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Developing the CTCR Learning Model to Enhance Elementary Students' Critical Thinking Skills: Implications for SDG 4 Quality Education

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ABSTRACT

Objective: *To develop a Critical Thinking Culturally Responsive (CTCR) learning model that is valid, practical, and effective for improving fifth-grade elementary students' critical thinking skills in science learning in East Kalimantan.* ***Method:*** *The study employed an Educational Design Research (EDR) approach using the Generic Design Research Model (GDRM) through five phases. Trials were conducted in three schools: Public Elementary School 011 Pela (limited trial, n = 6), Public Elementary School 016 Samarinda Ulu, and Muhammadiyah Elementary School Loa Janan (extended trial, n = 52).* ***Results:*** *The CTCR model achieved a very valid status (mean = 3.64) and was rated practical across all trial sites. The model was effective in improving students' critical thinking skills, as evidenced by a moderate mean N-gain of 0.52 and statistically significant gains across all classes ($p < 0.05$)* ***Novelty:*** *The CTCR model is the first to integrate Inquiry-Based Teaching, Critical Thinking Blended Learning, and Culturally Responsive Teaching into a single operational syntax for elementary schools in Indonesia, aligned with the Merdeka Curriculum, the Pancasila Student Profile, and the advancement of SDG 4 (Quality Education).*

INTRODUCTION

Critical thinking skills are regarded as key competencies in professional, academic, and broader life contexts today (Golegou et al., 2025). Because critical thinking is cumulative, a strong foundation in elementary education and long-term intellectual development is essential (Montano-Silva et al., 2025). Nevertheless, the consistent application of critical thinking instruction in the classroom, particularly at the elementary level, remains a persistent problem across educational systems worldwide (Golegou et al., 2025).

A particularly clear example of this challenge is evident in Indonesia. PISA 2022 results indicated a sustained decline in learning achievement among Indonesian students: science scores fell from 396 to 383 (OECD, 2023), a significant gap compared to the OECD average of 485. Indonesia has a very low percentage of students performing at Level 2 and almost none reaching Levels 5–6, which require independent knowledge management and creation (OECD, 2023). Only limited research has focused on how critical thinking should be developed at lower educational levels, as most existing studies continue to target secondary and higher education (Campo et al., 2023; Gómez et al., 2025; Lee et al., 2021; Streelasky, 2017).

This urgency is particularly acute in East Kalimantan, where elementary students still exhibit below-average national science literacy, and two-thirds of schools require critical-thinking interventions (Kemdikbudristek, 2023). Preliminary observation at several elementary schools in Samarinda and Kutai Kartanegara revealed that existing critical thinking development models had not yet effectively utilized local culture as a meaningful context for developing students' critical thinking abilities (Preliminary Observation, 2024). This condition is also relevant at the policy level, given that East Kalimantan is the site of

Indonesia's new capital city (IKN), where a generation capable of critical thinking and with a strong cultural identity must be developed as a national strategic priority (Sasmita et al., 2023).

Accumulated research has provided strong scientific evidence that traditional teacher-centered approaches are insufficient for developing higher-order thinking skills among elementary students (Bhardwaj et al., 2025; Pramusinta & Saputri, 2025; Yao, 2025). Gómez and Suárez (2020) and Duran and Dökme (2016) argue that Inquiry-Based Teaching (IBT) engages students in experiments, observations, data analysis, and the drawing of conclusions through thinking processes comparable to critical thinking. An extensive systematic review of 18 empirical studies published in K-12 science education acknowledged IBT as the most effective approach to critical thinking in the classroom (Fitriadi et al., 2024).

However, when the focus is restricted to IBT for elementary students in multicultural contexts, the picture becomes more complex. According to Fitrianto and Farisi (2025) and Jaiswal et al. (2025), learning becomes more meaningful when connected to students' culture, lived experiences, or local knowledge. Culturally Responsive Teaching (CRT) is a relevant approach because it leverages local histories and community narratives as students' epistemic resources, thereby positively influencing critical thinking and engagement (Caingcoy, 2023). The Dayak, Kutai, and Banjar cultural traditions of East Kalimantan constitute a rich heritage that is not yet regularly used as learning materials in elementary science instruction (Preliminary Observation, 2024).

The Critical Thinking Blended Learning (CTBL) media, characterized by the model's syntax of problem orientation, investigation, discussion, and simultaneous conclusion. While CTBL has shown positive results in Indonesian elementary schools, it has several limitations: (1) it does not consistently incorporate local cultural elements throughout all stages; (2) CTBL fails to apply CRT principles to link students' cultural knowledge to scientific concepts (Aikenhead & Jegede, 1999); and (3) teachers have limited resources to integrate local wisdom constructs into elementary science teaching (Mardayanti et al., 2025). These limitations collectively indicate that no single approach is sufficient for simultaneously developing critical thinking skills and cultural responsiveness in elementary science learning. IBT offers an inquiry-driven framework that enables students to construct knowledge actively (Hmelo-Silver et al., 2007), CTBL provides an instructional syntax for scaffolding critical thinking in Indonesian elementary classrooms that has been proven effective (Wahyuni et al., 2019), and CRT serves as a cultural bridge that connects students' local knowledge systems with scientific concepts (Gay, 2018; Ladson-Billings, 1995). The integration of these three approaches is therefore not merely additive but theoretically necessary. Each framework complements the others, collectively forming a coherent and culturally grounded instructional model for developing critical thinking in diverse Indonesian learning contexts.

Through a systematic analysis of 24 Scopus-indexed literature sources, three interrelated research gaps were confirmed. Theoretical Gap #1: No model yet integrates IBT, CTBL, and CRT within an operational framework for elementary science. Population Gap #2: There is virtually no empirical research on elementary schools in East Kalimantan that involves the Dayak, Kutai, and Banjar cultural contexts. Methodological Gap #3: Evaluative studies of existing models dominate the literature, with no new, improved models emerging from the feasibility criteria established by Nieveen et al. (2007).

The CTCR model addresses these gaps through three distinct innovations that distinguish it from its predecessor frameworks. Unlike standalone IBT models, which treat inquiry as a culturally neutral process (Hmelo-Silver et al., 2007), CTCR incorporates local wisdom as a significant source of knowledge, not just a motivating factor, throughout all five instructional phases, allowing cultural knowledge to actively influence students' inquiry processes rather than serving as a minor embellishment. Second, whereas CTBL (Wahyuni et al., 2019) offers a proven instructional syntax for critical thinking that lacks systematic cultural integration, CTCR extends CTBL's phase structure by explicitly incorporating CRT principles (Gay, 2018) at each phase, creating a culturally responsive scaffold that connects students' indigenous knowledge to scientific reasoning. Unlike existing CRT teaching styles, which primarily target secondary and higher education in Western countries (Ladson-Billings, 1995; Gay, 2018), CTCR is the first model validated for elementary science education in an Indonesian setting of indigenous culture, meeting Nieveen et al.'s (2007) tested guidelines for verification and effectiveness. These features position CTCR collectively as an original instructional framework that generates new knowledge for culturally responsive elementary science education, rather than a synthesis of existing approaches.

This study pursued four specific objectives: (1) to develop the CTCR instructional model along with its supporting learning tools including the model guidebook, lesson plans, student worksheets, student textbooks, and assessment rubrics through a systematic GDRM-based development process; (2) to assess the content and construct validity of the CTCR model and its instruments using expert validation with a 1–4 rating scale and Percentage of Agreement (PA) formula (Borich, 1994), with validity declared if mean score $P \geq 2.50$ and $PA \geq 75\%$; (3) to examine the practicality of the CTCR model as reflected in teacher implementation scores across all trial sites; and (4) to evaluate the effectiveness of the CTCR model in improving fifth-grade students' critical thinking skills, as measured by normalized gain (N-gain), paired and independent sample t-tests, and effect size indices across limited and extended trial settings.

This study contributes to achieving SDG 4 by developing a validated instructional model that enhances critical thinking skills in elementary science education. The CTCR model specifically addresses Targets 4.1 and 4.7 by improving learning outcomes through evidence-based methods and incorporating East Kalimantan local wisdom, including Dayak, Kutai, and Banjar cultural traditions, as epistemic resources that promote culturally inclusive and globally conscious science education.

RESEARCH METHOD

This study employed Educational Design Research (EDR) using the Generic Design Research Model (GDRM). GDRM was selected for three reasons: (1) it treats formative evaluation as an integral part of the development cycle; (2) it develops theory and products iteratively during implementation; and (3) it generates a systematic body of knowledge that extends beyond the specifics of any single implementation setting. The model encompasses five phases: (1) Problem Identification; (2) Tentative Product and Design Principles; (3) Tentative Product and Theory; (4) Prototyping and Evaluation of the Initial Product and Theory; and (5) Problem Resolution and Theory Development.

Research subjects were fifth-grade students from three elementary schools in East Kalimantan: Public Elementary School 011, Pela Tourism Village, Kutai Kartanegara (limited trial, one class); Public Elementary School 016, Samarinda Ulu; and Muhammadiyah

Elementary School, Loa Janan (extended trial, one class each). The three schools were selected using purposive sampling based on two criteria: (1) geographic diversity, representing rural (Public Elementary School 011, Pela Tourism Village, Kota Bangun), peri-urban (Muhammadiyah Elementary School, Loa Janan), and urban settings (Public Elementary School 016, Samarinda Ulu); and (2) contextual relevance, as all three schools are situated within or near designated ecotourism village areas and hold Adiwiyata (eco-school) certification, making them particularly suitable for research integrating East Kalimantan local wisdom into instruction. Fifth-grade students were selected because children at this developmental stage (approximately 10–11 years of age) are transitioning from concrete to early formal operational thinking, a period during which structured critical thinking instruction has been shown to yield significant cognitive gains. In addition, the fifth-grade curriculum under Indonesia's Merdeka Curriculum incorporates themes of biodiversity and environmental stewardship that directly align with local wisdom contexts in East Kalimantan. The staged trial design, one school for the limited trial followed by two schools for the extended trial, was adopted to minimize risks during initial prototype testing and to subsequently assess the model's effectiveness and transferability across contrasting geographic and socioeconomic contexts, thereby strengthening the generalizability of the findings. The study was conducted during the odd semester of the 2025–2026 academic year. Development proceeded through five GDRM phases: Phase 1 (preliminary field study and Scopus literature review); Phase 2 (focus group discussions with experts and practitioners to formulate design principles based on a synthesis of IBT, CTBL, and CRT); Phase 3 (development of Prototype 1: CTCR model book, lesson plans, student worksheets, student textbooks, assessment rubrics). The developed CTCR model comprises five instructional phases that integrate critical thinking skills with local wisdom, as presented in Table 1.

Table 1. CTCR learning model instructional syntax

No	Learning Phase	Teacher Activities	Student Activities	Critical Thinking Indicators
1	Culturally Based Problem Orientation	Presenting local wisdom phenomena, asking questions, and classifying students	Identification, observation, and interviewing	Basic Clarification (Ennis, 1985)
2	Locally Based Inquiry	Investigating problems	Collecting and selecting reliable sources of information	Basic Support (Ennis, 1985; Facione, 1990)
3	Discussion: Solving Problems Based on Traditional Cultural Capital	Form heterogeneous small groups based on cultural backgrounds	Discussing investigation data using local wisdom	Inference (Ennis, 1985; Facione, 1990)
4	Delivering Locally Based Arguments	Guiding group presentations using argument cards: opinion—evidence—reasons	Presenting group discussion results to the class	Further Clarification & Evaluation (Ennis, 1985; Facione, 1990)

No	Learning Phase	Teacher Activities	Student Activities	Critical Thinking Indicators
5	Conclusions & Implications	Guide class discussions to make conclusions and implications together	Making conclusions based on evidence and proposes action	Strategies & Self-Regulation (Ennis, 1985; Facione, 1990)

The CTCR model was implemented in a fifth-grade IPAS unit on local ecosystems to illustrate its use. The teacher in Phase 1 (Culturally Based Problem Orientation) presented the phenomenon of declining fish populations in the Mahakam Lake, a culturally significant wetland ecosystem in East Kalimantan, and asked students to link this phenomenon to local Kutai fishing traditions. Students in Phase 2 (Locally Based Inquiry) gathered information from community elders and digital sources to examine environmental factors influencing lake biodiversity. In Phase 3 (Discussion), small, diverse groups combined their findings using traditional ecological knowledge to interpret their results alongside scientific concepts. Groups presented their conclusions in Phase 4 (Delivering Locally Based Arguments) using structured argument cards that included opinion, evidence, and reasoning, drawing on both empirical data and cultural narratives. In Phase 5, students drew evidence-based conclusions and culturally relevant conservation actions, showcasing the integration of scientific thinking and local environmental responsibility.

Both the limited and extended trials were based on a single-group pretest-posttest design (Creswell, 2014; Fraenkel, Wallen, & Hyun, 2012; Borg & Gall, 2007). This design was chosen for three reasons that align with the conventions of Educational Design Research: (1) the main goal of this study was to develop a model and conduct formative evaluation, not to establish cause and effect, which meant that experimental control was less important than iterative refinement (McKenney & Reeves, 2012); (2) the small, geographically dispersed sample across three schools made it logistically and ethically impossible to assign participants to control and treatment groups randomly; and (3) within EDR frameworks, effectiveness is appropriately evaluated using multiple indicators that converge, including N-gain, effect size, and student feedback data, rather than relying solely on group comparisons (Plomp & Nieveen, 2013). The absence of a control group is a methodological limitation of this study, as it precludes definitive causal attribution of the observed learning gains to the CTCR model alone. Future studies employing quasi-experimental or randomized controlled designs are recommended to strengthen causal claims about the model's effectiveness. Three categories of instruments were employed: (1) validation tools, including model validation sheets for content and construct validity using a 1–4 rating scale and Percentage of Agreement formula (Borich, 1994) with reliability threshold $PA \geq 75\%$ and minimum validity $P \geq 2.50$; (2) practicality tools consisting of device validation sheets for learning tools; and (3) effectiveness tools comprising a critical thinking skills test (pretest–posttest) and a student response questionnaire.

Data analysis covered: validity (mean score P; criteria: 3.25–4.00 = very valid, 2.50–3.25 = valid); practicality (mean implementation score; similar criteria); effectiveness through CT scores ($P = \text{score}/\text{max} \times 100\%$), normalized gain (N-gain = (posttest−pretest)/(max−pretest); ≥0.7 high, 0.3–0.7 moderate, <0.3 low; Hasyim et al., 2020), paired t-test (limited trial), independent t-test and one-way ANOVA with Tukey HSD post-hoc test (extended trial), and student response percentage ($P = \Sigma K/\Sigma N \times 100\%$; ≥76% very positive, 51–75% positive;

Riduwan, 2007). The model was declared effective if N-gain reached at least the moderate category with $p < 0.05$.

RESULTS AND DISCUSSION

Results

Validity of the CTCR model

The CTCR model and all its supporting instruments were evaluated by three science education experts affiliated with Universitas Negeri Surabaya (UNESA). The panel consisted of one full professor and two doctoral-level lecturers, whose combined expertise guaranteed the content and construct validity of the CTCR model and its accompanying tools. Validation was carried out on a scale of 1 to 4. All instruments were in the very valid category, with an overall mean score of 3.64 and reliable reliability coefficients (PA ≥ 75%), as demonstrated in Table 2.

Table 2. Summary of CTCR model validity scores

Instrument / Material	Score	Criterion	Reliability
CTCR Model Book	3.58	Very Valid	Reliable
Critical Thinking Skills Test	3.61	Very Valid	Reliable
Student Worksheet	3.60	Very Valid	Reliable
Lesson Plan	3.54	Very Valid	Reliable
Observation Sheet	3.85	Very Valid	Reliable
Overall Mean	**3.64**	**Very Valid**	**—**

Practicality of the CTCR model

To measure CTCR model implementation, two observers conducted observations across 12 sessions at three schools. The resulting scores per phase are summarized in Table 3.

Table 3. CTCR model implementation scores per phase

Phase	Limited Trial Public Elementary School 011 Pela Score	Criterion	Extended Trial Public Elementary School 016 Samarinda Ulu	Criterion	Muhammadiyah Elementary School Loa Janan Score	Criterion
Phase 1 — Culture-Based Problem Orientation	2.91	Fairly Practical	2.97	Fairly Practical	3.00	Practical
Phase 2 — Local Culture-Based Investigation	3.02	Practical	3.10	Practical	3.05	Practical

Phase	Limited Trial Public Elementary School 011 Pela Score	Criterion	Extended Trial Public Elementary School 016 Samarinda Ulu	Criterion	Muhammadiyah Elementary School Loa Janan Score	Criterion
Phase 3 — Problem-Solving Discussion	3.09	Practical	2.90	Practical	3.11	Practical
Phase 4 — Culture-Based Argumentation Presentation	3.10	Practical	3.36	Practical	3.20	Practical
Phase 5 — Conclusion Drawing & Implications	3.05	Practical	3.19	Practical	3.25	Practical
Class Mean	**3.03**	**Practical**	**3.11**	**Practical**	**3.12**	**Practical**

Effectiveness of the CTCR model

Effectiveness was assessed through four-layer triangulation. Prior to instruction, most students were at the moderate and poor levels. Following CTCR implementation, 100% of students in Public Elementary School 011 Pela and Muhammadiyah Elementary School, and 96.4% in Public Elementary School 016, advanced to the good or very good level, demonstrating the model's pedagogical inclusivity. Table 4 presents the results of inferential statistical analysis.

Table 4. Paired t-test results and effect size of the CTCR model

Class / School	n	Pre	Post	Δ	p	d	η²	Effect
Limited Trial — Public Elementary School 011 Pela	6	54.67	80.28	+25.61	0.008	1.73	0.78	Very Large
Extended Trial — Public Elementary School 016 Samarinda Ulu	28	48.43	81.46	+33.04	0.000	2.81	0.89	Very Large
Extended Trial — Muhammadiyah Loa Janan Elementary School	24	50.71	72.90	+22.19	0.000	1.76	0.76	Very Large
Combined Extended Trial (n=52)	**52**	**—**	**—**	**+28.03**	**—**	**2.12**	**0.82**	**Very Large**

N-gain per critical thinking indicator is presented in Table 5. Almost all indicators fell into the moderate-to-high category, with a mean cross-class N-gain of 0.52, indicating that the CTCR model's five-phase syntax consistently supported the development of critical thinking skills across diverse school settings. The clarification indicator showed the highest consistency across all three schools (mean N-gain = 0.49), confirming that phase 1 (culturally based problem orientation) was effectively implemented in presenting local wisdom phenomena as cognitive entry points for students. The Inference and Implication indicators reached the high category at Public Elementary School 016 (N-gain = 0.80 and 0.86, respectively), suggesting that the cumulative and sequentially scaffolded syntax of CTCR enabled significant cognitive progression in urban school contexts where students may have greater prior exposure to inquiry-based tasks.

However, the reason indicator exhibited the greatest variation across schools, with Public Elementary School 016 recording the lowest N-gain (c = 0.23, low category). This finding warrants critical interpretation. The Reason indicator assesses students' ability to construct evidence-based justifications, a cognitively demanding skill that requires information retrieval, the ability to evaluate source credibility, and the articulation of logical connections between evidence and claims (Ennis, 1985; Facione, 1990). The comparatively low score at Public Elementary School 016 may be attributed to contextual factors specific to the urban school setting: Students in central urban environments may have less direct experiential familiarity with the local wisdom phenomena presented in phase 2 (locally based inquiry), reducing their capacity to draw on cultural knowledge as a reasoning resource. Additionally, the structured inquiry tasks in phase 2 may have insufficiently guided students through the cognitive process of distinguishing reliable from unreliable sources within the time constraints of a single lesson. These findings suggest that phase 2 of the CTCR model requires targeted refinement in two areas: (1) The inclusion of more explicit modeling by teachers of evidence-evaluation strategies, particularly through think-aloud protocols demonstrating how to assess source credibility in the context of local wisdom; and (2) the development of more structured reasoning templates within the worksheet to guide students step-by-step from evidence identification to claim justification, reducing cognitive overload during the inquiry phase.

Table 5. N-gain per critical thinking indicator across classes

Critical Thinking Indicator	Public Elementary School 011 (n=6)	Category	Public Elementary School 016 (n=28)	Category	Muhammadiyah Elementary School (n=24)	Category	Mean N-Gain
Fact Analysis	0.74	High	0.33	Medium	0.40	Medium	0.49
Reasoning	0.52	Medium	0.23	Low	0.56	Medium	0.43
Argumentation	0.48	Medium	0.58	Medium	0.52	Medium	0.52
Inference	0.62	Medium	0.80	High	0.35	Medium	0.59
Implication	0.52	Medium	0.86	High	0.39	Medium	0.59
Mean	**0.565**	**Medium**	**0.640**	**Medium**	**0.450**	**Medium**	**0.52**

Table 5 mean of student responses across all trial classes was 84.07%, a positive result. The highest response rate was achieved for Aspect B (material relevance and local culture), with a mean of 85.33%, especially for item B4, which elicited a response of 93.73% from participants, indicating whether learning helped students comprehend local environmental and cultural preservation. This finding supports the notion that students viewed East

Kalimantan cultural elements, such as Mahakam River wisdom, endemic organisms, and the Erau Festival, as authentic aspects of scientific learning rather than superficial contextual additions (Gay, 2018), demonstrating that culturally embedded content resonated significantly with students' everyday lives.

Not all aspects elicited equally strong responses. The lowest-scoring aspect requires particular attention, as students found this dimension of the CTCR model less engaging and less clearly implemented than the cultural relevance aspects. The discovery implies that future updates to the CTCR model should enhance instructional support in this area, particularly by offering teachers more explicit guidance and scaffolding techniques to guarantee consistent implementation quality across all model stages in Table 6.

Table 6. Student response per questionnaire aspect

Aspect	Public Elementary School 011 Pela	Public Elementary School 016 Smd	Muham. Loa Janan Elementary School	Mean	Category
A — Learning Interest & Motivation	79.17%	86.61%	84.72%	83.50%	Positive
B — Material & Local Culture Relevance	85.42%	88.62%	81.94%	85.33%	Very Positive
C — Critical Thinking Development	85.42%	87.05%	77.31%	83.26%	Positive
D — Active Engagement	83.33%	86.61%	79.86%	83.27%	Positive
E — Meaningfulness & Satisfaction	84.38%	87.50%	83.10%	85.00%	Very Positive
Overall Mean	**83.54%**	**87.27%**	**81.39%**	**84.07%**	**Positive**

Discussion

The validity achievement confirms the robustness of the CTCR construct, which is grounded in a solid conceptual foundation: a synthesis of IBT, CTBL, and CRT that systematically aligns each step in the syntax with specific critical thinking indicators (Actual, Rational, Argument, Inference, and Implication). The model book scored highest on the presentation component (3.67) because this explicit mapping facilitates easier tracking of pedagogical flow. The Implementation Observation Sheet achieved the highest score of all instruments (3.85, PA = 100%), demonstrating the well-established objectivity of the monitoring framework. This aligns with Hammond (2015), who emphasizes that culturally responsive models are effective only when supported by a well-defined, research-based framework.

Overall, the CTCR model was categorized as practical across all three trial schools, with mean implementation scores ranging from 3.03 to 3.25. Phase 1 (Culturally Based Problem Orientation) consistently received the lowest implementation scores (2.91–2.97), warranting deeper interpretation beyond a general reference to pedagogical demand. Three specific factors likely contributed to teachers' difficulty in implementing Phase 1 effectively. First, presenting local wisdom phenomena in a manner that generates genuine emotional resonance requires teachers to possess not only content knowledge but also deep familiarity with the cultural significance of local traditions, a form of cultural Pedagogical Content

Knowledge (PCK) that is rarely developed through standard teacher training programs in Indonesia (Shulman, 1986; Mardayanti et al., 2025). Second, Phase 1 requires teachers to simultaneously manage student curiosity, facilitate observational tasks, and orchestrate culturally embedded questioning. This multidimensional instructional demand proved challenging within a single lesson, particularly for teachers with limited prior experience with inquiry-based approaches. Third, the urban school context of Public Elementary School 016 Samarinda Ulu presented an additional challenge: students in central urban settings demonstrated less direct experiential familiarity with the local wisdom phenomena being introduced, requiring teachers to invest additional instructional time in building cultural background knowledge before inquiry could meaningfully proceed.

Gay (2018) asserts that CRT is effective only when it builds authentic emotional and cognitive connections between students' cultural backgrounds and the scientific concepts being constructed. To operationalize this principle more effectively in Phase 1, future implementations of the CTCR model should consider three practical strategies: (1) teachers should be provided with a curated repository of culturally specific multimedia resources including short documentary videos, oral history recordings, and photographic documentation of local ecological practices that can be used to introduce cultural phenomena in contextually rich and emotionally engaging ways; (2) pre-lesson cultural briefings or community elder involvement, even in brief formats, could significantly strengthen the authenticity of Phase 1 presentations and reduce the cultural knowledge gap between teachers and students; and (3) the model guidebook should include annotated lesson examples demonstrating how to frame culturally based problems using question stems that activate students' prior cultural experiences before transitioning to scientific inquiry. Phases 3 and 4 together achieved the highest implementation scores (3.09 and 3.10), indicating that the CTCR model's structured syntax provides teachers with an effective framework for facilitating discussion and high-level argumentation skills, which have long been considered difficult to develop at the elementary level (Facione, 1990; McNeill & Krajcik, 2011).

All classes showed statistically significant improvement ($p < 0.05$). A combined Cohen's d of 2.12 and $\eta^2 = 0.82$ indicates that 82.09% of the variance in critical thinking improvement can be explained by CTCR implementation, exceeding Hattie's (2009) meaningful effect threshold of $d = 0.40$ by more than fivefold. The one-way ANOVA revealed significant N-Gain differences between Public Elementary School 016 and Muhammadiyah Elementary School ($F = 26.282$; $p = 0.000$; $\eta^2 = 0.34$); however, Tukey HSD post-hoc tests confirmed no decline in effectiveness from the limited to the extended trial ($p = 0.29$ and $p = 0.24$), demonstrating the model's scalability.

The high student response to local cultural relevance (85.33%) and to item B4 (93.73%) confirms that local wisdom, particularly Mahakam River traditions, East Kalimantan endemic organisms, and the Erau Festival, genuinely serves as an authentic epistemic resource rather than a decorative context (Gay, 2018). This finding aligns with CRT theory, which posits that cultural connections are not supplementary additions but foundational to meaningful learning engagement (Ladson-Billings, 1995; Gay, 2000).

Beyond its instructional effectiveness, these findings also highlight the broader contribution of the CTCR model to SDG 4 (Quality Education). By promoting critical thinking through culturally responsive and evidence-based learning experiences, the model supports SDG Target 4.1 by improving learning outcomes and Target 4.7 by integrating local wisdom that fosters cultural awareness, respect for diversity, and responsible citizenship among elementary students.

CONCLUSION

Fundamental Finding: Researchers successfully developed the CTCR (Culturally Responsive Critical Thinking) learning model, which demonstrated validity, practicality, and effectiveness in enhancing critical thinking skills among fifth-grade elementary students in East Kalimantan science learning. Improvements in the model's effectiveness were statistically significant across all trial classes, as indicated by a p-value < 0.05, a moderate mean N-gain of 0.52, and an extremely favorable student response rate of 84.07%. Integrating local wisdom into structured, inquiry-based instruction appears to provide a culturally grounded and pedagogically effective approach to developing critical thinking in primary education. **Implication:** This study's primary contribution is the development of a validated instructional model that systematically links critical thinking frameworks (IBT, CTBL, and CRT) with East Kalimantan local wisdom, creating a replicable design for culturally responsive science teaching at the elementary level. These contributions also support the advancement of SDG 4, particularly Targets 4.1 and 4.7, by promoting quality learning outcomes, strengthening critical thinking skills, and integrating local wisdom to foster culturally inclusive and sustainable education. **Limitation:** Despite this, the study has several limitations. The sample size was small, the implementation was restricted to a single semester, the model was applied solely to science (IPAS) subject matter, and the trial sites were confined to East Kalimantan. The constraints may limit the applicability of the results. **Future Research:** Future research should extend the CTCR model to other IPAS content areas, including ecosystems, energy, and human body systems, to determine whether the model consistently enhances critical thinking skills in clarification, inference, evaluation, and self-regulation across various scientific subjects. Replication studies in various cultural contexts across Indonesia, including Papua, Nusa Tenggara, and Sulawesi, are encouraged to explore the applicability of integrating local wisdom as a pedagogical factor across the country's diverse indigenous knowledge systems. Future studies should also investigate student engagement, scientific literacy, and cultural identity as further learning outcomes, considering the CTCR model's dual focus on inquiry and cultural responsiveness. Independent implementation by classroom teachers, without researcher involvement, would further assess the model's applicability in real-world settings and its ease of adoption. Longitudinal studies tracking the sustained development of critical thinking skills and cultural awareness across multiple academic years are warranted, alongside exploration of a web-based or digital version of the CTCR model to evaluate its effectiveness and scalability in technology-enhanced learning environments.

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AUTHOR CONTRIBUTIONS

Muhammad Ikhsan contributed to the conceptualization of the study, development of the Critical Thinking Culturally Responsive (CTCR) learning model, research design, project administration, field implementation, data collection, and manuscript revision. **Rudiana Agustini** contributed to the conceptual framework, supervision, validation of the learning model and research instruments, methodological refinement, and critical review of the manuscript. **Erman** contributed to methodology development, data analysis, interpretation of findings, validation processes, and manuscript review and editing. All authors have read, reviewed, and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

CONFLICT OF INTEREST STATEMENT

The authors state that no financial or personal conflicts of interest exist that may have affected the content or findings of this research.

STATEMENT ON THE USE OF AI OR DIGITAL TOOLS IN WRITING

The authors declare that no artificial intelligence (AI) tools or other digital writing assistants were used in the preparation, analysis, or writing of this manuscript. All stages of the research process, including data analysis, interpretation, and manuscript writing, were conducted solely by the authors. The authors take full responsibility for the originality, accuracy, and integrity of the content presented in this article.

REFERENCES

Aikenhead, G. S., & Jegede, O. J. (1999). Cross-cultural science education: A cognitive explanation of a cultural phenomenon. *Journal of Research in Science Teaching, 36*(3), 269–287. https://doi.org/10.1002/(SICI)1098-2736(199903)36:3<269::AID-TEA3>3.0.CO;2-T

Asrijanty. (2021). *Panduan pembelajaran dan asesmen jenjang pendidikan dasar dan menengah*. Kemdikbudristek.

Atmojo, S. E., Anggriani, M. D., Rahmawati, R. D., Skotnicka, M., Wardana, A. K., & Anindya, A. P. (2025). Bridging STEM and culture: The role of ethnoscience in developing critical thinking and cultural literacy. *Jurnal Pendidikan IPA Indonesia, 14*(2), 251–266. https://doi.org/10.15294/jpii.v14i2.23505

Bhardwaj, V., Zhang, S., Tan, Y., & Pandey, V. (2025). Redefining learning: Student-centered strategies for academic and personal growth. *Frontiers in Education, 10*, 1518602. https://doi.org/10.3389/feduc.2025.1518602

Bjork, E. L., & Bjork, R. A. (2011). Making things hard on yourself, but in a good way: Creating desirable difficulties to enhance learning. In M. A. Gernsbacher et al. (Eds.), *Psychology and the real world* (pp. 56–64). Worth Publishers.

Borich, G. D. (1994). *Observation skills for effective teaching*. Macmillan.

Borg, W. R., & Gall, M. D. (2007). *Educational research: An introduction (8th ed.)*. Pearson.

Caingcoy, M. E. (2023). Culturally responsive pedagogy: A systematic overview. *Diversitas Journal, 8*(4), 3203–3212. https://doi.org/10.48017/dj.v8i4.2780

Campo, L., Galindo-Domínguez, H., Bezanilla, M., Fernández-Nogueira, D., & Poblete, M. (2023). Methodologies for fostering critical thinking skills from university students' points of view. *Education Sciences, 13*(2), 132. https://doi.org/10.3390/educsci13020132

Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches (4th ed.)*. SAGE.

Duran, M., & Dökme, I. (2016). The effect of the inquiry-based learning approach on student's critical-thinking skills. *Eurasia Journal of Mathematics, Science and Technology Education, 12*(12), 2887–2908. https://doi.org/10.12973/eurasia.2016.02311a

Ennis, R. H. (1996). Critical thinking dispositions: Their nature and assessability. *Informal Logic, 18*(2&3), 165–182. https://doi.org/10.22329/il.v18i2.2378

Facione, P. A. (1990). *Critical thinking: A statement of expert consensus for purposes of educational assessment and instruction.* California Academic Press.

Fitriadi, F., Herpratiwi, H., Yulianti, D., Setiyadi, A., Hariri, H., Sunyono, S., Haenilah, E., & Mukhlis, H. (2024). Enhancing critical thinking in elementary education: A systematic review. *Multidisciplinary Reviews, 8*(1), 2025157. https://doi.org/10.31893/multirev.2025157

Fitrianto, I., & Farisi, M. (2025). Integrating local wisdom into 21st century skills. *International Journal of Post Axial: Futuristic Teaching and Learning, 3(2),* 109-121. https://doi.org/10.59944/postaxial.v3i2.444

Fraenkel, J. R., Wallen, N. E., & Hyun, H. H. (2012). *How to design and evaluate research in education (8th ed.)*. McGraw-Hill.

Fry, K., Nakar, S., & Zorn, K. (2025). Professional learning interventions for inquiry-based pedagogies in primary classrooms. *Mathematics Education Research Journal, 37*, 853–887. https://doi.org/10.1007/s13394-024-00516-x

Gay, G. (2000). *Culturally responsive teaching: Theory, research, and practice.* Teachers College Press.

Gay, G. (2018). *Culturally responsive teaching: Theory, research, and practice (3rd ed.).* Teachers College Press.

Golegou, E., Wallace, M., & Peppas, K. P. (2025). The essential 21st century skills for the labour market and education: Conceptual overview. *Asian Journal of Education and Social Studies, 51*(6), 253–274. https://doi.org/10.9734/ajess/2025/v51i61991

Gómez, D., Maestre, A., Trujillo, A., Fuentes, C., Ortiz, D., & Alarcón, R. (2025). Determining factors for the development of critical thinking in higher education. *Journal of Intelligence, 13*(6), 59. https://doi.org/10.3390/jintelligence13060059

Gómez, R. L., & Suárez, A. M. (2020). Do inquiry-based teaching and school climate influence science achievement and critical thinking? *International Journal of STEM Education, 7*(1), 43. https://doi.org/10.1186/s40594-020-00240-5

Hammond, Z. (2015). *Culturally responsive teaching and the brain*. Corwin.

Hasyim, F., Prastowo, T., & Jatmiko, B. (2020). The use of Android-based PhET simulation to improve students' critical thinking skills. *International Journal of Interactive Mobile Technologies, 14*(19), 31–41. https://doi.org/10.3991/ijim.v14i19.17218

Hattie, J. (2009). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. Routledge.

Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark. *Educational Psychologist, 42*(2), 99–107. https://doi.org/10.1080/00461520701263368

Joyce, B., Weil, M., & Calhoun, E. (2009). *Models of teaching (8th ed.).* Pearson.

Karmila, W., Achmad, S., & Utami, U. (2023). High-order questions improve students' critical thinking skills in elementary schools. *International Journal of Elementary Education, 7*(2), 299–308. https://doi.org/10.23887/ijee.v7i2.61607

Kemdikbudristek. (2023). *Laporan hasil asesmen nasional 2023.* Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi RI.

Khasanah, K., Subekti, E. E., & Setyaningsih, A. N. (2025). Penerapan culturally responsive teaching untuk mengoptimalkan kemampuan berpikir kritis. *Journal on Education, 7*(2), 10154–10167. https://doi.org/10.31004/joe.v7i2.8021

Ladson-Billings, G. (1995). Toward culturally relevant pedagogy. *American Educational Research Journal, 32*(3), 465–491. https://doi.org/10.3102/00028312032003465

Lee, N., Wang, Z., & Lim, B. (2021). The development of critical thinking: What university students have to say. *Teaching in Higher Education, 29*(1), 286–299. https://doi.org/10.1080/13562517.2021.1973412

Mardayanti, F., Capah, A., Tanjung, K., & Sitorus, S. (2025). Pengaruh model pembelajaran kontekstual berbasis kearifan lokal. *Konstanta: Jurnal Matematika dan IPA, 3*(2), 86–92. https://doi.org/10.59581/konstanta.v3i2.5103

Masithoh, S., Widodo, W., & Muhid, A. (2025). Profile of critical thinking skills in elementary school students. *Journal of Innovation and Research in Primary Education, 4*(3), 929–937. https://doi.org/10.56916/jirpe.v4i3.1469

McKenney, S., & Reeves, T. C. (2012). *Conducting educational design research.* Routledge.

McNeill, K. L., & Krajcik, J. (2011). *Supporting grade 5–8 students in constructing explanations in science.* Pearson.

Montano-Silva, R., Cabrera, L., Arias, J., Abraham-Millán, Y., & Crispin-Castellanos, D. (2025). An educational strategy for developing cognitive skills in preschool children. *Health Leadership and Quality of Life, 4,* 657. https://doi.org/10.56294/hl2025657

Nieveen, N., McKenney, S., & van den Akker, J. (2007). *Educational design research.* Routledge.

OECD. (2019). *PISA 2018 results (Volume I).* OECD Publishing. https://doi.org/10.1787/5f07c754-en

OECD. (2023). *PISA 2022 results (Volume I).* OECD Publishing. https://doi.org/10.1787/53f23881-en

Plomp, T., & Nieveen, N. (Eds.). (2013). *Educational design research: Part A: An introduction.* SLO.

Pramusinta, Y., & Saputri, D. (2025). Exploring elementary students' critical thinking skills. *Jurnal Ilmiah Sekolah Dasar, 9*(2), 292–300. https://doi.org/10.23887/jisd.v9i2.86178

Ramlawati, Sari, N. I., Kusumawati, R., Yesin, M., Ilmi, N., & Arsyad, A. A. (2025). The effect of differentiated science inquiry learning model based on teaching at the right level on students' critical thinking and science process skills. *Jurnal Pendidikan IPA Indonesia, 14*(1), 1–16. https://doi.org/10.15294/jpii.v14i1.19479

Riduwan. (2007). *Skala pengukuran variabel-variabel penelitian.* Alfabeta.

Rusmin, L., Misrahayu, Y., Pongpalilu, F., Radiansyah, R., & Dwiyanto, D. (2024). Critical thinking and problem-solving skills in the 21st century. *Join: Journal of Social Science*, *1*(5), 144–162. https://doi.org/10.59613/svhy3576

Sam, R. (2024). Systematic review of inquiry-based learning: Assessing impact and best practices in education. *F1000Research, 13,* 1045. https://doi.org/10.12688/f1000research.155367.1

Sarwanto, S., Fajari, L. E. W., & Chumdari, C. (2021). Critical thinking skills and their impacts on elementary school students. *Malaysian Journal of Learning and Instruction, 18*(2), 151–184. https://doi.org/10.32890/mjli2021.18.2.6

Sasmita, R., Sapriya, S., & Maryani, E. (2023). Critical thinking on social studies learning for elementary school students. *Nazhruna: Jurnal Pendidikan Islam, 5*(3), 1377-1387. https://doi.org/10.31538/nzh.v5i3.2355

Satria, A. A., Saputro, S., Sutarno, Harjana, & Hadi, F. N. (2024). Learning model experiential-based environmental socio-scientific issues (ESSI) and their effect on critical and creative thinking skills. *Jurnal Pendidikan IPA Indonesia, 13*(3), 471–482. https://doi.org/10.15294/jpii.v13i3.1993

Streelasky, J. (2017). Elementary students' perceptions of their school learning experiences: children's connections with nature and indigenous ways of knowing. *Children, Youth and Environments, 27*(1), 47–66. https://doi.org/10.7721/chilyoutenvi.27.1.0047

Sumarni, W., Sumarti, S. S., Dewi, S. H., & Imaduddin, M. (2025). Collaborative Ethno-STEAM enriched Project-Based Learning (CoE-STEAM-PjBL). *Jurnal Pendidikan IPA Indonesia, 14*(3), 458–468. https://doi.org/10.15294/jpii.v14i3.25487

United Nations. (2015). *Transforming our world: The 2030 agenda for sustainable development* (A/RES/70/1). United Nations General Assembly. https://www.un.org/sustainabledevelopment/development-agenda/. Accessed on May 13, 2026.

Wahyuni, S., Gusti Made Sanjaya, I., Erman, & Jatmiko, B. (2019). Edmodo-based blended learning model as an alternative of science learning. *International Journal of Emerging Technologies in Learning, 14*(7), 98–110. https://doi.org/10.3991/ijet.v14i07.9980

Wilujeng, I., Ain, T. N., Rilianti, A. P., Hasyim, F., & Fiqiyah, M. (2025). The effectiveness of H5P-assisted differentiated-independent learning model to increase low-ability students' scientific literacy. *Jurnal Pendidikan IPA Indonesia, 14*(1), 32–41. https://doi.org/10.15294/jpii.v14i1.19560

Wilson, M. M., Zafar, F., & Nichol, C. (2025). Fostering inquiry: The impact of cross-curricular professional development on STEM teacher practices. *Education Sciences, 15*(4), 421. https://doi.org/10.3390/educsci15040421

Yao, Y. (2025). Strategies and practices for cultivating students' critical thinking in primary school. *Edelweiss Applied Science and Technology, 9*(4), 451–460. https://doi.org/10.55214/25768484.v9i4.5999

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