

Analysis of Science Teachers' Content Knowledge on the Concept of Global Warming

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Abstract

The ability of teachers to interpret the curriculum is essential in the preparation stage of teaching. This ability includes how teachers sequentially organize content from simple to more complex material. Teachers are also expected to master the subject matter, meaning they have broad and deep understanding of the material. Therefore, the aim of the research is to explore teachers' understanding of the material taught. This research was conducted using a descriptive method by applying an instrument for understanding the concept of global warming. The participants in this study were 19 Science teachers who are members of the Science Teachers Working Group (MGMP) in Majene Regency, West Sulawesi. The results showed that, in general, Science teachers have fairly good CK, evidenced by the percentage of teachers with moderate and high CK being 55% and 15%, respectively. Teachers understand the topic being discussed. However, not in depth or not mastered well. This is evidenced by the lack of depth of teachers' answers related to a problem, in other words, teachers cannot elaborate on the answers with things that can be accepted by students.

Keywords: *Content Knowledge, Global warming, Teacher, TPACK*

Introduction

One measurement of a teacher's professional competence is how well they understand the field of knowledge they are pursuing. This ability can be described as the mastery of material (Reza et al., 2023; Yanti et al., 2019). Teachers who have pursued a study program in Science Education can be easily assumed to master all areas of Science. However, over time, the notion of merely mastering the material has shifted to something more complex. Although teachers master their material, it is also important to consider how the material can be easily received by students (Liu, 2023). For example, by creating a flow of material from easy to difficult. There are several methods to create a material flow, such as using analogies, creating concept maps, or project-based learning (Hasanah & Anfa, 2021; Pedro & Edinson, 2021; Redhana et al., 2021; Warouw et al., 2023). This is done so that teachers can enhance students' cognitive abilities related to the material.

In addition to cognitive abilities, students are expected to master the material with a multidisciplinary approach and be able to relate it to everyday life (Han & Shim, 2023). This is what makes teachers not only need to master the material but also required to have deep and broad knowledge so that they can create a material flow as previously explained (Yanti & Rahmadhani, 2023). This competence is referred to as Content Knowledge (CK). This competence is one of the three frameworks of teacher professionalism competencies included in Technological Pedagogical and Content Knowledge (TPACK) (Koehler & Mishra, 2006).

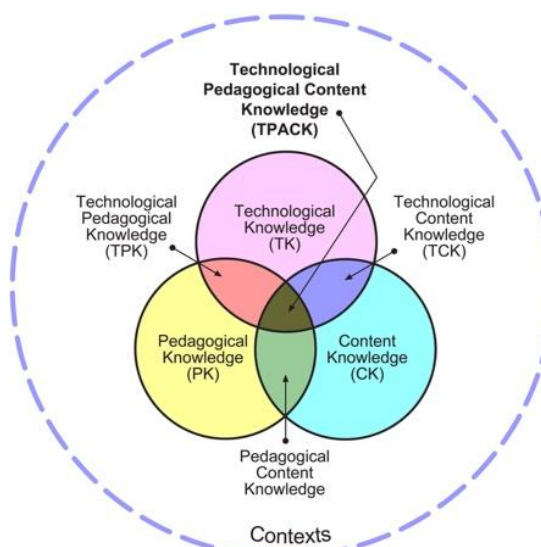


Figure 1. TPACK Integration Framework (Koehler & Mishra, 2006)

Figure 1 is the key to successful teaching. TPACK depicts teachers with the ability to master the material and choose methods that match student characteristics, as well as the appropriate use of technology in illustrating the material being taught (Hanik et al., 2022; Long et al., 2022; Yanti et al., 2024). Therefore, TPACK is suitable to be used as a reference in the implementation of educational programs or teacher professionalism development (Cui & Zhang, 2021; Zhang & Tang, 2021).

Furthermore, the TPACK framework is not just about mastering educational technology, but also the application of Artificial Intelligence in teaching, hence referred to as AI-TPACK (Mishra et al., 2023). This demonstrates that TPACK is a flexible and adaptive framework to the times. However, research discussing TPACK tends to link its three components, namely technological, pedagogical, and content knowledge (Celik, 2023; Yanti et al., 2020; Yanti & Mawarwati, 2023). Therefore, there is no clear and in-depth depiction of one knowledge component, including Content Knowledge, especially on global warming material.

At the junior high school level, the concept of global warming is included in Basic Competence (KD) 3.9, which is "Analyzing climate change and its impact on ecosystems" (Ministry of Education and Culture, 2017). The content of the global warming concept is taught to instill awareness in students about the importance of preserving the environment (Darajati, 2020; Venghaus et al., 2022; Weber & Wiesmeth, 2018). Additionally, the concept of global warming can be reviewed with multi-, inter-, and trans-disciplinary approaches due to its high complexity and uncertainty in both short-term and long-term events. Some studies also show that in the concept of global warming, students often experience misconceptions, especially on topics like temperature change and greenhouse gas emissions (Aini et al., 2023). Based on this, the urgency of this research is to avoid student misconceptions related to the concept of global warming. Research results indicate that one cause of misconceptions is the incorrect processing of material by teachers (Hamzah et al., 2019; Rohmah et al., 2023; Wulandari et al., 2022). The discussion in this proposal will follow the pattern of solving the problem statement, which is How is the Content Knowledge of Science teachers on global warming material?

The research problem lies in the lack of in-depth analysis related to Science teachers' content knowledge. This is assumed to cause misconceptions among students. Therefore, the proposed solution is an in-depth investigation of Science teachers' content knowledge using test instruments that depict how deep and broad teachers understand the global warming

material. The instrument used is an open-ended question, meaning the answers to the questions posed to teachers are not only judged by correctness but can also fully describe the teacher's content knowledge and be explained objectively. Because the tendency so far is that the ability of teachers to understand the material is assessed using test instruments. This problem-solving approach is expected to become a new method in the selection process of teacher candidates in various institutions.

Research on TPACK has been widely conducted (Fuada et al., 2020; Hanik et al., 2022; Yang et al., 2021). Almost every study has a common discussion, focusing on TPACK integration. Research conducted by Yanti, M (Yanti & Mawarwati, 2023) shows that the TPACK ability of prospective teachers in Science subjects is in the medium category because they are still in the third semester, resulting in less teaching experience. However, research discussing TPACK elements separately is still limited. A study specifically discussing Content Knowledge was conducted by Ekawati (Ekawati et al., 2018), which compared the Content Knowledge of two Mathematics teachers. The results showed that teachers with low Content Knowledge tend to follow the book without any development aspects. The instrument used was a paper and pencil test, where the teacher's answers were determined based on correctness. However, there has been no research that specifically examines teachers' content knowledge in the field of physics and uses an open-ended question instrument.

This research uses a new approach in terms of data acquisition by applying open-ended questions so that teachers' answers can be analyzed more deeply (Martins et al., 2022; Suntoro & Setyaningsih, 2022; Turino Januar Budyanto et al., 2023). Therefore, the aim of the research is to explore teachers' understanding of the global warming material.

Method

This research is descriptive, aligning with the research objective, which is to analyze Science teachers' content knowledge on the concept of global warming. The descriptive method does not provide any treatment or manipulation but describes the conditions as they are (Erickson, 2017; Miksza & Elpus, 2018; Siedlecki, 2020). The participants in this study were 19 Science teachers who are members of the MGMP Science in Majene Regency, selected using purposive sampling. Purposive sampling is a sample selection procedure with criteria determined by the researcher (Fraenkel, 2012). The criteria are (a) the research sample is a junior high school Science teacher, (b) included in a specific teaching duration category. Teachers are grouped into three groups: fresh graduates, teachers with more than 5 years of experience, and teachers with more than 10 years of teaching experience. The contribution of research participants is categorized as inkind, meaning their contribution is in the form of labor in carrying out all stages of the research.

The open-ended questions instrument contains open questions to analyze teachers' ability to understand the concept of global warming.

Table 1. Open-Ended Questions Instrument for Teacher

No	Questions clue	Amount of question
1	Atmosphere layers	2
2	Increasing Earth temperature	2
3	Source of Greenshouse gases	1
4	Global warming process	2
5	Effect of global warming	1

In this study, data obtained analyzed descriptively, where teachers' content knowledge data is obtained based on the answers given in the instrument.

Results

Pedagogical Content Knowledge, abbreviated as PCK, refers to the knowledge possessed by an educator regarding effective teaching methods and strategies. This is implemented through an understanding of how to organize a lesson, the methods of delivering material, and classroom management conducted by the teacher to motivate students to learn. However, in a lesson, the delivery method is not the only main thing; there is another aspect that supports this process, which is Content Knowledge. As previously discussed, CK specifically refers to the knowledge that describes how well a teacher masters a subject matter to be taught. The focus of this research is to comprehensively describe teachers' CK. Therefore, the data in this study is obtained through the application of an open-ended question instrument consisting of several questions. However, before that, the science teachers participating in this study were grouped based on their teaching experience with the following results

Table 2. Grouping of research participants based on teaching experience.

Teaching experience	Amount of teachers
Fresh graduate	6
More than 5 years	9
More than 10 years	4

Based on the grouping in Table 2, the teachers' responses to the open-ended question instrument were analyzed. The discussion in this research focuses on the answers to each provided question. These answers were analyzed descriptively with the following results

Question 1: Is the Earth getting warmer? Provide reasons.

This question provides initial information and can indicate whether the teacher has misconceptions about the topic of global warming. In this question, most science teachers provided the same answer, agreeing with the statement that the Earth is getting warmer. However, the reasons given were quite varied. Fresh graduate teachers, coded as A in this article, provided fairly comprehensive answers by adding that human activities have a significant impact on the phenomenon of the Earth's warming. One such answer was, "Yes (getting warmer), because the number of vehicles can cause a rise in temperature, and deforestation/land clearing can also increase temperatures." In addition to that answer, there were also teachers who mentioned the greenhouse effect as the cause. This statement is not wrong, but it would be better if it were developed further to provide a more comprehensive explanation. Although these answers could be further developed, there were also incorrect answers. In these responses, teachers believed that the cause of the increase in the Earth's average temperature was the thinning of the atmospheric layer, and some mentioned that it was due to the melting of ice at the poles. The answers given by teachers varied greatly in their breadth and depth. This indicates that there are teachers who understand this concept well, and some who do not

Question 2: Can global warming be stopped? Explain your reasons!

This question refines the statement or the teacher's answer from the previous question. Global warming is a serious issue caused by increased greenhouse gas emissions, primarily from human activities. Although it's not possible to completely stop global warming, there are steps that can be taken to slow down and reduce its impact. One way to address global warming

is by reducing greenhouse gas emissions and transitioning to renewable energy sources. This includes using cleaner and environmentally friendly energy and conserving electricity. Additionally, planting more trees and developing technology to absorb CO₂ are steps that can be taken, even though such technology can be very expensive. However, significant challenges remain, as many human activities contributing to global warming are difficult to completely avoid. Therefore, even though we cannot completely stop global warming, we can do much to reduce and slow down the process. The answers from science teachers indicate that global warming can be stopped. However, it requires collaboration from all parties globally because this is a very complex issue. Generally, the teachers' opinions are correct, but it cannot be said that it can be stopped, only that its impact can be reduced.

Question 3: How can human activities affect global warming?

Human activities have a significant impact on global warming in various ways. One of the main causes of global warming is the burning of fossil fuels such as oil, gas, and coal, which produces greenhouse gases like carbon dioxide (CO₂) that are trapped in the atmosphere and cause Earth's temperature to rise. Additionally, deforestation is a serious issue because forest clearing for agriculture and development reduces the number of trees that can absorb CO₂, leaving more greenhouse gases in the atmosphere. Industrial and agricultural activities also contribute, as industrial processes often involve burning fuels and using chemicals that increase harmful gas emissions. Rapid population growth and increased consumption demand more energy and consumer goods, leading to more emissions from the transportation and production sectors. Lastly, everyday habits like using air conditioning, motor vehicles, and high electricity consumption also contribute to the increase of greenhouse gas emissions. Overall, all these activities have led to increased concentrations of greenhouse gases in the atmosphere, contributing to global warming and broader climate change. Efforts to mitigate these impacts are crucial for maintaining environmental balance and the health of our planet.

Question 4: What is the difference between weather and climate?

This question indicates the teacher's ability to differentiate between weather and climate. Weather refers to the Earth's average atmospheric conditions at a specific time, whereas climate refers to weather conditions over a long period. Upon deeper analysis, the answers from the science teachers to this question show that, in general, they understand and can distinguish between these two concepts.

Question 5: Can global warming occur anywhere?

This question tests the teachers' knowledge regarding the locations where global warming occurs. Teachers should answer that global warming occurs across the entire Earth's surface, not just at one point.

Question 6: How can global warming affect human health and agricultural land?

Global warming has significant impacts on human health and agricultural land. In terms of health, global warming can trigger various problems. Climate change caused by global warming can affect environmental factors such as air, water, and food quality. This can lead to an increase in respiratory diseases, waterborne diseases, and other health issues. Additionally, the rise in global temperatures can exacerbate existing health conditions and increase the risk of heat-related illnesses, such as heatstroke. In the agricultural sector, global warming can lead to extreme weather patterns, such as droughts and floods, negatively affecting food production. This phenomenon can decrease agricultural production capacity and threaten food security, especially in countries heavily reliant on agriculture like Indonesia. Unsustainable agricultural practices also contribute to greenhouse gas emissions, worsening global warming. Therefore, global warming not only threatens human health but also the sustainability of food production and economic well-being in many countries.

Question 7: Are there any benefits of global warming? Explain your reasons.

This question tests the teachers' knowledge regarding the benefits of global warming. Ideally, what benefits the Earth and its living organisms is the greenhouse effect. This phenomenon is caused by the trapping of greenhouse gases in the Earth's atmospheric layer. These gases trap heat so it can be reflected back to the Earth's surface. This phenomenon makes the temperature on Earth not too extreme between day and night, allowing humans and other living beings to adapt well. However, the presence of the greenhouse effect is often misunderstood as if it significantly contributes to global warming. Instead, it is the increasing concentration of these greenhouse gases that exacerbates warming. The greenhouse effect, which initially served to warm the Earth, now makes it much hotter due to the increased amount of these gases. Therefore, if the question is about the benefits of global warming, it can be said that there are none. This phenomenon makes the Earth increasingly hot and disrupts the natural balance.

Question 8: What things can slow down or stop global warming? Explain.

This question focuses on tactical steps that can be taken to reduce the impact of global warming. Teachers outlined actions such as using renewable energy and planting trees but could not explain in detail why these actions could be used as steps to reduce the impact of global warming

Question 9: How do you teach this material to students? Describe the model, method, and media used.

This question explores the teachers' creativity in teaching global warming material. Most chose to teach this material using a student-centered approach, such as problem-based or project-based learning models. However, none of the teachers provided detailed explanations regarding the implementation of the chosen teaching models

The teachers' answers were then thoroughly analyzed and scored into three categories, with results shown in Figure 2.

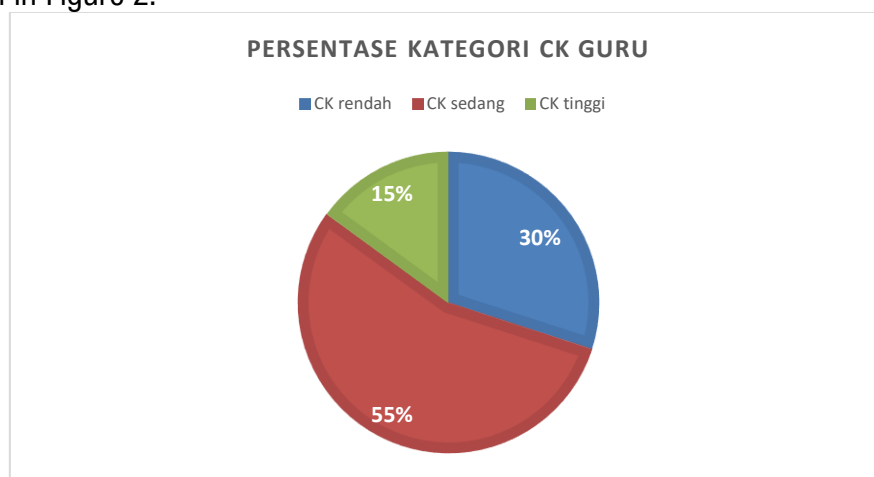


Figure 2. Percentage of teachers' CK categorized as low, medium, and high

Based on the figure, CK is divided into three levels: low, medium, and high. This discussion will delve into the influence of each CK level on classroom dynamics and relate it to findings from previous research

Discussion

Teachers with Low Content Knowledge

Teachers with low CK have limited understanding of the concept of global warming. They tend to deliver material mechanically without in-depth explanations or practical applications. This

is in line with research by Ekawati et al. (2018) which found that teachers with low CK often follow textbook guidelines without the initiative to develop the material further. Consequently, teachers with low CK usually apply traditional and non-interactive teaching methods, such as one-way lectures.

In the classroom context, teachers with low CK create a learning atmosphere that tends to be passive. Students participate less often because they are less encouraged to explore the material in depth or ask critical questions. Research by Safitri, Wulandari, and Herlambang (2022) shows that students in classes with less varied teaching experience misconceptions more often, especially in topics such as global warming. This means that low teacher CK not only limits student participation but also has the potential to cause misconceptions that worsen student understanding.

Teachers with Moderate Content Knowledge

Teachers who are at the moderate CK level have a better understanding of the material, but this understanding still does not cover all the complex aspects of the concept of global warming. They may be able to explain basic principles well, but are not always successful in linking concepts to broader contexts or practical applications.

Research conducted by Fuada et al. (2020) showed that teachers with moderate CK often use methods such as concept maps or analogies to explain material. However, although these methods are more effective than one-way teaching, they are not enough to trigger high participation in class. Students tend to be more involved in Q&A discussions, but these interactions usually only occur among higher-achieving students. Students who have difficulty understanding the material may still be reluctant to participate actively. Hanik et al. (2022) emphasized the importance of increasing teacher CK to create a more inclusive and participatory learning environment, especially in complex subjects such as science.

Teachers with High Content Knowledge

Teachers with high CK have the ability to integrate the concept of global warming with real-life examples and natural phenomena. They use more innovative learning methods, such as project-based learning or group discussions, which encourage students to think critically and be more involved in the learning process. Research by Yanti et al. (2019) support this finding, where teachers with high CK are able to choose pedagogical strategies that are more appropriate to student characteristics, which ultimately increases student participation.

In classes taught by teachers with high CK, students do not only listen to or answer teacher questions, but they also actively collaborate with peers, ask critical questions, and explore solutions to real problems they face in the context of global warming. This creates a dynamic and interactive learning environment. Zhang and Tang (2021) showed that high CK not only improves the quality of learning but also helps students develop a deeper and more comprehensive understanding of the material being studied.

In relation to previous research, this study is in line with the findings of Ekawati (2018) and Yanti et al. (2019) which show that teacher CK greatly influences the effectiveness of learning. However, this study provides a new contribution by focusing on global warming material, the complexity of which often causes misconceptions in students (Hamzah et al., 2019). This study also combines an open-ended question approach in measuring teacher CK, unlike previous studies that usually only use closed tests. In addition, this study supports the argument of Loughran et al. (2008), which states that a deep understanding of essential concepts is key to increasing student participation in class. However, this study goes further by showing that student participation is not only influenced by the teacher's understanding of the material but also by the teacher's ability to relate the material to real-life phenomena and use interactive teaching methods.

Conclusion

Based on the results of the analysis of the teacher's answers, Content Knowledge with the highest percentage is in the moderate category. This means that teachers understand the topic being discussed, namely global warming. However, not in depth or not mastered well. This is evidenced by the lack of depth of teachers' answers related to a problem, in other words, teachers cannot elaborate on the answers with things that can be accepted by students.

The suggestion for further research is to link teachers' understanding of global warming material with student performance in class. So that this research is a complete study in terms of describing the cause and effect relationship.

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