Assessing Pre-Service Science Teachers' Understanding of Global Warming through the Content Representation (CoRe) Instrument

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Abstrak

Penelitian ini bertujuan mengevaluasi pemahaman konseptual calon guru IPA pada materi pemanasan global menggunakan instrumen Content Representation (CoRe). Desain penelitian bersifat deskriptif dengan pengambilan sampel bertujuan pada mahasiswa tahun kedua Program Studi Pendidikan IPA. Data dikumpulkan melalui delapan butir CoRe yang mendorong responden menguraikan konsep esensial, alasan pentingnya konsep, urutan pengajaran, kondisi siswa, faktor pertimbangan, strategi asesmen, serta kendala yang dihadapi. Jawaban dinilai menggunakan rubrik empat tingkat untuk mengekstraksi profil kekuatan dan kelemahan. Hasil menunjukkan pemahaman berada pada kategori sedang dan cenderung rendah; responden relatif mampu menyebut konsep inti dan alasan pentingnya, tetapi masih lemah dalam menata urutan konseptual, menautkan konteks siswa dengan keputusan pengajaran, serta merumuskan indikator pemahaman yang spesifik. Temuan ini menegaskan perlunya penguatan penguasaan mekanisme konten, literasi asesmen pemahaman, dan praktik berbasis bukti melalui microteaching dan tugas analisis data. Penelitian merekomendasikan integrasi CoRe sebagai wahana refleksi terstruktur dalam kurikulum kependidikan.

Kata Kunci: Asesmen pemahaman, Calon guru IPA, CoRe, Pemanasan global, PCK, Urutan konseptual

Abstract

This study evaluates pre-service science teachers' conceptual understanding of global warming using the Content Representation (CoRe) instrument. A descriptive design was employed with purposive sampling of second-year science education students. Data were gathered through eight CoRe prompts eliciting essential concepts, rationales, instructional sequencing, student considerations, decision factors, assessment strategies, and anticipated challenges. Responses were scored with a four-level rubric to derive profiles of strengths and weaknesses. Findings indicate overall understanding at a medium yet tending-to-low level; participants could identify core ideas and justify relevance, but struggled to organize coherent conceptual sequences, connect student context to instructional decisions, and articulate specific indicators of understanding. These results underscore the need to strengthen mechanism-based content knowledge, assessment literacy for conceptual understanding, and evidence-informed practice through microteaching and data-analysis tasks. The study recommends integrating CoRe as a structured reflection tool within teacher education curricula.

Keywords: *assessment of understanding, CoRe, conceptual sequencing, global warming, pre-service science teachers, PCK*

INTRODUCTION

One measure of a teacher's professional competence is how well they understand the discipline they teach. This capability can be framed as mastery of subject matter (Reza et al., 2023; Yanti et al., 2019). For teachers who graduate from Science Education programs, it is often assumed that they command all areas within science. Over time, however, that assumption has shifted toward a more complex view. Even when teachers know the content well, it is equally important to consider how that content can be made accessible to students (Liu, 2023). For example, by sequencing material from simpler to more complex ideas. Several approaches can support such sequencing, including the use of analogies, concept mapping, and project-based learning (Hasanah & Anfa, 2021; Pedro &

Edinson, 2021; Redhana et al., 2021; Warouw et al., 2023). These strategies are employed to help teachers strengthen students' cognitive development related to the targeted content.

Beyond cognitive abilities, students are expected to master subject matter through a multidisciplinary approach and connect it to everyday life (Han & Shim, 2023)(Han & Shim, 2023). This expectation means teachers must do more than merely know the content; they are required to possess broad and deep knowledge that enables them to design coherent learning sequences as described earlier (Yanti & Rahmadhani, 2023). This competence is known as Content Knowledge (CK). It is one of the three domains comprising the framework of teacher professionalism referred to as Technological Pedagogical and Content Knowledge (TPACK) (Koehler & Mishra, 2006, 2016).

One measure of teachers' professional competence is the extent to which they understand the discipline they teach. This capability can be articulated as mastery of subject matter (Reza et al., 2023; Yanti et al., 2019). For graduates of Science Education programs, it is often assumed that they command the full range of scientific domains. Over time, however, this assumption has shifted toward a more complex view. Even when teachers know the content well, it is equally important to consider how that content can be made accessible to students (Liu, 2023)—for example, by sequencing material from simpler to more complex ideas. Several approaches can support such sequencing, including the use of analogies, concept mapping, and project-based learning (Hasanah & Anfa, 2021; Pedro & Edinson, 2021; Redhana et al., 2021; Warouw et al., 2023). These strategies are intended to help teachers strengthen students' cognitive development related to the targeted content.

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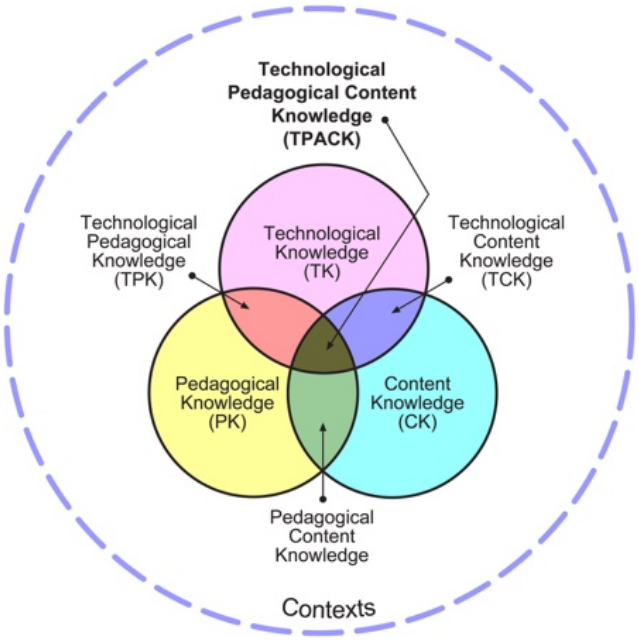

Figure 1. TPACK Framework (Koehler & Mishra, 2016)

Figure 1 points to a central key to successful instruction. The TPACK framework portrays teachers who not only master content but also select pedagogical methods aligned with learner characteristics and leverage technology to represent ideas effectively diajarkan (Hanik et al., 2022;

Long et al., 2022; Yanti et al., 2024). Accordingly, TPACK serves as a suitable reference for teacher education and professional development programs (Cui & Zhang, 2021; Zhang & Tang, 2021).

Beyond conventional educational technologies, TPACK also accommodates the integration of Artificial Intelligence in instruction (AI-TPACK), highlighting its flexibility and adaptability to contemporary developments (Mishra et al., 2023). Nevertheless, many TPACK studies emphasize the interplay among technology, pedagogy, and content, offering limited depth on each component in isolation—particularly Content Knowledge (CK) in the context of global warming (Celik, 2023; Yanti et al., 2020; Yanti & Mawarwati, 2023).

At the lower secondary level, global warming appears in the standard "Analyze climate change and its impact on ecosystems" (Kementrian Pendidikan dan Kebudayaan, 2017). The topic aims to cultivate environmental stewardship and demonstrate science's relevance to everyday life (Darajati, 2020; Venghaus et al., 2022; Weber & Wiesmeth, 2018). Given its complexity and uncertainty, global warming benefits from multi-, inter-, and transdisciplinary perspectives. At the same time, prior work documents persistent student misconceptions—especially regarding temperature change and greenhouse-gas emissions (Aini et al., 2023).

Building on the foregoing, the urgency of this study is to prevent student misconceptions about global warming by first evaluating pre-service science teachers' understanding of the topic using the Content Representation (CoRe) instrument. The empirical rationale is clear: prior research shows that teachers' misprocessing of subject matter is a major trigger of classroom misconceptions (Hamzah et al., 2019; Rohmah et al., 2023; Wulandari et al., 2022). Through CoRe-based mapping, this study seeks early identification of pre-service teachers' conceptual–= pedagogical gaps from the selection of essential ideas and instructional sequencing to indicators of understanding so that targeted interventions can be designed to curb sources of misconceptions from the pre-service stage. In line with this study's context, we hypothesize that the measured level of conceptual understanding will fall in the low-to-medium range, given that the respondents are pre-service teachers with limited practical experience

METHOD

This study employed a descriptive design, consistent with the aim of analyzing pre-service science teachers' content knowledge on the topic of global warming. A descriptive method involves no treatment or manipulation; rather, it portrays conditions as they are (Erickson, 2017; Miksza & Elpus, 2018; Siedlecki, 2020).

Participants were pre-service science teachers enrolled in the Science Education Program, Faculty of Teacher Training and Education (FKIP), Universitas Sulawesi Barat, selected using purposive sampling—a procedure in which inclusion criteria are predefined by the researcher (Fraenkel, 2012). The criteria were: (a) second-year pre-service science teachers, and (b) having passed the courses *Earth and Space Science* and *General Physics*.

The study utilized the Content Representation (CoRe) instrument. CoRe is a tabular tool in which the top row lists the essential concepts—that is, the subtopics chosen to teach global warming—while the left column contains a set of prompts that must be answered for each essential concept (Loughran et al., 2008). The specific prompts included in the CoRe instrument used in this study are summarized in Table 1.

Tabel 1. Content Representation Qestions

CoRe Questions	Essential Concept 1	Essential Concept 2
1. What will you teach students about this concept?		

2. Why is this concept important for students to learn? 3. Which related ideas/concepts do you consider not yet appropriate for students at this level? 4. What difficulties do you experience in teaching this concept? 5. What student characteristics or contexts do you take into account when teaching this concept? 6. What factors do you consider in deciding how to teach this concept? 7. What instructional sequence do you choose for teaching this concept? 8. How do you determine whether students have understood the concept or not?	

RESULTS

The central problem addressed in this study is the limited, in-depth analysis of pre-service science teachers' content knowledge, which is assumed to contribute to student misconceptions. To address this gap, we conduct a focused investigation of pre-service teachers' content knowledge on global warming using the Content Representation (CoRe) instrument, which captures both the breadth and depth of their understanding. Unlike conventional test formats that primarily judge correctness, CoRe employs open-ended prompts, enabling responses that reveal the coherence, completeness, and justifiability of the teachers' content knowledge.

Before presenting the findings, we briefly outline how CoRe was implemented. Respondents completed eight reflective prompts covering: what is taught, why it matters, which related ideas are postponed, anticipated teaching difficulties, salient student characteristics, instructional decision factors, preferred instructional sequencing, and means of verifying student understanding. Each prompt elicited a concise, classroom-oriented narrative (approximately three to six sentences). Responses were evaluated with a four-level rubric emphasizing conceptual accuracy, depth of reasoning, contextual relevance, and clarity of success indicators. A score of 4 denotes specific, accurate, mechanism- and evidence-informed answers grounded in classroom context; a score of 3 indicates adequate specificity with partial or inconsistent use of evidence or criteria; a score of 2 reflects general or superficial statements; and a score of 1 signals inaccuracies, irrelevance, or minimal articulation. Item scores were then averaged to profile each respondent's response quality and categorized as low, medium, or high to foreground conceptual–pedagogical strengths and gaps discussed in the subsequent Results and Discussion.

Figure 2. Score Percentage of CoRe answers

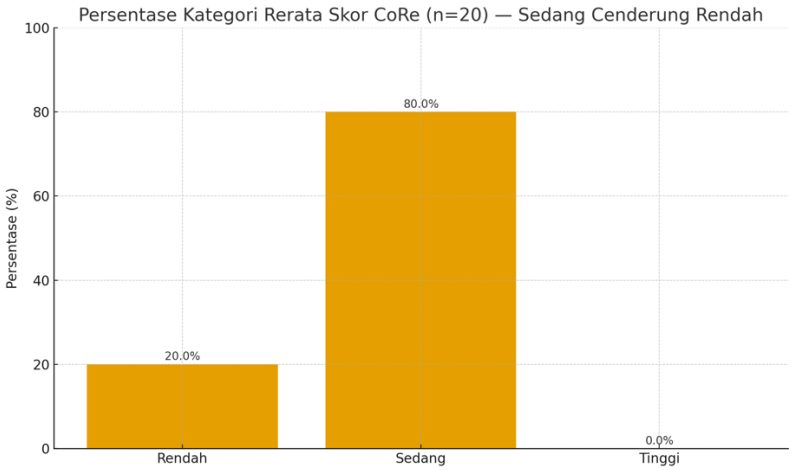

Figure 3. Average percentage of CoRe Categories

Using the Content Representation (CoRe) instrument, the initial mapping of pre-service science teachers' conceptual understanding shows Medium (80%), Low (20%), and no High categorizations. This pattern confirms the study's central concern: pre-service teachers' understanding remains medium and tending toward low—they can identify core ideas, but depth of reasoning, linkage among concepts, and sound pedagogical decision-making are not yet robust.

Across the eight CoRe prompts (what is taught, why it matters, postponed concepts, anticipated difficulties, student context, decision factors, instructional sequence, and indicators of understanding), score 2 predominates on most items, indicating responses that are largely general or declarative and not consistently evidence-informed. Score 1 still appears on the student-context and instructional-sequence items, suggesting challenges in connecting classroom realities to instructional choices. Score 3 emerges only sparingly—more often on the "importance" and "postponed concepts" items—while score 4 is virtually absent. Taken together, these results underscore the need to strengthen evidence-based reasoning, coherent conceptual sequencing, and the articulation of specific indicators of understanding to advance pre-service teachers' content knowledge.

DISCUSSIONS

1. Students understanding about global warming

Building on the "medium–tending-to-low" profile captured by CoRe, the principal implication is to reframe the evaluation of global-warming understanding for pre-service science teachers toward conceptual evidence rather than definitional recall. The CoRe outputs make visible persistent weaknesses on items that demand mechanistic reasoning—for example, articulating the radiation–absorption–re-radiation relations and differentiating natural greenhouse effects from anthropogenic global warming—as well as on specifying clear indicators of attainment. Accordingly, evaluation should incorporate claim–evidence–reasoning tasks using authentic data (e.g., anomaly temperature graphs, atmospheric CO_2 concentrations, sectoral emissions), supported by performance rubrics that explicitly probe conceptual accuracy, mechanistic justification, and transfer to local contexts. These recommendations are consistent with literature indicating that CoRe is effective in surfacing content–pedagogy gaps and guiding the design of more meaningful assessments (Sannert et al., 2025; Yanti et al., 2020)

Compared with prior studies on pre-service science teachers, our findings align with the broader tendency for content mastery to plateau at a medium level (Chan, 2023). Earlier research also notes that respondents readily state "what to teach" and "why it matters," yet struggle when asked to elaborate coherent conceptual sequencing and specific indicators of understanding. The distinctive feature of our results is the sharper shortfall on evidence-based reasoning, particularly in formulating indicators of understanding and justifying instructional sequences both clustering at mid-to-lower performance levels. This contrasts with some reports that describe more even gains in assessment planning; in our context, conceptual assessment literacy and sustained use of evidence appear not yet habitual.

The still-generic descriptions of student context indicate that the knowledge of students' understanding component of PCK encompassing awareness of preconceptions, common misconceptions, variation in readiness to learn, and language/representational barriers—has not yet been fully internalized as a basis for instructional decision-making. Consequently, knowledge of instructional strategies also appears underdeveloped: conceptual sequencing and the choice of approaches remain largely generic because they are not derived from a specific learner profile (e.g., differentiating strategies for students with low versus high data literacy, or using multimodal representations to bridge particular misconceptions).

Fragility in these two components then resonates into knowledge of assessment within PCK: success indicators tend to be global and are not designed to capture shifts in understanding that are meaningful for actual learners (for instance, indicators that trace the reduction of greenhouse-effect misconceptions or the ability to interpret locally sourced graphs). Thus, the medium–tending-to-low outcomes on the "student context" and "decision factors" items are not merely matters of incomplete responses; they signal that the bridge across PCK components—from recognizing learner characteristics, to selecting fit-for-purpose strategies, to designing aligned assessments—has not been firmly constructed. Going forward, CoRe can serve as a scaffolding vehicle to link these three components explicitly: each statement about student context should be followed by a strategic consequence in the instructional design and an observable assessment indicator, so that PCK develops not only as declarative knowledge but as an operational pedagogical rationale in practice.

A plausible explanation for this profile relates to the respondents' status as pre-service teachers at an early stage of their professional trajectory. Their opportunities for teaching practice and engagement with empirical classroom data are likely limited; as a result, their "why" and "how" arguments—especially on items requiring evidence and measurable indicators—tend to be declarative rather than analytic. In addition, the habit of designing conceptual sequences that integrate

phenomena model data application appears to be underdeveloped in microteaching scenarios, yielding linear, definition-centered progressions.

Within the global-warming topic, the findings also point to persistent, characteristic misconceptions among pre-service/early-career teachers—for example, equating the greenhouse effect with global warming or conflating ozone issues. Without early diagnosis, such misconceptions easily carry over into classroom practice and shape choices of sequencing and examples (Hanke & Schmalor, 2025; Pardo et al., 2024). Accordingly, the student context → strategy → assessment chain needs to be strengthened through CoRe-based scaffolding that prompts pre-service teachers to articulate strategic consequences for every piece of information about learners, while simultaneously developing specific, evidence-informed indicators of understanding (Sannert et al., 2025)

2. Implications for Education Curricula

Implikasi langsung bagi pengembangan kurikulum di program kependidikan adalah perlunya Two areas of strengthening are recommended. First, deepening content through mechanisms by sharpening interconcept linkages and guiding students to construct explicit maps of essential concepts. Second, assessment for conceptual understanding through the routine use of specific success indicators, data-driven analytic tasks, and structured feedback. The integration of evidence-based activities—for example, interpreting trend graphs, analyzing local case studies, and engaging in claim–evidence–reasoning—should become a regular feature of both content and pedagogy courses so that students habitually connect concepts to data and context (Nilsson & Karlsson, 2018; Schultze et al., 2018)

For pedagogical competence development, these findings call for a refinement of microteaching that evaluates not only presentation performance but also the quality of conceptual sequencing and the rationale for assessment (Dragnić-Cindrić & Anderson, 2025). Microteaching scenarios should be engineered to surface difficult instructional decisions—such as selecting prerequisite concepts, timing the introduction of counterexamples, or probing characteristic misconceptions so that pre-service teachers must articulate the reasons behind their choices. This approach is strengthened by CoRe-based rubric feedback, enabling students to see a direct link between the quality of their reflective responses and the instructional designs they will enact in practice.

Substantively, the results corroborate the study's hypothesis: participants' understanding sits at a medium, tending-to-low level, with clear weaknesses in depth of reasoning, in establishing coherent conceptual sequences, and in formulating evidence-based indicators of understanding. The findings align with prior work in the prevalence of declarative responses and a tendency toward linear sequencing; they differ in our context by showing weaker evidential argumentation; and they are distinctive in the contrast between the ability to list concepts and the ability to operationalize assessment of understanding (Behling et al., 2025; Konadu & Student, 2025)

The broader implication for the field is the need to bridge content knowledge and assessment literacy early in teacher preparation. When pre-service teachers are habituated to interrogate data, test conceptual claims, and articulate clear success indicators, they not only understand the ideas but also learn how to verify students' understanding. Over time, this shift can enrich science teaching in schools by making pedagogical decisions more transparent, measurable, and locally relevant.

This study has limitations. The small, single-institution sample constrains generalizability. The data were collected through reflective CoRe responses and therefore depend heavily on respondents' written articulation; without classroom observations or instructional artefacts, some aspects of practice may be underrepresented. In addition, although rater agreement was supported by a rubric, scorer bias remains possible. These limitations motivate follow-up studies with more diverse

samples, triangulation via observation and product analysis, and stronger procedures to enhance scoring reliability.

CONCLUSION

This study shows that pre-service science teachers' conceptual understanding of global warming mapped with the Content Representation (CoRe) instrument rests at a medium, tending-to-low level. Participants can identify core ideas and articulate why the topic matters, yet they struggle with mechanistic reasoning, coherent conceptual sequencing, and the formulation of specific, evidence-informed indicators of understanding. Descriptions of student context remain general and are not consistently translated into instructional decisions, indicating that key strands of PCK knowledge of students, instructional strategies, and assessment are not yet tightly integrated.

Accordingly, we recommend reframing evaluation from definitional recall to conceptual evidence, emphasizing two priorities: (1) deepening content through mechanisms by sharpening interconcept linkages and making essential concept maps explicit; and (2) assessment for conceptual understanding via clear success criteria, data-driven analytic tasks, claim–evidence–reasoning, and structured feedback. Microteaching should assess not only presentation but also the rationale for sequencing and assessment, supported by CoRe-based rubrics. While the small, single-institution sample and reliance on reflective responses limit generalizability, the study provides an actionable diagnostic to bridge content knowledge and assessment literacy early in teacher preparation, fostering pedagogical decisions that are more transparent, measurable, and locally relevant.

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