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Using the TPACK Framework to Map Indonesian Secondary Science Teachers' Experiences in Conducting Laboratory Learning during the Covid-19 Pandemic

Penggunaan Kerangka TPACK untuk Memetakan Pengalaman Guru Sains Sekolah Menengah Indonesia dalam Melaksanakan Pembelajaran Laboratorium Selama Pandemi Covid-19

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Abstrak

Pandemi Covid-19 membawa beberapa tantangan terhadap keberlanjutan kegiatan pendidikan di seluruh dunia. Dalam konteks Indonesia, pemerintah mewajibkan peralihan dari pembelajaran tatap muka ke pembelajaran daring yang membebani guru sains dalam mempertahankan pengajaran laboratorium. Karena penutupan sekolah, guru sains sekolah menengah di Indonesia terpaksa mengubah metode pengajaran laboratorium mereka dengan mengintegrasikan teknologi digital. Oleh karena itu, metodologi kualitatif dan metode studi kasus digunakan untuk menyelidiki pengalaman guru sains sekolah menengah di Indonesia dalam melakukan pembelajaran laboratorium di tengah wabah Covid-19. Selain itu, kerangka kerja TPACK digunakan sebagai dasar teoritis untuk memetakan pengalaman peserta. Data diperoleh menggunakan wawancara semi-terstruktur dengan pertanyaan terbuka dengan dua guru sains sekolah menengah di Indonesia. Data kemudian dianalisis menggunakan strategi analisis tematik untuk mengidentifikasi tema-tema yang muncul dari pengalaman peserta. Tema-tema yang muncul adalah pemilihan konten pengajaran, pengajaran konsep sains yang membutuhkan kegiatan laboratorium, penggunaan teknologi digital untuk memfasilitasi siswa dalam melakukan kegiatan laboratorium, penggunaan teknologi digital untuk menilai hasil belajar laboratorium siswa, dan menghadapi tantangan dalam mengintegrasikan teknologi digital ke dalam pengajaran laboratorium. Pengalaman-pengalaman ini dipetakan ke dalam sejumlah domain pengetahuan TPACK, seperti CK, PK, PCK, TK, TCK, TPK, dan XK, menggunakan kerangka kerja TPACK sebagai panduan. Namun, tidak ditemukan indikasi TPCK dalam pengalaman para peserta.

Kata kunci: Covid-19; Pengajaran Laboratorium; Guru Sains Sekolah Menengah; TPACK.

Abstract

The Covid-19 pandemic brought some challenges to the continuity of educational activities around the world. In the Indonesian context, the government mandated the shift from face-to-face classrooms to online learning which burdened science teachers in maintaining laboratory instructions. Due to the closure of the schools, Indonesian secondary science teachers were forced to alter their methods of laboratory instruction by integrating digital technologies. Therefore, a qualitative methodology and a case study method were used to investigate the experiences of Indonesian secondary science teachers in conducting laboratory learning amid the Covid-19 outbreak. Moreover, the TPACK framework was utilised as a theoretical basis to map participants' experiences. The data was obtained using semi-structured interviews with open-ended questions with two Indonesian secondary science teachers. The data then was analysed using a thematic analysis strategy to identify themes that emerged from the participants' experiences. The emerging themes were choosing teaching content, teaching science concepts that require laboratory activities, using digital technology to facilitate students in conducting laboratory activities, using digital technology to assess students' laboratory learning outcomes, and facing challenges in integrating digital technology into laboratory teaching. These experiences were mapped into a number of TPACK knowledge domains, such as CK, PK, PCK, TK, TCK, TPK, and XK, using the TPACK framework as a guide. However, no indication of TPCK was found in the participants' experiences.

Keywords: Covid-19; *Laboratory Teaching; Secondary Science Teachers; TPACK*

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INTRODUCTION

In December 2019, the first SARS-CoV-2 infection case was reported in Wuhan, China (Azhari & Fajri, 2021). Subsequently, on 11 March 2020, the World Health Organization (WHO) labelled this phenomenon a pandemic after evaluating the global-scale transmission of the virus (WHO, 2020). Governments from almost all countries in the world, including Indonesia, are compelled to implement rules such as isolation and lockdowns to slow the spread of the disease (WHO, 2020). These prohibitions have affected many facets of human life, including education, where students around the world cannot participate in in-person classroom instruction (UNESCO, 2021).

With regard to the Indonesian context, the Indonesian government issued a nationwide policy for the education sector that mandated all teaching and learning activities be switched to remote learning during the outbreak (Rasmitadila et al., 2020). Regarding subjects that require a substantial amount of laboratory work, such as science, this rule could bring significant difficulties (Putri et al., 2020). Due to the online nature of educational activities and the school closures, Indonesian science teachers may not have access to school laboratories for conducting laboratory practice. In relation to this situation, Wisanti et al. (2021) revealed that during the pandemic, the majority of Indonesian science teachers decided to replace laboratory activities with alternative assignments. In addition, it was discovered that some educators eliminated laboratory activities from the syllabus (Wisanti et al., 2021). From these findings, it was evident that Indonesian science teachers were burdened with carrying out the activities of laboratory instruction during the outbreak.

According to a number of studies, students should engage in laboratory activities due to a lot of benefits they might obtain. Hamidu et al (2014), for example, claimed that these exercises can improve students' conceptual understanding of diverse scientific topics and enable them to incorporate them into real-world situations. Moreover, laboratory work can assist students to develop 21st-century skills, such as problem-solving, social, and communication skills (Nonye et al., 2012). In addition, Almroth (2015) explained that laboratory activities may assist students to improve critical thinking abilities by encouraging them to raise questions and can facilitate social contact and peer education since students are asked to collaborate in groups. Almroth (2015) further explained that by conducting laboratory activities, students will acquire a variety of technical skills and have regular access to advanced technologies in laboratory settings (Almroth, 2015). In light of these benefits, teachers are obligated to continue laboratory instruction throughout the pandemic, since a loss of laboratory activities might lead to a decline in the scientific performance, skills, and learning outcomes of their pupils.

Nonetheless, a number of research studies showed that conducting laboratory instruction during the Covid-19 outbreak might be difficult for secondary science teachers. Shidiq et al. (2021) discovered that because school closures hindered access to school laboratories, it was difficult for science teachers to supervise students who conduct laboratory work at home. It was also noted that when they did not monitor students, it was doubtful that students will acquire neither the necessary laboratory abilities nor precisely conduct laboratory tasks based on the correct methods (Shidiq et al., 2021). Moreover, the difficulty of accessing school laboratories during the outbreak demanded the incorporation of digital technology into laboratory teaching. Babinčáková and Bernard (2020) provided an illustration of science teachers' effort to integrate digital technology into laboratory instruction by revealing that some of the participants in their study utilized live demonstration videos to assist students in doing laboratory tasks in online classes. In addition, because the Covid-19 outbreak brought sudden changes from offline to online learning, it may be difficult for science teachers to use digital technology appropriately in laboratory instruction because they were not accustomed and trained to teach in an online environment prior to the outbreak (Jain et al., 2020).

By taking those concerns into account, this research aimed to investigate the experiences of Indonesian secondary science teachers in conducting laboratory learning during the Covid-19 outbreak and used the TPACK framework to understand their experiences. This framework was utilized to map teachers' experiences into several knowledge domains. Besides that, this framework was also used to guide the construction of interview questions used to obtain data in this study. Below are the TPACK framework knowledge domains from the latest version.

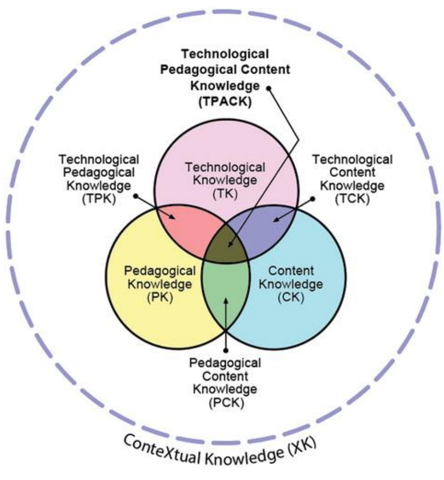

Figure 1. Latest version of the TPACK knowledge domains (Mishra, 2019).

The TPACK knowledge domains can be briefly described below:

- Content Knowledge (CK) - knowledge of the subjects and resources being taught;
- Pedagogical Knowledge (PK) - knowledge of how to use various educational strategies;
- Pedagogical Content Knowledge (PCK) - a comprehension of appropriate pedagogy to use when teaching particular topics;
- Technological Knowledge (TK) - an awareness of how to use technology;
- Technological Content Knowledge (TCK) - knowledge of how content and technology can influence and limit one another;
- Technological Pedagogical Knowledge (TPK) - an awareness of how the use of technology in a particular situation might change teaching and learning;
- Technological Pedagogical Content Knowledge (TPCK) - an awareness of how content, pedagogy, and technology interact; and
- Contextual Knowledge (XK) – an awareness of the variables that can affect teachers' integration of technology

(Koehler & Mishra, 2009; Mishra, 2019)

To guide the exploration, two research questions were articulated:

- What are Indonesian secondary science teachers' experiences in conducting laboratory learning during the Covid-19 pandemic?
- What are TPACK domains that emerged from Indonesian secondary science teachers' experiences in conducting laboratory learning during the Covid-19 pandemic?

This research might contribute to filling a gap in the area of laboratory teaching during the Covid-19 outbreak in the Indonesian context. In addition, current Indonesian-based studies on the use of the TPACK framework primarily used a quantitative methodology to evaluate the level of teachers' TPACK domains (Juanda et al., 2021; Kartimi et al., 2021). Therefore, this study might be used as an example of how to qualitatively understand teachers' teaching experiences using the TPACK framework.

METHOD

A qualitative methodology and a case study approach were used in this research project (Yin, 2003). Purposive sampling was employed to choose study participants (Bryman, 2016; Merriam & Tisdell, 2015). Participants in this study were chosen using a variety of criteria. First of all, the participants were secondary school science educators from Indonesia with previous experience in running laboratory learning during the Covid-19 outbreak. Additionally, they were teachers who incorporated digital technology into laboratory learning amid the outbreak. The following procedures were done in order to find participants for this study. It began by locating potential participants who matched the aforementioned criteria. Participants were then selected from the researcher's personal contacts due to the short research duration. Then, WhatsApp was used to initiate personal communication with the participant candidates. An invitation message was delivered to potential participant candidates after the researcher obtained ethical permission from Monash University Human Research Ethics Committee (MUHREC). The potential participants were subsequently invited to read, complete, and return a formal written consent form stating their consent to participate in this study. Two participants were recruited by means of these approaches. The participants were Alif (pseudonym) who taught biology in a private school in Lampung province for two years and Budi (pseudonym) who taught an integrated science subject (biology, physics, and chemistry) at a public junior high school in Jawa Barat province for nine years. This study employed semi-structured interviews with open-ended questions to gather data. The interviews were conducted in November 2021 using Zoom because the participants and the researcher were geographically separated. Then, using thematic analysis, the information gathered from the interviews was analyzed (Braun & Clarke, 2006).

RESULT AND DISCUSSION

Result

The results were organized into five emerging themes, including teachers' experiences in choosing laboratory teaching content, teaching science concepts that require laboratory activities, using digital technology to facilitate students in conducting laboratory activities, using digital technology to assess students' laboratory learning outcomes, and facing challenges in integrating digital technology into laboratory teaching.

Choosing Teaching Content

Driven by the TPACK framework, questions regarding teaching content were asked to know the participants' understanding related to the subject matters that require laboratory activities. Budi explained how he chose a science concept that required laboratory practices in his integrated science classes. He said:

> There is a science concept in grade eight that requires laboratory practices, which is the concept of "motion". In the beginning, the concept of "motion" is taught as a part of biology. After that, students will learn about the concept of "motion" related to Newton's laws in physics by performing an experiment in the laboratory.

Regarding Alif, he slightly explained a biology topic in his classes that necessitated laboratory practices. He stated that "one of the biology topics that needs laboratory work is the concept of enzymes. Laboratory activities are needed to know how enzymes work and the factors that affect enzyme performance".

Teaching Science Concepts that Require Laboratory Activities

In both participants' cases, the teaching contents related to science concepts that require laboratory activities were taught before students performed laboratory activities. During the pandemic, the science teachers in this study used different instructional strategies to teach science topics in their laboratory instruction. The teaching strategy used in Alif's classes was group discussions using Zoom. He stated:

> During online learning, my students were divided into groups. I used Zoom to divide the groups using the breakout room menu. They first watched a video containing a laboratory experiment from YouTube and discussed the concept related to the experiment.

Budi, on the other hand, used a question-and-answer approach in his laboratory instruction. He also used YouTube as a teaching resource. However, he preferred to utilise WhatsApp rather than Zoom to teach science concepts in his laboratory instruction. He told the story as follows:

> The learning was in real-time using WhatsApp groups, so we used the chat feature. I first provided some stimulus to students, such as an image or video from YouTube containing a laboratory experiment. Then, I asked students to answer a question related to the image or video during lesson time.

Budi also explained the reason why he frequently used WhatsApp compared to video conferencing tools in his laboratory instruction. He said:

> I rarely used video conferencing software, such as Zoom or Google Meet. It is because when I used WhatsApp, which is relatively a familiar technology even before the pandemic, my students still found it difficult to follow the instructions. Thus, if I used Zoom or Google Meet quite often, they might face more difficulties.

Using Digital Technology to Facilitate Students in Conducting Laboratory Activities

When asked to describe the types of digital technology they employed to assist their students in carrying out laboratory activities, the participants mentioned that they used virtual laboratories. The way they integrated virtual laboratories into their teaching strategies varied. For instance, Budi employed PhET (an online virtual laboratory platform) and let his students engage completely with the technology. He described, "I gave a PhET link to my students regarding the science topic that will be practised. After they opened the link, they could try to change the experiment variables in PhET by themselves."

Alif, although not mentioning what virtual laboratory platform he used, adopted a different strategy in which his students were unable to engage with the virtual laboratory in a direct way. Instead, he recorded a laboratory simulation he conducted in a virtual laboratory platform and uploaded the video to YouTube where his students will be able to view it. He stated:

> One of the technologies I used in the biology practicum was a virtual laboratory about catalase enzymes combined with YouTube. First, I recorded an experiment conducted in the virtual laboratory and uploaded it to YouTube. Then, during the lesson, students observed the results of the experiment from the YouTube link that I gave. Thus, it was like only a tutorial. My students were not able to change the variables in the experiment and could only do an observation from the video.

Using Digital Technology to Assess Students' Laboratory Learning Outcomes

The participants also employed digital technologies to evaluate students' learning progress in their laboratory instruction during the outbreak. For instance, Budi stated that he evaluated his students' laboratory performance by asking them to record science practicums that they performed at home. He said, "I gave my students worksheets containing a guideline for doing a science practicum at home. Then, I asked them to record the practicum and upload the video to YouTube to be marked." Additionally, Budi also utilised other digital technology and believed that the pandemic provided him the chance to employ various digital technology to assess students' learning progress. He said:

> One advantage of online learning during the pandemic is that it is very easy to make assessments using digital technology. Apart from videos, the digital tool that I used to evaluate students' learning outcomes was Google Form. So, after providing students with learning materials and facilitating them to conduct laboratory activity using PhET, I gave them some questions in Google Form. Thus, they can answer questions related to the science concept that has been taught.

In addition, Budi also used game-based learning tools like Kahoot and Quizizz to measure students' understanding of the scientific concepts included in his laboratory instructions. As these platforms possessed competition aspects, Budi discovered that using Kahoot and Quizizz might motivate his students to learn. He described:

> Occasionally, I also used Kahoot or Quizizz. It turned out to be quite motivating for students and could make students enthusiastic. So, it was a kind of trigger for students. For example, if during today's lesson I used Kahoot or Quizizz as an evaluation, they will expect more in the next lesson by saying, 'Sir, let's play Kahoot again or Quizizz again' because they could see the scores of their fellow students since each question would show their scores and position compared to the others.

In contrast, Alif used Liveworksheet, an online worksheet platform, to assess students' learning progress. He saw this platform as an interactive assessment tool that made it simpler for him to track the progress of students in laboratory activities during online learning. He articulated:

> I used an online platform called Liveworksheet. I could upload the PDF files of student worksheets that I have created to this platform. Then, the worksheets could be filled directly using phones or laptops. For multiple-choice questions, students could immediately check the answers. If it is an essay, they could also write directly on this platform. Thus, it was quite interactive and helped me assess my students' learning outcomes during online learning.

In addition, Alif also used Google Form which was integrated into the Learning Management System (LMS) of his school. He stated, "I also used another digital technology for quizzes. Sometimes, I made a quiz on Google Form and then uploaded the link to our school LMS. Therefore, my students could easily access the quiz using the link I gave."

Facing Challenges in Integrating Digital Technology into Laboratory Teaching

The participants used virtual laboratories in their laboratory teaching. However, employing this type of technology also caused some challenges for them. For instance, Alif mentioned that English was the only available language in the virtual laboratory he utilised, making it challenging for his students to comprehend and operate it. Budi, who used PhET as a virtual laboratory platform, similarly encountered the lack of suitable language in this virtual tool. He said that "the problem with PhET is that the majority of the laboratory simulations are not in Bahasa Indonesia [the Indonesian language]". Additionally, he noted that this platform still lacked laboratory simulations of some science concepts. He stated that "PhET is also still very limited regarding the variety of simulations. For example, there is a concept about "pressure" in physics, but it is not available in PhET."

The interviews also revealed that there was support from the government that the participants received in order to sustain teaching and learning throughout the outbreak. However, the participants also felt that the government's assistance was still insufficient for their laboratory instructions. Regarding this, Alif narrated that:

> There was support from the government, one of which was the provision of free internet packages from the Ministry of Education and Culture. I forgot how much the amount of the packages, but it was quite helpful [.....] but not every month I got it. At that time, it was stopped, and then the internet packages were distributed again. However, the internet packages were still insufficient because I need to access Zoom and upload virtual laboratory simulation videos to YouTube which required high internet bandwidth.

In Budi's experience, he noted that the government-provided internet packages cannot be utilised to access PhET as the virtual laboratory platform he used to assist students in carrying out laboratory work. He also stated that non-educational software can be accessed using the internet packages. He said:

> As far as I know, the internet packages from the government could not be used to access PhET. I really did not know how they locked it. But, it seems weird that it could be used to access e-commerce apps when I tried it.

Discussion

The participants' experiences in conducting laboratory instruction in the midst of the pandemic were mapped using the TPACK framework. The second research question concerning the TPACK domains that surfaced from participant experiences was addressed using this mapping.

Experiences Related to CK

The results showed that both participants were able to articulate the science concepts that need laboratory work. For instance, Budi and Alif each can describe the concept of "motion" and "enzymes," respectively. Using the lens of the TPACK framework, their experiences demonstrated their CK. According to Koehler and Mishra (2009), CK consists of teachers' knowledge of the theories and concepts within the subject matter they teach.

Experiences Related to PK

The results also revealed how the participants used certain teaching strategies throughout their laboratory lessons in the midst of the pandemic which was evident from the use of a question-and-answer format and group discussions. The results also demonstrated that the participants were able to evaluate students' academic progress regarding laboratory activities during the pandemic. Therefore, these experiences were mapped to PK which comprises "knowledge about techniques or methods to be used in the classroom; the nature of the target audience; and strategies for evaluating student understanding" (Mishra & Koehler, 2006, p. 1027).

Experiences Related to PCK

PCK is "knowledge of pedagogy that is applicable to the teaching of specific content" (Mishra & Koehler, 2006, p. 64). Related to this, the results showed that the participants also implemented pedagogical strategies such as group discussions and question-and-answer to teach science topics that demand laboratory activities. However, the participants did not explain whether or not they used these instructional strategies only to instruct students about science concepts that necessitate laboratory practices.

Experiences Related to TK

According to the results, both participants used various digital technologies to deliver learning materials, assist their students in carrying out laboratory tasks, and evaluate their students' learning progress. Therefore, these experiences were mapped to TK as the ability to use a specific technology (Koehler & Mishra, 2009; Mishra & Koehler, 2006).

Experiences Related to TCK

According to Koehler and Mishra (2009), teachers with TCK should be able to choose the technology that is most suited for teaching a certain subject. In this study, the choice to use virtual laboratories to facilitate students in conducting laboratory activities showed that both participants could demonstrate their TCK. The potential of this technology to illustrate and replicate science experiments virtually shows the suitability of this technology to be used in laboratory instruction (Babateen, 2011). The use of virtual laboratories during the pandemic, which can be seen from the participants' experiences in this research, was also consistent with some earlier studies indicating that most science teachers used virtual laboratories since they were unable to use school laboratories due to school closures during the pandemic (Saputro et al., 2020; Shidiq et al., 2021).

Experiences Related to TPK

The participants' use of technology in laboratory instruction may also be a representation of their TPK. Koehler and Mishra (2009) asserted that TPK consists of awareness of the potential of technology to be used based on a certain pedagogical plan. In this study, TPK can be seen from the use of WhatsApp to conduct a question-and-answer approach and Zoom to conduct group discussions. Moreover, Koehler and Mishra (2009) also argued that a crucial part of TPK is that teachers should comprehend "the affordances of technology and how they can be leveraged differently according to changes in context and purposes" (p. 65).

Experiences Related to TPCK

According to the results, there was no indication of the participants' TPCK. In relation to this, Benson and Ward (2013) found that only 1 out of 4 participants in their research could show how technological, pedagogical, and content knowledge domains interacted in their teaching activities. Therefore, the manifestation of TPCK was infrequently identified in teachers' teaching practices.

Experiences Related to XK

Context is crucial in determining whether or not teachers integrate technology effectively into their teaching practices (Blackwell et al., 2016; Foulger et al., 2021). In relation to this, Porras-Hernández and Salinas-Amescua (2013) divided contextual factors that could affect teachers' use of technology into three levels, including micro, meso, and macro. Additionally, the most recent TPACK model created by Mishra (2019) demonstrated that contextual knowledge "would be everything from a teacher's awareness of available technologies, to the teacher's knowledge of the school, district, state, or national policies they operate within" (p. 76).

The XK of the participants in this study can also be determined from their experiences in carrying out laboratory instructions in the midst of the pandemic. For instance, Budi incorporated Quizizz and Kahoot because he was aware of the potential of these tools to encourage students through the competitive nature of these platforms. This experience was mapped to XK related to the micro-level context which includes teachers' beliefs and attitudes toward the affordances of technology (Ifinedo & Kankaanranta, 2021; Porras-Hernández & Salinas-Amescua, 2013). This result was also in line with that of Llanos et al. (2021), who indicated that the use of game-based learning tools like Kahoot and Quizizz can be advantageous in laboratory activities since it can increase students' motivation to understand science topics and be successful in answering questions.

The participants' awareness of a problem related to the lack of sufficient virtual laboratory platforms also served as a representation of their XK. The participants were concerned about the shortage of virtual laboratories that support *Bahasa Indonesia* (Indonesian language). In addition, Budi's situation demonstrated that there was a problem with the lack of virtual laboratory simulations that addressed some science concepts. This showed that the participants were aware of the technology's accessibility, which represented their understanding of the micro-level context (Ifinedo & Kankaanranta, 2021; Porras-Hernández & Salinas-Amescua, 2013). These results further corroborated a study from Babateen (2010) that suggested one barrier to adopting virtual laboratories is the lack of language options because English was mostly used in this technology.

Lastly, it was also clear from the participants' understanding of the problem of inadequate government support that they could demonstrate XK regarding the macro-level context. One of the indicators of contextual knowledge at this level is the awareness of the government policies in supporting teachers in integrating digital technology into their teaching practices (Ifinedo & Kankaanranta, 2021; Porras-Hernández & Salinas-Amescua, 2013).

CONCLUSION

Based on the findings and data analysis, it can be concluded that there were five emerging themes related to the participants' experiences in conducting laboratory learning during the Covid-19 pandemic. These were experiences in choosing teaching content, teaching science concepts that require laboratory activities, using digital technology to facilitate students in conducting laboratory activities, using digital technology to assess students' laboratory learning outcomes, and facing challenges in integrating digital technology into laboratory teaching. Analyzed through the lens of the TPACK framework, several knowledge domains emerged except TPCK, including CK, PK, PCK, TK, TCK, TPK, and XK. It is recommended for future research to compare science teachers' experiences in conducting laboratory learning before, during, and after the Covid-19 outbreak with a bigger sample size. Such research might reveal whether or not there are variations in the implementation of laboratory learning between different contexts.

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