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The Process-Outcome Disparity in Culturally Responsive Physics Instruction: A Qualitative Case Study from Indonesia

Nurul Husnah[1], M. A. Martawijaya[1], Mahir[1], Mutahharah Hasyim[1]
[1]Universitas Negeri Makassar, South Sulawesi, Indonesia

Corresponding author e-mail: martawijayamagus@unm.ac.id

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Abstract: This study examines the implementation and contextual relevance of the CRT approach in Indonesian senior high school Physics education. Employing a qualitative case study design, data were gathered through classroom observations and systematic document analyses (RPP and student outputs) from a single subject at State Senior High School 10 Makassar. The key results demonstrate that while the teacher achieved high pedagogical fidelity successfully fostering inclusive interactions (Score 5.0) and stimulating critical thinking (Score 4.0) by contextualizing abstract concepts the implementation was structurally incomplete. This resulted in an extreme cultural competence gap, characterized by high teacher effort (Score 4.5) contrasting dramatically with minimal cultural manifestation in student outputs (Score 1.0). This disparity is primarily attributed to a structural weakness in formal assessment design that fails to explicitly demand culturally reflective outcomes, coupled with significant external systemic barriers (50% minimal community participation). The research's novelty lies in its triangulated, quantitative-qualitative documentation analysis used to precisely measure this 4.5 vs. 1.0 disparity, shifting the scholarly focus from individual capacity to systemic issues. The findings offer crucial practical implications for urgent assessment reform to mandate culturally reflective learning outcomes and emphasize the contribution of strengthening holistic institutional commitment and community partnership to bridge the process-to-outcome gap.

Keywords: Culture-Based Learning, Culturally Responsive Teaching, Implementation Analysis, Physics Education

A. Introduction

The pursuit of equitable and effective science education necessitates pedagogical frameworks that validate and leverage students' cultural identities, particularly in culturally diverse nations like Indonesia. At the forefront of this effort is Culturally Responsive Teaching (CRT), a pedagogical model fundamentally defined by its triadic focus on promoting academic achievement, maintaining cultural competence, and fostering sociopolitical critique (Paris and Alim, 2022; Gay, 2018). CRT functions by utilizing students' cultural backgrounds, prior knowledge, and experiences as conduits for meaningful learning, aiming to bridge the critical gap between students'

home culture and the culture of the school. The integration of local cultural contexts within science learning has been shown to enhance students' ability to explain scientific phenomena more meaningfully, as they connect abstract concepts with their everyday experiences (Barajas-Salazar et al., 2025).

Building upon this foundation, the evolution toward Culturally Sustaining Pedagogy (CSP) emphasizes the imperative to not merely respond to, but actively sustain and perpetuate students' cultural and linguistic wealth (Paris and Alim, 2022). The CRT learning approach enables students to construct conceptual understanding through representations that are closely aligned with their cultural identity (Tanjung et al., 2025). This concept is particularly crucial in STEM subjects, such as Physics, where abstract concepts (e.g., Einstein's Relativity, as relevant in this study) are often perceived as culturally neutral or detached from students' daily realities. The interconnectedness between science material and students' cultural experiences plays a significant role in developing context-oriented science literacy (Rozi et al., 2025). Successful CRT/CSP implementation requires teachers to master Content Integration and translate cultural capital into tools for Knowledge Construction. This finding corroborates the notion that structural factors, rather than merely teacher skill, inhibit CRT success (Darling-Hammond et al., 2020).

Despite widespread acknowledgement of the potential of CRT and CSP to enhance engagement and outcomes, a significant gap persists in the empirical literature. The majority of existing studies often focus on qualitative analyses of teacher practice or survey-based assessments of student perception, largely neglecting a rigorous and quantitative-qualitative analysis of fidelity. There is a scarcity of research that meticulously analyzes the alignment (or misalignment) between the teacher's instructional intent and process fidelity as reflected in planning documents and the demonstratable cultural and cognitive competence evident in students' tangible outputs (product fidelity) within specific STEM subjects. Therefore, this research aims to analytically describe the enactment of the CRT approach and critically assess its contextual relevance in a Physics classroom at State Senior High School 10 Makassar. By rigorously measuring the process-to-product alignment, this study seeks to provide a detailed empirical metric that identifies structural barriers hindering the holistic realization of CRT's core tenets.

B. Methods

This study employed a Qualitative Case Study design to gain an in-depth, holistic understanding of the complex dynamics surrounding the implementation of CRT in a naturalistic setting (Yin, 2018). We focused on a single, critical case: the Physics classroom at State Senior High School 10 Makassar, involving one Physics teacher and thirty students. The single-case selection was deliberately strategic, as this particular school was identified where a teacher was already actively engaging in pedagogical practices *intended* to integrate cultural content, making it an information-rich case

(Yin, 2018). This approach moves beyond studying a 'typical' scenario, allowing for rigorous scrutiny of implementation fidelity and the misalignment dynamics that occur where the commitment to CRT is demonstrably present. Analyzing this critical case provides crucial evidence regarding the structural and external barriers that limit holistic CRT achievement, even under optimal intentional conditions. This study employs a qualitative case study design to deeply explore and analyze the process-outcome disparity observed in the implementation of CRT in Physics instruction. Qualitative research is essential for providing a comprehensive understanding of complex human and social phenomena, and the case study approach allows for an intensive exploration of a single, bounded system (a specific teacher's practice in a defined setting), enabling detailed data analysis of classroom observations and student outputs (Creswell and Poth, 2018).

Data collection utilized Data Source Triangulation to ensure the robustness and validity of the findings. Triangulation among observational data, interviews, and learning artifacts is essential to ensure the validity of the CRT implementation claims (Patras et al., 2024). The primary data sources were 1) Non-participant classroom observations of instructional processes; 2) Systematic Document Analysis of Lesson Plans (RPP), student notes, and student assignments/outputs; and 3) Teacher Reflections. This triangulation allowed for the explicit comparison between the teacher's instructional intent (process), as documented in the RPP, and the students' demonstrable cultural competence (product), as evidenced in their assignments.

The collected data were synthesized using the Systematic Interactive Analysis Model (Miles et al., 2020), which involves a recursive, three-stage process: 1) Data Reduction: The initial vast corpus of raw data (field notes, RPP sections, student scores, and textual assignments) was condensed by focusing on indicators explicitly related to the dimensions of CRT (e.g., Cultural Competence, Critical Consciousness, and Equitable Pedagogy). The data reduction process was conducted continuously both during and after the data collection phase. Data derived from classroom observations (in the form of interaction transcripts and field notes) and document analysis (RPP) were filtered to retain and group only the segments explicitly relevant to the two primary research dimensions: a) The level of Pedagogical Fidelity (specifically, scores for teacher-student interactions and cognitive stimulation), and b) The level of Cultural Manifestation (specifically, indicators of the use of cultural frameworks, language, and local context in student work outputs). Data categorized as outliers or those not directly linked to the CRT/CSP framework and assessment were eliminated from further analysis, thereby ensuring a strict focus on the 4.5 vs. 1.0 gap issue; 2) Data Display: The reduced data were organized into structured matrices and visualizations specifically the quantitative-qualitative comparison matrix to display the contrast between the teacher's process scores and the students' product scores (the 4.5 vs. 1.0 disparity); and 3) Conclusion Drawing and Verification: Initial conclusions were drawn based on the visualized data displays. These findings were continuously

verified against the original observation and document sources to ensure that the interpretations accurately reflected the evidence and were structurally sound.

C. Results and Discussion

Results

Data Reduction

The initial phase of analysis involved Data Reduction, encompassing the processes of summarizing, focusing, and selecting relevant data segments from the comprehensive raw material. As the initial stage in the qualitative data analysis process and to ensure the credibility of the findings, all collected data underwent a Data Reduction phase (Creswell and Poth, 2018). Data reduction encompassed summarizing, selecting key points, and eliminating extraneous information, with the objective of making the final data more verifiable and easily interpretable. However, the reduced data sets are not presented in this section.

Data Analysis

The findings of this study are presented through the triangulation of three primary data sources: classroom observations, analysis of RPP, analysis of student learning products (notes/assignments), and analysis of teacher reflections.

1. Observation Analysis: Robust Foundational Interactions vs Systemic Barriers

Structured observation analysis on the implementation of CRT in Physics instruction in Grade XII MIPA 4 demonstrated significant success in establishing a robust foundation for inclusive social interaction, but this success was counterbalanced by inherent structural challenges. 1) Strength in Interaction (Inclusive Process): Eight out of ten teacher observation indicators were met. The teacher consistently integrated abstract content (such as Einstein's Relativity) with student experiences and local folktales through discussion, and employed easily comprehensible vernacular. Crucially, the teacher exhibited high identity affirmation by valuing cultural diversity and allowing students the freedom to use their own language in discussions, thus validating student culture as an asset. The positive impact on students was evidenced by increased self-confidence and appreciation for diversity; and 2) Critical Gap (Structural Divergence): The main challenge lies in the failure of CRT transfer to deeper, systemic levels. The teacher did not further incorporate students' prior knowledge into new material development and failed to engage parents/community due to time constraints and parental schedules. This condition was exacerbated by a non-culturally responsive physical environment the classroom lacked decorations reflecting diversity, and teaching materials were found to be insufficiently relevant to students cultural perspectives.

In summary, the observation results conclude that while caring relationships and social interaction were successfully established, deep content integration and systemic environmental empowerment remain key areas for development.

2. RPP Analysis: Fidelity of Intent vs Formal Objective Structure

The RPP analysis was conducted to assess the teacher's planning readiness in accommodating CRT principles. Generally, the RPP showed a strong intent to design inclusive instructional processes, but revealed significant weaknesses in formal structure and assessment aspects. 1) Strength in Planning (Activity Design): The RPP successfully designed learning activities that accommodated different learning styles and explicitly sought to leverage students' cultural backgrounds to build relevance for Physics concepts. It also granted flexibility of participation and showed an intent to integrate learning resources via the utilization of student cultural narratives and experiences; 2) Formal Challenges (CRT Structure): The greatest challenge lies in the formality of the CRT structure. The RPP failed to list explicit learning objectives aimed at fostering cultural competence or appreciation for diversity. Crucially, the assessment criteria did not consider the students' cultural context, creating a disconnect between inclusive teaching processes and standardized assessed outcomes. Furthermore, limitations in teacher reflection and student feedback on cultural relevance were not documented. The RPP analysis concludes a strong alignment at the process interaction level, but a critical weakness in the formal structure of Culturally-Based Learning Objectives and Assessment Criteria.

3. Student Product Analysis (Notes/Assignments): The Process-to-Outcome Gap

Analysis of student notes and written assignments was performed to measure the extent to which cultural integration was reflected in the final student products. 1) High Academic Proficiency and Structure: Student work demonstrated high academic proficiency it was neat, systematic, and showed a strong command of universal Modern Physics concepts. Students provided accurate conceptual explanations (e.g., flaws in atomic theories) and systematic problem-solving strategies, indicating a strong metacognitive process; 2) CRT Implementation Gap: Despite high academic quality, the analysis found a minimality of explicit cultural references. The material and responses to problems (such as UN sample questions) were universal and not directly linked to specific cultural contexts. This confirms a process-to outcome gap: the inclusive classroom discussions failed to transfer cultural manifestation into the students' written work. Students reverted to the standard Hegemonic Academic Culture format, likely stemming from the lack of culturally responsive assessment design in the RPP.

4. Teacher Reflection Analysis: Commitment and Critical Self-Awareness

The analysis of teacher reflections indicated a high level of professional self-awareness and commitment to CRT implementation. 1) Reflection on Success (Qualitative): The teacher successfully created cultural connections (linking Relativity to folktales) and emphasized the achievement of a "safe space" where every opinion was valued, which is fundamental to CRT; 2) Critical Reflection (Structural Challenges): The teacher honestly acknowledged that implementation was hampered by structural challenges. These included the necessity of achieving deep integration of local wisdom (moving beyond superficial connections), the sub-optimal involvement of parents/community (external support), and the condition of the non-culturally responsive physical environment; and 3) Concrete Action Planning: The reflection was followed by concrete action plans aligned with CRT principles, such as conducting intensive research on local wisdom and exploring innovative ways to increase community engagement.

The findings, which were systematically derived from the triangulation of classroom observations, lesson plan analysis, student work products, and teacher reflections, reveal a significant Process-Product Disparity in the efficacy of CRT implementation. High pedagogical fidelity was confirmed at the process level, evidenced by robust inclusive social interaction, successful identity affirmation, and a strong fidelity of intent within planning documents, thus establishing an Equitable Pedagogy in the classroom dynamic. However, this success was consistently arrested at the process stage, failing to translate into measurable outcomes. The Student Product Analysis revealed a critical Process-to-Outcome Gap defined by the minimality of explicit cultural references, where students reverted to the Hegemonic Academic Culture format. Nevertheless, the success in fostering critical thinking indicates that CRT holds significant potential in Physics, a potential further supported by research on the development of culturally-based assessment instruments focused on critical thinking ability (Martawijaya et al., 2024). This divergence is fundamentally linked to structural barriers, particularly the critical weakness in the formal structure of Culturally-Based Learning Objectives and Assessment Criteria, coupled with the failure of systemic environmental empowerment, including sub-optimal community engagement and the lack of a culturally responsive physical environment. In essence, the implementation has yet to transition from procedural adherence to achieving demonstrable Knowledge Construction and measurable Cultural Competence in student outputs, necessitating fundamental reform in assessment and systemic support.

Data Triangulation

The findings of this study are presented through the triangulation of four primary data sources: classroom observations, analysis of RPP, analysis of student learning products (notes/assignments), and analysis of teacher reflections. Data Triangulation

was specifically conducted to compare and integrate findings obtained from all analytical streams. This systematic process enhanced the validity and analytical rigor of the findings by identifying consistency patterns, exposing divergences, and providing a comprehensive understanding of CRT implementation in Physics learning. Through this holistic approach, the study generated a holistic depiction of how CRT principles were enacted and interpreted their implications for instructional practice.

Table 1. Data Triangulation of CRT Implementation

No	CRT Aspect	Synthesis and Divergence	Implications/ Recommendations
1	Building Student Identity	There is strong consistency between teacher efforts (as observed and reflected) and the instructional RPP in fostering students' identity through acknowledgment and appreciation of their experiences and languages. However, a significant divergence was found in students' written work, which does not explicitly reflect cultural identity. This indicates that although the process has been carefully designed and implemented, students' cultural identity expression in learning products remains limited.	1. Strengthen the integration of cultural elements in students' learning products through concrete strategies that explicitly manifest local wisdom and students' cultural experiences. For example, designing assignments that link Physics concepts with cultural phenomena, developing culturally based projects, or creating structured reflective formats. 2. Increase the specificity and application of local wisdom by conducting contextual research on Makassarese cultural practices relevant to Modern Physics content, and integrating these findings into lesson plans, instructional materials, and assessment examples.
2	Developing Cultural Strength	Consistency was observed in teacher intentions (reflections and lesson plans) to connect learning materials with local wisdom. However, a notable divergence appeared in students' notes, which lacked explicit connections between Physics content and their cultural backgrounds indicating that cultural potential has not been fully utilized or expressed in written outcomes.	Encourage deeper contextualization of Physics content through culturally embedded analogies and examples that resonate with students lived experiences.
3	Promoting Social Justice	Consistency was found in teacher reflections and instructional designs promoting social justice through discussions on diversity and mutual respect. Nevertheless, this could not be directly confirmed through students' technical work, which focused primarily on Physics content.	1. Promote authentic cultural relevance by fostering inclusive dialogue and community-based engagement. 2. Increase family and community participation through collaborative projects, parental involvement sessions, and the inclusion of local leaders as guest speakers.

4	Fostering Critical Thinking	Strong consistency was observed across all data sources lesson plans, observations, and students' work indicating that CRT-based instruction effectively fostered critical thinking and metacognitive engagement.	Sustain and extend metacognitive practices by integrating structured reflection tasks and inquiry-based problem solving in Physics learning.
5	Engaging Family and Community	Consistency between teacher reflections and lesson plans was evident in their intention to involve communities; however, real engagement was minimal, as explicitly admitted by teacher's and unsupported by student data.	Implement proactive strategies to enhance home–school–community partnerships, such as family-based learning projects and community-integrated Science fairs.
6	Creating a Culturally Responsive Physical Environment	Consistency was found between lesson plans (as planning documents) and teacher reflections (as evaluative notes) recognizing the need to enrich the physical learning environment. Nonetheless, classroom observations revealed a limited presence of cultural representation within the school environment.	Initiate the enrichment of classroom and school spaces with local cultural symbols, artifacts, and thematic decorations that promote students' sense of belonging and identity.

The table disaggregates the findings of the CRT implementation into six core aspects, focusing on where the process demonstrated fidelity (consistency) and where the transfer to outcomes failed (divergence).

Building Student Identity

Synthesis and Gap: A strong consistency was observed between the teacher's intention and the instructional design to valorize student identities and experiences. However, a significant divergence was noted in student learning products. Student written work or assignments did not explicitly reflect their cultural identities, suggesting that cultural affirmation was arrested at the process stage (instruction) and failed to transfer to the outcome stage (assessment). Recommendation: Concrete strategies are required to mandate cultural manifestation in the final products, such as project-based assignments that are compulsory in linking Physics concepts with local wisdom (e.g., creating a model of a traditional tool based on Physics principles).

Developing Cultural Strength

Synthesis and Gap: The teacher's intent to connect the material with local wisdom (such as Makassar local wisdom) was present in the planning. The gap occurred because student notes or work results showed a lack of explicit connection. This indicates that the potential of culture as cultural capital was not fully utilized or articulated in writing by the students. Recommendation: Teachers must use more

culturally embedded and highly relevant analogies and examples so that students automatically bridge the material concepts with their life context.
Promoting Social Justice

Synthesis and Gap: Teachers were consistent in planning and reflecting on discussions concerning diversity, equity, and mutual respect. However, this aspect could not be confirmed through students' technical work results, which is plausible given the focus on Physics content. Consequently, the component of students' Sociopolitical Consciousness is not measurable in formal assessments. Recommendation: The expansion of social justice must be achieved through authentic dialogue and community engagement. The involvement of parents and local figures as speakers can enhance students' understanding of social issues relevant to their community.

Fostering Critical Thinking

Synthesis and Gap: This was the most successful aspect. Strong consistency was found across all data (Lesson Plans, observations, and student assignments), indicating that the use of CRT-based instructional models successfully cultivated critical thinking and student metacognitive engagement. Martawijaya et al. (2024) also discusses the development of an instrument to measure Critical Thinking ability based on CRT in Physics. Recommendation: This success must be sustained and expanded by routinely integrating reflection tasks and inquiry-based problem-solving into Physics instruction.

Engaging Family and Community

Synthesis and Gap: The intention to involve the community was present in the teacher's plans, but the actual engagement was minimal—acknowledged by the teacher and unsupported by student data evidence. External involvement constitutes a significant structural barrier. Recommendation: Implement proactive strategies such as family-based learning projects or science exhibitions that involve the active participation of the community outside the school.

Creating a Culturally Responsive Physical Environment

Synthesis and Gap: Teachers recognized the necessity of a responsive physical environment (consistency of intent), but classroom observations indicated limitations in cultural representation (divergence of practice). The school/classroom environment has not become a space that visually affirms student cultural identity. Recommendation: Initiate the enrichment of the classroom and school environment with local cultural symbols, artifacts, or thematic decorations to reinforce the students' sense of belonging.

The systematic disaggregation of CRT implementation findings across six core aspects reveals a recurring pattern of high pedagogical fidelity in teacher intent juxtaposed with significant transfer failure (divergence) into measurable student outcomes and systemic support. Specifically, the analysis confirms strong consistency in process-level efforts, such as the successful valorization of Student Identity and the effective cultivation of Critical Thinking and Metacognitive Engagement. However, this success is consistently arrested at the process stage, evidenced by a critical divergence in student products which fail to explicitly manifest cultural representation, leading to the component of Sociopolitical Consciousness being unmeasurable in formal assessments. Furthermore, major structural barriers were identified in the limited utilization of cultural capital for deep content connection and, critically, the minimal community/family engagement and the lack of a culturally responsive physical environment necessary to reinforce the students' sense of belonging. This pattern suggests that while the relational and instructional elements of CRT are successfully present, the implementation has yet to transition from procedural adherence to systemic, outcome-driven practice.

Data Visualization

To facilitate a more concise and visual understanding, the key findings from the discussion on CRT implementation are summarized through the following data visualizations. These visual representations specifically highlight the strengths of CRT implementation (process-oriented aspects), the gaps between processes and outcomes, and the structural as well as external challenges encountered during implementation

1. Relevance of CRT Implementation in Physics Learning

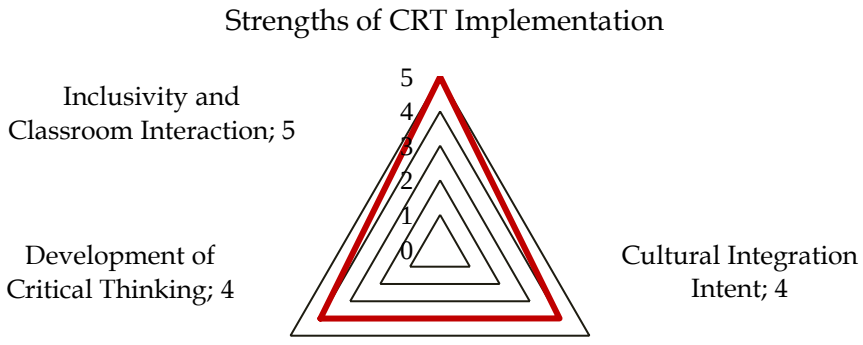

Figure 1. Strengths of CRT Implementation

Figure 1, which illustrates the strengths of CRT implementation, visualizes three major dimensions of pedagogical strength through a radar chart (scale 0–5). Visually, Figure 1 emphasizes that the teacher has successfully established a strong pedagogical foundation by creating a humanizing and inclusive learning environment (inclusion) that achieved the maximum score of 5, demonstrating a high level of cultural integration intent (score 4), and effectively stimulating higher-order cognitive thinking, which also reached a high score of 4. The implementation of CRT has established a robust pedagogical foundation, characterized by three principal strengths achieved at a high level:

Inclusivity and Classroom Interaction (Maximum Score of 5): This represents the highest strength, demonstrating the teacher's complete success in fostering a humane, safe, and welcoming learning environment. The teacher's ability to understand students' cultural characteristics serves as a foundation for the realization of responsive and inclusive pedagogical practice (Ogodo, 2024). The teacher effectively valued student diversity, encouraged active participation, and cultivated positive relationships, which are key prerequisites for successful CRT implementation.

Intent for Cultural Integration (Score of 4): The teacher displayed a strong commitment, awareness, and structured planning to incorporate cultural aspects into Physics instruction. Integrating CRT can strengthen students' ability to identify, reason, and communicate science ideas more structurally (Riley, 2025). This intent was manifested through the RPP which explicitly connected the subject matter to relevant cultural contexts, alongside the teacher's acknowledged plans for further local wisdom research.

Critical Thinking Development (Score of 4): This strength indicates that the inclusive environment created by the teacher was highly effective in stimulating students' higher-order cognition (Martawijaya et al., 2024). The CRT approach facilitates the emergence of academic safety, which enables students to express scientific argumentation with greater enthusiasm (Choirrunisa, 2025). This is evidenced by in-depth classroom discussions and analysis of student notes, which revealed a strong conceptual understanding and the presence of metacognitive processes (self-reflection and self-correction).

The research findings indicate an extreme cultural competence gap, characterized by the high level of teacher effort (mean score 4.5) that dramatically contrasts with the minimal cultural manifestation in student outputs (mean score 1.0). Figure 1 illustrates this disparity, where the axes representing Pedagogical Fidelity (e.g., Inclusive Interaction and Critical Thinking Stimulation) demonstrate high scores, while the axes for Cultural Manifestation (e.g., Use of Cultural Frameworks and Linguistic Pluralism) are concentrated at the lowest scores. This pattern visually confirms that although the learning process successfully triggered cognitive engagement, it ultimately failed to translate into a culturally responsive product.

Overall, the Radar Diagram visualization affirms that the core strengths of CRT implementation reside in the classroom interaction process and the teacher's intentional commitment, thus forming a solid foundation for culturally responsive pedagogical practice.

2. Discrepancy Between Process and Cultural Outcomes

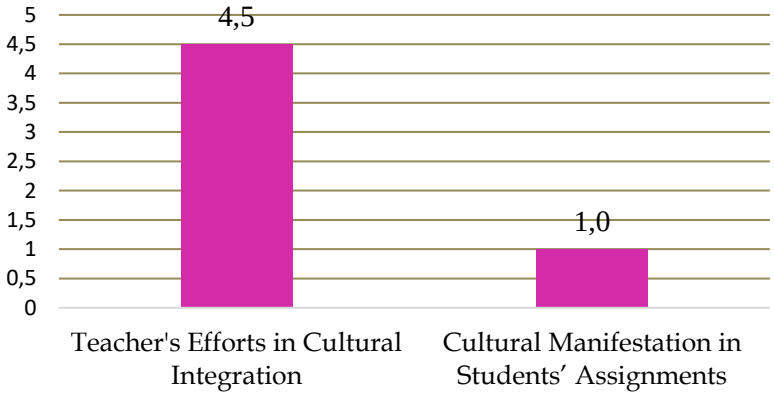

Figure 2. Gap Between Process and Cultural Outcomes

The Bar Chart (Figure 2) clearly visualizes a critical divergence in the implementation of CRT, specifically between the teacher's intention/process and the students' outcomes/products. 1) Teacher Process Strength: The teacher's efforts in Cultural Integration achieved a significantly high score of 4.5 (out of a maximum 5), consistent with the high levels of Inclusivity and Integration Intent. Teachers who receive professional development support based on CRT are more capable of designing science concept representations that are aligned with the students' cultural background (Najah, 2025). This aligns with the high score achieved, which confirms that the teacher successfully built an equitable pedagogy that was highly responsive, inclusive, and consistent in the class interaction process.; 2) Student Product Weakness: A sharp contrast is observed in the Cultural Manifestation in Student Notes/Assignments score, which plummeted to just 1.0. This extremely low score indicates that despite the culturally responsive and inclusive process, the explicit learning outcomes (written products) of students failed to display sufficient cultural evidence or representation; and 3) Core of the Gap: This extreme gap between the 4.5 (process) score and the 1.0 (product) score suggests that CRT implementation was stalled at the process stage and had not successfully translated the teacher's pedagogical efforts into visible Knowledge Construction and Cultural Competence in student outputs. Consequently, strategies designed to transfer cultural understanding from classroom discussions to explicit learning products must become the primary area requiring drastic reform.

The findings unequivocally highlight an Extreme Process-Product Disparity in the efficacy of CRT implementation, marked by a quantitative contrast between high

pedagogical fidelity and minimal outcome manifestation. The teacher's effort in Cultural Integration achieved a significantly high score of 4.5 (out of a maximum of 5), confirming the successful establishment of an inclusive, consistent Equitable Pedagogy within classroom interaction dynamics. However, this process success was not successfully translated into explicit student outputs, as evidenced by the sharp drop in the Cultural Manifestation in Student Notes/Assignments score to a mere 1.0. This extreme divergence (4.5 vs. 1.0) suggests that CRT implementation was stalled at the process stage, failing to convert the teacher's pedagogical efforts into measurable Knowledge Construction and Cultural Competence in student products. Consequently, the primary area requiring urgent reform is the restructuring of assessment and the design of explicit strategies to mandate the transfer of cultural understanding from classroom discourse to verifiable written outcomes.

Further analysis of student outputs is corroborated by qualitative data regarding their epistemological beliefs. Figure 2 presents the detailed percentage of students who tend to maintain naive epistemological beliefs specifically, the perception that Physics and local wisdom are separate and non-integrable entities. This trend constitutes a fundamental barrier to the transfer of results (Outcome 1.0), as students automatically revert to a hegemonic academic format which they perceive as the 'correct Physics answer' when faced with formal assessment.

3. Implementation Challenges of CRT

The following table presents the levels of challenges in implementing CRT:

Table 2. Level of Challenges in the Implementation of CRT

No	Aspects of Implementation Challenges	Barrier Level	Implications for CRT Relevance
1	Local Wisdom Integration	40%	The level of integration reached only 40%, categorized as a high-level challenge. This figure validates a significant gap between teacher strong cultural intention (Score 4.5) and its deep realization within the curriculum, confirming that the integration of local wisdom remains a substantial challenge requiring concrete strategic actions.
2	Parental and Community Involvement	50%	A 50% challenge level indicates that only half of the engagement potential has been realized, confirming a critical divergence between the intended engagement in the RPP and classroom reality posing a major barrier to holistic CRT implementation.
3	Culturally Responsive Physical Learning Environment	50%	The challenge level reached 50%, validating the presence of significant structural constraints. This indicates that efforts to make the physical environment (decorations/artifacts) culturally reflective remain halfway accomplished, thereby hindering students' sense of belonging and the visual validation of their cultural identity.

Overall, the implementation of CRT faces significant and urgent structural challenges that substantially reduce its potential relevance. These challenges are categorized into two major areas, both of which require systemic rather than merely pedagogical interventions. 1) Curricular Integration Challenges (Internal): The integration of local wisdom has reached only 40%, falling within the high-challenge category. This figure clearly validates a substantial gap between the teacher's strong intention to integrate culture and its deep realization within the curriculum and students' learning tasks; and 2) Ecosystem Challenges (External): The most critical and demanding barriers are situated within the dimension of Sociopolitical Consciousness, indicated by a uniform 50% score across two key indicators: a) Parental and Community Involvement: The 50% achievement rate signifies that half of the potential for strategic partnerships remains unrealized, constituting a crucial obstacle to achieving holistic CRT implementation; b) Culturally Responsive Physical Environment: The 50% level validates the existence of structural constraints, as classroom and school environments have not yet optimally reflected or valued students' cultural diversity. Therefore, the high level of external barriers (50%) underscores that the success of CRT depends not solely on teachers' instructional capacity, but also on proactive strategies to strengthen school–home partnerships and institutional commitment to establishing a learning environment that visually supports identity validation and fosters students' sense of belonging.

Discussion

The Paradox of Procedural Fidelity without Outcome Transfer

1. The Correlation Between the 4.5 vs 1.0 Gap and Assessment Robustness

The 4.5 vs. 1.0 gap refers to the disparity between the demands of educational practice (4.5) and the actual educational outcomes (1.0). Bennett (2023) proposes a socio-culturally responsive assessment model grounded in the principles of fairness, inclusivity, and cultural validity. 1) Process 4.5: The working and social environment necessitates critical thinking, complex problem-solving, creativity, collaboration, and adaptability (21st-century skills). The relationship between epistemological beliefs and engagement in higher-order cognitive processes (such as Critical Thinking) is crucial. According to Panergayo et al. (2023), teachers' success in achieving a Score of 4.5 indicates their capability in triggering cognitive processes. However, students' underlying epistemological beliefs about the nature of Physics knowledge became a barrier to the transfer into results (products). Students might be capable of thinking critically about Physics concepts, but they do not allow this critical understanding to be culturally manifested because their views on the validity of Physics knowledge remain rigid; and 2) Outcome 1.0: Educational results, particularly in assessment, frequently concentrate on testing rote memorization, factual knowledge, and mass-producible routine skills. Students' epistemological beliefs can be either naive (believing that Physics knowledge is singular, fixed, and decontextualized) or

sophisticated (believing that Physics knowledge is dynamic and constructed). According to Panergayo et al. (2023), students' failure in cultural manifestation (Cultural Manifestation Score 1.0) might be attributed to the naive epistemological beliefs they hold: they perceive Physics (abstract concepts) and local wisdom as two separate and unenterable entities. This causes them to automatically revert to a hegemonic academic format which they believe to be the "correct Physics answer." Assessment power is rooted in its capability to either incentivize or impede the development of relevant skills and Culturally Responsive Assessment (CRA) must integrate students' cultural backgrounds and experiences to mitigate bias and support equitable outcomes (Evans and Taylor 2025). a) The Constraint (Gap): Outcome-oriented assessments (1.0) (e.g., content-based multiple-choice exams) signal to students and educators that only superficial, easily measurable knowledge is valued, effectively impeding skills development. The minimal cultural manifestation (1.0) is a direct consequence of this misalignment, as the formal assessment (a key system component) failed to reinforce the cultural goals set in the instruction (Darling-Hammond et al., 2020); b) The Driver (Leveraging Assessment Power): The 4.5 vs. 1.0 gap is a reflection of the failure of traditional educational and assessment systems to adapt to contemporary needs. To bridge this gap, assessment must be utilized as a driving force (leverage) through mandatory and comprehensive reform. This reform must transform assessment to become authentic, simulating real-world challenges, and demanding the application and synthesis of knowledge (assessing skills). While the teacher demonstrated high pedagogical fidelity (4.5), the system itself was incoherent (Darling-Hammond et al., 2020). Specifically, reform must focus on authentic project-based outcomes that explicitly evaluate the application of local knowledge to solve contemporary issues. This aligns with the understanding that successful CRT should ultimately inspire students to design technological innovations that address cultural challenges, thereby fostering entrepreneurial capabilities (Tanjung et al., 2025).

2. The distinction between CRT and CSP

CRT and CSP are two critical pedagogical frameworks focusing on the academic success of students from diverse cultural backgrounds, yet they maintain distinct orientations. CRT primarily concentrates on building a bridge between students' home culture and school culture to responsively address their learning needs. The ultimate goal is to promote academic achievement by utilizing culture as scaffolding or a teaching aid; thus, the key concepts emphasized are Cultural Relevance and Academic Equity.

CRT and CSP represent two pivotal pedagogical frameworks aimed at fostering academic success for students from culturally diverse backgrounds, though their orientations remain distinct. CRT primarily seeks to establish a responsive link, or bridge, between the student's home and school cultures to effectively address their learning requirements. The fundamental objective is to promote academic

achievement by strategically utilizing culture as instructional scaffolding. Consequently, CRT emphasizes Cultural Relevance and Academic Equity as its core tenets. Conversely, CSP, as proposed by Paris and Alim (2022), is recognized as an evolutionary advancement of CRT, employing a more proactive stance. CSP's central focus is to position schools as sites that actively sustain and affirm students' diverse languages, literacies, and cultural practices. In this model, culture is not merely a teaching aid, but rather an ultimate outcome to be preserved. This orientation promotes academic achievement simultaneously with students' cultural, social, and linguistic sustainability. As such, the key concepts underpinning CSP involve Cultural and Linguistic Pluralism, Transformation, and Social Justice. In summary, while CRT endeavors to ensure the relevance of instruction, CSP strives to render education sustainable and perpetuate the multifaceted cultural identities of its diverse student body (Ajani, 2025).

3. The Link: Without Assessment Reform, CRT Remains Superficial

In-class implementation of CRT, which aims to utilize students' cultural contexts to facilitate learning, tends to remain superficial or cosmetic if not supported by aligned assessment reform. Assessment functions as a core determinant within the educational system, and the misalignment between the pedagogy (CRT) and the evaluation (traditional assessment) results in a conflict that impedes CRT's efficacy. 1) Conflict of Objectives: If educators implement students' cultural context in instruction (in line with CRT principles), but the summative assessment remains a culturally insensitive, rote-based examination, the message conveyed to students is that their cultural context holds no value (Gay, 2018). Testing exclusively on standardized factual knowledge neglects the depth of contextual understanding fostered through CRT; 2) Instructional Alignment Mandated by Testing: The washback effect of assessment significantly drives instruction. Educators, operating under pressure to meet the targets of traditional assessments (often large-scale standardized examinations), will feel compelled to forgo more authentic and in-depth CRT practices. The focus subsequently shifts toward easily measurable test material, sacrificing the development of higher-order skills and deep cultural connections; and 3) Unjust Measurement: Traditional assessments frequently contain cultural or linguistic bias. This results in students from minority backgrounds being evaluated unfairly or invalidly, despite having engaged deeply in CRT-based learning. Without culturally responsive assessment, the benefits and equity promised by CRT are eroded by biased measurement.

Without comprehensive reform, any effort to implement CRT) or CSP remains highly susceptible to being superficial or merely cosmetic. The systemic power of assessment (known as the washback effect) dictates the ultimate value proposition within formal educational contexts. Traditional assessments, which are frequently rigid, standardized, and fixated on rote memorization, act as an 'anchor' that invariably pulls teaching practices back toward culturally insensitive focuses, regardless of the

teacher's intention to employ responsive pedagogy. Gay (2018) asserts that if assessment fails to test the contextual understanding fostered by CRT, it implicitly communicates to students that their cultural context and knowledge hold no currency for formal academic success. Reinforcing this perspective, Hashim and Ali (2022) emphasize, particularly in the context of science, that for culturally responsive pedagogy to successfully transfer pedagogical fidelity into measurable outcomes, assessment must be fundamentally reformed and aligned. This requires explicitly demanding demonstrations of understanding using students' cultural frameworks, languages, and local contexts an objective achievable only through authentic or project-based assessment. Therefore, assessment reform becomes a prerequisite for the success and depth of CRT. Assessment must be aligned with CRT principles, for instance, through authentic or project-based assessment that enables students to demonstrate their understanding using their own cultural frameworks and contexts.

The process-outcome gap (4.5 vs. 1.0) highlights the failure of the education system, particularly traditional assessment, to develop the skills required in the digital age (Hickman, 2023). To address this, the power of assessment must be leveraged through a comprehensive reform (Luque-Jimenez et al., 2023). In parallel, CRT and CSP approaches offer a framework for more equitable and inclusive instruction, where CSP (Paris and Alim, 2022) surpasses CRT by proactively fostering students' cultural identities rather than merely responding to them. However, any effort to implement CRT/CSP will remain superficial without assessment reform. Traditional assessment acts as an anchor, pulling teaching practices back toward shallow, rote memorization and culturally insensitive focuses. Assessment must be aligned, for instance, through authentic assessment or project-based assessment that allows students to demonstrate their understanding using their own cultural frameworks, language, and contexts (Hasyim and Ali, 2022). Therefore, assessment reform that aligns with inclusive and authentic principles is key to bridging the 4.5 vs. 1.0 process-outcome gap and providing the necessary depth for CRT.

4. Structural and Systemic Barriers to Holistic Implementation

a. Comprehending the 50% Challenge

The concept of the 50% Challenge refers to the reality that a student's academic success and development are not solely determined by in-school occurrences (which may account for only approximately 50% or less of their waking hours during the academic year), but are also profoundly influenced by the remaining 50% the out-of-school environment including the community, physical surroundings, and socio-economic conditions. The key challenges faced by teachers regarding this 50% include:

Community and Socio-Economic Challenges: These encompass poverty, food insecurity, lack of access to mental health services, family disruption, and limited social capital or educational resources within the surrounding environment. These

factors collectively create an "opportunity gap" that is difficult to remediate solely through curricular interventions.

Physical Environmental Challenges: These include housing quality (e.g., lead exposure or substandard living conditions), neighborhood crime and violence rates, a lack of green spaces or safe recreational areas, and environmental pollution. These factors directly impact student attendance, concentration, and cognitive health. These out of school 50% factors frequently constitute structural barriers that impede students from fully benefiting from the instruction provided by teachers.

b. The Role of Socio-Political Consciousness

The concept of Sociopolitical Consciousness, introduced by Gloria Ladson-Billings as a fundamental pillar of Culturally Relevant Pedagogy (CRP), has been increasingly recognized and expanded upon in recent scholarship as a prerequisite for educators aiming to promote equity. Contemporary research asserts that this consciousness requires teachers to perceive student challenges not as individual deficits, but as manifestations of systemic inequities and structural failures. Consequently, educators are urged to transcend cosmetic instructional practices and transition into roles as agents of advocacy and justice (Vijfeijken et al., 2024; Holincheck et al., 2024; and Le et al., 2023). This concept has evolved and found manifestation within the CSP framework (Paris and Alim, 2022), which contends that the proactive sustenance of student languages and cultures is unattainable without a transformative consciousness regarding institutional treatment of diverse cultural groups. Therefore, for educators, sociopolitical consciousness serves as a critical lens enabling the analysis of curricula, the identification of systemic biases, and the preparation of students as change agents capable of challenging and transforming social injustices a role heavily emphasized in post-pandemic educational literature focused on an equity 'hard reset' (Brown et al., 2023; and Castro et al., 2025). The Sociopolitical Consciousness Required of Teachers: 1) Transcending Methodology: Ladson-Billings emphasizes that CRP is not merely about utilizing ethnic food or music in instruction (cosmetic practices), but rather about assisting both students and teachers in understanding, critiquing, and resolving social injustice; 2) Acknowledging Individual Limitations: By enhancing sociopolitical consciousness, educators recognize that the challenges students bring into the classroom (e.g., sleep deprivation, hunger, trauma) are not the failures of the individual student or their parents, but rather manifestations of systemic and structural failures (e.g., racism, poverty, discriminatory housing policies); 3) The Teacher as a Limited Activist: Sociopolitical consciousness motivates educators toward advocacy, yet it also highlights the inherent limitations of their efforts. While teachers can utilize critical literacy to discuss injustices, they lack the authority to directly reform housing zoning policies or increase the budget for social services that constitute the roots of the 50% Challenge.

Thus, sociopolitical consciousness underscores that the 50% Challenge is inherently structural, which logically dictates that the solutions must likewise be structural and must transcend the capacity of an individual educator.

c. Institutional Responsibility

Given that the 50% Challenge is systemic in nature, the burden of bridging this gap must be shifted from the shoulders of individual teachers to broader Institutional Responsibility, encompassing schools, educational districts, and other governmental agencies. School leadership must evolve beyond mere managerial roles into positions that proactively advance equity and support transformative change. Khalifa (2020) proposes the Culturally Responsive School Leadership (CRSL) framework, which explicitly mandates that educational leaders analyze and reform policies, practices, and school structures that perpetuate systemic inequities. This responsibility extends beyond the internal school environment. Stosich (2024) further asserts that educational leaders must utilize continuous improvement approaches to systematically advance equity, ensuring that reform is an ongoing process rather than a one-time intervention.

This institutional focus translates into two dimensions of responsibility: 1) School Organization: Schools must cease operating as isolated units. Institutions should be redesigned as Integrated Schools or Community Schools that provide holistic services under one roof (e.g., mental health services, food centers, and employment support for families); 2) Systemic Partnerships: Educational institutions must proactively collaborate with non-educational agencies (e.g., child welfare services, public health services, municipal governments) to directly address the physical environmental and community conditions that impact student.

Ishimaru (2020) perspective explicitly suggests that placing the expectation on teachers (even those with high sociopolitical consciousness) to 'fix' students' home or community circumstances is both inequitable and ineffective. Change within the 50% external environment can only be achieved through the massive mobilization of institutional resources. Teachers are critical frontline agents, but they are components of a larger system that must be held financially and operationally responsible for integrating social services into its core functions.

The 50% Challenge (community and physical environmental factors) indicates significant structural barriers to student success. The literature on sociopolitical consciousness (Ladson-Billings, 2021) helps educators understand that these barriers are systemic, not individual. However, this understanding alone is insufficient. To effectively address the 50% Challenge, institutional responsibility is required, involving the reform of schools into community centers and the creation of systemic partnerships with other social agencies (Ishimaru, 2020; Khalifa, 2020; Stosich, 2024). In summary, teachers can identify the problems, but only institutions and cross-sector

collaboration can provide the necessary solutions and resources to remediate them. Hinz and Swennen (2025) asserts that the current global education agenda necessitates transformative change, with teachers recognized as key figures, yet this transformation must be supported by the larger system.

d. The Unrealized Potential of Cultural Capital in Physics

1) The Challenge of Integrating Local Wisdom (40%) into Education

The concept of the 40% Challenge in the educational context refers to the difficulty of integrating resources and knowledge derived from Local Wisdom (such as indigenous knowledge, traditional practices, and community values) into the formal curriculum and instruction. Mathis (2023) researches Physics teachers' dispositions towards Culturally Relevant Pedagogy; hence, the importance of teachers identifying students' cultural resources. Although educators may acknowledge that approximately 40% of educational content could (and should) be linked to local and cultural contexts to enhance student relevance and engagement, the reality is that this integration often remains superficial and faces significant challenges: 1) Lack of Teacher Resources: Educators frequently lack sufficient training or adequate time to research, validate, and structure curricula that integrate Local Wisdom in a profound manner; 2) Cultural Misconceptions: Integration often halts at a cosmetic level (e.g., utilizing local place names in word problems) rather than engaging with the essence of cultural knowledge and epistemology (Paris and Alim, 2022); 3) Pressure from Standardized Curriculum: The imperative to meet dense national curriculum standards and content-oriented assessments frequently dictates that time must be allocated to core material, consequently positioning the integration of Local Wisdom as a supplementary activity. Constraints on CRT implementation commonly include limitations on planning time, a lack of culturally responsive material examples, and the administrative burden on teachers (Patras et al., 2024).

2) The Resistance of Abstract Physics Concepts to Cultural Integration

Subjects with highly abstract concepts, such as Physics, exhibit significant resistance to the profound integration of Local Wisdom. This occurs for several reasons: 1) The Epistemological Nature of Physics: Senghul, O. (2024) demonstrates that Physics teachers' epistemological beliefs influence their classroom practices. Local Wisdom (e.g., knowledge of winds, ocean currents, or harvest cycles) may offer a phenomenological and pragmatic understanding of the environment, but it rarely possesses the theoretical-mathematical framework required to explicate the abstract laws of modern physics. Modern Physics is constructed upon a universal epistemology that relies on: Mathematical Formalism: Concepts such as quantum mechanics, relativity, or electromagnetism are articulated through a highly abstract and non-intuitive mathematical language. Objective Scientific Method: Physics knowledge is validated through replicable experiments and formulated into universal

laws, which philosophically endeavor to detach from specific cultural contexts. 2) Conceptual Disparity: Abstract physics concepts (e.g., $E = mc^2$, wave-particle duality, or enthalpy) lack readily available conceptual or linguistic equivalents within Local Wisdom. Attempting to directly link the two risks either reducing cultural complexity or oversimplifying the physics concepts.

3) The Deep Integration of Local Wisdom and Scientific Epistemology

Deep integration transcends the use of local wisdom merely as an analogy (e.g., utilizing indigenous house architecture to demonstrate equilibrium). Profound integration focuses on the epistemology, praxis, and values of the culture itself, rather than solely its content. The characteristics of the intended deep integration are as follows: 1) Epistemological Analysis: Deep integration necessitates those students compare and critique the ways knowledge operates within Local Wisdom and Physics. Example: Comparing how indigenous cosmology explains the universe with the scientific cosmological model, and exploring why each model is valid within its own cultural and scientific framework; 2) Investigation of Local Phenomena: Educators utilize local problems as the starting point for physics investigations, aligning with the principles of CSP (Paris and Alim, 2022). Example: Instead of merely using the traditional boat as an example, students are tasked with redesigning the boat's propulsion system based on hydrodynamic calculations to improve efficiency, while utilizing local materials; 3) Critical Cultural Literacy: This integration aligns with the Sociopolitical Consciousness pillar, prompting students to inquire: "Whose knowledge does this physics benefit or disadvantage?"; 4) Redesigning Practical Activities (Practicum): Designing laboratory activities (practicum) that utilize local materials and tools to investigate physics concepts (e.g., employing traditional time measurement methods to calculate velocity), thereby making the scientific process itself culturally relevant.

Peter and Lopush (2025). focuses on culturally responsive assessment practices within a multilingual context. Therefore, although physics concepts are universal, deep integration resides in the pedagogical process and the critical analysis of how that knowledge is generated, validated, and holds meaning across different cultural contexts. De Costa and Ustuk (2025) emphasizes the necessity for teachers to possess a sociopolitical understanding that transcends technical classroom teaching practices.

The 40% Challenge in integrating Local Wisdom into the curriculum is largely attributed to the heavy standard curriculum load, lack of teacher capacity and training, and superficial integration practices (Paris and Alim, 2022). This challenge is exacerbated in subjects like Physics, where highly abstract concepts exhibit strong resistance due to the universal epistemology of physics, which is grounded in mathematical formalism and culturally neutral laws. To overcome these barriers, deep integration that transcends cosmetic analogies is required (Gay, 2018). Deep integration focuses on cultural epistemology and praxis, necessitating

Epistemological Analysis, where students compare the operational methods of scientific and indigenous knowledge, as well as culturally relevant investigation of local phenomena and redesigning practical activities (Practicum). This approach also touches upon critical cultural literacy, empowering students to critique whose knowledge is benefited by the instruction. Therefore, the success of integration resides in the pedagogical process and the critical analysis of the knowledge itself, transforming physics learning into an equitable and culturally relevant experience.

D. Conclusions

This analytical study concludes that the implementation of CRT in senior high school Physics instruction achieves a high degree of process fidelity, fostering critical thinking and inclusive classroom environments. However, the overall contextual relevance remains partial, fundamentally limited by a significant structural gap between the teacher's robust instructional intent (Score 4.5) and the student-manifested cultural output (Score 1.0). This failure is attributed to two systemic flaws: inadequate structural demands within formal assessment mechanisms and significant external barriers, notably the 50% inadequacy in school-community partnerships. This research contributes to CRT theory by empirically validating the conceptualized disconnect between Content Integration and the achievement of the higher CRT tenets: Knowledge Construction and Cultural Competence. The precise quantitative-qualitative measurement of the 4.5 vs. 1.0 disparity provides a unique metric, indicating that the mere inclusion of culturally relevant material (high process intent) is insufficient if the theoretical model of evaluation does not explicitly validate and require students' cultural reflection or meaning-making. This calls for a theoretical refinement emphasizing assessment design as an intrinsic, mandatory component of the CRT framework. For practitioners and curriculum developers, the findings necessitate an urgent re-evaluation of RPP components. The primary practical implication is the mandatory reform of formal assessment tools. Assessments must transition from merely testing universal content knowledge to requiring students to explicitly use local cultural frameworks or wisdom the previously integrated content to construct new knowledge or solve Physics problems. This practical shift is paramount to translating the teacher's commendable pedagogical efforts into measurable, culturally-responsive learning outcomes. The pronounced 50% barrier stemming from weak community engagement and non-responsive physical environments demands policy-level intervention. Institutional leaders and policymakers must transition from supporting individual teacher efforts to cultivating a whole-school institutional commitment to CRT. Policy changes should focus on establishing formal, reciprocal partnerships with local communities and allocating resources to create physical learning spaces that reflect and validate students' diverse cultural identities, thereby dismantling external systemic obstacles that hinder holistic implementation. Future research should focus on intervention and longitudinal studies to address the structural flaws identified. Specifically, we recommend: 1) Conducting intervention research utilizing validated CRT-based instruments (e.g.,

student worksheets/LKPD) where cultural output is explicitly evaluated, to test their effectiveness in closing the 4.5 vs. 1.0 gap; 2) Exploring the long-term impact of institutional policy changes aimed at strengthening school community partnerships and funding culturally affirming physical school environments; and 3) Investigating the correlation between teacher training in assessment literacy specific to measuring cultural competence and the resulting student outcomes.

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