Jurnal Review Pendidikan Dasar:
Jurnal Kajian Pendidikan dan Hasil Penelitian
Vol 11(3), Oktober 2025

e-ISSN: 2460-8475
http://journal.unesa.ac.id/index.php/PD
https://doi.org/10.26740/jrpd.v11n3.p331-344

Junior High School Students' Responses To 3C3R Problem-Based Learning in Climate Change Education

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Abstract: Climate change education requires learning designs that connect scientific content with real-world contexts and sustain student engagement. The 3C3R problem-based learning (PBL) model comprises content, context, connection, researching, reasoning, and reflecting. Limited research has examined junior secondary students' responses to this model in climate change education. This study examined Grade 7 students' responses to a climate change unit taught using 3C3R PBL and identified the activities they endorsed more and less readily. A descriptive quantitative design involved 28 students at an Indonesian public junior high school who completed a 25-item Likert-scale questionnaire. Rasch modelling and Wright map analysis were used to examine item measures and response patterns. Item measures ranged from −1.18 to 1.31 logits. Teacher-planned problems, honest self-assessment, and group poster presentations were most readily endorsed. Communication during discussion, task sharing, experiment design, and reporting practical results were least readily endorsed. Agreement remained the most frequent response for all items. The findings suggest that structured tasks and visible products were favourably received, while collaborative and inquiry-oriented activities may require additional scaffolding. Given the single-class sample and self-reported data, findings are context-specific.

Keywords: 3C3R Problem-Based Learning; Climate Change Education; Student Responses; Rasch Model; Wright Map.

How to Cite: Perdani, A.S., Mu'aziyah, S.E.S., Jannah, Y.M., & Perez, D.N. (2025). Investigating Students' Perspectives on Implementation of 3C3R PBL on Climate Change Topic Using the Rasch Model. *Jurnal Review Pendidikan Dasar: Jurnal Kajian Pendidikan dan Hasil Penelitian, 11*(3), 331-344. https://doi.org/10.26740/jrpd.v11n3.p331-344

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Article Info:
Received: 29 June 2025; Accepted: 14 September 2025; Published Online: 28 October 2025

Published by:
Pendidikan Dasar Universitas Negeri Surabaya

INTRODUCTION

Climate change education calls for approaches that connect scientific knowledge with students' experiences and encourage meaningful engagement. A systematic review by Rousell and Cutter-Mackenzie-Knowles (2020) found that young people's understanding of climate change was often limited and recommended participatory, interdisciplinary, and affect-driven approaches. Monroe et al. (2019), in a review of 49 intervention studies, identified relevant, meaningful, and experiential activities as common features of effective climate change education. Zeidler et al. (2005) also emphasised ethical reasoning and personal engagement when teaching socially relevant scientific issues.

Problem-based learning (PBL) supports learning through facilitated problem solving and aims to develop flexible knowledge, problem-solving skills, self-directed learning, collaboration, and intrinsic motivation (Hmelo-Silver, 2004). Hung (2006) proposed the 3C3R framework for designing PBL problems. Its core components are content, context, and connection, while its processing components are researching, reasoning, and reflecting.

Previous studies have examined 3C3R and related PBL approaches in science education. Malik et al. (2020) reported an N-gain of 0.65 in students' critical thinking after a 3C3R-based physics unit. Magaji (2021) identified prior-knowledge application, collaboration, modelling, and feedback as features of PBL in secondary science classrooms, while also noting limitations related to teachers' pedagogical knowledge and research time. Bardsley and Bardsley (2007) described a problem-based climate change activity that students found challenging and engaging. In contrast, Wahelo et al. (2025) reported limited contextualisation and implementation barriers among geography teachers in Ethiopian secondary schools. Broader PBL research has also examined effects on knowledge and skills (Dochy et al., 2003). Hung (2011) linked variations in findings to differences in PBL models and implementation, while Fredricks et al. (2004) described student engagement in behavioural, emotional, and cognitive terms. Hmelo-Silver (2004) noted comparatively limited attention to collaboration and intrinsic motivation in PBL research.

Existing studies on 3C3R and PBL in climate change education have primarily examined learning outcomes, teacher implementation, and classroom experiences. Limited research has examined how junior secondary students respond to specific

features of a 3C3R-based climate change unit, including instructional clarity, collaboration, engagement, problem solving, and reflection. This aspect remains underexplored in Indonesian junior high school contexts. Likert-type questionnaire responses are ordinal. Boone et al. (2011) explained the relevance of Rasch analysis for survey development and analysis in science education, while Boone (2016) described its use in constructing Wright maps to interpret survey measures. Rasch modelling can therefore help identify which aspects of a learning experience students endorse more or less readily.

The aim of this study was to examine Grade 7 students' questionnaire responses to a climate change unit taught using the 3C3R PBL model in an Indonesian junior high school context. Addressing an underexplored aspect of 3C3R PBL, the study used Rasch modelling and Wright map analysis to identify which aspects of the learning experience were more and less readily endorsed by students. Accordingly, the study was guided by two research questions: (1) Which aspects of the 3C3R PBL learning experience were most readily endorsed by students? and (2) Which aspects of the 3C3R PBL learning experience were less readily endorsed by students?

METHODS

Research design

This study used a descriptive quantitative design to examine students' responses to a climate change unit based on the 3C3R PBL model. Data were collected once, after the unit, using a student response questionnaire. Rasch modelling was used to place students and items on a common logit scale and order items by endorsement difficulty. Descriptive percentages were also calculated to summarise responses across categories.

Participants and context

The participants were 28 Grade 7 students enrolled in a natural science course at a public junior high school in Indonesia. All received climate change instruction using the 3C3R PBL model as part of the regular curriculum. The researcher taught the unit and prepared the learning materials, including student worksheets. Responses were collected anonymously. With 28 participants, each student represented approximately 3.6% of responses to an item.

Learning intervention

The learning unit followed Hung's (2006) 3C3R framework, comprising content, context,

connection, researching, reasoning, and reflecting. Real-life climate change scenarios connected scientific content with students' daily experiences. Activities included pretests and posttests, guided student worksheets (*Lembar Kerja Peserta Didik, LKPD*), small-group investigations, practical activities, group poster presentations, self-assessment, and peer assessment.

Students completed a structured questionnaire containing 25 Likert-scale items on instructional clarity, collaboration, engagement, problem solving, and reflection. Items addressed specific activities, including problem planning, worksheet use, practical work, group assignments, poster presentations, and assessment. The five response categories were Strongly Agree, Agree, Undecided, Disagree, and Strongly Disagree. Full item statements are presented in Table 1.

Data analysis

Responses were analysed using the Rasch rating-scale approach for ordered categories (Andrich, 1978). Rasch analysis converts ordinal responses into logit measures and places persons and items on a common linear scale (Boone et al., 2011; Planinic et al., 2019). The procedures for estimating person and item measures follow the educational applications described by Boone and Noltemeyer (2017). Lower item measures indicate items that students endorse more readily, whereas higher measures indicate items that are less readily endorsed. The Wright map displays person and item measures on a common vertical scale, enabling comparison of students' response patterns with item endorsement levels. It was used to address both research questions.

Items were grouped into four endorsement levels according to natural breaks in the item-measure distribution: highly endorsed (−0.74 logits or lower), endorsed (−0.61 to −0.06 logits), less readily endorsed (0.04 to 0.52 logits), and least readily endorsed (0.72 logits or higher). Percentages were rounded to the nearest whole number. Because each participant represented approximately 3.6% of responses, the distributions were interpreted with consideration of the small sample. Respondent codes on the Wright map were generated separately from questionnaire records and cannot be linked to individual students. The analysis focused on person measures, item measures, and response distributions. It did not include a control group or an analysis of learning outcomes. Findings therefore describe students' reported perceptions within this class.

RESULTS

Distribution of students and items on the Wright map

Figure 1 presents student and item measures on a common logit scale. Students appear on the left and the 25 questionnaire items on the right. Lower item measures indicate more readily endorsed items, whereas higher measures indicate less readily endorsed items. Item measures ranged from −1.18 logits (Item 3) to 1.31 logits (Item 8), a span of 2.49 logits. Respondent codes indicate positions on the map and cannot be linked to individual students because the questionnaire data were collected anonymously.

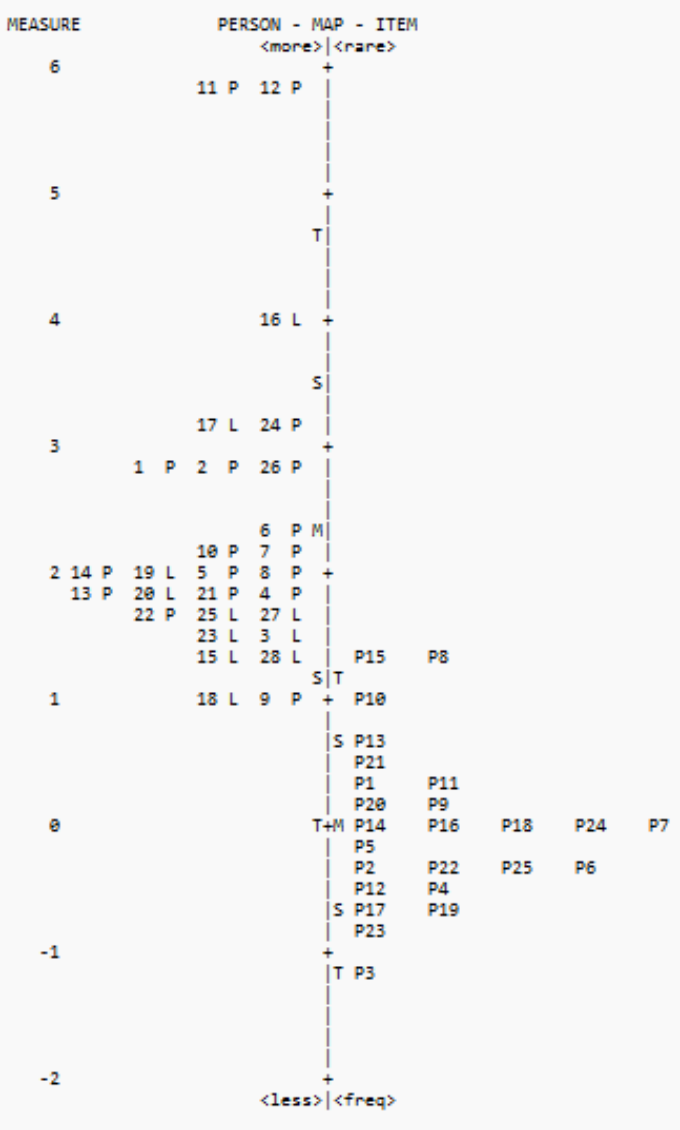


Figure 1. Wright map of student responses to the 3C3R PBL learning process.

The respondent codes on the map should be read as position labels. They were generated separately from the questionnaire records, and students did not write their

names on the questionnaire. This anonymity was intended to allow honest responses to the 3C3R PBL learning process. Consequently, the map describes the spread of student agreement without identifying individuals.

Item measures and endorsement levels

Table 1 presents the 25 questionnaire items, their measures, and endorsement levels. Three items were classified as highly endorsed, eleven as endorsed, seven as less readily endorsed, and four as least readily endorsed. The classification followed the natural breaks in the item-measure distribution described in the Methods.

Table 1. Item measures and endorsement levels of student responses to 3C3R PBL in the climate change unit

Item	Statement	Item measure (logit)	Endorsement level
8	Discussion activities help me improve my communication skills.	1.31	Least readily endorsed
15	I share tasks with friends when working on group assignments.	1.26	Least readily endorsed
10	Designing global warming experiments increases my interest in seeking information.	1.00	Least readily endorsed
13	I report the results of my group's practical work by writing them on the worksheet.	0.72	Least readily endorsed
21	I am interested in listening to presentations from other groups.	0.52	Less readily endorsed
1	The teacher informs students of the learning objectives for the global warming material.	0.29	Less readily endorsed
11	I enjoy doing global warming practical activities.	0.29	Less readily endorsed
20	Group learning activities make it easier for me to determine when group assignments are completed.	0.21	Less readily endorsed
9	Discussion activities motivate me to seek information from various sources (books, the internet, etc.) needed for discussion.	0.13	Less readily endorsed
14	I express my ideas when working on group assignments (designing experiments and making posters).	0.04	Less readily endorsed
18	I enjoy doing assignments in groups.	0.04	Less readily endorsed
7	The questions in the worksheets help me learn to solve problems.	−0.06	Endorsed
16	I enjoy making global warming posters.	−0.06	Endorsed
24	I can give honest assessments to other groups.	−0.06	Endorsed
5	Global warming and climate change are environmental problems that I also experience in my daily life.	−0.16	Endorsed

2	The questions in the initial test on global warming increased my interest in participating in the learning process.	−0.26	Endorsed
6	The questions in the worksheets increase my interest in learning.	−0.26	Endorsed
22	The assessments made by the teacher during the learning process motivate me to be more actively involved.	−0.26	Endorsed
25	After participating in the learning process, I can answer the final test questions more easily.	−0.26	Endorsed
4	The teacher prepares the student worksheets used in the learning process well.	−0.49	Endorsed
12	The global warming practical activity improves my understanding of environmental issues.	−0.49	Endorsed
19	I am responsible for working on assignments in groups.	−0.61	Endorsed
17	I presented a poster created by my group on the topic of global warming.	−0.74	Highly endorsed
23	I can give an honest assessment to my group.	−0.88	Highly endorsed
3	The teacher plans the problems effectively for the learning process on global warming.	−1.18	Highly endorsed

Response distributions

Table 2 presents response percentages for all 25 items. Agreement, combining Strongly Agree and Agree, was the most frequent response category for every item, ranging from 64% for Item 10 to 100% for Items 3, 4, 5, and 23. The highest proportion of Disagree responses was 25% for Items 10 and 15. These distributions complement the item measures by showing the frequency of responses within each category.

Table 2. Percentage distribution of student responses by item (n = 28)

Item	Agreement (Strongly Agree + Agree)	Undecided	Disagree	Strongly Disagree
8	82	18	0	0
15	68	7	25	0
10	64	11	25	0
13	82	11	7	0
21	86	14	0	0
1	82	18	0	0
11	93	4	4	0
20	89	11	0	0
9	96	4	0	0
14	93	7	0	0
18	93	0	7	0
7	96	4	0	0
16	89	4	7	0
24*	89	7	4	0
5	100	0	0	0

2	96	4	0	0
6	96	0	4	0
22	93	7	0	0
25	93	4	4	0
4	100	0	0	0
12	93	7	0	0
19*	89	7	4	0
17	93	4	0	4
23	100	0	0	0
3	100	0	0	0

Note. *Items 19 and 24 were summarised jointly in the response data, so the same combined distribution is shown for both. Percentages may not total 100% because of rounding.

Summary of results by research question

For RQ 1, the most readily endorsed aspects were teacher planning of problems (Item 3, −1.18 logits), honest self-assessment (Item 23, −0.88 logits), and group poster presentations (Item 17, −0.74 logits). Other favourably endorsed aspects included group responsibility (Item 19, −0.61 logits), the contribution of practical activities to understanding (Item 12, −0.49 logits), and worksheet preparation (Item 4, −0.49 logits).

For RQ 2, the least readily endorsed aspects were communication during discussion (Item 8, 1.31 logits), sharing group tasks (Item 15, 1.26 logits), designing experiments (Item 10, 1.00 logits), and reporting practical results on worksheets (Item 13, 0.72 logits). Agreement remained the most frequent response for all items, although Item 10 had the lowest agreement rate (64%) and Items 10 and 15 had the highest Disagree rate (25%).

DISCUSSION

This study examined Grade 7 students' responses to a climate change unit taught with the 3C3R PBL model. Students most readily endorsed teacher-planned problems, honest self-assessment, and group poster presentations. Communication during discussion, task sharing, experiment design, and reporting practical results were less readily endorsed. The following discussion interprets these patterns in relation to previous research and identifies implications for classroom practice.

Structured problem design and visible products received the highest endorsement

Structured problem design, self-assessment, poster presentations, relevant contexts, and guided worksheets received favourable responses. The highest endorsement for teacher-planned problems is consistent with Hung's (2006) emphasis on problem design in the

3C3R framework. Students may have found these activities accessible because they involved clearly defined tasks and observable outputs. Blumenfeld et al. (1991) similarly discussed how meaningful questions and tangible products can support student motivation. The positive responses to poster presentations are consistent with this account.

The findings also align with Monroe et al. (2019), who identified relevant and experiential activities as useful features of climate change education. Bardsley and Bardsley (2007) reported that students found a problem-based climate change activity challenging and engaging. The favourable responses to worksheets may reflect the support that structured questions provide for complex learning tasks, as discussed by Hmelo-Silver et al. (2007). Rousell and Cutter-Mackenzie-Knowles (2020) also emphasised affective engagement in climate change education, while Fredricks et al. (2004) distinguished behavioural, emotional, and cognitive dimensions of student engagement.

The present findings require cautious interpretation. Although 93% of students agreed that the final test was easier to answer after the unit, this represents perceived ease rather than measured learning gains. Malik et al. (2020) reported an N-gain of 0.65 for critical thinking in a 3C3R-based physics unit, but differences in participants, subject matter, and outcome measures prevent direct comparison. Wahelo et al. (2025) identified implementation barriers and weak contextualisation in Ethiopian secondary schools. Differences in context and teacher preparation may help explain variations across studies. In the present study, the teacher also prepared the learning materials and taught the unit, which may have influenced students' responses. Teachers may therefore consider combining carefully designed problems, relevant contexts, guided worksheets, and visible products with assessment routines that encourage honest reflection.

Collaborative tasks were less readily endorsed

Items on communication in discussion (Item 8), sharing tasks (Item 15), and reporting practical results on the worksheet (Item 13) had some of the highest item measures, and Items 18, 14, and 20 on group enjoyment, expressing ideas, and completing group work were also located above the endorsed items. The share of students who selected Disagree was 25% for Item 15, and the share who selected Undecided reached 18% for Item 8. These figures indicate that a minority of students experienced group work as less

supportive, and agreement remained the most frequent response for every item. According to Johnson and Johnson (2009), social interdependence theory identifies elements that support cooperative learning, including positive interdependence, individual accountability, promotive interaction, social skills, and group processing. If these elements were not made explicit in the group tasks, some students may have experienced uneven task sharing, which would fit the pattern observed for Item 15.

Research by Gillies (2016) emphasised the role of the teacher in developing students' thinking and learning in cooperative learning, and Gillies (2014) examined the types of interaction and talk that mediate its success. These accounts suggest that communication skills, which Item 8 addresses, may need explicit teaching and repeated practice. A different pattern was reported by Magaji (2021), who found that collaborative learning was the dominant skill promoted by PBL in secondary science classrooms. This variation may be associated with differences in data sources (observations, interviews, and focus groups in that study, and a questionnaire in the present study), in students' prior experience with group work, and in the support available during group tasks. The observation of Hmelo-Silver (2004) that research on collaboration in PBL was comparatively limited indicates that item-level evidence of this kind contributes to a less examined goal of PBL.

With 28 students, each response shifts a percentage by about 3.6 points, so the collaboration pattern requires replication before firm conclusions are drawn. According to Järvelä and Hadwin (2013), successful collaborative learning benefits from support for regulation at the individual and group levels. Järvelä et al. (2015) described tools designed to support socially shared regulation in groups, and that work concerns computer-supported settings, so its adaptation to face-to-face junior high school groups needs empirical testing. Teachers may assign group roles, use task-sharing records, and allocate time for group processing as practical measures. Future studies can test whether such measures raise endorsement of the collaboration items.

Inquiry-oriented and reflective activities needed more support

Items on designing experiments (Item 10), seeking information through discussion (Item 9), listening to other groups (Item 21), and the teacher informing students of learning objectives (Item 1) were located among the less readily endorsed items, and Item 10 had the lowest agreement of all items at 64%. The processing components of 3C3R, which

are researching, reasoning, and reflecting, call for student-initiated inquiry. As described by Hmelo-Silver (2004), PBL students engage in self-directed learning, which may be demanding for students who are new to the approach. According to Hung (2011), human factors and variations in implementation can shape PBL outcomes. Wahelo et al. (2025) identified time demands and student resistance among the barriers to PBL in secondary schools, so different patterns may emerge in classrooms with longer implementation periods or with students who have more experience of inquiry tasks.

Item 12, on the contribution of practical activities to understanding, was located at the endorsed level, and Item 11, on enjoying practical activities, was located at the less readily endorsed level. This difference suggests that students' perception of the learning value of practical work and their enjoyment of it may vary independently. The questionnaire cannot explain the reason, and interviews could clarify it. For reflection, Zohar and Barzilai (2013) reported that the most prominent practice for fostering metacognition in science education was the use of metacognitive cues and prompts. The lower endorsement of listening to other groups (Item 21, 14% Undecided) and of learning objectives (Item 1, 18% Undecided) may be associated with how explicitly such prompts and goals were presented, and this interpretation is tentative.

The debate on guidance in PBL is relevant to these items. Kirschner et al. (2006) argued that minimal guidance during instruction is less effective, and Hmelo-Silver et al. (2007) replied that PBL incorporates scaffolding that supports learners. This exchange indicates that the level and form of scaffolding matter for the student experience. Teachers may state learning objectives at the start of a unit, provide templates for designing experiments, structure whole-class sharing with listening tasks, and add reflection prompts. Hmelo-Silver and Barrows (2006) described facilitation strategies, including questioning, that support learners' knowledge building, and such strategies could guide teacher actions during experiment design and group reflection.

Theoretical and methodological implications

The Wright map displays a hierarchy in which activities with clear structure and visible outputs are located lower, and activities that require student-initiated inquiry and interpersonal coordination are located higher. As described by Hung (2006), 3C3R distinguishes core components, which support content and context, from processing components, which concern researching, reasoning, and reflecting. The observed

hierarchy appears to correspond to this distinction. The interpretation is tentative because the items were not written to represent each component and the study did not compute component-level measures. According to Boone et al. (2011), Rasch analysis allows hierarchies of this kind to be examined on a linear scale, and future instruments could map items explicitly onto the six 3C3R components.

Limitations and directions for future research

Several limitations should be noted. The data come from one class of 28 students without a comparison group, and the responses are self-reported perceptions that may be influenced by the dual role of the teacher-researcher. Reliability indices and item fit statistics were not reported in this article, so the measurement quality of the questionnaire should be examined in future studies. Anonymous coding prevents linking questionnaire responses to achievement data. Future research could replicate the study with larger samples across several schools, combine questionnaire data with achievement tests, classroom observation, and interviews, and test scaffolds for collaboration, experiment design, and reflection.

CONCLUSION

This study examined Grade 7 students' responses to 3C3R PBL in a climate change unit using Rasch modelling and Wright map analysis. Students most readily endorsed teacher-planned problems, honest self-assessment, and group poster presentations. Items on communication in discussion, task sharing, experiment design, and reporting practical results were less readily endorsed, although most responses to these items still fell in the agreement categories. These findings extend previous research on 3C3R PBL by providing item-level evidence on student responses in an underexplored context. They suggest that teachers implementing 3C3R may combine well-structured problems and visible products with explicit scaffolding for collaboration, experiment design, and reflection. Given the single-class design, the small sample, and the self-reported data, the findings should be interpreted as context-specific. Replication with larger and more diverse samples, together with measures of learning outcomes, is recommended.

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