The Development of Problem-Based Culturally Responsive Learning in Enhancing Critical Thinking Skills and Cultural Literacy of Science Students

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ABSTRACT

Aim. The study aims to design and evaluate a Problem-Based Culturally Responsive Learning (PBCRL) model to improve Critical Thinking Skills (CTS) and Cultural Literacy (CL) among Indonesian students.

Method. The research applied the Tjeerd Plomp development research procedure and engaged 289 Science Education students from three universities. The PBCRL model integrated problem-based learning and culturally responsive teaching into a five-stage structure. Expert validation and empirical testing confirmed the validity and reliability of both the model and its instruments. The model was initially implemented in a limited classroom setting to examine practicality and later extended to larger classes for broader testing.

Results. The PBCRL model showed high practicality during initial trials. MANOVA results indicated a significant positive effect on CTS and CL, while N-Gain analysis demonstrated moderate effectiveness in improving both competencies.

Conclusions. The findings confirmed that the PBCRL model is both practical and effective in enhancing CTS and CL. It provides a structured, culturally relevant framework for science education in Indonesia.

Cognitive Value. This research adds value by demonstrating that integrating cultural relevance with problem-based learning strengthens students' higher-order thinking and cultural literacy. It also delivers a validated and empirically tested instructional model that educators and researchers can adopt for multicultural classroom contexts.
Keywords: critical thinking skills, cultural literacy, problem-based learning, culturally responsive teaching, science education

Introduction

The learning process is always expected to improve to keep up with the times and is closely related to natural phenomena and systematic objects. However, the development of the times does not mean solving previous problems. There are still many things we need to expose the potential of science learning, one of which is culture. In reality, science can be learned through the culture involved in our daily lives. Culture, like the environment, will influence and instil itself in a person's identity. Local communities develop culture through shared ideas and transmit it across generations. Culture is a complex that includes knowledge, beliefs, arts, morals, laws, customs and abilities, and habits acquired by humans as members of society (Tylor, 1871). Humans are members of society. Culture consists of everything learned from normative behaviour patterns, including all ways or patterns of thinking, feeling, and acting. Local communities create culture through their collective thinking and pass it down from generation to generation. Koentjaraningrat (1986) classifies the form of culture into three forms, namely: (a) the form of culture as ideas, notions, values, or norms; (b) social systems are activities or patterns of human action when interacting in community life; and (c) physical culture as objects of concrete human work (artefacts, crafts, and art). Cultural manifestations are reflection of the daily life of local communities. Cultural values guide the choice of actions, evaluate people and events, and explain their actions (Schwartz, 1999).

Cultural diversity in each region includes social aspects and has the potential to contain scientific aspects that have yet to be optimally explored (Widarti et al., 2025). Researchers consider cultural differences to be one of the causes of variations in learning outcomes in higher education. Cultural differences, which shape how students learn and how teachers taught them in earlier schooling, can prevent students from achieving optimal learning outcomes (Rychly & Graves, 2012). Learning outcomes are the result of thinking to solve a problem. Relevant critical thinking processes must be conducted to produce the best solution for each problem. Critical thinking is a self-regulated judgment that produces interpretations, analyses, evaluations, and conclusions in addition to explanations of the evidence, conceptual, methodological, logical, or conceptual, that form the basis of the judgment (Facione, 2015). Critical thinking, at its core, requires recognising issues, uncovering implicit assumptions, assessing available evidence, and forming reasoned conclusions (Danczak et al., 2017). Critical thinking is a rational and thoughtful process aimed at determining what actions to take or what beliefs to accept (Ennis, 2018). Furthermore, Ennis formulated twelve indicators of critical thinking and summarised them in five activities, namely a) Basic clarification, b) Bases for a decision, c) Inference, d) Advanced clarification, and e) Non-constitutive but helpful - Employing rhetorical strategies.

Students need critical thinking skills (CTS) to formulate solutions to problems. There is also a positive correlation between CTS and learning achievement (Chusni et al., 2022), with self-efficacy (Nur'azizah et al., 2021; Rusmansyah et al., 2021), with scientific reasoning (Dowd et al., 2018), and with creative thinking (Fatmawati et al., 2019; Winarto et al., 2022). However, research results show that 19 out of 100 students have well-developed CTS (Fitriani et al., 2019). Students have difficulty explaining concepts comprehensively (Kusumah, 2019). Students are not used to analysing problems (Jumrodah et al., 2019; Kirana & Kusairi, 2019). Students'

CTS is still low (Irwanto et al., 2018; Islamiyati et al., 2023; Susilawati et al., 2022; Syawaludin et al., 2019).

In order to maximise science learning in a cultural context, other supporting competencies are needed, one of which is Cultural Literacy (CL). CL is the ability to understand and participate in a culture that is not only limited by expressions and language, but can be depicted through behaviour, food, clothing, art and ceremonies and is an expression of values, traditions, mindsets, beliefs, perceptions, and status (Hirsch et al., 1987). Scholars define CL as the capacity to comprehend, apply, and identify both the differences and similarities in individuals' attitudes, behaviour, beliefs, and communication styles (Riani et al., 2018). CL is the ability of individuals and communities to act towards their social environment as part of the culture and country (Selvi, 2024). Students need to master CL in order to be able to establish good communication in the current millennial era (Pujiono & Sahayu, 2021). There are four skills in CL, namely: a) Cross-cultural awareness, b) local cultural awareness, c) critical reflection and thinking, and d) personal skills for acting as a change agent (Polistina, 2009).

Cultural literacy skills are crucial in an increasingly open society, as they provide the tools needed to engage with diverse cultures. However, many cultural elements remain unaddressed in the educational process, particularly within science instruction. On the other hand, the concern of the younger generation for the environment around them tends to decrease over time (Tabi'in, 2017). Students still demonstrate a low level of CL (Nudiati & Sudiapermana, 2020). One thing that lecturers need to focus on is how the cultures in the classroom can run in harmony with the knowledge being taught to achieve learning objectives. A stronger foundation will support the creation of systematic and structured learning.

As discussed above, there needs to be innovation in learning models that accommodate culture without creating gaps but still achieve learning objectives. This research aims to design a learning model that systematically enhances students' CTS and CL, with culture serving as the central theme in problem-based learning. The resulting framework is called the Problem-Based Culturally Responsive Learning (PBCRL) Model. PBCRL integrates principles from both Problem-Based Learning (PBL) and Culturally Responsive Teaching (CRT). PBL, introduced by Howard Barrows at McMaster University's Faculty of Medicine in Canada (Barrows, 1996; Silva et al., 2018). PBL employs real-world problems as learning triggers (Kelly & Finlayson, 2007), PBL follows five stages: (a) presenting a problem to students, (b) organising students for inquiry, (c) facilitating independent or group investigations, (d) guiding the development and presentation of solutions, and (e) evaluating and reflecting on the problem-solving process (Arends, 2012). Educators design PBL to address real-life issues (Orozco & Yangco, 2016) and it is widely recommended for developing students' CTS, as it encourages collaborative idea-sharing in the pursuit of solutions (Yuan et al., 2014).

PBL can provide positive impacts in various aspects, but there are still difficulties experienced by students related to cultural differences in the classroom with diverse cultural backgrounds (Imafuku et al., 2014). CRT was selected to attend PBL in the PBCRL model to overcome these weaknesses. Scholars define CRT as the practice of using cultural characteristics, experiences, and perspectives of diverse ethnic students to teach them more effectively (Gay, 2002). Furthermore, Gay presents the CRT framework, namely: (a) developing a knowledge base of cultural diversity, (b) designing culturally relevant curriculum-responsive teaching, (c) demonstrating cultural awareness and building a learning community, (d) building cross-cultural communication, and (e) building harmony in classroom teaching. Culturally responsive learning highly values and integrates the appropriate student culture into the learning process (Vavrus, 1997).

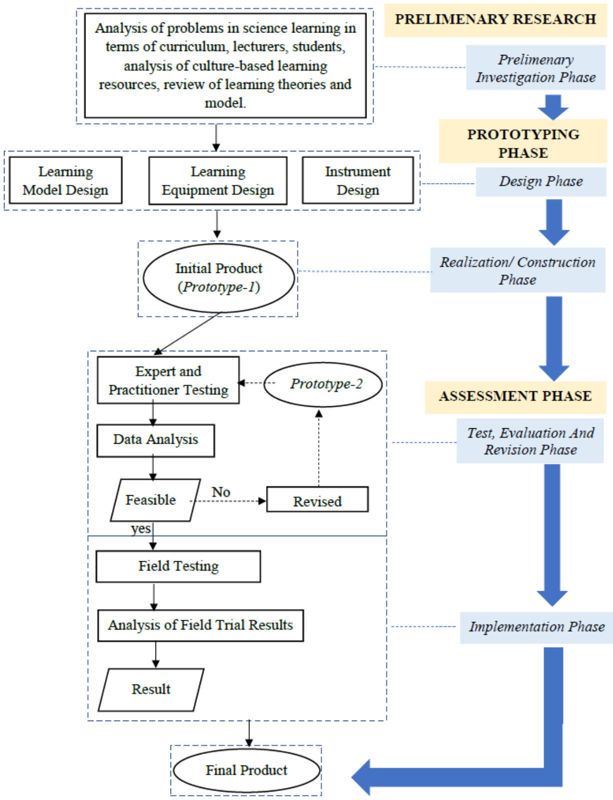
The PBCRL model incorporates learning activities based on Vygotsky's social constructivism theory. Students are led to construct their knowledge by engaging in social interactions based on cultural knowledge. The implementation of activities to construct or build knowledge itself can train students to reason and think critically, namely training students to work together, share ideas, share experiences, knowledge, communicate with each other so that positive interactions occur and ultimately can be actively involved in learning together (Hasnawati, 2006). Students carry out social interactions through cultural devices where thinking is demanded in situations as similar as possible to the real world (situated learning). Cross-cultural communication activities occur between students. This interaction aims to bridge differences in cultural identity and increase cultural knowledge. The primary focus of learning is not only oriented towards learning outcomes but is more emphasised on the thinking process or the process of acquiring knowledge so that learning becomes more meaningful (Doolittle & Camp, 1999; Slavin, 2018). Students will carry out structured and systematic activities packaged in the stages of the PBCRL model supported by relevant learning devices to produce a positive impact, namely increasing CTS and CL.

Method

Research Design

This research follows Tjeerd Plomp's development research model, which consists of three principal phases, namely (a) preliminary research, (b) prototyping phase, and (c) assessment phase (Plomp & Nieveen, 2013). Similarly, the researcher details the three stages in five steps of development research. The research design is shown in Figure 1.

Figure 1
Research Design



Source. Own research.

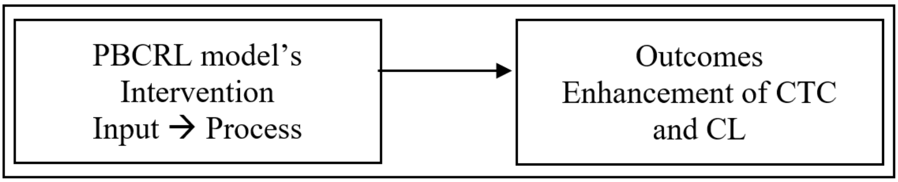
Participants

The study followed five stages: (a) preliminary investigation, (b) design, (c) realisation/construction, (d) testing, evaluation, and revision, and (e) implementation. The preliminary investigation took place at three universities on Java Island—Universitas Sarjanawiyata Tamansiswa, Universitas Negeri Yogyakarta, and Universitas Tidar—selected purposively along with their students. Data was gathered through observations and interviews with three lecturers and 12 students, and the findings informed the study's data requirements. The researchers developed the PBCRL model and test instruments using relevant literature, empirical data, and factual evidence. Five experts in education and science reviewed these products, providing recommendations on their construction and content. These inputs formed the basis for revisions. Subsequently, 161 Science Education Study Programme students from the three universities participated in empirical testing of the instruments, which generated data on validity, reliability, difficulty level, and discriminatory power. The practicality of the PBCRL model was assessed by three observers over four learning sessions involving 116 students at two universities, who also completed the CTS and CL tests.

Procedure

Experts assessed the research products and declared them feasible. Based on this validation, the researchers implemented the products with students. Figure 2 presents the PBCRL intervention model.

Figure 2
PBCRL Model Intervention Design



Source. Own research.

The researchers implemented the PBCRL model at two universities over a seven-week period. Table 1 shows the planned schedule for implementation.

Table 1
Technical Implementation of the PBCRL Model

Week	Expected Final Competencies	Study Materials	Methods	Media	Learning Experience
3 – 4 (2 x 100 minutes)	Students explain, analyse culture, local wisdom, andlocal potential.	Culture, Local Wisdom, andLocal Potential		Video, ppt	Students actively construct knowledge through literacy, discussion, andcritical thinking toexplainandanalyse culture, local wisdom, andlocal potential.

Week	Expected Final Competencies	Study Materials	Methods	Media	Learning Experience
5 – 7 (3 x 100 minutes)	Students detail, describe, analyse traditional knowledge inrelationtoscientific science.	Traditional Knowledge andScientific Science	Implementation-ofPBCRL, with stages: 1. Identificationof-culture 2. Problem formulation 3. Building cross-cultural communicationforproblem solving 4. Presentationof-work results 5. LMS analysisandevaluation	LMS, video, ppt	Students actively construct knowledge through literacy, discussion, and-critical thinking indetail, describe, andanalyse local traditional knowledge and-connect ittoscientific concepts. Theme: Kotagede Silver Crafts
11 – 12 (2 x 100 minutes)	Students identify, describe, andreconstruct community knowledge intoscientific knowledge.	Mapping Community Knowledge intoScientific Knowledge		LMS, video, ppt	Students actively construct knowledge through literacy, discussion, andcritical thinking toidentify, describe, andreconstruct community knowledge intoscientific knowledge, presented asamapping product.

S*ource*. Own research.

The intervention involved structured learning sessions where students engaged in problem-based and culturally responsive tasks. Observers monitored the sessions to evaluate adherence to the model and the quality of its delivery. Students completed the CTS and CL tests both before and after the intervention to measure changes in competencies.

Data Analysis

Following the development of the initial product (prototype-1), the researchers engaged five experts in education, science, and culture to undertake a validity assessment. Each expert received a structured questionnaire addressing three dimensions of the PBCRL model: (a) objectives and rationale, encompassing the relevance and urgency of model development to field requirements, the coherence of its theoretical foundation, anticipated learning outcomes, and class organisation; (b) construction and substance, including syntax, reaction principles, social systems, support mechanisms, and both primary and secondary instructional impacts; and (c) Language including elements of clarity, logic, easy to understand, and not giving rise to multiple interpretations. Validation of test questions in the aspects of (a) Material, including the relevance of question items to material concepts, learning objectives, and student characteristics, and is a reflection of the results of model implementation in learning; (b) construction, evaluating the clarity of instructions, appropriateness of scoring guidance, content relevance, and independence from preceding items construction, evaluating the clarity of instructions, appropriateness of scoring guidance, content relevance, and independence from preceding items; and (c) language. The researchers employed a four-point Likert scale — very suitable (score 4), suitable (score 3), less suitable (score 2), and not suitable (score 1) — and analysed the resulting data using the Aiken equation proposed by Lewis R. Aiken (Aiken, 1980). They subsequently categorised the V values in accordance with the criteria presented in Table 2. The experts also offered feedback, which the researchers used to revise prototype-1, leading to the development of prototype-2.

Table 2
The Aiken's Coefficient Conversion Category

Aiken's V – score	Validity Category
0.80 – 1	Very High
0.60 – 0.79	High
0.40 – 0.59	Medium
0.20 – 0.39	Low
0.00 – 0.19	Very Low

S*ource*. Own research.

The researchers conducted empirical tests on the cultural literacy test questions and critical thinking skills tests before implementing them in the classroom. They administered the test to 161 students across three universities. They assessed validity using the Pearson Product Moment formula (Table score for N = 161, DF = 159 is 0.155) and measured reliability using the Cronbach's Alpha test. To obtain a more comprehensive evaluation of measurement quality, the instrument data was further analysed using the Georg Rasch measurement model to assess both person reliability and item reliability beyond classical reliability indices. The analysis was conducted separately for the Critical Thinking Skills (CTS) and Cultural Literacy (CL) instruments prior to the main statistical analysis. The results showed acceptable person reliability and strong item reliability, indicating that the instruments were suitable for subsequent multivariate analysis, including MANOVA. They examined the difficulty level to determine how challenging the items were for the test takers. They also evaluated discriminatory power to assess the ability of the items to distinguish between high-ability and low-ability test takers. In this study, the researchers accepted items if the discriminatory power results fell within the sufficient, reasonable, or excellent categories. They revised items in the bad category before further use, and they excluded items in the terrible category entirely.

The researchers reviewed practicality by examining the implementation of the PBCRL model during learning. They conducted four face-to-face learning sessions and engaged three lecturers as observers. They focused the practicality review on the accuracy of activities and time in the following aspects: (a) model implementation, (b) reaction principles, (c) social systems, and (d) support systems. The observers provided quantitative data, and the researchers then interpreted these data according to Table 3.

Table 3

Practicality Category

Achievement (%)	**Category**
$85 < X \leq 100$	Very practical
$75 < X \leq 85$	Practical
$65 < X \leq 75$	Quite practical
$55 < X \leq 65$	Less practical
$45 < X \leq 55$	Very Low

S*ource*. Own research.

The study examined the influence of the PBCRL model on students' critical thinking skills (CTS) and cultural literacy (CL) using a MANOVA test ($\alpha = 0.05$), following the completion of prerequisite analyses. The hypotheses were:

H_o: There is no simultaneous effect of the instructional model (PBCRL vs. PBL) on CTS and CL.

Ha: The instructional model (PBCRL vs. PBL) exerts a simultaneous effect on CTS and CL.

They accepted the hypothesis if the significance value (sig.) was less than α. They then measured the effectiveness of implementing the PBCRL model using the N-Gain score (Hake, 1999).

Results

This research has produced a PBCRL model designed to enhance students' CTS and CL. The study comprised five stages, which are outlined below.

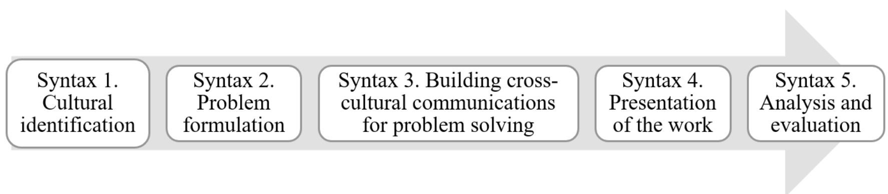
In the preliminary investigation phase, the researchers found that students' CTS were still underdeveloped. Although students already demonstrated the ability to identify a problem, they still struggled to make decisions (solutions). They needed to elaborate more, thus facilitating further clarification regarding what should be accepted as a solution to the problem.

This weakness also indicates weak student literacy. In lectures involving culture, lecturers generally only instruct students to study a particular culture. The condition causes students' CL to be low. Students are less familiar with culture outside of lecturers' instructions. In further understanding, cross-cultural awareness is relatively lacking. Reflection and critical thinking are still minimal when constructing culture into scientific knowledge. Not infrequently, this results in students tending to be apathetic.

Innovation is required in the learning process based on identifying problems that appear in the classroom. Educators need to organise learning systematically and structured it clearly. One way forward is for researchers to develop a new learning model that accommodates culture and science. Integrating PBL and CRT in the new learning model (PBCRL) is complementary. The basic foundation of constructivist theory in the PBCRL model will likely stimulate students in finding, building, constructing, and transforming complex information. Thus, it will improve students' CTS and CL.

The researchers developed the PBCRL model to include five elements, namely: (a) syntax, (b) reaction principles, (c) social systems, (d) support systems, and (e) instructional impacts and accompanying impacts (Joyce et al., 2015). PBCRL also follows the requirements of the learning model: (a) coherent with rational theory, (b) learning outcomes achieved, (c) requiring certain educator behaviour, and (d) requiring a certain class structure Arends (1997). Figure 3 presents Prototype-1 of the PBCRL model.

Figure 3
The PBCRL Steges



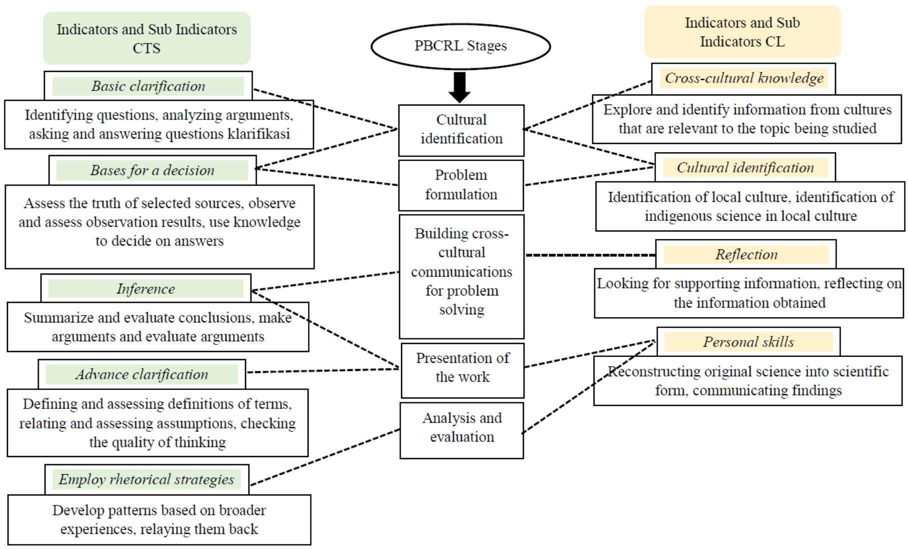
Source. Own research.

The PBCRL model has five stages. (a) In the cultural identification stage, students work in groups to build cultural knowledge based on specific topics or study materials. Students explore various scientific phenomena that originate from the culture of each group member. For example, the Lecturer gives a topic about elements, compounds, and mixtures; then, students explore the culture of each region related to the topic the lecturer has determined. (b) Problem formulation: Students, together with their groups, formulate, study, and analyse problems by the topic. (c) Building cross-cultural communication for problem-solving, students discuss in groups to formulate the identified problems. (d) Presentation of work results; the results of discussions in groups are communicated to the entire class. (e) Analysis and evaluation, where students conduct analysis and evaluation based on class responses and suggestions.

This model is expected to improve students' CTS and CL. The assumption is that each stage contributes to instructional impacts. Figure 4 presents the instructional impacts that appear in the PBCRL model.

Figure 4

The Influence of Stages in The PBCRL model on CTS and CL

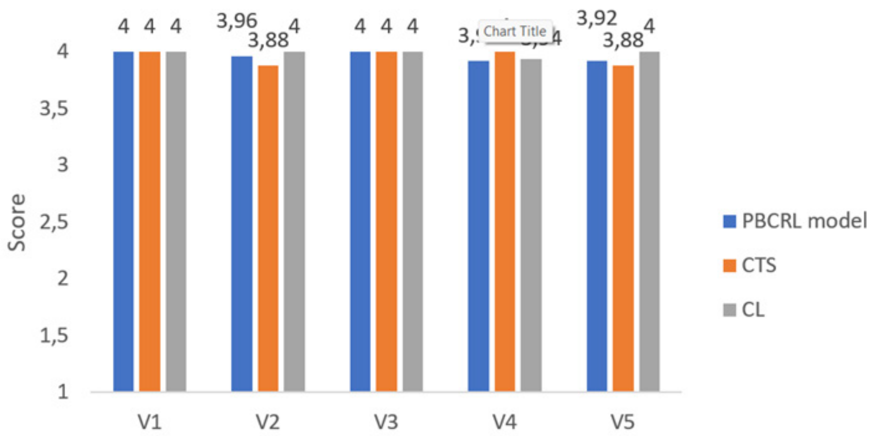


Source. Own research.

The researchers designed the activities in each stage to contribute to students' CTS and CL. There are five CTS indicators and four CL indicators. They measured CTS and CL using test instruments. They developed the question items by considering the related indicators. In this phase, the researchers constructed the overall blueprint of the research and development product and named it Prototype-1.

The test and evaluation product involved five Validators (V) assessing the PBCRL model product, CTS test questions, and CL test questions. Figure 5 presents validation data for each product.

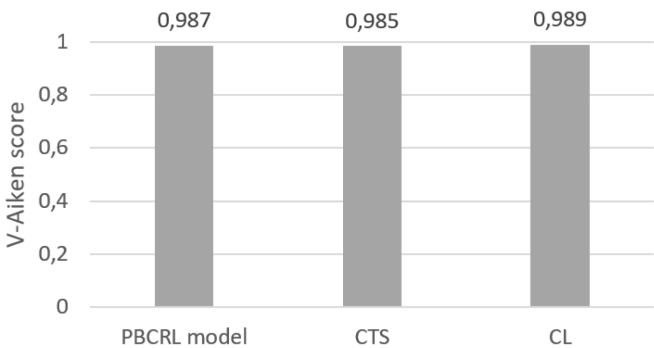
Figure 5
Expert Validation Results



Source. Own research.

The experts noted that the questions were good and required only minor improvements. Specifically, they suggested including the question grid, answer key, and assessment rubric on the same sheet. Figure 6 shows the results of the V-Aiken score calculation.

Figure 6
V-Aiken Score of Research Products



Source. Own research.

Based on the data above, the three results are in the range of 0.8 - 1. Overall, the data indicate that the instrument is valid and falls within the very high category, making it ready for the next phase of the research.

Firstly, the researchers conducted validity, reliability, difficulty index, and discrimination tests on the test-question instrument before applying the model. They tested the instrument on 161 Science Education Study Programme students from three universities. Data analysis confirmed that all questions on the CTS and CL were valid, as the r value exceeded the r table (r table = 0.155; α = 0.05; df = 159). Furthermore, the reliability test with Cronbach-Alpha Test Results obtained 0.709 (∑ of item vars = 20.630, ∑ vars = 58.042), which indicates a high-reliability grade category. To obtain a more robust measurement evaluation, Rasch analysis was subsequently conducted, revealing good person reliability (CTS = 0.72; CL = 0.72) and excellent item reliability (CTS = 0.97; CL = 0.94), supporting the robustness of the instruments. Therefore, the analysis confirmed that the questions were reliable. In addition, the CTS and CL item difficulty-level test resulted in medium-level (M). Here, students answered the test questions consistently. They did not perceive them as too difficult or too easy. The discrimination test produced results ranging from fair to good. There are no items with poor category results. Consequently, researchers can use all items in the CTS and CL test for broader trials.

Secondly, the researchers also tested the practicality of the PBCRL model in a limited class at one University. They conducted four observation sessions. Based on the four meetings, the PBCRL model implemented in the class is very practical. Table 3 presents results' summary of the practicality-observations from the model during learning is presented in.

Table 3

Results of The Implementation of The PBCRL Model

Aspect	S1			S2			S3			S4		
	O1	**O2**	**O3**	**O1**	**O2**	**O3**	**O1**	**O2**	**O3**	**O1**	**O2**	**O3**
Score	3,95	3,85	3,9	4	3,95	3,90	4	3,95	3.95	4	3,95	4
Average	3.80			3.87			3.92			3.95		
Implementation	95.00%			96.67%			97.92%			98.75%		
Practicality criteria	Very practical			Very practical			Very practical			Very practical		

So*urce*. Own research.

Thirdly, the researchers extensively implemented the model at two universities (group 1 and group 2). Each group consists of one Experimental Class (EC) and one Control Class (CC). The research data are presented in Tables 4 and 5.

Table 4

Descriptive Statistics of Group 1

Var	Group	N	Mean	SD	Var.	Min	Max	Skewness	Kurtosis	Normality
CTS	EC	29	20.62	2.04	4.17	17.00	25.00	0.205	-0.503	Normal
	CC	29	14.07	2.95	8.71	7.00	20.00	-0.171	0.062	Normal

Var	Group	N	Mean	SD	Var.	Min	Max	Skewness	Kurtosis	Normality
CL	EC	29	17.76	2.02	4.12	15.00	23.00	0.711	0.278	Normal
	CC	29	11.79	2.58	6.67	8.00	17.00	0.125	-1.076	Normal

Source. Own research.

Table 5

Descriptive Statistics of Group 2

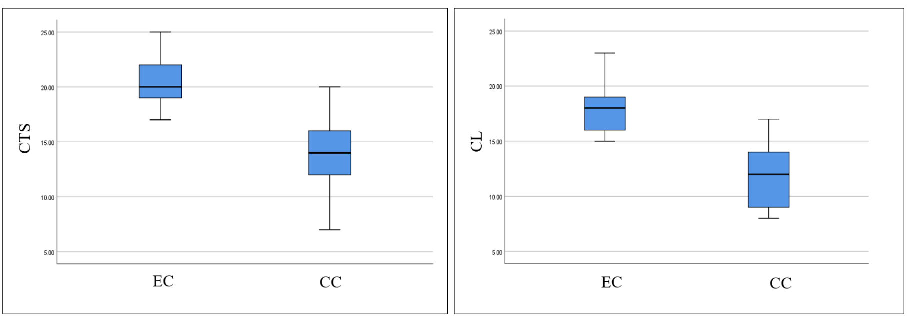
Var	Group	N	Mean	SD	Var.	Min	Max	Skewness	Kurtosis	Normality
CTS	EC	28	21.39	2.15	4.62	17.00	27.00	0.098	0.877	Normal
	CC	28	15.00	2.69	7.26	10.00	21.00	-0.184	0.063	Normal
CL	EC	28	17.96	2.06	4.26	15.00	22.00	0.024	-0.958	Normal
	CC	28	12.57	2.48	6.18	8.00	17.00	-0.325	-0.349	Normal

Source. Own research.

The Box M analysis prerequisite test for both groups showed a Sig. ≥ 0.05 (H_0 is accepted). Thus, ox's M test indicated homogeneity of covariance matrices between groups ($p \geq .05$). Similarly, Levene's test results produced a Sig. ≥ 0.05, which means that the variance between the control and experimental classes is not different. Likewise, the Shapiro-Wilk test showed a Sig. ≥ 0.05, so the data distribution for each variable meets the assumption of normality. Figure 7 and Figure 8 present boxplots of CTS and CL scores by group to provide a visual representation of score distribution. The median scores of the experimental group appear higher than those of the control group, while the spread of scores remains relatively comparable. No substantial outliers were observed, suggesting that the data met the assumptions required for subsequent multivariate analysis. Therefore, the data met the required assumptions and the analysis proceeded with MANOVA. Tables 6 and 7 present the MANOVA analyses.

Figure 7

Boxplots of CTS and CL for Group 1



Source. Own research.

Table 6

MANOVA Test Results Group 1

Multivariate Tests	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Pillai's trace	.719	70.388a	2.000	55.000	.000	.719
Wilks' lambda	.281	70.388a	2.000	55.000	.000	.719
Hotelling's trace	2.560	70.388a	2.000	55.000	.000	.719
Roy's largest root	2.560	70.388a	2.000	55.000	.000	.719

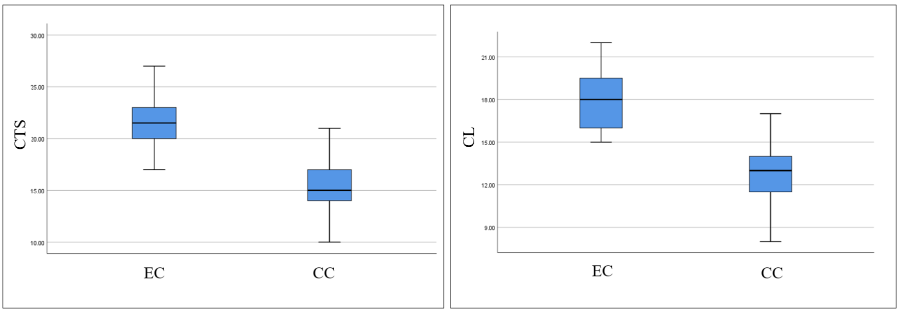
Univariate Tests Dependent Variable		Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
CTS	Contrast	622.414	1	622.414	96.635	.000	.633
CL	Contrast	516.017	1	516.017	95.663	.000	.631

Note. [a] Exact statistic

Source. Own research.

Figure 8

Boxplots of CTS and CL for Group 2



Source. Own research.

Table 7

MANOVA Test Results Group 2

Multivariate Tests	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Pillai's trace	.676	56.167a	2.000	53.000	.000	.694
Wilks' lambda	.324	56.167a	2.000	53.000	.000	.694
Hotelling's trace	2.082	56.167a	2.000	53.000	.000	.694

Multivariate Tests		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Roy's largest root		2.082	56.167a	2.000	53.000	.000	.694
Univariate Tests Dependent Variable		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
CTS	Contrast	585.018	1	585.018	91.961	.000	.641
CL	Contrast	423.500	1	423.500	72.848	.000	.591

N*ote*. [a] Exact statistic.
Source. Own research.

Based on the result, in Table 6 and Table 7, the analysis acquired a Sig. = 0.000 ≤ α, which confirms that simultaneously, the PBCRL model influences CTS and CL. The contribution to each variable in group 1 is 63.3 % to CTS and 63.1 % to CL. In group 2, the model contribution reached 64.1 % for CTS and 59.1 % for CL. Moreover, both groups showed an increase in the average CTS and CL scores in the experimental class compared with the control class. The calculation of N Gain in group 1 produced a score of 0.53 with a moderate category. The N Gain value in group 2 was 0.57 with a moderate category. In summary, these findings demonstrate that the implementation of the PBCRL model achieved a reasonably effective level of improvement in CTS and CL across both groups.

Discussion

To begin with, lecturers cannot ignore the existence of culture in the classroom. The crucial challenge lies in how science lecturers accommodate diversity by actively bringing culture into teaching. In line with this, lecturers design the curriculum and teaching practices so that they reflect students' cultures by linking classroom activities to their cultural and home experiences (Siwatu, 2007). Furthermore, they adapt instruction to suit students' developmental needs, addressing their emotional, cognitive, and educational requirements to enhance student learning. Culture thus emerges as the dominant factor in teaching and learning (Romanowski & Karkouti, 2021).

Moreover, the characteristics of students generally vary with their respective cultural backgrounds. To respond to this diversity, lecturers apply various teaching methods that align with student needs and cultural characteristics (Rahmawati et al., 2019). This study therefore developed a PBCRL model with five syntaxes that can accommodate culture while preserving the essence of the learning process. The development of the PBCRL model places the Lecturer as a guide on the side, presenting problems, asking questions, and facilitating dialogue and investigation by acting responsively to existing diversity. This activity practically produces the principle of reaction, one of the components of developing the learning model.

The social system is designed to centre on students from various regions in Indonesia. Cultural identification activities will direct students to interact with each other and create close relationships. At this point, students will realise their differences and use these differences as learning resources. Lecturers then stimulate students through problem formulation activities through appropriate instructions. The existence of cross-cultural communication activities when solving problems allows students to communicate more deeply, work together, build social solidarity and tolerance, and respect each other. In learning, students are seen enthusiastically telling the culture of their home region. Each student takes the stage to present their culture, while peers actively listen and exchange stories in a supportive and comfortable environment.

At the start of each semester, lecturer set out a learning plan that regulates the topics studied during the lecture. They manage PBCRL implementation in the classroom as part of the support system. In practice, the first step in this model is cultural identification. The advantage of this model is that each student can freely explain the original culture of their respective regions. Moreover, lecturers encourage students to communicate in order to present concepts effectively. Here, culture is a source of learning and a means of communication. Working in culturally diverse learning environments brings both challenges and benefits, while supporting collaboration and problem-solving (Romanowski & Karkouti, 2021). Students will allow their friends to express their opinions. Students are also trained to accept several differences that may be apparent when friends express their opinions. They will listen as a form of knowledge exploration activity.

As a result, the variety of cultures presented will help students enrich their cultural knowledge. This is the initial step in CTS and CL activities, which are important components in leading students to make the right decisions on each problem. Step by step of the PBCRL model stimulate CTS and CL. Reflection on these experiences creates meaning, enabling students to internalise new understandings and develop transformative perspectives that enhance their ability to interact meaningfully with differences (García Ochoa et al., 2016). There are also accompanying impacts during the implementation of the model. Group activities in the PBCRL model can form a framework for communication, student collaboration, and mutual respect.

Equally important, group activities in the PBCRL model actively foster communication, collaboration, and mutual respect. The PBCRL model therefore improves CTS and CL and offers teachers a powerful approach for addressing multicultural classrooms. Finally, by grounding science learning in cultural values and products, students find it easier to grasp scientific concepts. Structured and continuous interactions between students will lead to awareness of differences so that they can reduce discriminatory attitudes.

Conclusions

This study has successfully developed a PBCRL model aimed at improving CTS and CL. The development of the model consists of five phases. PBL and CRT inspire the design of the model. Based on the theories studied, both are complementary for students to construct a cultural concept in science learning. The PBCRL consists of five steps, namely: (a) cultural identification, (b) problem formulation, (c) building cross-cultural communication for problem-solving, (d) presenting work results, and (e) analysis and evaluation. Through these steps, the PBCRL model actively accommodates students' cultural backgrounds and positions culture as a source of learning while encouraging interaction among students. Following this, the research team validated the PBCRL product by involving five experts in the field. The experts, using the Aiken formula, awarded the PBCRL model a very high score of 0.987. Subsequently, the team applied the model at several universities to test its practicality and efficiency. During four lecture sessions, three observers conducted systematic assessments. Importantly, their evaluations confirmed that the PBCRL model was practical for classroom application. In addition, the researchers designed and empirically validated CTS and CL test instruments to measure the instructional impact of the PBCRL model. When analysing the data, the MANOVA test produced a significance score of 0.000, which confirmed the strong influence of the model on CTS and CL. Moreover, the calculation of the N-Gain score obtained a value of 0.53 and 0.57. These results demonstrated that the implementation of the PBCRL model effectively enhanced students' CTS and CL.

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