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Analysis of the Implementation of Science Learning based on Teachers' Technological Pedagogical and Content Knowledge (TPACK) Capabilities

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Abstract
Teachers play a crucial role in facilitating students' understanding and making science material more accessible. To achieve this, educators must possess the capability to use technology, select appropriate learning models, and possess sufficient knowledge of the material - collectively termed as Technological Pedagogical Content Knowledge (TPACK). Therefore, this research aimed to analyze the implementation of science learning based on the teacher's TPACK ability level. The qualitative descriptive research method was employed, involving three science teachers selected through convenience sampling and identified as Teacher A, Teacher B, and Teacher C. TPACK ability data was obtained using a TPACK measurement questionnaire developed by Shmidt et al., (2009) with a total of 54 statement items with three general dimensions. They are Technological Knowledge (TK), Pedagogical Knowledge (PK), and Content Knowledge (CK). The analysis involved observing each teacher during science lessons evaluating the alignment of planning and implementation through an observation sheet. The results of the analysis show that teachers with high TPACK abilities also have more complex science learning in terms of material, method, and technology selection. The results of this research can be used as a reference for teachers in designing and applying learning, especially in terms of integrating technology into science learning.

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INTRODUCTION

The study of natural science material explores the workings of the natural environment, encompassing both observable physical aspects and micro-level activities that are imperceptible to the naked eye. Additionally, it delves into processes in nature that unfold over extended periods. Through the examination of science material, individuals can formulate predictions grounded in observed phenomena. Notably, science material is dynamic and highly adaptable, allowing for continuous development. Consequently, the findings of scientific research serve as valuable considerations for decision-making and policy formulation (Lawrence et al., 2022). The characteristics of science material indicate that science material has a fairly abstract nature and the acquisition of concepts, material, or laws studied in it comes from empirical research. The abstract and empirical nature of science material has its difficulties in teaching. An example of abstract material is the processes occurring in the atmosphere which cause global warming. And, to understand this material is also supported by other abstract sub-materials, for example, heat transfer, electromagnetic wavelengths, and black body radiation.

Science learning requires activities that involve hands-on or minds-on activity. Hands-on activity means students are actively involved in learning, carrying out several experimental activities, and explorationing to understand a basic concept of material (Shana & Abulibdeh, 2020). A hands-on activity encourages and increases students' interest in learning science by considering science not just theory because it is accompanied by fun practical work (Furtak & Penuel, 2019; Musharrat, 2020). Hands-on activity is certainly not enough and is complemented by minds-on activity, where the teacher designs questions that provoke students to think and connect the previous activity physically (Furtak & Penuel, 2019; Nagaraj et al., 2022).

Learning that involves hands-on and minds-on activity requires teacher's creativity in designing learning. The definition of hands-on activities encompasses instructional endeavors that involve direct engagement by students. This learning paradigm extends beyond a mere focus on laboratory applications, allowing students to utilize everyday tools and equipment relevant to the subject matter in their daily lives (Ateş & Eryilmaz, 2011).

During the hands-on activity, students engage in learning by doing. In contrast, minds-on learning invlolves students contemplating and reflecting on what they are learning and doing (Prastika et al., 2020). This activity also includes higher-order thinking skills, such as problem solving (Kaniawati et al., 2021). Consequently, students should actively participate both physically and mentally in science learning. Minds-on activity starts from determining essential concepts and methods on how to assess student activities. Also, think about how to utilize technology to support and help students understand concepts (Long et al., 2022; Yanti & Yusnaini, 2018). Applying the appropiate learning model will help to improve students' thinking skills (Suastra et al., 2021; Wahyono et al., 2017). Also, proper science learning lead students to have a useful characters for their future lives. These characters are responsibility, honesty, collaboration, creativity, and discipline (Anita & Novianty, 2020; Markula & Aksela, 2022). Complex reasoning, reflective practice, and a strong understanding of the nature of science and mathematics are desired outcomes for students studying science (Gellerstedt et al., 2018; Yorkovsky & Levenberg, 2021).

Students gain several advantages in studying science when the teacher teaches science material correctly, of course, by remembering the abstract and empirical characteristics of science material. A framework has been introduced by Koehler & Mishra (2006) that can accommodate these abilities, namely Technological Pedagogical and Content Knowledge (TPACK). The integration of the three components is illustrated in Figure 1.

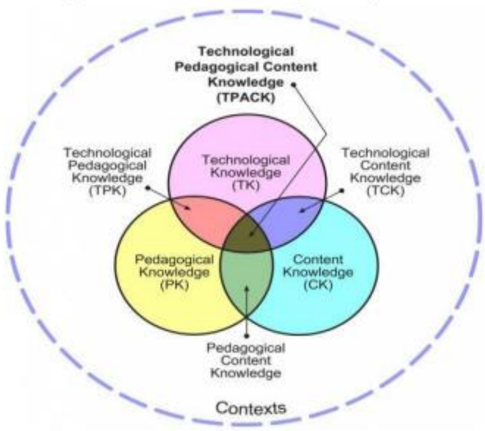

Figure 1. TPACK Framework

TPACK is a framework that describes how teachers can integrate technology effectively into learning (Koehler & Mishra, 2006). This framework is a refined framework of the work of Shulman (1987), which has formulated teacher abilities in terms of pedagogical and material knowledge, called Pedagogical Content Knowledge (PCK). But, as time goes on, the need for technology has also spread to the world of education, so teachers are also required to master these TPACK abilities.

TPACK is very perfect in describing the three competencies contained in it. Technological Knowledge is how teachers choose tools that help in conveying concepts, especially science material (Choi & Young, 2021). Furthermore, the pedagogical knowledge section emphasizes how teachers choose learning models, methods, and strategies that can make students actively involved. Study Yang et al. (2021) and Suyamto et al. (2020) stated theoretically, a teacher's pedagogical ability can be seen by how the teacher creates a lesson plan covering all learning components. Finally, content knowledge is the foundation a teacher should have, where teachers are required to adjust the depth and breadth of the material taught following curriculum provisions. However, this content is often ignored on the assumption that teachers have expertise according to their educational level (Hossain et al., 2021)

The particular research was designed to analyze differences in the implementation of science learning carried out by teachers based on their TPACK level. This research is important as evidence that TPACK is a unique ability for teachers because teachers have their own interpretation of their learning.

When this framework was first introduced, the majority of research on TPACK was about how teachers or prospective teachers assessed their TPACK abilities. As done by Schmitd (2009), who measured the TPACK construct through self-assessment. Other research is shown by Thohir et al., (2022), who measure teacher TPACK competency by conducting 2 rounds of self-survey. The results show that the TPACK capability generally is above 75% or in the excellent category. However, self-assessment itself is less effective if it is the only reference for assessing teachers' TPACK abilities (Ocak & Baran, 2019). Then, it needs to perform further studies or investigations than self-assessment, for example, the implementation in a lesson to provide a complete picture of TPACK (Hapsari et al., 2022).

Therefore, this research provides a complete picture of teachers' TPACK abilities in teaching science material. However, it is still preceded by giving a questionnaire for self-assessment as a construct of TPACK ability. The novelty of this research is that it combines self-assessment and learning implementation, where each lesson will be analyzed for its implementation and specific on how to make students actively involved. Student activity is assessed by how the teacher creates activities that involve Hands-on and Minds-on Activity.

Hence, the primary objective of this research is to analyze the execution of science learning undertaken by the teachers. This aim will be pursued by answering specific research inquiries: (1) What constitutes the Technological Pedagogical Content Knowledge (TPACK) proficiency of teachers concerning global warming material, and (2) in what manner is the instructional implementation conducted by teachers related to their respective TPACK proficiency levels?

RESEARCH METHOD

The research method used a qualitative descriptive research method. According to Creswell (2012), the Descriptive method is used to explain, analyze, and classify things through surveys, interviews, and observations. This research aims to identify the implementation of science learning carried out by teachers based on their TPACK ability level. Therefore, before conducting observations, the teacher's TPACK abilities must first be analyzed through the questionnaire provided. During the implementation of learning, the teacher will be assessed through observation.

The selection of participants used the convenience sampling method. The sample selection method is based on the availability of elements and the ease of obtaining them. The convenience sampling method was used because the research used one school and only three teachers who taught science subjects and were willing to be participants. Participants in this research were science teachers at junior high school level in Sidrap district, South Sulawesi. Table 1 provides information on the background of science teachers at the school.

Tabel 1. Research Participant

Teacher Code	Training Experiences	Teaching Experiences
A	3 times/year	2 years
B	4 times/year	10 years
C	-	1 years

In this study, data was obtained through the TPACK Questionnaire, which aims to see teachers' perceptions of their TPACK abilities. The method is to provide answers to each statement item based on the given attitude rating. The instrument is the standard instrument from Schmidt et al., (2009) and consists of 54 statement items with three general dimensions. They are Technological Knowledge (TK), Pedagogical Knowledge (PK), and Content Knowledge (CK).

The next measurement is the observation of the teacher's learning by first collecting the essential concepts of the teaching. This research used Global Warming material as a reference in assessing. This material is open and has a lot of sub-material coverage, so it might show how the teacher breaks down the material into simpler ones. Implementation analysis is carried out with an observation sheet containing a learning plan written by the teacher. However, during the learning process, the sheet is filled with assessments based on events in the field. Implementation analysis includes dimensions of TPACK, in terms of the use of technology, learning methods and essential concepts that need to be taught. In the output, students understand the global warming material.

RESULT AND DISCUSSION

1. Teacher's TPACK ability

In the first stage, the teacher evaluates his TPACK abilities through a questionnaire. This assessment uses global warming material as a reference. Global warming material is material that can be explored. It means this material can be taught using various methods. Based on the questionnaire filled out by the teacher, there were different results for each indicator. The results are illustrated in Figure 2.

The results are answers to a science teacher questionnaire that describes each teacher's TPACK knowledge when teaching global warming. The TPACK ability of science teachers shows varying results, and the results for each sub-indicator are not optimal. In general, teacher A has an ideal TPACK with a score of 100%, while teachers B and C show different results. To confirm these findings, the next analysis is the implementation of learning carried out by each teacher, which is discussed in the next section.

2. Analysis of the Implementation of Science Learning

a. Analysis of the implementation of Teacher A's learning

The main task of a teacher in carrying out learning is to plan, implement, and evaluate the learning itself. In this research, the planning takes the form of selecting essential concepts, the methods used, and the type of technology chosen to make it easier for students to understand the Global Warming material. Table 2 shows the suitability of planning and implementation in the classroom carried out by Teacher A.

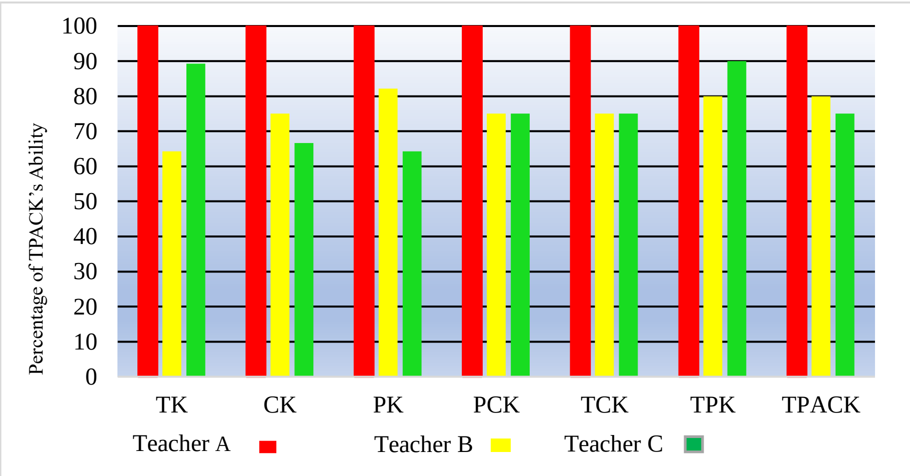

Figure 2. TPACK Results of Science Teacher

Tabel 2. Analysis of the implementation of Teacher's A learning

Essential concept	Plan		Implementation	
	Methods/ Model/Approach	Media/technology	Methods/ Model/Approach	Media/technology
Atmosphere layers	Interactive Conceptual Instruction	Picture	Interactive Conceptual Instruction	Picture
Hear transfer	Interactive Conceptual Instruction	Virtual simulation	Interactive Conceptual Instruction	Heat transfer animation
Blackbody radiation	Interactive Conceptual Instruction	Virtual simulation	Demonstrasi	-
Electronic wavelength	Interactive Conceptual Instruction	Wien shift graph	Ceramah	

Essential concept	Plan		Implementation	
	Methods/ Model/Approach	**Media/technology**	**Methods/ Model/Approach**	**Media/technology**
Scattering and reflection concept	Interactive Conceptual Instruction	Phet simulation of scattering and reflection	Interactive Conceptual Instruction	Simulasi Phet tentang hamburan dan pantulan
Global Warming effect	Interactive Demonstration	Video about the impact of global warming	Interactive Demonstration	Video tentang dampak global warming, praktikum sederhana
Mitigation Concept	Design Based Science		Design based science	disiapkan oleh siswa sesuai rancangan

At the first meeting, Teacher A chose the Interactive Conceptual Instruction (ICI) method. ICI is the basis for learning thinking skills, meaning a learning model for forming concepts or understanding based on thinking skills (Samsudin et al., 2017). This model was chosen with the hope that students will be able to make sense of something after seeing data, and facts of reality to connect one with another so that it becomes a concept.

Teacher A assumes that this model is very suitable for conveying the topic of the greenhouse effect and global warming. Then, the essential concepts in this topic are the concept of atmospheric layers, heat transfer, black body radiation, electromagnetic wavelengths, and scattering and reflection. Previous research using the ICI model was also carried out by Kaniawati (2021). The particular research has the same purpuse, which makes the students understand the concept better. However, the difference is that the previous research uses demonstration tools and computer simulations, whereas this research only uses simulations. By the point at the beginning of this paper, the focus is on students being able to develop their hands-on and minds-on activities so two types of media are used.

The ICI model has four stages, namely (1) Conceptual focus, (2) Research-based material, (3) use of text, and (4) classroom interaction (Johan et al., 2018). The conceptual Focus Stage involves the development of new ideas centered on conceptual understanding and demonstrating key phenomena for study. During this stage, Teacher A directs attention by posing the question, "Why is the Earth's temperature not significantly different at night compared to during the day?" This query aims to prompt students to consider that, despite different phases, the Earth maintains a relatively consistent temperature. Responses from students varied; some predicted, "Because the Sun and Earth are very far away," while others suggested, "because the sun doesn't shine at night." Notably, Teacher A did not immediately validate or refute the students' answers.

Subsequently, Teacher A presented a video featuring a farmer successfully farming in winter. The teacher guided students toward understanding the greenhouse effect by posing the question, "Why don't plants freeze during winter?" Students provided diverse answers, and some stating, "because they are illuminated by lights," and others suggesting, "because they are in a room." This stage allows us to witness the emergence of concepts that students are starting to form. While they may grasp the answers, the connection to the phenomenon of global warming has yet to be established. To facilitate this connection, Teacher A shows demonstration equipment as presented in Figure 3.

Figure 3. Greenhouse effect demonstration tools

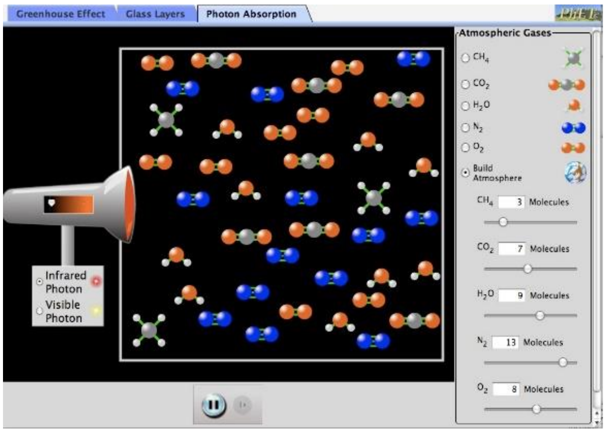

Figure 4. Phet simulation used by students

Teacher A relates that the demonstration in Figure 3 has similar properties to what happens on Earth and is called a greenhouse gas. After that, Teacher A explained the concepts of atmospheric layers, heat transfer, black body radiation, and electromagnetic wavelengths according to the method described on the implementation sheet.

The Research-Based Material Stage involves exercises grounded in research to enhance students' comprehension. In this phase, Teacher A organizes students into groups and instructs them to complete a worksheet utilizing the PhET simulation (Figure 4). This simulation serves as a tool to provide students with insights into electromagnetic wavelengths, scattering, reflection, and their correlation with the Earth's average temperature. Following the simulation and worksheet activities, students solidify their understanding of the greenhouse effect, global warming, and its causes.

Throughout this stage, students actively participate in both hands-on and minds-on activities simultaneously, fostering a holistic grasp of the concepts. The integration of PhET simulations proves advantageous, as these tools offer realistic simulations that are easily comprehensible for students (Chotimah et al., 2023).

The stage of text use aims to increase students' understanding to a deeper level. Learning using textbooks can involve students using metacognition, thinking processes, and critical and creative thinking skills. At this stage, Teacher A asks students to read books or e-books about the greenhouse effect, global warming, and its causes. Students not only read the textbooks, but also are directed to read information from the internet and then write it into a mind map (Wita, 2017). The purpose, the teacher knows how deeply the students understand this concept. The teacher asks the students to make a mind map of what they have learned today. When students engage in independent learning through reading, they have the chance to construct their knowledge. Subsequently, this knowledge is represented in a mind map. It provides an effective means to gauge the depth of their understanding of the material. This observation is supported by Utami & Yuliyanto (2020), who utilized concept maps and concluded that their utilization enables students to discern the extent of their comprehension and identify areas that may require further understanding.

The classroom interaction stage is characterized by active engagement within the class. During this phase, students are allocated time to explore knowledge collaboratively with their peers or other groups. In this context, students articulate their findings by presenting their interpretations in tabular format and documenting the outcomes of the simulation activities. Subsequently, other groups respond and engage in a dynamic exchange of ideas. Also, it is good for exchanging information and making students' knowledge deeper because they obtain new information from their friends. This finding is supported by Fuad's (2020) research, the discussion method can develop students' critical thinking skills when they evaluate valid information and prepare answers during discussions.

At the second meeting, Teacher A used the interactive demonstration method. The interactive demonstration, represents a constructivist-centered learning model. Within this framework, students are prompted to predict experimental outcomes, observe the actual results, and engage in discussions concerning the previously made predictions (Yulianti et al., 2018). The choice of this method is due to the character of students who prefer demonstration lessons as the physical examples of students are connected to the real world. Then, it will be easier to understand. Interactive demonstrations are used by teachers to convey the essential concepts of the impact of global warming. In the introductory activity, Teacher A showed a video containing tidal floods caused by rising sea levels. After that, Teacher A asked students to predict the causes of rising sea levels. All students have one prediction. Learning by video can promote independent learning tools for students, providing an enjoyable and effective means for comprehending the presented material (Alanis et al., 2021).

In the core activity, the teacher divides students into several small groups and asks students to discuss to agree on one best prediction, which will later be presented as a group prediction. Next, Teacher A asked the students "Which iceberg or glacier causes sea levels to rise?" Students responded to the teacher's question. Some answered glacier, iceberg, or both. Students pay attention to the demonstration carried out by Teacher A while holding a glass containing water and ice cubes. Teacher A asks, "If the ice cubes in this glass melt, will the water in the glass spill?" After that, the teacher explains how ice cubes occupy space, which will later fill itself when it changes phase to liquid. As a result, students could sort out predictions from the teacher's previous questions, which are the icebergs or glaciers.

In the closing activity, the teacher asks group representatives to present and discuss the answers to their group's predictions in the context of the demonstration. Then, Teacher A asked students to relate the rise in sea levels to several pictures that displayed in front of the class. Sari et al. (2020) also implemented the Interactive Demonstration Method in learning. The outcomes indicated its effectiveness in enhancing student learning outcomes. This approach proves proficient in aiding students' comprehension of concepts, facts, and principles.

At the third meeting, Teacher A used the Design Based Science (DBS) model. it aims to train the last essential concept, which is the concept of mitigation or solutions to global warming. The concept of mitigation and solutions is very suitable to be taught with DBS it aims for students to design their solutions to the problems presented (Breukelen et al., 2017; Kim et al., 2015). In this process, students experience their cognitive construction as a result of designing learning as good learning qualities and outcomes.

The design-based research model is fundamentally centered on the integration of theory construction with the effective design of learning environments and practical applications (Pugh et al., 2023). The model has five phases, namely (1) Identify and define context, (2) Background research, (3) Develop personal and group idea, (4) Construct 2D or 3D artifacts, and (5) feedback.

In the Identify and Define context phase, Teacher A focuses on students by playing a video about climate change and its impact on the ecosystem. In this video, Teacher A focuses students on natural disasters, erratic rainfall, rising sea levels, and the extinction of flora and fauna species. So that students know the focus of the problem to be studied.

In the background research phase, Teacher A provided information about the influence of greenhouse gases on Earth's temperature by showing graphs of CO_2 emissions and Earth's temperature. Students analyzed the graph until they discovered that the increase in Earth's temperature was caused by CO_2 gas emissions. Teacher A also showed sources of CO_2 gas along with their removal and global warming reading material. Using the knowledge in this phase, students identify the causes and elimination of greenhouse gases and propose solutions to the problem of global warming.

In the Development of the personal and group idea phase, Teacher A explained that a good solution is innovative, can be made/implemented, and the tools and materials are easy to obtain. Students and their group friends discuss to determine the most likely solution to the problem. After finding a solution, in the construct 2D or 3D artifact phase, students realize what has become an idea. Teacher A only supervises students in making designs to overcome the problem of global warming while assessing student activities. The final phase of feedback is a phase to communicate the solutions offered and responded to by other groups. This model was also implemented by Azizan & Abu Shamsi (2022), the result indicated that online DBL contributes to easy access to learning, enhances creativity, and enables students to think outside the box.

b. Analysis of the implementation of Teacher B's learning.

Teacher B in implementing learning is presented in table 3.

Table 3. Analysis of Teacher's B Learning Implementation

Essential concept	Plan		Implementation	
	Methods/ Model/Approach	**Media/technology**	**Methods/ Model/Approach**	**Media/technology**
Blobal warming definition	Demonstration	Video	Direct instruction	-
The process of global warming	Experiment	Experiment tools and materials	Experiment	Experiment tools and materials
Global warming effect	Direct Instruction	Data/articles about the impact of global warming	Direct instruction	Data/articles about the impact of global warming
Combating global warming	Portofolio assingment	Data/articles about overcoming global warming	Portofolio assingment	Data/articles about overcoming global warming

The implementation of global warming learning for teacher B was designed in 2 meetings. At the first meeting, teacher B started the lesson by stating the learning objectives. Consequently, teacher B used the practicum method. In general, from the learning implementation analysis table, Teacher A has more detailed learning compared to Teacher B, seen from how Teacher A divides more sub-materials compared to Teacher B. In detail, Teacher B begins his learning, explained below.

In the introductory activity, Teacher B explained two learning objectives, namely that students could understand the meaning and process of global warming. After that, the teacher explains the learning of that day. The teacher divides students into several groups. Students sat in their groups. Teacher B started the explanation by asking students, "Why is the Earth getting hotter?." Then, students randomly answer with their various predictions. Next, teacher B continued the question. "Why is the climate starting to be difficult to predict?." For the second question, most students were silent. The teacher linked this incident to global warming. In terms of practice, teacher B uses the question-and-answer method at the beginning of the lesson. This method can provide a direct picture of students' knowledge (Gusti, 2018). When creating questions, they must be by learning outcomes, arouse students' interest in answering and be open-ended questions where the answer to the question is not just focused on one answer (Anthony 2018; Cornelia 2021). Then, with practical activities, students can understand the process of global warming. The teacher explains the materials that must be provided and invites students to take them to the laboratory.

In the core activity, students start doing practicum according to the LKS (students's worksheet) distributed by the teacher. The equipment used by students is presented in Figure 5. Students practice simulating the occurrence of global warming. Students used two jars, one jar covered with plastic and the other left open. Both jars are filled with towels and soaked in warm water. After that, students measure the temperature changes in the jar over a certain time interval. Figure 5 is an example of practical work carried out by students.

Figure 5. Global warming practical equipment

After students obtain temperature data in the jar, students are asked to write down the results of their observations in a table and present them in graphical form. In the closing activity, teacher B asked the representatives of each group to present the results obtained and then responded to other groups. After that, the teacher concluded the practicum activity by saying that the practicum carried out by the students had similar characteristics to global warming.

At the second meeting, teacher B seemed more flexible in using teaching strategies. In the introductory activity, teacher B conveyed the learning objectives, which are the impacts and solutions of global warming. The core activity of this second lesson is for teacher B to explain one by one the impacts of global warming to students, with the help of PowerPoint and occasionally showing videos. After that, teacher B opened a question session to students. In the closing activity, the teacher gives portfolio assignments to students. In the end, students look for articles from any source about resolusing global warming.

c. Analysis of Teacher Science Learning Implementation C

Teacher C in implementing the TPACK strategy is presented in Table 4.

Table 4. Analysis of Teacher's C Learning Implementation

Essensial Concept	Plan		Implementation	
	Methods/Model/Approach	Media/technology	Methods/Model/Approach	Media/technology
Global warming process	Problem based learning	Video	Direct Instructions	-
Factors causing global warming	Problem based learning	Video	Direct Instructions	-
Marking of ERK processes and global warming	Problem based learning	Video	Direct Instructions	-
Global warming Effect	Problem based learning	Video	Direct Instructions	-
Global warming solution	Problem based learning	Video	Direct Instructions	-

The implementation of Teacher C's TPACK design was also divided into two meetings. In both meetings, teacher C seemed to dominate the learning. Teacher C only uses the lecture method and occasionally uses PowerPoint as a tool to explain the process of global warming. The analysis shows quite contrasting differences between each teacher in presenting Global Warming material, selection of diverse essential concepts, and some selected meetings. In general, more complex learning is shown by teacher A, then teacher B and the simplest of the learning is carried out by teacher C. It is followed by the percentage score of the TPACK value, respectively, that the TPACK ability categories of teachers A, B and C are high, medium and low.

Teachers with adequate TPACK abilities tend to pay attention to student characteristics in determining all components of their learning. In choosing the type of technology, teacher A uses a lot of types of technology, such as picture illustrations, Phet media, animation, and video. The selection is based on the essential concept to be conveyed. The use of clear and attractive visuals can help students see the differences in each sub-material (Huang et al., 2022). Furthermore, Phet is used to explain the most abstract material (Anisa & Astriani, 2022). That way, students are involved in running the Phet media that lead them to draw their own conclusions. Learning using this media enables students to develop their skills and knowledge in finding solutions to problems (Scott & Nimon, 2020). From this, it can be seen that teacher A not only uses technology from an instrumental perspective but can adapt it to learning objectives (Sembiring, 2022).

Teacher B used simple technology in the form of videos due to teachers' limitations in accessing appropriate technology and using technology that is often encountered, namely the use of video. This was also confirmed by research conducted by Nevrita et al. (2020)

that, in general, teachers have incorporated technology into their learning, even though the technology is relatively simple, and 36% of teachers use video, when compared with PPT, animation, Audio Visual, Multimedia, E-module, and Audio. However, correct learning videos allow students to grasp learning material quickly (Higgins et al., 2018). The interesting fact of teacher B is the use of scientific article data related to Global Warming material. It shows that teacher B has good literacy by providing the latest teaching materials and data in research articles. Study from McFarland et al. (2021) shows that the more often you read and interpret data, the better your students' ability to predict and draw conclusions based on the data.

Teacher C does not seem to use technology features in the learning due to the lack of knowledge and confidence in using the technology (Xiong et al., 2022). This can certainly be improved through more routine use of technology (Hossain et al., 2021). Research result from Yildiz Durak, (2021) shows that it is needs self-efficacy in using technology that has a strong correlation with the ability to use the technology itself. So, it needs to build self-confidence before deciding to learn a technology.

The results of the analysis of learning implementation generally show the teacher's TPACK abilities. In terms of selecting essential concepts that support Global warming material, everything has been well accommodated. Furthermore, in terms of selecting learning models and strategies, it is also sufficient to make students actively involved, except for teacher C who ultimately uses the lecture method. Then, in terms of the use of technology, it is also quite diverse, such as simulations, animations, images, Phet, tools for demonstrations, and even the use of scientific articles. Information from this research might be used to carry out teacher competency development programs. Especially, the training in the use of technology in learning. Many habits can be done, such as writing learning plans on virtual platforms (Kapici & Akcay, 2023).

This research aimed to analyze the implementation of science learning for teachers based on their Technological Pedagogical Content Knowledge (TPACK) abilities. The findings found that Teacher A, possessing an exemplary TPACK profile, adeptly offers comprehensive depiction of conceptual depth, diverse teaching methods, and a wide array of technological tools. Consequently, future research could extend its application, not only to practicing teachers but also to prospective teacher students. It serves as an illustration of how to aspire to become an ideal teacher by seamlessly integrating the three dimensions of TPACK: technology, pedagogy, and content.

CONCLUSION

The research aimed to analyze the implementation of science learning based on the teacher's TPACK ability level. The analysis showed that in sequence, the high, medium and low TPACK performance were Teacher A, Teacher B, and Teacher C. This finding was confirmed by analyzing the implementation of the three learning activities. Teachers with high TPACK abilities can organize and implement more complex and detailed learning, such as in terms of selecting essential concepts, methods, and the type of technology used. The limitation of this research is the limited number of samples and generalization to a broader population is difficult. Besides that, this research does not provide special treatment for teachers, so the portraits given when teaching really come from the teachers themselves.

The implication of this research is as a new reference in assessing teachers' TPACK abilities. So, in assessing TPACK abilities, teachers no longer use self-assessment but also need to be confirmed in the form of learning planning to learning implementation. The uniqueness of TPACK itself lies in its dynamic nature. It might state that there is no ideal TPACK reference for implementing learning. However, as much as possible, learning is designed to meet learning objectives with methods that keep students involved and by using technology that makes things easier for students.

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