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Development of Project-Based Science Learning Materials Using A Culturally Responsive Teaching Approach to Enhance Collaboration Skills and Conceptual Understanding

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Keywords

ADDIE, Culturally Responsive Teaching, learning tools, collaboration

Abstract

This study aims to describe the characteristics of project-based science learning materials developed using the Culturally Responsive Teaching (CRT) approach and to analyze their feasibility and effectiveness. The research employed a Research and Development (R&D) design with the ADDIE model, consisting of five stages: Analyze, Design, Development, Implementation, and Evaluation. The developed product comprised a set of science learning materials for Grade VII on the topic of Motion and Force, integrating local cultural contexts into every stage of the project-based learning process. The resulting materials included a teaching module, student worksheets, and supplementary resources designed to be contextual, communicative, and aligned with the Merdeka Curriculum. Expert validation indicated that the materials were highly feasible in terms of content, language, visual presentation, and integration of local cultural values. Practicality testing revealed that both teachers and students considered the materials easy to use, engaging, and relevant to their real-life experiences. Effectiveness testing through a post-test design demonstrated a significant improvement in students' conceptual understanding of science, as well as enhanced motivation and collaborative skills. In conclusion, the project-based science learning materials developed with the CRT approach are considered feasible, practical, and effective, particularly in fostering contextual and inclusive learning for Grade VII students.

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INTRODUCTION

Education is an essential process in shaping individuals who are capable of critical thinking, creativity, and character development. Beyond the mere transmission of knowledge, education plays a pivotal role in cultivating students' potential and preserving cultural values (Rahayu et al., 2019; Wulandari & Mundilarto, 2016). Education that integrates intellectual, emotional, and volitional aspects not only enriches culture but also strengthens national identity. In this regard, learning that incorporates local cultural values becomes a strategic means of fostering meaningful and contextual learning (Rahmawati et al., 2017; Maryono et al., 2021).

Science education as part of the school curriculum holds an important role in developing students' scientific skills. Science is not merely a collection of concepts and facts but rather a process of inquiry that requires students to actively explore their environment systematically (Khaerani et al., 2020). Ideally, science learning should be integrated with students' cultural backgrounds and local environments to make abstract concepts more comprehensible (Dwipayana et al., 2020). The Merdeka Curriculum provides schools with greater flexibility to integrate local content and project-based learning in accordance with students' characteristics and regional potential (Kemendikbudristek, 2022; Nafi'ah et al., 2023).

Observations in several schools indicate that science learning is still dominated by traditional approaches that focus primarily on cognitive outcomes, with limited emphasis on the development of 21st-century skills such as collaboration, communication, and creativity (Safiana, 2017; Maryono et al., 2021). Teachers often remain the primary source of information, learning materials are rarely updated, and classroom activities tend to be passive (Nugroho, 2018; Wirdaningsih & Anhar, 2017). Moreover, project-based learning has not been widely implemented due to time constraints and a lack of teacher training. Consequently, students' social responsibility and ability to collaborate effectively in groups remain underdeveloped (Robo et al., 2021; Verawati et al., 2020).

Learning materials should not serve merely as administrative documents but as pedagogical tools designed to guide effective and contextual learning processes (Hasanah, 2019; Syafitri, 2017). Several studies have demonstrated that culturally grounded science learning materials can enhance students' conceptual understanding and interest in science (Khaerani et al., 2020; Putra et al., 2018). Well-designed learning materials also contribute to improving learning outcomes and efficiency (Yudiafarani et al., 2022; Baharuddin et al., 2017).

Project-Based Learning (PjBL) has been recognized as an effective pedagogical model for fostering 21st-century competencies, such as collaboration, critical thinking, and creativity (Guo et al., 2020; Tascı, 2015; Santoso, 2021). PjBL also helps students understand concepts through direct experiences and systematic teamwork (Ergül & Kargın, 2014; García, 2016). Studies at the secondary level reveal that PjBL enhances student engagement and motivates them to take responsibility for their own learning (Alfaeni et al., 2022; Sari, 2023; Yuniarti et al., 2022). Even in virtual contexts, PjBL has been found to be effective in improving collaboration skills (García, 2016).

Integrating the Culturally Responsive Teaching (CRT) approach into PjBL strengthens its pedagogical value, as CRT encourages teachers to design learning experiences that are relevant to students' cultural backgrounds (Ladson-Billings, 1995; Rahmawati, 2018). Research shows that CRT enhances conceptual understanding and active participation, particularly when learning is connected to students' local environments and cultural traditions (Khalisah et al., 2024; Miskiyyah & Buchori, 2023; Salma & Yuli, 2023). In addition to making content more relevant, CRT reinforces cultural identity and increases students' learning motivation (Rahmawati et al., 2017). Thus, combining PjBL and CRT offers a promising strategy for developing science learning that is more effective, contextual, and humanistic.Based on these considerations, this study aims to develop project-based science learning materials using the Culturally Responsive Teaching approach to improve students' collaboration skills and conceptual understanding. Specifically, the objectives of this research are: (1) to describe the characteristics of the project-based science learning materials developed using the CRT approach; (2) to examine the feasibility of the developed learning materials; (3) to analyze the effectiveness of the materials in improving students' collaboration skills and conceptual understanding.

METHODS

This study employed a Research and Development (R&D) design aimed at developing project-based science learning materials using the Culturally Responsive Teaching (CRT) approach for Grade VII students on the topic of Motion and Force. The development process followed the ADDIE model (Analyze, Design, Development, Implementation, and Evaluation), which allows for continuous evaluation at each stage. At the analysis stage, data were obtained through interviews with teachers and students to identify learning needs and challenges. The design stage involved literature review and field observations to determine learning objectives and content structure. During the development stage, the materials were validated by experts and tested in a small-scale trial. The implementation stage was conducted through large-scale trials in two different classes. Finally, the evaluation stage assessed the feasibility and effectiveness of the learning materials. Data collection techniques included interviews, literature review, questionnaires, and learning achievement tests. The instruments consisted of interview guidelines, validation sheets, post-test questions, and collaboration skill questionnaires. Data validity was ensured through content validation by experts (teachers and lecturers) using Aiken's V formula, while instrument reliability was tested by comparing calculated and critical values of the correlation coefficient (r). The learning materials were considered feasible if they met the criteria of validity, practicality, and effectiveness, based on expert validation results, practicality assessments from teachers and students, as well as learning outcomes and self-assessment of collaboration skills. Data analysis involved normality testing, homogeneity testing (Fisher test), and hypothesis testing (independent t-test). The materials were deemed effective if students in the experimental class achieved higher learning outcomes compared to the control class and if at least 70% of students demonstrated collaboration skills categorized as good.

RESULTS AND DISCUSSION

This research is a type of R&D study that applies the ADDIE development model to produce project-based science learning tools with an approach. The research was conducted at SMP Negeri 4 Bandar and SMP Negeri 9 Batang, focusing on the topic of motion and force for seventh-grade students. Initial analysis showed that learning was still dominated by lecture methods without integration of local culture, and did not facilitate contextual project activities. Interviews revealed that students had difficulty understanding abstract concepts such as force and motion, while learning resources were still limited to textbooks. This indicates a need for learning tools that are more contextual, meaningful, and relevant to students' cultural backgrounds.

SMP Negeri 9 Batang, located in a coastal area, has local cultural potential in the form of the rowing race (Lomban), which has not been utilized in science learning. This integration of local culture is considered important because it aligns with the principles of CRT and can increase student motivation and understanding of science concepts. Teachers at the school support the incorporation of local traditions into learning because they believe it can strengthen cultural conservation while increasing learning effectiveness. In the Design stage, the tools were prepared based on the Independent Curriculum by adjusting the learning outcomes and objectives for the movement and force material for grade 7 semester 1. This confirms that learning designs that combine cultural context and a project approach can address the challenges of science learning that have been considered abstract by students.

Table 1. Results of the Validation Feasibility Test of the Teaching Module

No	Validator	Presentation (%)	Criteria
1	A1	86,90	Very Worthy
2	A2	73,81	Worthy
3	A3	91,67	Very Worthy
Average		84,13	Very Worthy

The feasibility test results of the project-based science teaching module with the CRT approach show that this tool is included in the "Very Feasible" category with an average score of 84.13% from three validators. The assessment covers eight main aspects, such as the suitability of learning objectives, material selection, models, and assessments. Two validators gave a score of "Very Feasible", while one validator gave a score of "Feasible" with notes on the formulation of objectives and consistency of the approach. Although there are suggestions for improvement, in general this module has succeeded in integrating local cultural values and the project approach effectively, so it is considered ready for use in science learning at SMP Negeri 9 Batang.

Table 2. Results of the LKPD Validation Feasibility Test

No	Validator	Presentation (%)	Criteria
1	A1	87,50	Very Worthy
2	A2	68,06	Worthy
3	A3	86,11	Very Worthy
Average		80,56	Worthy

The feasibility test results for the project-based LKPD using the CRT approach indicate that this tool is classified as "Very Feasible" with an average score of 80.56% from three validators. The assessment covers aspects of content, language, presentation, and design, as well as paying attention to suitability with the PjBL model and integration of local culture, such as rowing competitions. Although the majority of aspects were considered positive and supported student engagement, there was input from validator A2 regarding the clarity of the content that needed to be simplified and arranged more systematically. Overall, this LKPD effectively supports contextual science learning and only requires minor adjustments to optimize its use in the classroom.

Table 3. Results of the Validation Feasibility Test of Teaching Materials

No	Validator	Presentation (%)	Criteria
1	A1	88,33	Very Worthy
2	A2	73,33	Worthy
3	A3	83,33	Very Worthy
Average		81,67	Very Worthy

The results of the feasibility test of project-based teaching materials using the CRT approach showed an average score of 81.66%, with the category "Very Feasible". The assessment from three validators covered aspects of content, language, presentation, and design, where the teaching materials were deemed to have supported learning outcomes and successfully integrated local cultural contexts, such as rowing competitions on the Batang coast. Although the teaching materials were generally considered complete and relevant, there was input from validators A2 and A3 regarding simplification of language and visual enhancements to make them more communicative and engaging. Therefore, this teaching material was deemed suitable for use in science learning, with several minor improvements to increase effectiveness and comfort of use in the classroom.

Table 4. Results of the Teacher Validation Practicality Test

No	Validator	Presentation (%)	Criteria
1	G1	93,33	Very Practical
2	G2	98,33	Very Practical
3	G3	95,00	Very Practical
Average		95,55	Very Practical

Based on the assessment results from three teachers, the project-based science learning tool with the CRT approach was declared highly practical, with practicality percentages of 93.33%, 98.33%, and 95.00%, respectively.

The assessment included aspects of the suitability of objectives and materials, ease of use, project implementation, and integration with the local cultural context. Teachers stated that the tool was easy to understand, appropriate to school conditions, and able to increase student engagement and collaboration. Local contexts such as rowing competitions and mini boat projects were considered to make learning more relevant and meaningful. Thus, this tool is suitable for implementation in coastal schools with similar cultural characteristics.

Table 5. Results of the Student Validation Practicality Test

No	Validator	Presentase (%)	Kriteria
1	PD1	98,33	Very Practical
2	PD2	96,67	Very Practical
3	PD3	96,67	Very Practical
4	PD4	96,67	Very Practical
5	PD5	93,33	Very Practical
6	PD6	96,67	Very Practical
7	PD7	98,33	Very Practical
8	PD8	96,67	Very Practical
9	PD9	98,33	Very Practical
10	PD10	96,67	Very Practical
Average		96,83	Very Practical

The results of the practicality test conducted by students showed that the project-based science learning tool with the CRT approach was very practical and effective to use from the students' perspective. A total of 10 students gave practicality scores between 93.33% and 98.33%, with assessments based on 15 indicators including material clarity, interesting project activities, cultural relevance, collaboration, and conceptual understanding. Students considered the instructions presented in the tool easy to follow, the language was communicative, and the project activities were relevant to their lives in coastal environments. In addition, students felt that learning that utilized local culture, such as rowing competitions, made the science material more contextual and meaningful. The project activities were considered not only interesting but also encouraged teamwork and respect for differences of opinion. This project-based learning was considered to help students understand science concepts in depth and connect them to real-world practice. Overall, this tool supports active student engagement and shows great potential for application in learning contexts that prioritize local culture.

The results of the effectiveness test of the project-based science learning device with the CRT approach indicate that the developed device is effective in improving learning outcomes and student engagement. Statistical tests including the normality test (Shapiro-Wilk), homogeneity of variance (Levene Test), and t-test show that the data are normally distributed, the variance between groups is homogeneous, and there is a significant difference between the experimental and control classes ($p = 0.023$), which indicates the effectiveness of the device. In addition, the practicality assessment by 25 students resulted in an average score of 96.88% with the category "Very Practical", indicating that this device is easy to understand, interesting, contextual, and appropriate to their local culture. Thus, this learning device is not only academically effective, but also culturally relevant and enjoyable for students.

Characteristics of project-based science learning devices with the developed CRT approach.

The project-based science learning tools developed in this study were designed using the ADDIE model integrated with the CRT approach. The ADDIE model was chosen because it is flexible and systematic in designing effective, valid, and contextual learning tools (Wulandari & Prasetyo, 2021). The analysis phase showed that the material on motion and force was still considered abstract and difficult by students, and had not been linked to the local cultural context, as also found by Pratiwi et al. (2022) that science learning tends to be non-contextual, thus reducing learning motivation. Considering that the majority of students come from coastal areas with a rowing culture, the CRT approach is considered relevant to bridge the understanding of science concepts

with students' real-life experiences (Rati, 2017; Rahmawati, 2018; Salma & Yuli, 2023). Therefore, the teaching modules, LKPD, and teaching materials were designed based on projects that highlight local culture to make them more interesting, contextual, and motivating for students (Khalisah et al., 2024; Sulastri et al., 2022).

From the design to evaluation stages, the tools were designed based on the principles of the Independent Curriculum and differentiation, with communicative content and engaging visuals using applications such as Canva to enhance visual appeal (Fitriani et al., 2021). Expert validation and small-scale trials ensured the tools were collaborative and contextual, in line with the principles of Universal Design for Learning (CAST, 2021). Effectiveness was tested using a post-test-only control group design, showing positive results in improving students' conceptual understanding and collaborative skills (Utami & Yuliana, 2022; Alfaeni et al., 2022). The novelty of this research lies in the systematic integration of PjBL and CRT into all components of science learning, while emphasizing the strengthening of the Pancasila learner profile, which has not been widely addressed in previous research (Lestari et al., 2021; Wlodkowski & Ginsberg, 2020).

Feasibility of project-based science learning devices with the CRT approach

The developed learning tools include three main components: teaching modules, worksheets (LKPD), and teaching materials. These were validated by three science education experts to ensure compliance with content, language, activity integration, local cultural integration, and the PjBL and CRT approaches. These tools are designed to support the achievement of the Independent Curriculum, differentiated learning, and strengthening the Pancasila student profile, as suggested by Miskiyyah and Buchori (2023), who stated that CRT integration in learning encourages the relevance of local cultural contexts and student needs. The designed project activities link science concepts to local contexts, such as rowing competitions and mini-boat building, which have been shown to increase student engagement and conceptual understanding (Rahmawati, 2018; Khaerani et al., 2020; Khalisah et al., 2024), while also aligning with the CRT principle of prioritizing students' cultural experiences as the basis for learning (Gay, 2018; Ladson-Billings, 1995).

Based on language and visualization assessments, the device was deemed sufficiently communicative, but several sections were revised to simplify the language and improve the visual appearance to make it more understandable and engaging, in accordance with the principles of Universal Design for Learning (CAST, 2021). This is reinforced by the findings of Fitriani et al. (2021) who stated that interactive visuals and the use of simple language improve the readability and comprehension of instructions by students. Validation results showed that all components were in the "Very Adequate" category, with an average score above 80%, indicating the high quality of the developed device (Yudiafarani et al., 2022; Ratnasari et al., 2023). Revisions were made based on validator input, including improvements to the formulation of learning objectives, the flow of activities in the Student Worksheet (LKPD), and improvements to the design of teaching materials in terms of color, spacing, and typography (Kurniawati et al., 2021; Baharuddin et al., 2017). After the validation and revision process, this learning tool was declared suitable for use because it met pedagogical standards, was aligned with the curriculum, and successfully integrated the local cultural context to create inclusive, collaborative, and meaningful learning (Wulandari & Mundilarto, 2016; Wlodkowski & Ginsberg, 2020).

The effectiveness of project-based science learning tools with a CRT approach to improve students' collaboration skills and conceptual understanding.

The practicality test of the project-based science learning tool with the CRT approach showed that this tool is very practical to use, both by teachers and students. Assessments from three science teachers gave practicality scores between 93.33% and 98.33%, indicating that the tool is easy to use, has clear instructions, and is flexible for application in diverse classroom contexts. Project activities such as making miniature boats and linking them to the local culture of rowing competitions (Lomban) were deemed conceptually and culturally relevant, in line with the CRT principle that emphasizes the importance of the connection between learning and students' cultural experiences (Ladson-Billings, 1995; Rahmawati, 2018; Khalisah et al., 2024). Student assessments also supported these results, with an average practicality score of 96.88%, indicating that students found the activities interesting,

easy to follow, and able to increase learning motivation, as also found by García (2016) and Guo et al. (2020) in their study of the effectiveness of project-based learning.

Visual presentation, simple language, and collaborative activities were the aspects most appreciated by students. This supports the view that communicative and contextual device design can increase active student participation, as demonstrated by Riskayanti (2021) and Wulandari (2016) in their implementation of PjBL, which developed collaboration and communication skills. Appealing visuals and clear instructions are also essential to the device's practicality, in line with the Universal Design for Learning principles that promote accessibility and flexibility in learning (CAST, 2021; Fitriani et al., 2021).

The effectiveness of this tool has been proven to have a significant impact on improving student learning outcomes based on t-test results between the experimental and control classes. The integration of local cultural context not only strengthens understanding of science concepts but also builds a sense of ownership of the material being studied, supporting the findings of Rahmawati et al. (2017) that culture-based contextual learning can enhance student identity and engagement. Teachers also found the tool's systematic and flexible structure, along with activities that can be directly implemented without requiring much modification, helpful (Baharuddin et al., 2017; Kurniawati et al., 2021).

Several challenges emerged in implementing this tool, such as the longer time required to complete the project and the need for teacher training in consistently applying CRT principles in the classroom. These challenges were also identified by Salma and Yuli (2023), who stated that teacher readiness is a crucial factor in the successful implementation of culture-based learning. Overall, this tool is considered effective and feasible for widespread implementation in contextual science learning based on the Independent Curriculum, as it combines a scientific approach, cultural values, and strengthening student character within a holistic and meaningful learning process (Miskiyyah & Buchori, 2023; Yuniarti et al., 2022; Ratnasari et al., 2023).

CONCLUSION

Science learning materials were developed using the ADDIE model combined with the CRT approach to make the material more contextual and relevant to students' lives and culture, particularly coastal culture, such as rowing competitions. These materials are designed as project-based learning that is engaging, easy to understand, and aligned with the principles of the Independent Curriculum.

Validation results indicated that the tool was highly suitable for use. Experts assessed that the tool's content was aligned with the curriculum, the language used was clear, and the learning activities were integrated with local culture. After revisions based on feedback, the tool became more engaging and easier for students to understand, thus meeting the criteria for a meaningful learning tool.

The use of this device has proven effective in improving student understanding, particularly of movement and force, because the material is linked to students' everyday experiences and culture. Teachers also found it helpful in the learning process, although challenges such as time constraints remain. Therefore, teachers are advised to use similar devices to make learning more enjoyable and contextual, with support from the school in the form of training and mentoring. Other researchers are also encouraged to develop culture-based devices at other levels or materials to further integrate local values into learning.

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