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# Elementary Teachers' Science Background and Its Impact on Their Science Teaching

Arifin Septiyanto [a]
Ari Widodo [a]
Eka Cahya Prima [a]

[a] Universitas Pendidikan Indonesia, Department of Science Education, Bandung, Indonesia

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## ABSTRACT

**Background**: Mastery of science content is crucial to effectively convey information, foster understanding, and inspire curiosity among students. Teachers' lack of understanding of science content will also impact the implementation of science learning in the classroom, especially on student understanding. **Objectives**: The study determines the depth of the concept and level of science content knowledge of elementary school teachers regarding their science backgrounds. **Design**: This research is qualitative research with a case study design. **Setting and Participants**: The participants in this study were four teachers with different science backgrounds who volunteered to be the subject of research. **Data collection and analysis**: The data were analyzed descriptively by combining all sources. In the first stage, researchers analyzed the learning video using video analysis techniques and the concept-depth observation sheet. Source triangulation was then carried out by interviewing four elementary school teachers. The data sources for this research are observation sheets, video recordings, and interview results. **Results**: The results showed that the science background of elementary school teachers does not affect the depth of concepts that teachers teach or the level of competence in content knowledge (CK) of science teachers. **Conclusions**: The learning process during the teaching experience better describes the extent of the depth of concepts and the level of competence in content knowledge (CK) of science teachers. This research implies that elementary school teachers need the importance of lifelong learning concepts and professional development in teaching science in the classroom.

**Keywords**: The depth of science concept; Science background; Elementary teachers ;

Corresponding author: Eka Cahya Prima. Email: ekacahyaprima@upi.edu

**Formação em Ciências de Professores do Ensino Fundamental e seu Impacto no Ensino de Ciências**


# RESUMO

**Contexto**: O domínio do conteúdo de ciências é fundamental para transmitir informações de forma eficaz, promover a compreensão e inspirar a curiosidade dos alunos. A falta de compreensão do conteúdo de ciências por parte dos professores também afetará a implementação do aprendizado de ciências em sala de aula, especialmente a compreensão dos alunos. **Objetivos**: O estudo determina a profundidade do conceito e o nível de conhecimento do conteúdo de ciências dos professores do ensino fundamental com relação à sua formação em ciências. **Design**: Esta pesquisa é qualitativa com um projeto de estudo de caso. **Ambiente e participantes**: Os participantes deste estudo foram quatro professores com diferentes formações em ciências que se ofereceram como voluntários para serem sujeitos da pesquisa. **Coleta e análise de dados**: Os dados foram analisados descritivamente por meio da combinação de todas as fontes. Na primeira etapa, os pesquisadores analisaram o vídeo de aprendizagem usando técnicas de análise de vídeo e a planilha de observação em profundidade do conceito. Em seguida, a triangulação das fontes foi realizada por meio de entrevistas com quatro professores do ensino fundamental. As fontes de dados para esta pesquisa são as folhas de observação, as gravações de vídeo e os resultados das entrevistas. **Resultados**: Os resultados mostraram que o histórico de ciências dos professores do ensino fundamental não afeta a profundidade dos conceitos que os professores ensinam nem o nível de competência em conhecimento de conteúdo (CK) dos professores de ciências. **Conclusões**: O processo de aprendizado durante a experiência de ensino descreve melhor a extensão da profundidade dos conceitos e o nível de competência no conhecimento do conteúdo (CK) dos professores de ciências. Esta pesquisa implica que os professores do ensino fundamental precisam da importância dos conceitos de aprendizagem ao longo da vida e do desenvolvimento profissional no ensino de ciências em sala de aula.



**Palavras-chave**: Profundidade do conceito de ciência; Formação científica; Professores do ensino fundamental.


# INTRODUCTION

During the learning process, one thing that must be considered is the depth and coverage of the scientific content that the teacher will present. The depth and coverage of science content in schools are related to the teacher's ability to master science concepts(Laelandi et al., 2022). Moreover, the depth of science material taught results from integrating the teacher's knowledge and the material's content(Evens et al., 2018). The integration process is crucial for the success of the learning process(Susanto et al., 2020). The depth of material in the science learning process cannot be separated from the teacher's ability to design the learning process well. A good learning process can later improve students' mastery of concepts and scientific attitudes(Mesci et al., 2020). Therefore, a good teacher can conceptualize science material in a planned manner.

One of the science learning objectives is teaching science content, which is the result of science products(Iwuanyanwu, 2019; Soysal, 2022; Taber, 2013). Science content is essential to be taught to students so that they have experiences about nature and phenomena that occur (Baptista & Molina-Andrade, 2021). In general, science content differs in its level of abstractness, the use of terminology, complexity, and the interconnectedness of the material in it (Anam et al., 2017, 2020). Starting from that, teachers should understand the characteristics of the material so that they can design and implement learning according to the material being taught. However, several studies have found that elementary school teachers need more understanding of science content. A teacher who needs understand the content cannot provide quality lessons (Rollnick, 2017). Based on interviews with elementary school teachers, the cause of the difficulty in understanding science concepts in schools is that science contains many abstract concepts, mathematical equations, and images that are difficult to explain physically. It will lower elementary school teachers' confidence and ultimately hamper learning (Amy Catalano et al., 2019; Harlen & Holroyd, 1997; Nikolopoulou & Tsimperidis, 2023; Rahayu & Osman, 2019).

According previous studies, teachers' content mastery can influence the science learning process in the classroom (Damavandi & Kashani, 2010; Kamamia et al., 2014; Muttaqiin et al., 2021). Teachers' mastery of content knowledge provides an overview of how a given group of teachers conceptualizes the content of a particular subject matter or topic (Akinleye & Mutiat, 2021). Mastery of science content allows teachers to organize selected materials in good order when preparing lesson plans, think about ideas and information related to the subject, and improve the quality of teaching (Kamamia et al., 2014). Lack of mastery of science content will limit teachers' ability to plan and deliver effective science instruction (Heywood, 2007; Luera, 2005; Mundry, 2005; Parker & Heywood, 2000). As a result, the learning process could not improve, and misconceptions occur in students (Anam et al., 2017; Appleton, 2008).

Factors contributing to the lack of science content knowledge are that teachers are less qualified to teach science at the primary school level (Appleton, 2008; Atwood et al., 2010; Harlen & Holroyd, 1997; Krall et al., 2009). This is because primary school teachers are classroom teachers and have to teach many subjects where the content to be mastered covers all these subjects. As a result, the science lessons content is only a small part of the overall science concept. In addition, the problem of understanding the science concepts of elementary school teachers is not only because teachers have to teach many subjects but also because their educational backgrounds vary greatly (Widodo et al., 2017). Indonesian law requires elementary school teachers to have a bachelor's degree but also allows non-elementary teacher education graduates to become elementary school teachers. Due to this "relatively open" recruitment system, some primary school teachers do not have strong science content. The worst-case scenario is that an elementary school teacher may only teach science in school from elementary to junior high.

Teachers' lack of understanding of science content will also impact their pedagogical content knowledge (PCK) skills (Evens et al., 2018; Rollnick, 2017; Susanto et al., 2020). Teachers cannot integrate their content knowledge with their pedagogical skills. Although teachers have good pedagogical knowledge, they cannot choose the right learning strategies according to the material taught (Parker & Heywood, 2000). Thus, teachers will only teach students according to their experience.

Based on what has been mentioned above, this study aims to investigate the content knowledge of elementary school teachers in teaching science based on the background of how much elementary school teachers learn science content. The research questions that will be discussed include:

1. How does the role of school teachers' scientific backgrounds affect the depth of science concepts?
2. How does an elementary school teacher's scientific background affect the level of content knowledge (CK) competency of science teachers?

## THEORITICAL BACKGROUND

### Mastery of Science Content

A concept is defined as something that can be accepted in the mind or a general or abstract idea (Borghi et al., 2017). It was further explained that science learning requires knowledge of the concepts contained in each lesson unit. The concepts possessed by a person are the result of the learning process. These concepts will become the basis for someone's thinking to solve problems and find out things related to them (Mufida & Widodo, 2021). One of the characteristics of effective science learning is the delivery of science concepts in depth so that students are able to build knowledge from the concepts they get (McConnell et al., 2013). Concepts are presented from easy to difficult, and from concrete to abstract concepts. Hierarchy in conveying concepts is a basic form of teaching concepts (Manrique et al., 2019). Then, in terms of depth, it can be seen from the main concept as an introduction, the existence of sub-concepts as support and explanation, to the linkages between concepts and detailed sub-concepts (Rohmah et al., 2022). The number of interrelated concepts and sub-concepts is also a measure of the depth of a concept conveyed by the teacher. However, there are still teachers who have difficulty conveying concepts due to their limited conceptual abilities (Hashweh, 1987), so that the concepts conveyed are in accordance with the teacher's abilities.

Understanding and mastering natural science concepts is crucial for assessing success in learning. Concept mastery, seen as a cognitive ability, plays a pivotal role in this evaluation. The effectiveness of this mastery is achieved when students can simplify complex and abstract materials, making them more accessible and interpretable in daily life (Baumfalk et al., 2019). The correct mastery of science content not only ensures comprehension but also sparks creativity among students (Cherif et al., 2016). Creative thinking empowers students to generate innovative ideas and products that have practical applications in their lives. It's important to note that the categories of creative thinking among students can vary, influenced by their unique experiences and knowledge base (Tu et al., 2018; Yalçın, 2022). In essence, the ability to creatively apply and extend learned natural science concepts reflects a deeper and more comprehensive understanding of the subject matter (Wicaksono et al., 2020).

## METHODOLOGY

### Research Design

This study is qualitative research with an exploratory case study design. This research investigates the depth and level of elementary school teachers' content knowledge when teaching science in the classroom based on their science background.

## Participants

The participants in this study were four teachers with different science backgrounds who voluntarily participated. The participants' educational backgrounds are as follows:

- **Teacher 1** is an elementary school teacher who graduated from the Japanese Language Education Department. In high school, she majored in social studies. Throughout her schooling, she developed a strong affinity for language lessons, including Japanese and other languages. Math, on the other hand, became her least preferred subject due to the abundance of numbers involved. Currently teaching sixth grade, she possesses 15 years of teaching experience. It is noteworthy that she has not encountered any science content since her high school education.

- **Teacher 2** is an elementary school teacher who graduated from the Indonesian Language and Literature Education Department. During his high school years, he pursued a science major. However, his true passion lies in Indonesian lessons during his school days. Physics, on the other hand, became his least favored subject. Currently teaching fourth grade, he has gained five years of teaching experience. It is worth noting that his exposure to science content was solely limited to his high school education.

- **Teacher 3** is an elementary school teacher who graduated from the Elementary Teacher Education Department. When he was in high school, he majored in science. Then, when he was in school, he liked chemistry. His least favorite subject is physics. Currently, he teaches sixth grade and has accumulated three years of teaching experience. In his role as an elementary school teacher, he draws upon science content from his high school education all the way through his fifth semester in college.

- **Teacher 4** is an elementary school teacher who graduated from the Science Education Department. At the time of high school, she majored in science. Then, when she was in school, she liked biology. Her least favorite subject is physics. Currently teaching fifth grade, she has three years of teaching experience. As an elementary school teacher, she incorporates science content from her high school education all the way through her college studies, covering a full semester's worth of content.

### Data Collection

The data sources for this research are observation sheets, video recordings, and interview results. The data collection techniques used in this research include three stages:

- **Observation.** An observation here is used to determine the depth of the concept of elementary school teachers when teaching science content in the classroom for one meeting. Teachers were asked to write down the concepts taught during the learning process on the observation sheet. In filling in the science concepts on the observation sheet, teachers are free to write concepts without any restrictions. After the teacher fills in the science concepts being taught, the researcher matches these concepts to the list of essential concepts made by the researcher. A list of essential concepts is made on the basis of students' book sources. Then, the observation sheet was also used to measure the level of science content knowledge of school teachers based on the observation sheet modified from (Eliyawati et al., 2023; Morrell et al., 2020; NSW, 2018).
- **Video.** During the learning process, researchers recorded videos from the beginning to the end of learning. Video data has the advantage of allowing researchers to analyze it repeatedly. Four learning videos were collected as data. The videos obtained were from each elementary school teacher's lesson during one meeting. Students were informed that the video would not be publicized and that only researchers and teachers would have access to it during the video recording. The camera was positioned in the corner of the classroom with a wide angle, which allowed for playback of the entire class. It was also placed at the back of the classroom to keep the students focused.
- **Interview.** Interviews were conducted when the learning videos were obtained. Interviews were conducted to determine the background of the elementary school teacher, the teacher's knowledge of science content, and the teacher's preparation for teaching science. Interviews were conducted after researchers analyzed the learning videos directly. The results of this interview were used to support data from observations and video analysis results.

## Data Analysis

After collecting data, the researcher analyzed the data by combining the available data sources. The researcher first analyzed the observation sheet about the depth of science concepts that teachers teach. The results of the observation sheet analysis were then confirmed and validated using thematic analysis of each scene in the video to support the results on the depth of concept of elementary school teachers. Thematic video analysis was chosen because the video can be played repeatedly (Widodo, 2006), there was interobserver reliability control (James W. Stigler, Patrick Gonzales, Takako Kawanaka, Steffen Knoll, 1999), and video recordings can be reproduced and moved easily (Widodo & Ramdaningsih, 2006). Learning activities were recorded in their entirety, without any editing or cutting, for research. After analyzing the video and the observation sheet, the data were triangulated with the results of interviews conducted with four elementary teachers. The interview findings were used to validate the observations and identify important aspects occurring in each scene of the video.

# RESULTS AND ANALISES

Depth of concept is an essential part of the learning process because the deeper the concept is taught, the more information can be used as a reference by students. The depth of a teacher's concept is determined by knowing how much the teacher understands and masters the science concepts to be taught. Table 1 shows a general comparison of data between Teacher 1 and Teacher 3 in the solar system theme, regarding the number of concepts conveyed in the core learning activities.

**Table 1**

*Comparison of the number of concepts conveyed by Teacher 1 and 3 on the theme of the solar system*

| Essential concept | Teacher 1 | Teacher 3 |
|---|---|---|
| **Galaxies** | Not delivered | Not delivered |
| **Orbit** | Retrieved | Retrieved |
| **Earth Rotation** | Retrieved | Retrieved |
| **Earth Revolution** | Retrieved | Retrieved |

| | | |
|---|---|---|
| **Star** | Not delivered | Not delivered |
| **The Sun** | Not delivered | Retrieved |
| **Planet** | Retrieved | Retrieved |
| **Solar System** | Retrieved | Retrieved |
| **Inner Planets** | Retrieved | Not delivered |
| **Outer Planet** | Retrieved | Not delivered |
| **Satelite** | Retrieved | Retrieved |
| **Space Objects** | Retrieved | Not delivered |
| **Comet** | Retrieved | Not delivered |
| **Difference between meteroites, meteorites, and meteors** | Retrieved | Not delivered |
| **The percentage of concepts delivered** | **78.57%** | **50%** |

Teacher 1 and Teacher 3 have different educational backgrounds. Teacher 1 never received any science subjects from high school to college. On the other hand, Teacher 3 studied science subjects until the fifth semester of college. However, the research results presented in Table 1 reveal a disparity in the concepts taught by Teachers 1 and 3 regarding the solar system theme. Teacher 1 conveyed 11 of the 14 essential concepts related to the solar system theme, while Teacher 3 conveyed seven of the 14 concepts. This indicates that the depth of concepts provided by Teacher 1 (78.57%) is higher compared to Teacher 3 (50%). The depth of concepts conveyed by Teacher 2 can be seen in Table 2.

**Table 2**

*Essential concepts presented by teacher 2 on force*

| Essential concept | Teacher 2 |
|---|---|
| **Definition of force** | Retrieved |
| **Force and motion** | Retrieved |
| **Force and direction of objects** | Not delivered |
| **Force and shape of objects** | Retrieved |
| **Force and velocity of objects** | Retrieved |
| **Force system in humans** | Not delivered |
| **Definition of muscle force** | Not delivered |

| | |
|---|---|
| **Friction force** | Not delivered |
| **Causes of friction force** | Not delivered |
| **Friction force and surfaces** | Not delivered |
| **Friction force and mass of objects** | Not delivered |
| **The percentage of concepts delivered** | **36.36%** |

Teacher 2 is a teacher with a limited background in science. Teacher 2 only studied science subjects until high school. The data from Table 2 reveals that Teacher 2 only teaches 4 of the 11 concepts that should be taught on force in Grade 4. These findings indicate that the depth of concepts conveyed by Teacher 2 is not significantly aligned with what should be taught. Further results regarding the depth of concepts conveyed by Teacher 4 can be seen in Table 3.

**Table 3**

*Essential concepts presented by teachers 4 on substance and mixture*

| Essential concept | Teacher 4 |
|---|---|
| **Material** | Not delivered |
| **Single substance** | Retrieved |
| **Characteristics of a single substance** | Retrieved |
| **Elements** | Not delivered |
| **Compound** | Not delivered |
| **Mixture** | Retrieved |
| **Characteristics of mixtures** | Retrieved |
| **Homogeneous mixture** | Not delivered |
| **Heterogeneous mixture** | Retrieved |
| **Difference between singles and mixed substances** | Retrieved |
| **The percentage of concepts delivered** | **60%** |

Based on data data in Table 3 shows that Teacher 4 conveyed six concepts out of 10 that should be conveyed on the topic of single and mixed substances in Grade 5. Teacher 4 is the teacher who received the highest amount of education in the field of science subjects. He studied science subjects from elementary school all the way through college, majoring in Science Education.

However, the depth of essential science concepts at the primary school level of Teacher 1 got the highest result with a percentage of 78.57%. While the depth of essential science concepts at the elementary level with the lowest results is Teacher 2, with a percentage of 36.36%; then, the depth of essential science concepts in Teacher 3 is 50%, and Teacher 4, is 60%. This finding is reinforced by the results of the interview, which explain that during teaching, Teacher 1 never stopped learning and always collected updated information about essential science concepts, even though the curriculum in Indonesia is always changing, as shown by the following interview excerpt:

> *"Before starting classroom learning, I have a habit of crafting a learning plan, which involves familiarizing myself with learning resources suitable for children. Furthermore, I take pleasure in gathering and condensing science learning books from different curricula used in Indonesia"*

Meanwhile, Teachers 2 and 3, who received science content starting from high school, learned science only relying on textbooks because they rarely received training in science learning, as shown in the following interview excerpt:

> *"I have never received special training in teaching science while teaching in elementary school. The only training I have attended was curriculum analysis training in elementary school. Then I use textbooks as my reference in teaching in class."*

The results of the elementary school teachers' depth of concept were then validated using the results of the level of content knowledge (CK) of science teachers. The level of competency in content knowledge (CK) for elementary school teachers is divided into five dimensions, which include knowing the content, substance, and structure of the content, content selection and organization, knowing different ways to understand a particular concept, and identifying curriculum standards related to specific concepts.

In terms of "knowing the content," it refers to the teachers' understanding of accurately explaining science concepts and their relevance to everyday life problem-solving, as conveyed through various sources. During the learning process, they can develop accurate and in-depth science concepts and relate them to solving problems in daily life. For example, Teacher 1 related the concept of the solar system to the time division experienced by Indonesian people, and Teacher 4 related the concept of the mixture to the process of making drinks. The Interview results supported this result where Teacher 1 and Teacher 4 can distinguish between science and non-science.

> *"Natural science is a science that studies natural phenomena and all their connections in it. Social science tends to be lessons that are easy to memorize, for example, the Indonesian language."(Teacher 1)*

> *"Mathematics and natural science are subjects that involve scientific literacy and problem-solving concepts. On the other hand, social science tends to focus less on the direct study of nature."(Teacher 4)*

However, Teachers 2 and 3 are in a different situation as they have not yet made a clear distinction between natural and social science. This is because both teachers have a dislike for natural science, which is a subjects they do not prefer.

> *"Actually, all subjects are equal, but there are certain lessons that, when taught using unsuitable methods, become subjects that I dislike. Natural science is one of those subjects" (Teacher 2 and Teacher 3)*

In the dimension of Substance and Structure of the Content, it relates to how teachers understand the characteristic structure of science concepts without factual errors and misinterpretations. Based on the video, teachers 2 and 3 had misconceptions when conveying science concepts. For example, when Teacher 2 conveyed the concept of force in grade 4 elementary school, he conveyed that motion is the result of force. If there is no force, objects cannot move. Teacher 3 also still has misconceptions about teaching the concept of satellites. She explained that the moon is a star that can produce its own light. These results can be related to the interview results, where in teaching science in the classroom, teachers 2 and 3 have some difficulties.

> *"The greatest challenge in teaching natural science lies in having appropriate facilities and infrastructure that align with the content being taught. As a result, the learning process becomes solely reliant on the available resources." (Teacher 2 and Teacher 3)*

The dimension of selecting and organizing content is related to the process of selecting, sorting, and connecting concepts taught by elementary science teachers. According to the results of interviews, almost all teachers in choosing concepts and sorting concepts refer to general concepts to specific concepts or from the easiest concepts to abstract concepts. The following is an illustration of the results of researcher interviews with four teachers who come from different educational backgrounds.

> *I" determine the material I teach from the general to specific or from the easiest to the most complex."(Teacher 1, Teacher 2, Teacher 3, and Teacher 4)*

Nevertheless, the analysis of the video revealed that in terms of content selection and organization, Teachers 1 and 4 demonstrated a higher level of proficiency compared to Teachers 2 and 3. This was evident as Teachers 1 and 4 adopted a more systematic approach, starting from low-level concepts and gradually progressing toward more complex levels during their lessons. In contrast, Teacher 3's presentation of concepts appeared to be random, while Teacher 2 tended to provide numerous examples that seemed repetitive.

On the dimension of knowing different ways to understand certain concepts, it discusses the development of science content using various methods and in accordance with the provided teaching methods and media throughout the learning process. Teacher 1 used the project and demonstration methods during the learning process. The media used by the teacher when teaching the topic of the solar system are power points, videos, and materials used for student projects. Teacher 2 only uses the lecturing method without using any media during class. Then, Teacher 3 carried out learning with the lecturing method but by using power point media. Teacher 4 conducted the lesson on single and mixed substances using the demonstration method. Teacher 4 brought coffee and tea solutions, which were demonstrated to students to understand the concept. These results follow the interview results where Teacher 2 only used the lecturing method during the learning process without any inquiry activities characteristic of science lessons. Meanwhile, Teachers 2, 3, and 4, at the beginning of learning, prioritize inquiry activities that object observation preceded through videos or directly.

> *I"n the classroom, due to all the limitations in terms of facilities and infrastructure for the inquiry process, in the end, I still lecture by connecting the students' prior knowledge with the concepts to be taught"(Teacher 2).*

In the final dimension, which is identifying curriculum standards related to specific concepts, it pertains to the teachers' ability to demonstrate content in accordance with curriculum standards by connecting the main concepts with students' prior content knowledge. Based on the video, Teacher 2 only conveyed concepts that are fixated on textbooks and needed help to connect lesson content with students' prior knowledge in the learning process. Meanwhile, teachers 1, 3, and 4 have demonstrated concepts involving many daily examples. They could also connect students' prior knowledge with the knowledge to be taught. Science curriculum standards in Indonesia require teachers to integrate knowledge, skills, and attitudes toward science. Teacher 2 could not provide a detailed answer when asked about the most important science skill. The following is an elementary school teacher's response regarding the most important thing about science.

> *The most important skill is how students interpret the science material (Teacher 2).*
>
> *The most important skill of science is to invite students to observe the environment and natural phenomena with the regularities in it."(Teacher 1, Teacher 3, and Teacher 4)*

The findings from all dimensions of content knowledge indicate variations in the level of content knowledge (CK) among elementary school teachers. The findings describing the level of content knowledge of primary school teachers when teaching science in terms of their study background in obtaining science content can be seen in Table 4.

**Table 4**

*Level of content knowledge of elementary science teacher*

| **Dimensions** | **Level of Science teacher** | | |
|---|---|---|---|
| | **Beginner teacher** | **Experience teacher** | **Professional teacher** |
| **Know the content** | Teacher 2 | Teacher 3 | Teacher 1 and Teacher 4 |
| **Substance and Structure of the content** | Teacher 2 | Techer 1, Teacher 3, and Teacher 4 | |
| **Content Selection and Organization** | | Teacher 2 and Teacher 3 | Teacher 1 and Teacher 4 |
| **Knowing** | Teacher 2 | Teacher 3 and | Teacher 1 |

| Dimensions | Level of Science teacher | | |
|---|---|---|---|
| | Beginner teacher | Experience teacher | Professional teacher |
| **different ways to understand particular concept** | | Teacher 4 | |
| **Identify curriculum standards related to specific concepts** | Teacher 2 | Teacher 1, Teacher 3, and Teacher 4 | |

Based on the level of competency in content knowledge (CK) shown in Table 4, Teacher 1 is classified as a professional teacher in three dimensions and an experienced teacher in two dimensions of content knowledge (CK). Teacher 2 falls under the beginner teacher level in almost all aspects of content knowledge, except for the content selection and organization dimension. Teacher 3 is categorized as an experienced teacher in the aspect of content knowledge (CK). Meanwhile, Teacher 4 is classified as an experienced teacher in three dimensions and a professional teacher in two dimensions of content knowledge (CK). Based on the results in Table 4, it can be concluded that Teacher 1 is recognized as a professional teacher, Teacher 3 and Teacher 4 are classified as experienced teachers, while Teacher 2 demonstrates that he is positioned as a beginner teacher.

The results reveals that Teacher 1 obtained the highest percentage, with a score of 78.57%, indicating a deep understanding of the concepts. On the other hand, Teacher 2 achieved the lowest score of 36.36% in terms of the depth of essential science concepts at the elementary level. Teacher 3 demonstrated a 50% depth of essential science concepts, while Teacher 4 scored 60%. Teacher 2 and 3 possess a restricted understanding of science concepts because of their limited science backgrounds during their studies. However, different results were found for Teacher 1. Although she never learned about science content during his study period, she obtained the highest percentage of understanding of essential science concepts among other teachers. She even outperformed Teacher 4, who always learned science content during his study period. This is because, during teaching, Teacher 1 always continued learning and always collected updated information about essential science concepts, even though the curriculum in Indonesia is always changing.

The lack of background science knowledge forces elementary school teachers to rely on other sources to understand science phenomena, such as common sense, daily life practices, or sticking to books (Tekkaya et al., 2004; Widodo et al., 2017). According to the learning video analysis results, Teachers 2 and 3 tend to stick to textbooks and materials displayed in the form of power points when conveying the science concepts taught. While Teacher 1 conducted learning with the project method to strengthen students' concepts about the solar system, Teacher 4 used the demonstration method to explain the concept of single and mixed substances. The difference in how teachers convey concepts is partly influenced by the teacher's knowledge of the concept or content (Masduki et al., 2019; Walshaw, 2012). It is further explained that teachers with limited concept knowledge will need explaining the concept (Hurrell, 2021). Concept understanding is a competency that must be possessed by teachers in order to create good learning and prevent misconceptions (Anam et al., 2017, 2020; Fikriyah et al., 2020; Widodo et al., 2017).

These results follow several previous studies, which show that a lack of understanding of science concepts will hamper the learning process (Kazempour, 2014; P. S. Oh & Kim, 2013; Sundari, 2021; U. Cornelius-Ukpepi & O. Enukoha, 2013). Teachers with a limited understanding of science content will decrease their confidence(Amy Catalano et al., 2019; Harlen & Holroyd, 1997; Nikolopoulou & Tsimperidis, 2023; Rahayu & Osman, 2019). They tend to conduct learning activities monotonously (Indrayati, 2018). The limited depth of science concepts explained by teachers makes the concepts convey seem very simple (Darling-Hammond et al., 2020). Teachers tend to explain the meaning, coupled with related examples, without further explanation (Mufida & Widodo, 2021). This is directly confirmed by research conducted by (Saclarides and Munson 2021), where low material depth or concept mastery can be caused by material content that is not interpreted or explained properly (only explained in general terms or not explained at all) and not an explanation of the content. However, the teacher conveys difficulty in understanding the content. As a result, students tend to be silent and refrain from actively asking questions in class (Angraini et al., 2023; Bahmanbijari et al., 2019).

Meanwhile, the analysis results in Table 4 show that Teacher 1 is recognized as a professional teacher. Teachers 3 and 4 are classified as experienced teachers. Teacher 2 shows that he is positioned as as beginner teacher. During the learning process of Teacher 1 and 4, they capably developed accurate and in-depth science concepts. They could relate science concepts to solve problems in daily life. Teachers' understanding of science content is key to scientific literacy (OECD, 2018; J. Y. Oh, 2017). Furthermore, understanding science concepts is important in improving students' understanding of science concepts, successful learning of science content, and participation in scientific decision making (Bell & Lederman, 2003; Eastwood et al., 2012; Khishfe, 2020). Conceptual understanding also highlights the importance of having comprehensive and in-depth knowledge (Alao & Guthrie, 1999; Boh et al., 2014).Teachers who possess broad scientific knowledge are more adept at making connections between different concepts, whereas teachers with deep knowledge are better equipped to provide detailed explanations of a concept (Widiyatmoko, 2018).

In Teacher 2 and Teacher 3, there were still misconceptions when conveying science concepts. Misconceptions indicate a lack of basic knowledge essential to understanding the science principles and processes needed to teach the science curriculum (Greensfeld & Gross, 2020; Laeli et al., 2020). In general, teachers who have limited science content knowledge often heavily rely on textbooks as their main source of content knowledge and for lesson planning. However, this approach can be problematic because science textbooks may not always offer alternative methods to help students grasp concepts effectively. Consequently, teachers with limited science knowledge may require assistance in clarifying students' understanding (Lee & Barnett, 2004; Luera & Otto, 2005). In these cases, the content taught by teachers tends to be abstract. It cannot be directly observed (microscopic), so teachers find it difficult to explain due to inadequate facilities and infrastructure (Costa & Broietti, 2022). The possibility of misconceptions is also due to vernacular misunderstandings, i.e., misunderstandings due to teachers' less thorough reading skills or a lack of clarity in textbooks and other reading materials(Liu & Fang, 2016).

In delivering concepts, all teachers choose to sort them from the general to specific concepts or from the easiest to abstract concepts. The delivery of the main concept, followed by many sub-concepts, will make it easier for teachers to streamline learning materials and facilitate student understanding (Mufida & Widodo, 2021; Puspitarini & Hanif, 2019). However, based on the video analysis, it is found that in the selection and organization of content, Teacher 1 and Teacher 4 are at a higher level than Teachers 2 and 3. This is because, during the learning process, Teachers 1 and

4 tend to be more systematic, from low-level concepts to abstract levels. Meanwhile, Teacher 3 way of conveying concepts tends to be random, and Teacher 2 tends to give many examples and seems repetitive. Since the concept is delivered through oral presentation, the possibility of the repetition of the explanation is common. Therefore, the teacher will run out of time, and many concepts have yet to be conveyed.

This study has several implications, such as the fact that teachers deepen and enhance their understanding of science concepts based on their experiences. Previous research has shown that teaching experience has a positive influence on elementary school teachers' mastery of science concepts (Akarsu, 2007; Nixon et al., 2019; Smith et al., 2022). Furthermore, educational qualifications and teaching experience collectively have a positive and significant impact on teachers' professionalism in teaching science at elementary schools (Qomariah, 2016). Another perspective views learning as a participatory process, where individuals engage in various activities and are part of different groups. In this view, teachers are seen as active participants or "actors" in their own learning experiences. In other words, active participation and engagement in learning situations can enhance their understanding of concepts (Paavola et al., 2004). Teacher 1 evidenced, who applies the concept of lifelong learning by gathering various learning resources that can enhance their depth of conceptual understanding. Even though Teacher 1 does not have a science background, by collecting the science materials he needs and actively engaging, he can teach science effectively without relying on others (Ekelemu, 2014).

Furthermore, teachers should be provided with training that helps them learn from their experiences. This is because teacher professional development is needed to facilitate primary school teachers' learning and teaching of science to their students. Teacher professional development plays a crucial role in improving classroom teaching and enhancing student learning achievement (Pitsoe & Letseka, 2014). Several studies have demonstrated that teacher professional development effectively enhances teachers' conceptual understanding in various topics and improves their pedagogical practices (Desimone, 2009; Greitāns & Namsone, 2021; OnSabon, 2018; Utami et al., 2019; Vermunt et al., 2019; Widodo & Riandi, 2013; Winarsih & Mulyani, 2012). Through professional development, teachers use their newfound knowledge, skills, attitudes, and beliefs to enhance the content of their pedagogical approaches (Desimone, 2009).

## CONCLUSIONS

Based on the analysis results, it can be concluded that the science background of elementary school teachers does not affect the depth of the concepts they teach or their level of content knowledge (CK) in science. This is evidenced by the fact that the teacher with the highest level of content knowledge (CK) is Teacher 1, who does not have any science background. Teacher 1 demonstrates professionalism in terms of content knowledge (CK) competency standards, as indicated by the highest percentage of concept mastery at 76% compared to Teacher 2, Teacher 3, and Teacher 4. Teachers 3 and 4 are classified as experienced teachers with percentages of 50.5% (Teacher 3) and 69.2% (Teacher 4) for the depth of their science concepts, respectively. Meanwhile, Teacher 2 has a beginner level of content knowledge (CK), with a conceptual understanding percentage of 30.7%.

This research shows that content knowledge (CK) is fundamental for all science teachers. Teachers who have limited concept knowledge will have difficulty explaining essential science concepts. This study also has several implications that can be taken, namely, although elementary school teachers in Indonesia learn from different backgrounds, mastery of content knowledge (CK) can be fostered with the idiom of the concept of lifelong learning. Teacher 1 evidenced, who always continues to learn even though the curriculum has changed. Although learning is very important, teachers who have a science background and love science from an early age also significantly improve students' understanding of concepts. Therefore, in deepening science content, it is also very necessary to develop professionalism programs for elementary school teachers to better understand how to learn science and teach it to their students.

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## AUTHORS' CONTRIBUTIONS STATEMENTS

A.S., and A.W conceived the idea of the research presented. A.S., and E.C.P., collected the data. The three authors A.S., A.W., and E.C.P., actively participated in the development of the theory, methodology, data organisation and analysis, discussion of results and approval of the final version of the work.

## DATA AVAILABILITY STATEMENT

The data supporting the results of this investigation will be made available by the correspondent A.C.P., upon reasonable request.

## REFERENCES


Akarsu, B. (2007). What Are the Effects of Teaching Experience on In-Service Elementary Science Teachers' Conceptions of the Nature of Science? *ASTE Conference Proceedings*, 1–15.

Akinleye, O. O., & Mutiat, O. Y. (2021). Effect of Mastery Learning Strategy and Teachers Mastery of Content on Students' Attitude Towards Biology. *Journal of Science and Technology Education*, *3*(2), 2–17.

Alao, S., & Guthrie, J. T. (1999). Predicting conceptual understanding with cognitive and motivational variables. *Journal of Educational Research*, *92*(4), 243–254. https://doi.org/10.1080/00220679909597602

Amy Catalano, A., Asselta, L., & Durkin, A. (2019). Exploring the Relationship between Science Content Knowledge and Science Teaching Self-Efficacy among Elementary Teachers. *IAFOR Journal of Education*, *7*(1), 57–70. https://doi.org/10.22492/ije.7.1.04

Anam, R. S., Widodo, A., & Sopandi, W. (2017). Representation of Elementary School Teachers on Concept of Heat Transfer. *Journal of Physics: Conference Series*, *895*(1). https://doi.org/10.1088/1742-6596/895/1/012159

Anam, R. S., Widodo, A., & Sopandi, W. (2020). Conceptual Change Texts to Improve Teachersâ€™ Misconception at Verbal and Visual Representation on Heat Conduction Concept. *Jurnal Pendidikan Fisika Indonesia*, *16*(2), 63–71. https://doi.org/10.15294/jpfi.v16i2.20742

Angraini, E., Zubaidah, S., & Susanto, H. (2023). TPACK-based Active Learning to Promote Digital and Scientific Literacy in Genetics. *Pegem Journal of Education and Instruction*, *13*(2), 50–61. https://doi.org/10.47750/pegegog.13.02.07

Appleton, K. (2008). Developing science pedagogical content knowledge through mentoring elementary teachers. *Journal of Science Teacher Education*, *19*(6), 523–545. https://doi.org/10.1007/s10972-008-9109-4

Atwood, R. K., Christopher, J. E., Combs, R. K., & Roland, E. E. (2010). In-

Service Elementary Teachers' Understanding of Magnetism Concepts Before and After Non-Traditional Instruction The authors provide a descriptive study of in-service elementary teachers' understanding of magnetism concepts and confidence in their underst. *Science Educator*, *19*(1), 64–76.

Bahmanbijari, B., Nazarieh, M., Toufan, N., Dehghani, M. R., & Beigzadeh, A. (2019). Identification of the reasons behind students' lack of participation in classroom activities using a Delphi technique. *Future of Medical Education Journal*, *June*, 10–17. https://doi.org/10.22038/FMEJ.2019.15154.1091

Baptista, G. C. S., & Molina-Andrade, A. (2021). Science Teachers' Conceptions About the Importance of Teaching and How to Teach Western Science to Students from Traditional Communities. *Human Arenas*, *0123456789*. https://doi.org/10.1007/s42087-021-00257-4

Baumfalk, B., Bhattacharya, D., Vo, T., Forbes, C., Zangori, L., & Schwarz, C. (2019). Impact of model-based science curriculum and instruction on elementary students' explanations for the hydrosphere. *Journal of Research in Science Teaching*, *56*(5), 570–597. https://doi.org/10.1002/tea.21514

Bell, R. L., & Lederman, N. G. (2003). Understandings of the Nature of Science and Decision Making on Science and Technology Based Issues. *Science Education*, *87*(3), 352–377. https://doi.org/10.1002/sce.10063

Boh, W. F., Evaristo, R., & Ouderkirk, A. (2014). Balancing breadth and depth of expertise for innovation: A 3M story. *Research Policy*, *43*(2), 349–366. https://doi.org/10.1016/j.respol.2013.10.009

Borghi, A. M., Binkofski, F., Castelfranchi, C., Cimatti, F., Scorolli, C., & Tummolini, L. (2017). The challenge of abstract concepts. *Psychological Bulletin*, *143*(3), 263–292. https://doi.org/10.1037/bul0000089

Cherif, A., Roze, M., & Gailamas, S. (2016). The Free Classroom Creative Assignment: leveraging student strengths to enhance learning. *The International Schools Journal*, *35*(2), 57-.

Costa, S. L. R., & Broietti, F. C. D. (2022). Towards Greater Understandings of Scientific Practices in Science Education: An Analysis of the Publications. *Acta Scientiae*, *24*(6), 151–182. https://doi.org/10.17648/acta.scientiae.6913

Damavandi, M. E., & Kashani, Z. S. (2010). Effect of mastery learning method on performance and attitude of the weak students in chemistry. *Procedia - Social and Behavioral Sciences*, *5*, 1574–1579. https://doi.org/10.1016/j.sbspro.2010.07.327

Darling-Hammond, L., Flook, L., Cook-Harvey, C., Barron, B., & Osher, D. (2020). Implications for educational practice of the science of learning and development. *Applied Developmental Science*, *24*(2), 97–140. https://doi.org/10.1080/10888691.2018.1537791
Desimone, L. M. (2009). Improving impact studies of teachers' professional development: Toward better conceptualizations and measures. *Educational Researcher*, *38*(3), 181–199. https://doi.org/10.3102/0013189X08331140
Eastwood, J. L., Sadler, T. D., Zeidler, D. L., Lewis, A., Amiri, L., & Applebaum, S. (2012). Contextualizing nature of science instruction in socioscientific issues. *International Journal of Science Education*, *34*(15), 2289–2315. https://doi.org/10.1080/09500693.2012.667582
Ekelemu, E. (2014). Teacher attitude, experience and background knowledge effect on the use of inquiry method of Teaching IRJTE Teacher attitude, experience and background knowledge effect on the use of inquiry method of Teaching. *Global Research Journal of Education*, *2*(4), 198–206.
Eliyawati, Widodo, A., Kaniawati, I., & Fujii, H. (2023). The Development and Validation of an Instrument for Assessing Science Teacher Competency to Teach ESD. *Sustainability Article*, *15*(3276), 1–14.
Evens, M., Elen, J., Larmuseau, C., & Depaepe, F. (2018). Promoting the development of teacher professional knowledge: Integrating content and pedagogy in teacher education. *Teaching and Teacher Education*, *75*, 244–258. https://doi.org/10.1016/j.tate.2018.07.001
Fikriyah, A., Sandika, B., & Wijaya, E. Y. (2020). Evaluating pre-service science teachers' concept mastery in the topic of biodiversity during distance learning under circumstance of Covid-19 pandemic. *Jurnal Inovasi Pendidikan IPA*, *6*(2), 209–216. https://doi.org/10.21831/jipi.v6i2.35033
Greensfeld, H., & Gross, T. (2020). What do we know about teachers' knowledge? assessing primary science teachers' content knowledge in the jewish and arab sectors. *Eurasia Journal of Mathematics, Science and Technology Education*, *16*(10). https://doi.org/10.29333/EJMSTE/8473
Greitāns, K., & Namsone, D. (2021). in-Service Science Teachers' Professional Development Targeted To Promote Student Understanding of Core Scientific Concepts. *Proceedings of the 4th International Baltic Symposium on Science and Technology Education*, 49–58. https://doi.org/10.33225/balticste/2021.49
Harlen, W., & Holroyd, C. (1997). Primary teachers' understanding of

concepts of science: Impact on confidence and teaching. *International Journal of Science Education*, *19*(1), 93–105. https://doi.org/10.1080/0950069970190107
Hashweh, M. Z. (1987). Effects of subject-matter knowledge in the teaching of biology and physics. *Teaching and Teacher Education*, *3*(2), 109–120. https://doi.org/10.1016/0742-051X(87)90012-6
Heywood, D. S. (2007). Problematizing science subject matter knowledge as a legitimate enterprise in primary teacher education. *Cambridge Journal of Education*, *37*(4), 519–542. https://doi.org/10.1080/03057640701705856
Hurrell, D. (2021). Conceptual Knowledge OR Procedural Knowledge or Conceptual Knowledge AND Procedural Knowledge: Why the Conjunction is Important to Teachers. *Australian Journal of Teacher Education*, *46*(2), 57–71. https://doi.org/10.14221/ajte.2021v46n2.4
Indrayati. (2018). on Transforming Monotonous Classes : Implementing Problem Based Learning Conjoined With Cooperative Learning in College. *Journal of Educational Change*, *3*(April), 48–56. https://www.researchgate.net/journal/Journal-of-Educational-Change-1573-1812
Iwuanyanwu, P. N. (2019). What we Teach in Science, and What Learners Learn: A Gap that Needs Bridging. *Pedagogical Research*, *4*(2). https://doi.org/10.29333/pr/5780
James W. Stigler, Patrick Gonzales, Takako Kawanaka, Steffen Knoll, and A. S. (1999). The TIMSS videotape classroom study: Methods and findings research project on Eighth-grade. *Research and Development Report*, *February*.
Kamamia, L. N., Ngugi, N. T., & Thinguri, R. W. (2014). To Establish the Extent to Which the Subject Mastery Enhances Quality Teaching to Student-Teachers During Teaching Practice. *International Journal of Education and Research*, *2*(7), 641–648.
Kazempour, M. S. (2014). I can't teach science! A case study of an elementary pre-service teacher's intersection of science experiences, beliefs, attitude, and self-efficacy. *International Journal of Environmental and Science Education*, *9*(1), 77–96. https://doi.org/10.12973/ijese.2014.204a
Khishfe, R. (2020). Consistency of nature of science views across scientific and socio-scientific contexts. *International Journal of Science Education*, *39*(4), 403–432. https://doi.org/10.1080/09500693.2017.1287976
Krall, M., Lott, K. H., & Wymer, C. L. (2009). Inservice Elementary and Middle School Teachers' Conceptions of Photosynthesis and

Respiration. *Journal Science Teacher Education*, *20*(1), 41–55. https://doi.org/10.1007/s
Laelandi, R., Widodo, A., & Sriyati, S. (2022). Depth of Science Learning Materials in Schools and Student Concept Mastery. *Jurnal Penelitian Pendidikan IPA*, *8*(3), 1470–1478. https://doi.org/10.29303/jppipa.v8i3.1706
Laeli, C. M. H., Gunarhadi, & Muzzazinah. (2020). Misconception of Science Learning in Primary School Students. *3rd International Conference on Learning Innovation and Quality Education (ICLIQE 2019)*, *397*(Icliqe 2019), 657–671.
Lee, O., & Barnett, J. E. H. (2004). Professional Development in Inquiry-Based Science for Elementary Teachers of Diverse Student Groups. *Journal of Research in Science Teaching*, *41*(10), 1021–1043. https://doi.org/10.1002/tea.20037
Liu, G., & Fang, N. (2016). Student Misconceptions about Force and Acceleration in Physics and Student Misconceptions about Force and Acceleration in Physics and Engineering Mechanics Education *. *International Journal of Engineering Education*, *32*(1), 19–29.
Luera, G. R. (2005). What type and level of science content knowledge of elementary education students affect their ability to construct an inquiry-based science lesson? *Journal of Elementary Science Education*, *17*(1), 12–25.
Luera, G. R., & Otto, C. A. (2005). Development and Evaluation of an Inquiry-Based Elementary Science Teacher Education Program Reflecting Current Reform Movements. *Journal of Science Teacher Education*, *16*, 241–258.
Manrique, R., Pereira, B., & Mariño, O. (2019). Exploring knowledge graphs for the identification of concept prerequisites. *Smart Learning Environments*, *6*(1). https://doi.org/10.1186/s40561-019-0104-3
Masduki, Suwarsono, & Budiarto, M. T. (2019). The Influence of Teacher's Conception of Teaching and Learning on Their Teaching Practice. *Journal of Physics: Conference Series*, *1306*(1). https://doi.org/10.1088/1742-6596/1306/1/012043
McConnell, T. J., Parker, J. M., & Eberhardt, J. (2013). Assessing Teachers' Science Content Knowledge: A Strategy for Assessing Depth of Understanding. *Journal of Science Teacher Education*, *24*(4), 717–743. https://doi.org/10.1007/s10972-013-9342-3
Mesci, G., Schwartz, R. S., & Pleasants, B. A. S. (2020). Enabling Factors of Preservice Science Teachers' Pedagogical Content Knowledge for Nature of Science and Nature of Scientific Inquiry. *Science and*

*Education*, *29*(2), 263–297. https://doi.org/10.1007/s11191-019-00090-w
Morrell, P., Rogers, M. P., Pyle, E., Roehrig, G., & Veal, W. (2020). 2020 NSTA/ASTE Standards for Science Teacher Preparation. *ASTE*, 3.
Mufida, A. Al, & Widodo, A. (2021). Analisis kedalaman dan keterkaitan antar konsep ekosistem pada pembelajaran IPA di masa pandemi Depth analysis and relationships between concepts in natural science learning during the pandemic. *Jurnal Inovasi Pendidikan IPA*, *7*(2), 116–127.
Mundry, S. (2005). Changing Perspectives in Professional Development. *Science Educator*, *14*(1), 9–15.
Muttaqiin, A., Lufri, L., Yogica, R., & Fitri, R. (2021). Achievement of Students' Concept Mastery through Concept-based Learning and Drill Methods in Biology Instructional Methodology Course. *Journal of Physics: Conference Series*, *1940*(1), 0–6. https://doi.org/10.1088/1742-6596/1940/1/012118
Nikolopoulou, K., & Tsimperidis, I. (2023). STEM education in early primary years: Teachers' views and confidence. *Journal of Digital Educational Technology*, *3*(1), ep2302. https://doi.org/10.30935/jdet/12971
Nixon, R. S., Smith, L. K., & Sudweeks, R. R. (2019). Elementary teachers' science subject matter knowledge across the teacher career cycle. *Journal of Research in Science Teaching*, *56*(6), 707–731. https://doi.org/10.1002/tea.21524
NSW. (2018). Australian Professional Standards for Teachers. In *NSW Government*. https://doi.org/10.1017/9781108550703.014
OECD. (2018). PISA 2018 Results COMBINED EXECUTIVE SUMMARIES. In *OECD: Vols. I, II, III*. https://doi.org/10.1787/g222d18af-en
Oh, J. Y. (2017). Suggesting a NOS map for nature of science for science education instruction. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(5), 1461–1483. https://doi.org/10.12973/eurasia.2017.00680a
Oh, P. S., & Kim, K. S. (2013). Pedagogical Transformations of Science Content Knowledge in Korean Elementary Classrooms. *International Journal of Science Education*, *35*(9), 1590–1624. https://doi.org/10.1080/09500693.2012.719246
OnSabon, S. S. (2018). Efektivitas Pelatihan Guru Melalui Pendidikan Dan Latihan Profesi Guru. *Jurnal Penelitian Kebijakan Pendidikan*, *11*(3), 159–182. https://doi.org/10.24832/jpkp.v11i3.210
Paavola, S., Lipponen, L., & Hakkarainen, K. (2004). Models of Innovative Knowledge Communities and Three Metaphors of Learning. *Review of*

*Educational Research*, *74*(4), 557–576. https://doi.org/10.3102/00346543074004557
Parker, J., & Heywood, D. (2000). Exploring the relationship between subject knowledge and pedagogic content knowledge in primary teachers' learning about forces. *International Journal of Science Education*, *22*(1), 89–111. https://doi.org/10.1080/095006900290019
Pitsoe, V., & Letseka, M. (2014). Exploring Teacher Professional Development (TPD) through Foucault and Freirean lenses. *Pensee Journal*, *76*(9), 372–381.
Puspitarini, Y. D., & Hanif, M. (2019). Using Learning Media to Increase Learning Motivation in Elementary School. *Anatolian Journal of Education*, *4*(2), 53–60.
Qomariah, S. (2016). Pengaruh kualifikasi pendidikan dan pengalaman mengajar terhadap profesionalisme guru dalam pembelajaran ipa SD di gugus II distrik nabire. *Ilmu Pendidikan Indonesia*, *4*(3), 26–34.
Rahayu, T., & Osman, K. (2019). Knowledge Level and Self-Confidence on The Computational Thinking Skills Among Science Teacher Candidates. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, *8*(1), 117–126. https://doi.org/10.24042/jipfalbiruni.v8i1.4450
Rohmah, N. G., Leksono, S. M., & Nestiadi, A. (2022). Analisis Buku Teks IPA SMP Kelas VII Berdasarkan Muatan Kemampuan Berpiki Kreatif pada Tema Udaraku Bersih. *PENDIPA Journal of Science Education*, *6*(2), 353–360. https://doi.org/10.33369/pendipa.6.2.353-360
Rollnick, M. (2017). Learning About Semi Conductors for Teaching — the Role Played by Content Knowledge in Pedagogical Content Knowledge ( PCK ) Development. *Research in Science Education*, *47*, 833–868. https://doi.org/10.1007/s11165-016-9530-1
Smith, L. K., Nixon, R. S., Sudweeks, R. R., & Larsen, R. A. (2022). Elementary teacher characteristics, experiences, and science subject matter knowledge: Understanding the relationships through structural equation modeling. *Teaching and Teacher Education*, *113*, 103661. https://doi.org/10.1016/j.tate.2022.103661 .
Soysal, Y. (2022). Science Curriculum Objectives' Intellectual Demands: A Thematic Analysis. *Journal of Science Learning*, *5*(1), 127–140. https://doi.org/10.17509/jsl.v5i1.35439
Stephanie Saclarides, E., & Munson, J. (2021). Exploring the foci and depth of coach-teacher interactions during modeled lessons. *Teaching and Teacher Education*, *105*, 103418. https://doi.org/10.1016/j.tate.2021.103418
Sundari. (2021). Teacher Problems in the Application of Scientific Approach

to Learning during the Covid - 19 Pandemic in Elementary School. *International Conference on Early and Elementary Education*, *2014*, 75–84.
Susanto, R., Rachmadtullah, R., & Rachbini, W. (2020). Technological and pedagogical models: Analysis of factors and measurement of learning outcomes in education. *Journal of Ethnic and Cultural Studies*, *7*(2), 1–14. https://doi.org/10.29333/ejecs/311
Taber, K. S. (2013). Modelling Learners and Learning in Science Education. In *Modelling Learners and Learning in Science Education*. Springer. https://doi.org/10.1007/978-94-007-7648-7
Tekkaya, C., Cakiroglu, J., & Ozkan, O. (2004). Turkish pre-service science teachers' understanding of science and their confidence in teaching it. *Journal of Education for Teaching*, *30*(1), 57–68. https://doi.org/10.1080/0260747032000162316
Tu, J., Liu, L., & Wu, K. (2018). *Study on the Learning Effectiveness of Stanford Design Thinking in Integrated Design Education*. 1–21. https://doi.org/10.3390/su10082649
U. Cornelius-Ukpepi, B., & O. Enukoha, O. (2013). Limitations to Understanding Scientific Concepts and Academic Performance in Primary Science among Primary Six Pupils in Cross River State Nigeria. *International Journal of Evaluation and Research in Education (IJERE)*, *2*(2), 85–92. https://doi.org/10.11591/ijere.v2i1.1716
Utami, I. G. A. L. P., Prestridge, S., Saukah, A., & Hamied, F. A. (2019). Continuing Professional Development and teachers' perceptions and practices - A tenable relationship. *Indonesian Journal of Applied Linguistics*, *9*(1), 108–118. https://doi.org/10.17509/ijal.v9i1.12463
Vermunt, J. D., Vrikki, M., van Halem, N., Warwick, P., & Mercer, N. (2019). The impact of Lesson Study professional development on the quality of teacher learning. *Teaching and Teacher Education*, *81*, 61–73. https://doi.org/10.1016/j.tate.2019.02.009
Walshaw, M. (2012). Teacher knowledge as fundamental to effective teaching practice. *Journal of Mathematics Teacher Education*, *15*(3), 181–185. https://doi.org/10.1007/s10857-012-9217-0
Wicaksono, I., Supeno, & Budiarso, A. S. (2020). Validity and practicality of the biotechnology series learning model to concept mastery and scientific creativity. *International Journal of Instruction*, *13*(3), 157–170. https://doi.org/10.29333/iji.2020.13311a
Widiyatmoko, A. (2018). The Effectiveness of Simulation in Science Learning on Conceptual Understanding : A Literature Review. *Journal of International Development and Cooperation*, *24*(1), 35–43.

Widodo, A. (2006). The Feature of Biology Lessons: Results of a Video Study Ari. *The Second UPI- UPSI Joint Internatinal Conference*, *August*, 8–9.

Widodo, A., & Ramdaningsih, V. (2006). Analisis Kegiatan Praktikum Biologi di SMP dengan Menggunakan Video. *Jurnal Penelitian Pendidikan Biologi* , *9*, 146–158.

Widodo, A., & Riandi. (2013). Dual-mode teacher professional development: challenges and re-visioning future TPD in Indonesia. *Teacher Development*, *17*(3), 380–392. https://doi.org/10.1080/13664530.2013.813757

Widodo, A., Rochintaniawati, D., & Riandi. (2017). Primary School Teachers' Understanding of Essential Science Concepts. *Cakrawala Pendidikan*, *Oktober*(3). https://doi.org/http://dx.doi.org/10.21831/cp.v36i3.11921

Winarsih, A., & Mulyani, S. (2012). Peningkatan profesionalisme guru IPA melalui lesson study dalam pengembangan model pembelajaran PBI. *Jurnal Pendidikan IPA Indonesia*, *1*(1), 43–50. https://doi.org/10.15294/jpii.v1i1.2012

Yalçın, V. (2022). Design‑Oriented Thinking in STEM education: Exploring the Impact on Preschool Children's Twenty‑First‑Century Skills. *Science & Education*, *0123456789*. https://doi.org/10.1007/s11191-022-00410-7