 0.811. Test reliability calculated via Cronbach's Alpha reached a = 0.947, indicating extremely high internal consistency. Each item was scored on a 0–4 rubric, yielding a total raw score converted to a 0–100 scale.

Data Analysis Procedures

To evaluate skill gains, individual and normalized gain (N-Gain) scores were computed using Hake's formulation:

$$g = \frac{S_{po}}{S_{mc}}$$

N-Gain categories were classified as High (g > 0.70), Moderate (0.30 < 0.70), and Low (g < 0.30). Statistical prerequisite tests were conducted before inferential analysis:

a. Normality: Assessed via the Shapiro-Wilk test (appropriate for sample sizes n < 50 per group) with a = .05.
b. Homogeneity of Variance: Evaluated using Levene's test based on the mean with a = .05. Due to violations of normality and homogeneity assumptions in posttest distributions, hypothesis testing was performed using the non-parametric Mann-Whitney U test comparing independent posttest scores at a significance level of a = .05. All statistical analyses were conducted using SPSS version 26.0.

RESULTS AND DISCUSSION

Results

Descriptive Analysis of Critical Thinking Achievement

The overall descriptive statistics for pretest, posttest, and N-Gain scores across experimental and control conditions are summarized in Table 2.

Table 2. Descriptive Statistics of Critical Thinking Scores

Group	N	Pretest Mean (SD)	Posttest Mean (SD)	Mean N-Gain (g)	N-Gain Category
Experimental (X.3)	28	38.45 (5.12)	81.21 (8.42)	0.70 (0.11)	High
Control (X.2)	28	37.12 (5.38)	62.64 (9.15)	0.43 (0.13)	Moderate

As shown in Table 2, both groups-initiated instruction with virtually equivalent, low baseline critical thinking scores (38.45 vs. 37.12). Following the 4-session instructional intervention, the experimental group taught via Mind Mapping-assisted RICOSRE achieved a mean posttest score of 81.21, representing a high N-Gain (g = 0.70). Conversely, the control group taught via standard Discovery Learning achieved a posttest score of 62.64, corresponding to a moderate N-Gain (g = 0.43). To provide a granular view across critical thinking dimensions, performance was analyzed across Ennis's five indicators as presented in Table 3. Table 3. Indicator-Wise Posttest Achievement and N-Gain Scores

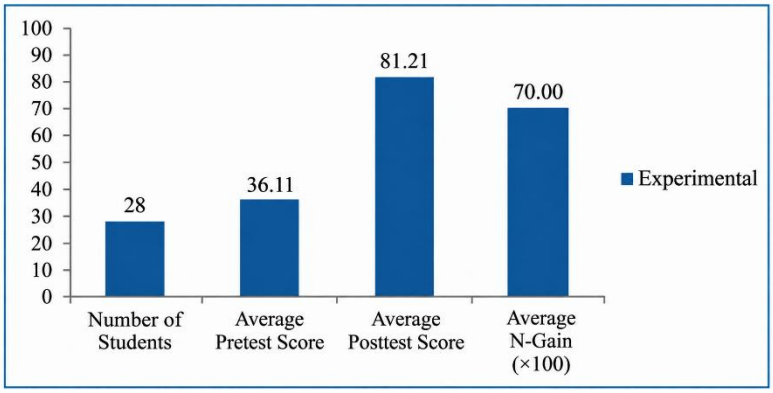

Figure 1. Data Description Diagram of Critical Thinking Skills Values of Experimental Class

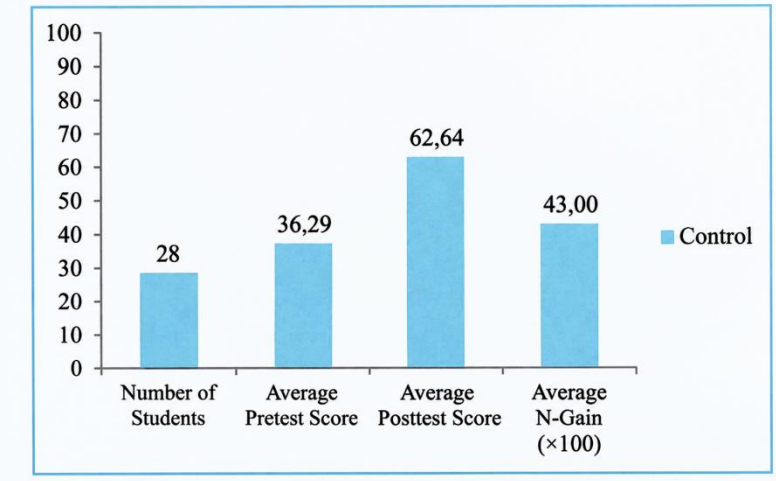

Figure 2. Diagram of Data Description of Critical Thinking Skills Values in the Control Class

Table 3. Indicator-Wise Posttest Achievement and N-Gain Scores

Critical Thinking Indicator	Experimental Posttest (%)	Control Posttest (%)	Experimental N-Gain (g)	Control N-Gain (g)
Elementary Clarification	85.71	67.86	0.76 (High)	0.48 (Mod)
Basic Support	82.14	4.29	0.71 (High)	0.44 (Mod)
Inference	78.57	60.71	0.65 (Mod)	0.38 (Mod)
Advanced Clarification	79.46	59.82	0.67 (Mod)	0.36 (Mod)
Strategy and Tactics	80.18	60.54	0.69 (Mod)	0.37 (Mod)

Statistical Prerequisite Tests

Normality Test: Because each sample group contained n = 28 students (n < 50), the Shapiro-Wilk test was interpreted to evaluate distributional normality. The decision rule dictates that a p-value > .05 indicates normal distribution.

Table 4. Shapiro-Wilk Normality Test Results

Variable/ Group	Statistic	*df*	*p*-value(sing)	Conclusion
Control Pretest	0.958	28	313	Normally Distributed
Experimental Pretest	0.945	28	147	Normally Distributed
Control Posttest	0.939	28	104	Normally Distributed
Experimental Posttest	0.904	28	014	Non-Normally Distributed

As shown in Table 4, the experimental posttest score distribution significantly departed from normality (W = 0.904, p = .014 < .05). Homogeneity Test Variance homogeneity across groups was tested using Levene's Test based on the mean.

Table 5. Levene's Test for Homogeneity of Variances

Test Basis	Levene Statistic	*df_1*	*df_2*	p-value (Sig.)	Conclusion
Based on Mean	3.310	1	54	023	Non-homogeneous

The Levene test yielded F (1, 54) = 3.310, p = .023 < .05, indicating that the population variances were non-homogeneous.

Inferential Hypothesis Testing

Because posttest data violated both normality and homogeneity assumptions, the non-parametric Mann-Whitney U test was performed on independent posttest scores to test the operational hypothesis (H_1).

Table 6. Mann-Whitney U Test Analysis on Posttest Scores

Test Statistic Parameter	Posttest Comparison Value
Mann-Whitney U	0.500
Wilcoxon W	406.500
Z-Score	-6.448
Asymp. Sig. (2-tailed)	< .001 (p = .000)

The Mann-Whitney U test yielded U = 0.500, z = -6.448, p < .001. Because p < .05, the null hypothesis (H_0) was rejected, and H_1 was accepted. This result demonstrates a statistically significant difference in posttest critical thinking achievement between students exposed to the Mind Mapping-assisted RICOSRE model and those exposed to conventional Discovery Learning.

The primary empirical finding of this study demonstrates that Grade 10 Biology students taught using the Mind Mapping-assisted RICOSRE model achieved statistically higher critical thinking posttest scores compared to those taught via standard Discovery Learning (U = 0.500, p < .001). Rather than establishing direct absolute causality, these quasi-experimental findings in intact classes suggest that integrating structured visual mapping within problem-solving syntax provides instructional scaffolding associated with critical thinking improvement in high school ecosystem topics (Sumah et al., 2024). The observed differences between treatment groups can be interpreted through the cognitive alignment between RICOSRE syntaxes, Mind Mapping features, and Ennis's critical thinking dimensions (Lianto & Rohayati, 2025):

1. Reading & Elementary Clarification: The initial Reading stage provided students with essential domain knowledge and contextual orientation before embarking on problem solving. This phase directly supported Elementary Clarification (g = 0.76), enabling students to identify key ecological issues without getting overwhelmed by unfamiliar terminology.
2. Identifying, Constructing, & Basic Support Visualization: The explicit integration of Mind Mapping during the Constructing phase served as a visual scaffold (Lianto & Rohayati, 2025). By organizing ecosystem components, energy flows, and environmental threats into hierarchical nodes with visual connections, students externalized complex causal relationships (Astuti et al., 2024). Theoretically, this structural mapping is intended to reduce working memory burden, facilitating higher performance in Basic Support (82.14%) and Strategy Tactics (80.18%).
3. Solving, Reviewing, Extending, & Advanced Reasoning: During Solving and Reviewing, students utilized their visual maps to evaluate environmental intervention scenarios and peer-assess arguments (Arafah et al., 2025; Winda & Suyanto, 2025). The final Extending phase encouraged knowledge transfer to new socio-ecological contexts, reinforcing Inference and Advanced Clarification.

In contrast, while Discovery Learning encourages self-directed exploration, its lack of explicit visual scaffolding and initial reading structure left students in the control group prone to conceptual confusion when tackling complex food web disruptions (Orhan, 2023). Consequently, control group students achieved lower overall gains (g = 0.43). These findings complement previous research by Badriah et al. (2024) regarding Collaborative Mind Mapping (CMM) and Irdalisa et al. (2024) on RICOSRE-QFT. However, this study extends the literature by demonstrating that individual Mind Mapping—when positioned specifically in the Constructing phase—effectively supports individual critical thinking dimensions without requiring digital software or collaborative mapping infrastructure.

Several limitations should be considered when interpreting these results:

1. Quasi-Experimental Design: Because intact classes were utilized, unmeasured baseline student characteristics (e.g., individual motivation, prior technical drawing skills) could not be completely controlled.
2. Contextual Scope: The intervention was restricted to Grade 10 students at a single secondary school, focusing specifically on ecosystem topics over four instructional sessions.
3. Unmeasured Cognitive Constructs: Direct internal mechanisms such as exact working memory load or metacognitive reflection were not directly measured via physiological or cognitive tests but rather inferred through written essay performance.

CONCLUSION

This study demonstrates that the application of the Mind Mapping-assisted RICOSRE model was associated with a statistically significant improvement in Grade 10 students' critical thinking skills in Biology ($U = 0.500$, $z = -6.448$, $p < .001$). The experimental group achieved a mean posttest score of 81.21 ($g = 0.70$, High category), significantly outperforming the Discovery Learning control group (62.64, $g = 0.43$, Moderate category). The findings suggest that embedding individual Mind Mapping within the Constructing syntax of RICOSRE offers effective visual scaffolding that aids high school students in clarifying, organizing, and evaluating ecological concepts. Based on these conclusions, secondary Biology educators are encouraged to adopt the Mind Mapping-assisted RICOSRE model as a structured pedagogical alternative for complex topics. Future research should explore the model's efficacy across broader geographic locations, different biological topics, and examine long-term retention of critical thinking skills.

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