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Cognitive Conflict Integrated CRT Approach Analysis of Students' Conceptual Understanding Using E-Modules

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Abstract: This study aims to analyse students' conceptual understanding and the needs for interactive teaching materials based on a cognitive conflict model integrated with a Culturally Responsive Teaching (CRT) approach. The research was conducted through a survey in three high schools in Padang City: SMAN 4, SMAN 9, and SMAN 11. A qualitative descriptive method was used, supported by a diagnostic test comprising 15 questions classified into four categories: conceptual understanding, lack of understanding, misconceptions, and not knowing the concept. The findings indicate that students' average conceptual understanding remains below 50%. Significant misconceptions were identified in dynamics (41.82%), while high levels of conceptual ignorance were found in kinematics (51.91%). The needs analysis shows that teachers and students require interactive and culturally relevant materials to address these persistent misconceptions and support clearer conceptual construction. The results suggest that teaching materials incorporating cognitive conflict strategies can effectively challenge students' initial ideas, while the CRT approach contextualises physics concepts within students' cultural experiences. In conclusion, the development of interactive e-modules integrating cognitive conflict and CRT is needed to address conceptual difficulties and improve students' understanding of fundamental physics concepts.

Keywords: Cognitive conflict; Conceptual understanding; Culturally responsive teaching; Misconceptions.

Introduction

Education in Indonesia is undergoing a period of accelerated development, particularly with regard to the curriculum. One major component of this transformation is the Merdeka Curriculum, which emphasizes flexibility, personalization, and cultural relevance. Rather than prescribing rigid instructional structures, the curriculum encourages teachers to design learning experiences that respond to students' characteristics, prior knowledge, and cultural backgrounds (Kemendikbudristek, 2022; Rahmadayanti & Hartoyo, 2022; Rosadi & Andriyani, 2021). This approach is intended to strengthen conceptual understanding by situating learning within meaningful, context-based environments.

Conceptual understanding is essential for developing higher-order thinking skills, particularly in physics, where students must apply abstract principles to explain real-world phenomena (Anderson & Krathwohl, 2001). However, many students continue to struggle with conceptual understanding because instruction frequently overlooks their initial conceptions, even though these preconceptions are known to be the root of systematic misconceptions (Arends, 2012; Piaget, 2013). Meaningful learning requires students to actively reconstruct their ideas through processes involving conflict, reflection, and reorganization of mental models. Therefore, identifying and confronting misconceptions is crucial in promoting conceptual change.

Despite curricular expectations, physics learning in many Indonesian classrooms remains dominated by teacher-centered practices. Students are often guided to manipulate equations without understanding the conceptual foundations of the physical principles involved. Consequently, they rarely have opportunities to test or challenge their pre-existing beliefs, leading to

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persistent misconceptions. Learning materials also tend to be generic and detached from students' local realities, limiting both cognitive and cultural relevance.

The Merdeka Curriculum highlights the importance of integrating students' cultural backgrounds into science instruction. However, cultural elements remain minimally incorporated into learning materials, indicating a gap between curricular philosophy and classroom implementation. Integrating cultural aspects is not only an ethical imperative but also an effective pedagogical tool. Culturally Responsive Teaching (CRT) emphasizes using students' cultural experiences, community knowledge, and everyday practices as scaffolds for academic understanding (Gay, 2021). By linking new concepts with familiar contexts, CRT enables learners to construct meaning more effectively (Villegas & Lucas, 2007). Thus, CRT is a promising approach to reducing the cultural disconnect that often weakens students' engagement and comprehension in physics learning.

E-modules have become increasingly popular as digital teaching materials that support independent and interactive learning. While e-modules offer advantages such as accessibility, interactivity, and flexible pacing, most existing designs primarily focus on content delivery rather than on restructuring students' conceptual frameworks or incorporating cultural dimensions. Therefore, their effectiveness depends not only on digital features but also on the pedagogical frameworks embedded within them.

Cognitive Conflict learning is a pedagogical model that has proven effective in promoting conceptual change. Research consistently demonstrates that intentional confrontation between students' misconceptions and scientifically accurate information encourages restructuring of erroneous mental models (Mufit, 2018; Mufit et al., 2020; Mufit et al., 2022). The four stages of this model—activation of preconceptions, presentation of conflict, conceptual construction, and reflection—stimulate deep thinking and facilitate conceptual restructuring. However, conflict-based activities in previous studies are rarely contextualized within students' cultural environments, even though culturally grounded contexts are known to enhance engagement and understanding.

CRT has been shown to promote meaningful understanding by providing culturally resonant entry points for learning (Gay, 2021). Research on CRT-based e-modules demonstrates their potential to improve conceptual mastery (Martha, 2023). However, CRT alone does not directly address the cognitive roots of misconceptions, indicating the need to pair CRT with approaches such as cognitive conflict that explicitly target conceptual change.

Existing studies, including the development of augmented reality materials (Dhanil & Mufit, 2024) and CRT-based e-modules (Martha et al., 2023), offer valuable contributions. Nevertheless, no prior research has developed an e-module that simultaneously integrates three essential components: (1) Cognitive Conflict to address the root causes of misconceptions, (2) CRT to provide cultural relevance and contextual grounding, and (3) digital e-module design to support structured, self-paced conceptual reconstruction. This triple-integration represents a clear novelty in Indonesian physics education research, addressing both cognitive barriers (misconceptions) and contextual barriers (cultural disconnect) within a single learning framework.

Given these gaps, this study focuses on preliminary research analyzing the application of an e-module that integrates the Cognitive Conflict model with CRT principles. By combining these two pedagogical approaches within a digital learning environment, this study offers a theoretically robust and contextually meaningful innovation to improve students' conceptual understanding in physics—addressing both epistemic and cultural challenges that have long hindered learning in Indonesian classrooms.

Method

This research employed a quantitative descriptive research method to analyze students' conceptual understanding. The instruments utilized encompass teacher interview sheets and conceptual understanding test sheets, which are diagnostic tests. This research was conducted at three SMANs in Padang City: SMAN 4, SMAN 9, and SMAN 11.

The diagnostic test consisted of 15 objective multiple-choice items accompanied by two-level confidence ratings ("sure" and "not sure"), which were divided into four conceptual understanding categories: "Understand the Concept," "Understand the Concept Not Sure," "Misconception," and "Don't Know the Concept." The explanations for these categories are provided in Table 1.

Table 1. Concept Understanding Division Category

Concept understanding level	Code	Question criteria	
		Objective questions	Belief
Understand the concept	UC	Correct	Sure
Understand the concept not sure	UCNS	Corect	Not Sure
Misconception	M	Wrong	Sure
Don't know the concept	DKC	Wrong	Not Sure

The questions were developed based on operational question indicators derived from the kinematics and dynamics learning objectives. The grid of question indicators is presented in Table 2.

Table 2. Question Grid

Material	Sub Material	Question Indicator	No Question
Kinematics	Uniform straight motion	Students identify the characteristics of uniform linear motion.	1; 2
	Uniformly accelerated linear motion (vertical motion)	Students determine acceleration and velocity in vertical motion.	3; 4
	Uniformly accelerated linear motion (free fall motion)	Students analyze motion parameters in free-fall situations.	5; 6
	Circular motion	Students interpret relationships between velocity, radius, and centripetal force.	7; 8
	Parabolic motion	Students calculate displacement/velocity components in projectile motion.	9; 10
Dynamics	Newton's laws	Students apply Newton’s laws to determine force, motion, or acceleration.	11; 12; 13; 14; 15

The data obtained were analyzed descriptively. The diagnostic results were converted into percentage scores using Formula 1.

$$S = \frac{N}{R} x\ 100\% \quad (1)$$

Information:
S: Diagnostic test score
R: Number of correct answers
N: Maximum test score

The average score for each value obtained is divided into criteria as shown in Table 3.

Table 3. Criteria for Assessing Students' Conceptual Understanding

Interval	Criteria
86%-100%	Very high
76%-85%	High
60%-75%	Medium
55%-59%	Low
≤54%	Very low

Result and Discussion

This research was conducted by interviewing teachers and diagnostic tests given to students. Interviews and research were conducted at 3 senior high schools in Padang city, namely SMAN 4, SMAN 9, and SMAN 11.

A study of teacher interviews at four schools in Padang, namely SMA Negeri 4 Padang, SMA Negeri 9 Padang, and SMA Negeri 11 Padang, revealed significant challenges in the educational environment. The prevailing pedagogical approach, characterized as teacher-centered or lecture-based, has been found to impede student learning and conceptual understanding. The utilization of learning models has been observed to prioritize the application of equations in answering questions, rather than fostering the development of concepts based on everyday phenomena. Furthermore, the integration of learning with local culture or the environment is lacking. As outlined in the Merdeka Curriculum, students should develop a meaningful understanding by considering local cultural aspects through a culturally relevant learning approach (Kemendikbudristek, 2022). Additionally, learning support sources, such as teaching materials, predominantly use printed teaching materials and occasionally use non-printed teaching materials. Interview data also indicate a clear need for technology-based and misconception-oriented teaching materials, particularly an e-module that explicitly targets conceptual errors in kinematics and dynamics. Teachers reported difficulties addressing misconceptions due to limited time, lack of diagnostic tools, and absence of interactive media—confirming the need for structured digital learning resources aligned with cognitive conflict principles.

The second result of this preliminary research was a learner analysis. The analysis of students conducted is an analysis of students' concept understanding which includes 15 fill-in questions. The results of the analysis can be seen in Table 4 dan Table 5.

Table 4. Analysis of Students' Concept Understanding of Motion Kinematics Material

School	Kinematics of motion (%)			
	UC	UCNS	M	DKC
SMAN 4 Padang	31.06	4.25	12.55	51.91
SMAN 9 Padang	35.56	5	17.22	41.11
SMA 11 Padang	40	0	15.45	42.73

Table 5. Analysis of Students' Concept Understanding of Motion Dynamics Material

School	Dynamics of motion (%)			
	UC	UCNS	M	DKC
SMAN 4 Padang	29.36	4.25	28.10	38.30
SMAN 9 Padang	33.64	4.55	24.55	37.27
SMAN 11 Padang	27.27	0	41.82	30.91

Tables 4 and 5 present the results of the diagnostic test administered, revealing that the average score of students who demonstrated comprehension of the concept was less than 50%. A significant number of students exhibited misconceptions, particularly in the dynamic's material, with a percentage as high as 41.82% at SMAN 11 Padang. While the majority of students lacked understanding of the concept, the highest score, 51.91%, was attained by SMAN 4 Padang for kinematics material. The findings of the diagnostic test indicate that students' conceptual understanding of kinematics and dynamics remains deficient, with a percentage of conceptual understanding falling short of 50%. Numerous research participants have attested to the prevalence of misunderstanding among students, often characterized by misconceptions. Students encounter challenges in comprehending the concept and often resort to memorizing formulas rather than prioritizing understanding (Duit, 2007). A comprehensive analysis of students' responses in kinematics reveals a prevalence of misconceptions concerning uniform straight motion (GLB), circular motion, and parabolic motion. Additionally, a significant number of students demonstrate a lack of comprehension for vertical motion and free fall motion. Furthermore, within the domain of dynamics, students frequently encounter misconceptions in the material pertaining to Newton's laws and the relationship between force and acceleration.

The results of this study indicate that the level of students' conceptual understanding in kinematics and dynamics remains low, with most students unable to make connections between physics concepts and their real-life applications. Poor conceptual understanding reflects the prevalence of misconceptions, which arise because the learning process does not emphasize the active construction of knowledge. Cognitive conflict-based learning models have been demonstrated to positively influence physics learning while simultaneously increasing students' motivation (Mufit & Fauzan, 2019). The implementation of these models has been shown to enhance conceptual understanding and rectify misconceptions, particularly among students with high academic abilities, thereby facilitating the acquisition of deeper and more comprehensive knowledge. A detailed exposition of the syntax of the cognitive conflict learning model is provided in Table 6.

Table 6. CRT integration cognitive learning model syntax

Phase	Syntax description
Activation of preconceptions and misconceptions	Recalling prior knowledge to find out the concept understanding and misconceptions of students before getting new knowledge Teacher activity: give a concept test to identify learners' initial concepts and misconceptions Learner activity: answering questions given by the teacher
Cognitive conflict presentation	Present a phenomenon that can trigger conflict in learners' minds with the CRT approach Teacher activity: present anomalous events and propose hypotheses to elicit cognitive conflicts among learners. Learner activities: provide answers to these hypotheses, engage in critical thinking, and explore ideas about the phenomenon.
Concept and equation discovery	The discovery of concepts and equations is facilitated through a combination of experimental methods and group discussions. Teacher activities: the organization of groups and facilitation of experiments and discussions Learner activities: the conduct of experiments and discussions to construct new knowledge through collaborative work on diverse concepts, the pursuit of logical connections, the evaluation of new information, and the refinement of existing knowledge
Reflection	Conduct class discussions and evaluations to obtain feedback regarding concept comprehension and misconceptions. Teacher activities: facilitate class discussions, distribute knowledge, resolve misconceptions Learner activities: group presentations, propose ideas, share ideas, revise ideas

The cognitive conflict model has been identified as a potentially effective solution to the aforementioned misconceptions. Students are presented with situations that contradict their initial understanding, thereby encouraging them to reconstruct their understanding. The cognitive conflict learning model is compatible with the integration of CRT (Culturally Responsive Teaching) in learning.CRT is a learning approach that involves the use of students' experience and culture to facilitate understanding of a concept of knowledge. The integration of CRT within the cognitive conflict model enables students to comprehend abstract concepts from diverse perspectives, thereby fostering a holistic and profound understanding. Moreover, the incorporation of e-modules, which are interactive teaching materials designed to address learning objectives in a systematic and engaging manner, can facilitate students' concept understanding. These e-modules contain materials, methods, boundaries and evaluation strategies, thus ensuring a comprehensive and effective learning experience.

Based on the description above, this study aims to explore the concept of applying the CRT approach in physics learning that focuses on analyses related to cognitive conflict-based learning in physics subjects with kinematics and motion dynamics material for students in the independent curriculum. The conceptual framework is presented in Figure 1.

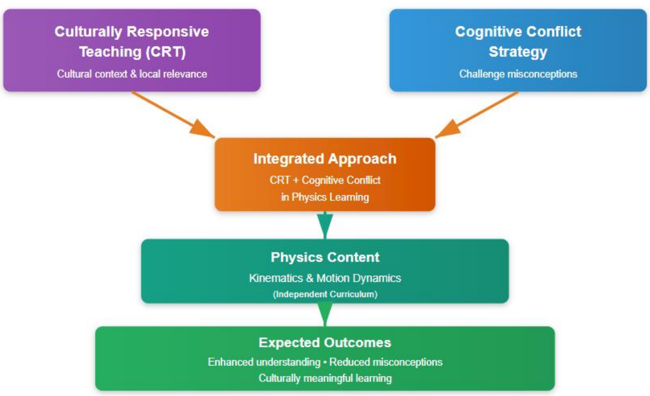

Figure 1. The Conceptual Framework

Conclusion

The study revealed that students' conceptual understanding in kinematics and dynamics was generally low, with less than 50% achieving correct comprehension. Misconceptions were particularly prevalent in dynamics (up to 41.82%) and conceptual ignorance was high in kinematics (51.91%). These results indicate a need for instructional strategies that actively address misconceptions and foster accurate understanding. Integrating the cognitive conflict model with the Culturally Responsive Teaching (CRT) approach, supported by interactive e-modules, is expected to enhance learning by engaging students' prior knowledge, cultural experiences, and providing systematic, interactive materials that promote deeper conceptual comprehension.

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Author Contributions

Conceptualization, Yulianda; methodology design, Yulianda; formal analysis, Yulianda; investigation, Yulianda; project administration, Yulianda; resources, Yulianda; writing—original draft preparation, Yulianda; writing—review and editing, Fatni Mufit and Fuja Novitra; literature review, Fatni Mufit and Fuja Novitra. All authors have read and approved the final version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest

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