DEVELOPMENT OF WEB-BASED TPACK SCAFFOLDING FOR ONLINE LEARNING TO ENHANCE TPACK SKILLS OF PRESERVICE CHEMISTRY TEACHERS

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ABSTRACT

This study aimed to develop and evaluate a web-based TPACK scaffolding for online learning to enhance the TPACK skills of preservice chemistry teachers. The preliminary study identified the lack of a clear perception of TPACK among preservice chemistry teachers. Therefore, we developed a web-based TPACK scaffolding tool consisting of five menus: Home, Instructions, Teaching Materials, TPACK Activity, and Evaluation. The tool provides scaffolding for preservice chemistry teachers to integrate TPACK into chemistry learning, such as a TPACK integrated syllabus, a TPACK integrated lesson plan, and a TPACK integration matrix in chemistry learning. We evaluated the readability and comprehensibility of the web-based TPACK scaffolding using the thinking aloud protocol (TAP) method. In addition, the participants provided suggestions for improving the website, such as adding an instruction button, grouping learning activities according to the sequence of scaffolding strategy steps, and grouping integrated TPACK lesson plans in chemistry learning according to grade levels in high school. The web-based TPACK scaffolding can support and guide preservice chemistry teachers in enhancing their TPACK skills. The tool can educate them about subject-specific pedagogy with TPACK integration and provide examples of TPACK activities that could be utilized in teaching and learning chemistry. The study's findings can enhance preservice teachers' TPACK skills and promote effective integration of technology in chemistry education.

Keywords: *web-based TPACK learning, scaffolding, online learning, TPACK skills, preservice teachers, design-based research*

INTRODUCTION

In the modern era, the utilization of Information and Communication Technology (ICT) in developing economies has led to a search for innovative learning designs that can improve the quality of education. To equip students with the necessary skills for the 21st century, they need to process information, use technology, and collaborate effectively (Kumala Dewi et al., 2019). These skills include ICT literacy, collaboration, communication, social competence, creativity, critical thinking, and problem-solving. Teachers must also possess the specific skills to apply suitable ICT tools using various pedagogical approaches to prepare students with 21st-century skills. Additionally, teachers must understand how and when to use technology effectively to enhance teaching and learning (Valtonen et al., 2017). Previous research has shown that integrating various technologies into learning can help preservice teachers understand how these technologies support a particular curriculum. However, there is still a need for more research to serve as a reference for teachers in understanding the potential of ICT to support teaching and learning. Finally, science teachers face particular subject-specific needs when using technology to connect subject matter with everyday phenomena to gain a scientific understanding (Siripongdee et al., 2020). Therefore, preservice teachers should have courses integrating ICT into learning. Even though preservice teachers are familiar with daily ICT, they still struggle to use it effectively in teaching and learning because they lack the skills and competencies to integrate technology (Chayati et al., 2020; Huwer et al., 2018).

Additionally, preservice teachers have difficulty understanding the pedagogical potential of various technologies and how to use them to develop 21st-century skills in students. One way to address this gap is by using Technological Pedagogical Content Knowledge (TPACK), a framework that emphasizes integrating technology, pedagogy, and content knowledge (Gawrisch et al., 2020; Tomczyk, 2020). By incorporating TPACK into their courses, preservice teachers can understand how to integrate technology into the learning process to enhance student learning. Also, designing a technology-enhanced learning environment can be an effective approach to developing TPACK skills in preservice teachers. This approach provides hands-on experience for preservice teachers to understand the potential of various technologies and how they can support student learning (Polly et al., 2010).

Scaffolding refers to offering support to learners to assist them in completing complex or challenging tasks. This support can take many forms, such as feedback, guidance, and resources. In light of the increasing digitization of educational processes and the move towards online activities, teacher education must focus on enhancing the quality of academic training for preservice teachers (Kapici & Akcay, 2023; Lazem, 2019; Mertz & Neiles, 2020). To this end, professional development should aim to bolster preservice teachers' competencies in technology integration. One sustainable and effective way to achieve this is by introducing new digital technologies, websites, and software as scaffolds for preservice teachers in teacher education. Such scaffolds can help teachers create effective online learning experiences using Web 2.0 tools, which provide diverse opportunities for accessible information, communication, collaboration, interaction, and feedback (Bustamante, 2020). By scaffolding with Web 2.0 tools, preservice teachers can develop their TPACK skills through various opportunities (Fung et al., 2019; Kul et al., 2019). For instance, they can utilize web-based discussion forums or social networking sites to collaborate with peers and share ideas and resources related to technology integration in teaching and learning. Collaborative platforms such as blogs and wikis can also offer preservice teachers opportunities to practice creating and sharing digital content with others. Additionally, they can benefit from real-time guidance and instructor or mentor feedback through video conferencing or screen-sharing applications (Cetin-Dindar et al., 2018).

Teacher education programs can improve the preparedness of new teachers to effectively integrate technology in their classrooms by scaffolding their learning experiences with Web 2.0 tools. This approach can help preservice teachers enhance their technology integration competencies and develop confidence in utilizing various technologies to support student learning. In light of these findings, we developed a Web-based TPACK Scaffolding platform to facilitate the design of technology-integrated chemistry learning. The website serves as a scaffold to support the development of TPACK skills by offering TPACK learning activities, design templates, and examples of TPACK-integrated chemistry learning. Our research aims to create a Web-based TPACK Scaffolding platform to enhance preservice chemistry teachers' TPACK learning and TPACK skills. To achieve this aim, we focused on the following specific objectives:

a. Describe the quality of web-based TPACK scaffolding for online learning to enhance the TPACK skills of preservice chemistry teachers.
b. Determine the effectiveness of web-based TPACK scaffolding for online learning to enhance the TPACK skills of preservice chemistry teachers.

LITERATURE REVIEW

TPACK Framework

The TPACK framework provides a way to understand the knowledge and skills teachers need to integrate technology effectively into their teaching. TPACK consists of three main components: technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK)(Bergeson & Beschorner, 2020). Technological knowledge refers to a teacher's understanding of using technology tools and resources, while pedagogical knowledge is their understanding of teaching and facilitating learning. Finally, content knowledge is the teacher's understanding of the subject matter they are teaching. However, the interactions between these three components are complex and constantly influence each other, leading to the development of additional frameworks such as pedagogical content knowledge (PCK), technological content knowledge (TCK), and technological pedagogical knowledge (TPK) (Cetin-Dindar et al., 2018; Rap et al., 2020). These frameworks focus on the intersection points between technology, pedagogy, and content knowledge, highlighting the importance of understanding how these components work together to enhance teaching and learning. Overall, TPACK and its related frameworks provide a comprehensive understanding of the knowledge and skills teachers need to integrate technology effectively into their teaching and emphasize the importance of understanding the interplay between technology, pedagogy, and content knowledge (Angeli & Valanides, 2009; Rap et al., 2020).

Table 1.
TPACK Component and Definition

TPACK Component	Definition
TK	Knowledge about how to use ICT hardware and software
PK	Knowledge about instructional methods, classroom management, lesson planning, educational theories, student learning, and assessment
CK	Knowledge of the subject matter to be learned or taught
PCK	Knowledge of how to facilitate students to learn specific content, and the learning environment, learning activities, and collaboration required
TPK	Knowledge of how the various technologies can be used in teaching and learning
TCK	Knowledge about how to use technology to represent and create content in different ways
TPACK	Knowledge of using various technologies and pedagogical techniques to teach specific content

Web-Based TPACK

Web-based training for teacher education has become a popular approach for several reasons. One of the main reasons is the rise of Web 2.0 technology, which has made it easier to create online learning environments that support two-way interaction, easily accessible information, and collaboration. With the help of various Web 2.0 applications, teacher education institutions can provide preservice teachers with the opportunity to integrate technology and pedagogical practices through online collaborative discourse. In this approach, teachers use Web 2.0 applications such as SkyDrive, wikis, Flickr, WordPress, and Google Apps to develop TPACK competencies. TPACK is a framework that helps teachers to integrate technology effectively into their teaching practice by combining three types of knowledge: content knowledge, pedagogical knowledge, and technological knowledge.

The Web 2.0 applications provide various resources to support the development of TPACK competencies. For example, SkyDrive and Google Apps allow teachers to store and share documents, presentations, and other resources online, making it easier for teachers to collaborate and share ideas with other teachers. Wikis provide a platform for teachers to collaborate on developing instructional materials and pedagogical strategies. Flickr and other image-sharing platforms allow teachers to find and use images in their instructional materials. WordPress is a platform that can be used to create online courses and blogs that support collaborative learning and interaction among teachers. Using web-based TPACK significantly and positively impacts preservice teachers' TPACK competence and self-efficacy, as shown in studies by researchers such as Kul et al. (2019) and Luo et al. (2020). By integrating web-based TPACK into teacher education programs, institutions can better prepare preservice teachers to implement technology-based learning to teach specific content. This approach also helps preservice teachers become more confident in integrating technology into their teaching practice.

Web 2.0 technology can scaffold teacher learning by providing interactive and collaborative platforms for teacher education. Using Web 2.0 tools, preservice teachers can engage in online learning activities that align with their learning goals, interests, and strengths (Deng et al., 2017). These activities may include discussion forums, collaborative group projects, and peer review sessions (Anilan & Berber, 2019). The scaffolding process begins with identifying the preservice teacher's needs, goals, and existing knowledge. Then, based on this information, an appropriate Web 2.0 tool that aligns with the learner's preferred learning style and interests can be selected. For instance, if a preservice teacher is more visually inclined, a tool like Flickr, a photo-sharing platform, can create visual representations of teaching concepts (Baddock & Bucat, 2008; Chen & Liu, 2020).

Web 2.0 tools can also provide access to information and resources that support the preservice teacher's learning. For instance, wikis can create collaborative online encyclopedias where preservice teachers can add and edit content related to their teaching subjects. Also, blogging platforms like WordPress can be used to create reflective journals where preservice teachers can document their learning process and receive peer feedback (Kumala Dewi et al., 2019; Lin & Jou, 2013). Finally, Web 2.0 technology can create online learning communities where preservice teachers can interact with their peers and instructors. These communities provide a space for collaboration, feedback, and support. By working in a community, preservice teachers can develop a deeper understanding of teaching concepts and enhance their TPACK competencies. Overall, the use of Web 2.0 technology can significantly enhance the scaffolding process for preservice teachers. Providing interactive and collaborative platforms, access to information and resources, and online learning communities, preservice teachers can develop their TPACK competencies and become effective teachers (Chiu et al., 2019; Fujiwara et al., 2020).

METHODOLOGY

Research Design

This study aimed to develop and evaluate the effectiveness of a web-based TPACK scaffolding module for preservice chemistry teachers to enhance their TPACK skills in creating subject-specific pedagogical strategies. TPACK stands for Technological Pedagogical Content Knowledge, which refers to the knowledge and skills needed to integrate technology into teaching and effectively learn. The researchers used a design-based research (DBR) method, which involves the iterative design, implementation, and evaluation cycles, to develop the web-based TPACK scaffolding module (Abdallah & Wegerif, 2014). The development process involved three design cycles based on the previous cycle's feedback and findings.

The first cycle focused on identifying the problem and designing the scaffolding module. We analyzed the TPACK skills of preservice chemistry teachers and designed the module accordingly. The second cycle evaluated the feasibility of the module. We conducted forum group discussions with experts (professional lecturers and chemistry teachers) to validate the module's content and design. We also performed a feasibility test to assess the usability and accessibility of the web-based module. The third cycle evaluated the effectiveness of the web-based TPACK scaffolding module in enhancing the TPACK skills of preservice chemistry teachers. We measured the participants' TPACK skills before and after using the module and compared the results to determine the module's effectiveness.

Participants

The research involved a group of 69 Chemistry Education students who were taking the Chemistry Learning Planning course at Universitas Sebelas Maret. The participants were selected randomly and divided into three phases: cycle one, cycle two, and implementation. The first cycle included six Chemistry Education students between 18 and 20 years old. In contrast, the second cycle had 30 Chemistry Education students between 18 and 20 years old and eight chemistry experts and professional teachers between 50 and 60 years old. Finally, the implementation phase included 74 Chemistry Education students between 18 and 20 years old. To be eligible for the study, participants had to be actively enrolled in the Chemistry Learning Planning course and have completed relevant courses on technology and education. This criterion was used to ensure that participants had a fundamental understanding of TPACK and technology in education, which could aid their comprehension.

In contrast, individuals who did not attend or complete the Chemistry Learning Planning course were excluded from participation in the study. This was done to ensure that only students with a prior learning experience in chemistry learning planning were included, as it would aid in their understanding of the study's purpose and context. By utilizing these specific inclusion and exclusion criteria, we aimed to obtain reliable and representative responses from the participants regarding the efficacy of the web-based TPACK scaffolding in enhancing the TPACK skills of Chemistry Education students. The study analyzed a group of Chemistry Education students who were enrolled in the chemistry learning planning course and selected randomly. Table 2 provides an overview of the participants' characteristics.

Table 2.
The Characteristics and Distribution of the Participants

Stages	Participant	Range Age (years)	Gender	
			Female (n/%)	Male (n/%)
Preliminary Analysis	69 preservice teachers	18–24	56/81.16%	13/18.84%
Cycle 1	6 preservice teachers	18–20	5/83.33%	1/16.67%
Cycle 2	30 preservice teachers	18–20	27/90%	3/10%
	8 experts	50–60	6/75%	2/25%
Cycle 3	74 preservice teachers	18–20	66/91.4%	8/8.6%

Instrumentation

We employed various data collection tools to assess the effectiveness of using web-based TPACK scaffolding in training programs for chemistry teachers. Initially, we administered a web-based survey comprised of 30 questions related to seven TPACK components, which included CK, PK, TK, PCK, TPK, TCK, and TPCK items. In addition, we conducted structured interviews with eight questions to validate the survey findings and ensure consistency. To assess the clarity and comprehension of web-based TPACK scaffolding in Cycle 1, we used the TAP tool. In Cycle 2, a validation sheet with eight assessors was utilized to validate the website's feasibility. The TPACK ability test was implemented in Cycle 3, which consisted of 20 pretests and posttest questions to measure the TPACK proficiency of aspiring chemistry teachers. The survey covered two CK items, three PK items, two TK items, four PCK items, three TPK items, three TCK items, and four TPCK items. By utilizing diverse tools that covered different aspects, the study gathered adequate data to evaluate the effectiveness of web-based TPACK scaffolding as a training method for chemistry teachers.

Validity and reliability

We used the Aiken validation analysis method to validate the instruments used in the research. The validation process involved six experts from different fields, including subject matter, instructional design, learning, evaluation, language, and education. The experts provided their opinions on the questionnaire and structured interviews to determine how much the instruments measured the desired TPACK construct. The Aiken validity analysis method was used to calculate the correlation coefficient between each question on the questionnaire and the overall questionnaire score to assess the empirical validity of the instrument (Saefi et al., 2020). The results showed that all instruments and media used in the study had Aiken validity scores above 0.75, indicating good empirical validity.

Table 3.
Aiken Validation Results

Product/Instrument	Number of Validators	Total Assessment Criteria	Standard Valid (V)
Web-Based TPACK Scaffolding	8	4	0.75
TPACK Evaluation Instrument	8	4	0.75
TPACK Understanding Questionnaire	8	4	0.75

We tested the reliability of the TPACK instrument using Cronbach's alpha method, which is commonly used to assess instrument reliability. The results showed that the instrument was reliable, with a Cronbach's alpha value of 0.85. This indicates that the instrument can be consistently relied on to measure specific individual abilities or characteristics and can be confidently used to

Table 4.
Data Collection in Three Stages

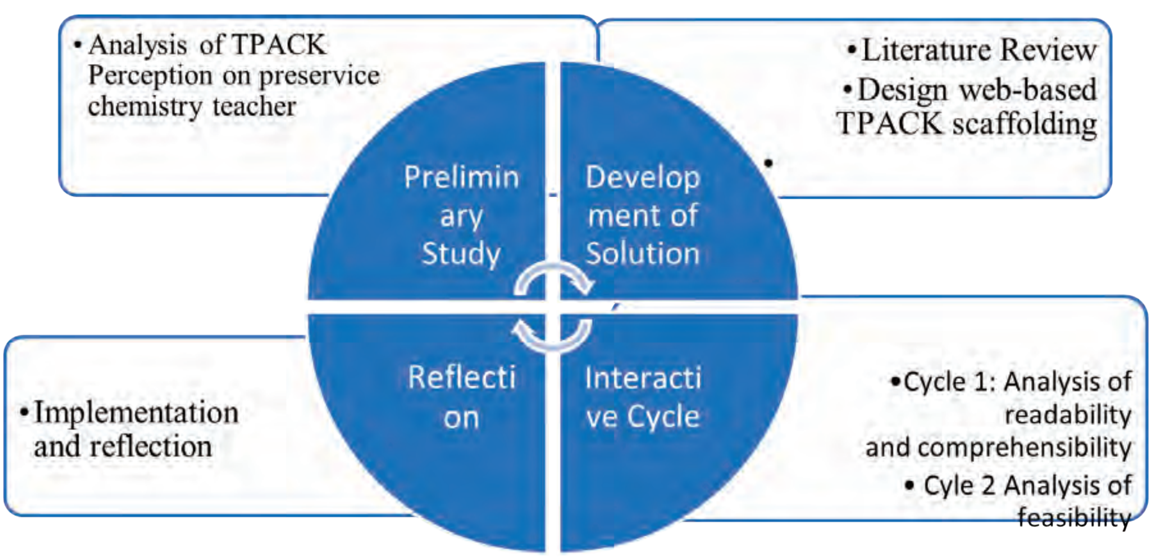
Data Collection	Participants	Purpose
Cycle 1		
TAP (Thinking Aloud Protocol)	6 preservice chemistry teachers	Overview of issues that need to be fixed when using web-based TPACK scaffolding. Overview of the responses from preservice chemistry teachers as users towards developing a web-based TPACK scaffolding.
Cycle 2		
1. FGD (Focus Group Discussion)	8 experts (professional lectures and chemistry teachers)	Overview of the functionality and suitability of the content, the visuals, and the communicative language of the web-based TPACK scaffolding.
2. Students' Reflection	35 preservice chemistry teachers	Overview of the content, language, display, and graphics of the web-based TPACK scaffolding based on user opinions.
Cycle 3		
Implementation	74 preservice chemistry teachers	Implementation in class with one experimental group and one control group.

assess TPACK levels in students taking instructional design courses. A high-reliability value also suggests that the TPACK instrument can produce accurate and valid data in measuring the same construct in the same population. Furthermore, Confirmatory Factor Analysis was used to test the model's fit. The results showed that the tested model had low error rates with a Root Mean Square Error of Approximation (RMSEA) value of 0.0633. In addition, the Comparative Fit Index (CFI) value of 0.965 indicated that the tested model fit well with the observed data. In contrast, the Tucker-Lewis Index (TLI) value of 0.918 indicated a high model fit. These fit-measure values suggested that the model had good quality, with an ideal TLI value of around 0.90.

ETHICAL APPROVAL

The description above outlines the ethical considerations and measures that were implemented in researching and developing a web-based TPACK scaffolding for online learning to enhance the TPACK skills of preservice chemistry teachers. These measures included obtaining necessary approvals from the school board and university ethics committee, ensuring the voluntary participation and confidentiality of participants, securely storing data, consulting with the institutional review

Figure 1.
Stages of Design-Based Research to Development Web-Based TPACK_Scaffolding



board, adhering to ethical principles of the APA and Declaration of Helsinki, obtaining written informed consent, and using the data for publication purposes with participants' agreement. These measures were in place to ensure the participants' safety, privacy, and well-being and to meet ethical standards.

DATA COLLECTION AND ANALYSIS

The study comprises four stages: Preliminary Analysis, Cycle 1, Cycle 2, and Cycle 3. Each stage was equipped with specific instruments and data analysis methods. The primary objective of the Preliminary Analysis stage was to ensure that the media created aligned with the issues present in the field. The initial data related to TPACK knowledge was gathered through a questionnaire administered to chemistry teachers, which we then analyzed to identify the weakest component of each TPACK. Finally, the data collected from the questionnaire was tabulated and analyzed to determine the highest and lowest scores of each TPACK content and how web-based TPACK scaffolding can address this issue.

In Cycle 1 of the study, six chemistry student teacher candidates were asked to use the TAP instrument to provide their initial response to the web-based TPACK scaffolding. We then analyzed the responses qualitatively to improve the scaffolding before moving on to the validation and limited field trial stages. Cycle 2 involved a validation stage where eight experts were invited to participate in a focus group discussion to validate the web-based TPACK scaffolding and its instruments. We analyzed theresults of the validation using the Aiken technique. Finally, a pilot project product trial was conducted with 35 volunteer students who had taken a learning planning course. We administered aquestionnaire to identify any shortcomings in the scaffolding's content, language, display, and graphics. We then used the results to improve the scaffolding before we used it in the actual course.

We divided the students into experimental and control groups in the implementation stage. Cycle 3. Both groups consisted of 37 students, and their pretest and posttest scores were evaluated using EXCEL and SPSS 24.00 software. We used a *t*-test to determine if there was a significant difference between the students' academic achievements in both groups before the application. The experimental group received the web-based TPACK scaffolding for online learning, while the control group received traditional instruction. We randomly assigned the preservice chemistry teachers to the experimental and control groups. We collected data from the pretests and posttests and analyze the data using descriptive and inferential statistics such as means, standard deviations, independent-samples *t*-test, and ANOVA to identify any significant differences between the experimental group and the control group.

RESULT AND DISCUSSION

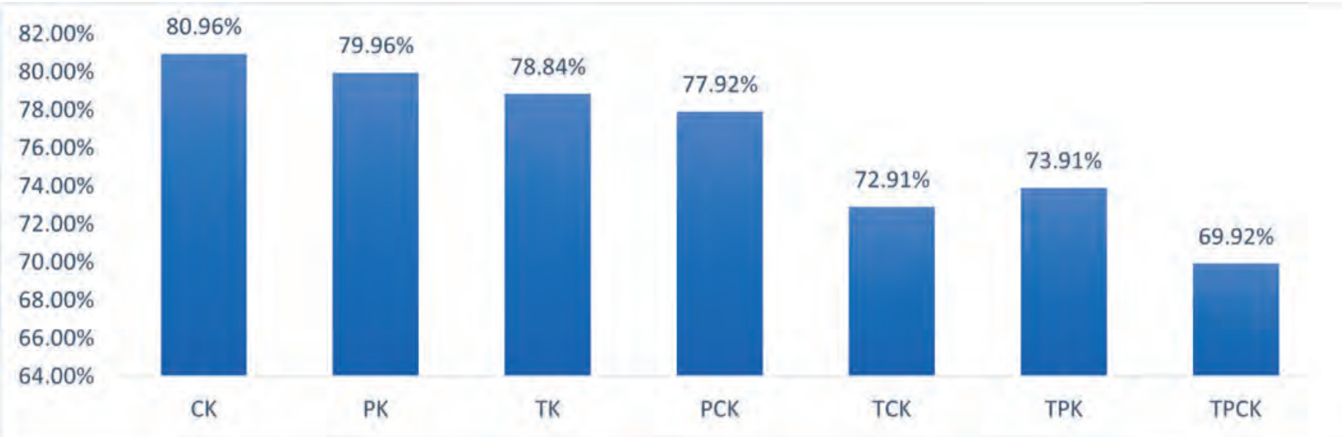
Preliminary Analysis

A preliminary study served to identify problems and needs in a study. We conducted a preliminary study to identify preservice chemistry teachers' perceptions of TPACK. The preliminary study results show that although preservice chemistry teachers understand CK, PK, and TK well, their understanding of integrating technology into content and pedagogy (TCK, TPK, and TPCK) still needs improvement.

We utilized the preliminary study results, which demonstrated that preservice chemistry teachers lacked a clear perception of TPACK, as a basis for developing a web-based TPACK scaffolding for online learning to enhance their TPACK skills. The aim of developing the web-based TPACK scaffolding for online learning was to support and guide preservice chemistry teachers in enhancing their TPACK skills. The tool was designed to educate them about SSP as an integrated TPACK lesson design in chemistry learning. It also introduced them to various TPACK activities that could be utilized in teaching and learning chemistry. Although the preservice chemistry teachers involved in the study understood CK, PK, TK, and PCK, they were not as familiar with TCK, TPK, and TPCK, making it challenging to incorporate technology effectively into their teaching practice (Gawrisch et al., 2020).

Nonetheless, the teachers acknowledged the importance of technology in education. Furthermore, they agreed that using technology appropriately could improve students' comprehension of the subject matter, indicating that they had the potential to develop their TCK, TPK, and TPCK knowledge through specialized training and support. Figure 2 shows the preservice chemistry teachers' responses in the preliminary study.

Figure 2.
Perception of Preservice Chemistry Teachers



Development

The preliminary study results were used to develop a web-based TPACK scaffolding for online learning to enhance the TPACK skills of preservice chemistry teachers. The developed tool comprises five menus: Home, Instructions, Teaching Materials, TPACK Activity, and Evaluation. The Home button functions to return to the home page, while the Instructions menu contains a guideline for preservice chemistry teachers to use the web-based TPACK scaffolding. The Teaching Materials menu contains examples of subject-specific pedagogy with TPACK integration, TPACK integrated syllabus, TPACK integrated lesson plan, and a TPACK integration matrix in chemistry learning (Bergeson & Beschorner, 2020; Kapici & Akcay, 2023). The TPACK Activity menu consists of activities for preservice chemistry learning with scaffolding strategy steps and the In1-On-In2 scheme as scaffolds to develop TPACK skills. Finally, the Evaluation menu consists of an assignment for preservice chemistry teachers to reflect on the process and outcomes of TPACK learning. The interface of the web-based TPACK scaffolding is presented in Figure 3.

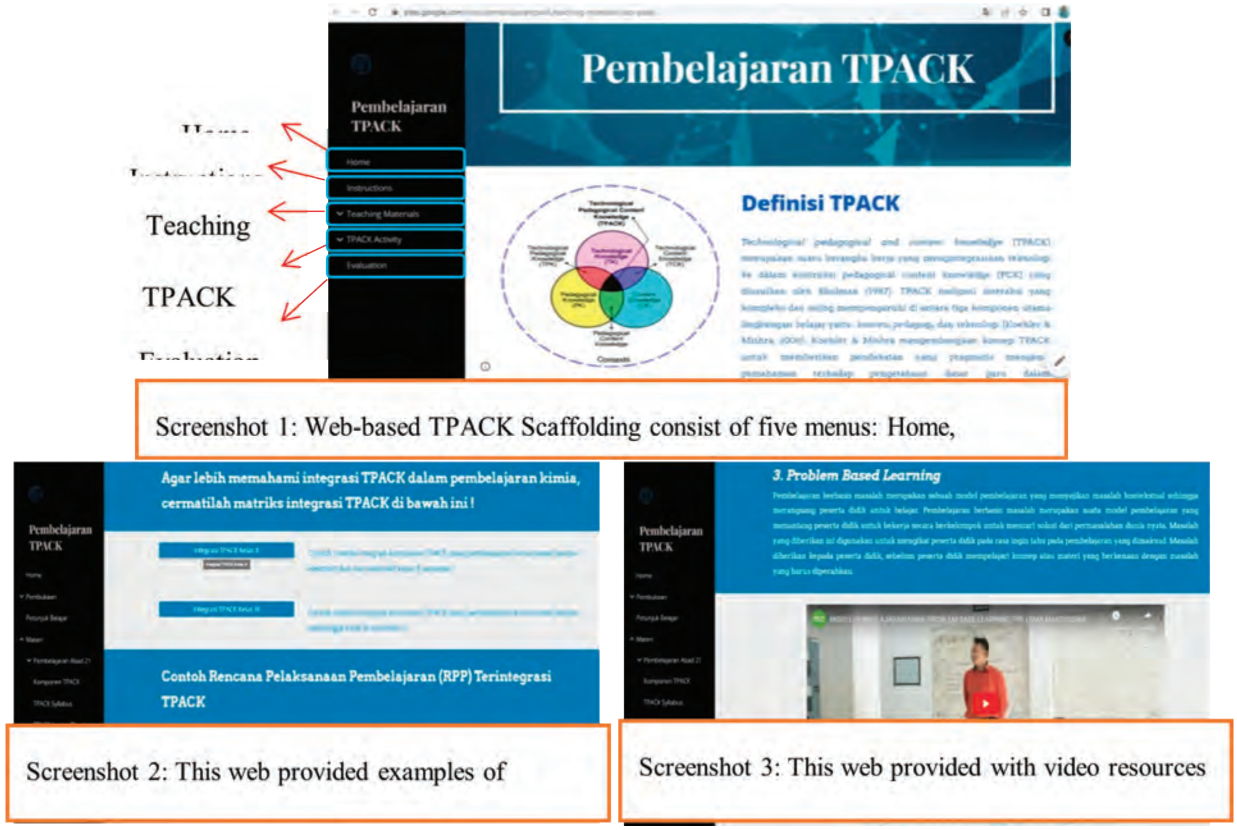
Web-based TPACK provides scaffolding for preservice chemistry teachers to integrate TPACK into chemistry learning. The Teaching Materials section uses various types of scaffolding to enhance teachers TPACK skills. The TPACK integrated syllabus and lesson plan can be an sample lesson that provides examples of learning designs on some chemistry subject matter that appropriately integrate each component of TPACK (Kapici & Akcay, 2023). The TPACK integration matrix contains descriptions and examples for each TPACK component integrated into the designed learning. In addition, Teaching Materials also has videos about technology-integrated chemistry learning that provide an overview of the ideal interaction of technology, pedagogy, and content in the classroom (Yu, 2021). Finally, the TPACK Activity section on web-based TPACK scaffolding contains some TPACK learning activities for preservice teachers that provide experience and practice skills to improve their understanding of the integration of TPACK into chemistry learning (Erna et al., 2021).

Cycle 1

This cycle evaluated the readability and comprehensibility of web-based TPACK scaffolding using TAP (thinking aloud protocol). The TAP method allows researchers to get an overview of what users think about the researcher's design (Fonteyn et al., 1993). In the TAP process, the participants think aloud while operating the web-based TPACK scaffolding. We asked participants to say whatever came into their minds as they operated the website. This might include what they are looking for, thinking, doing, and feeling. Participants gave several responses and suggestions based on their experience when using the website. Some of the responses are:

> *I think the integration of technology into learning is difficult. Learning activities must be structured to make it easier*

Figure 3.
The Interface of Web-Based TPACK Scaffolding



for preservice teachers to understand TPACK and implement various digital tools for their learning. (Participant A, 12 February 2021)

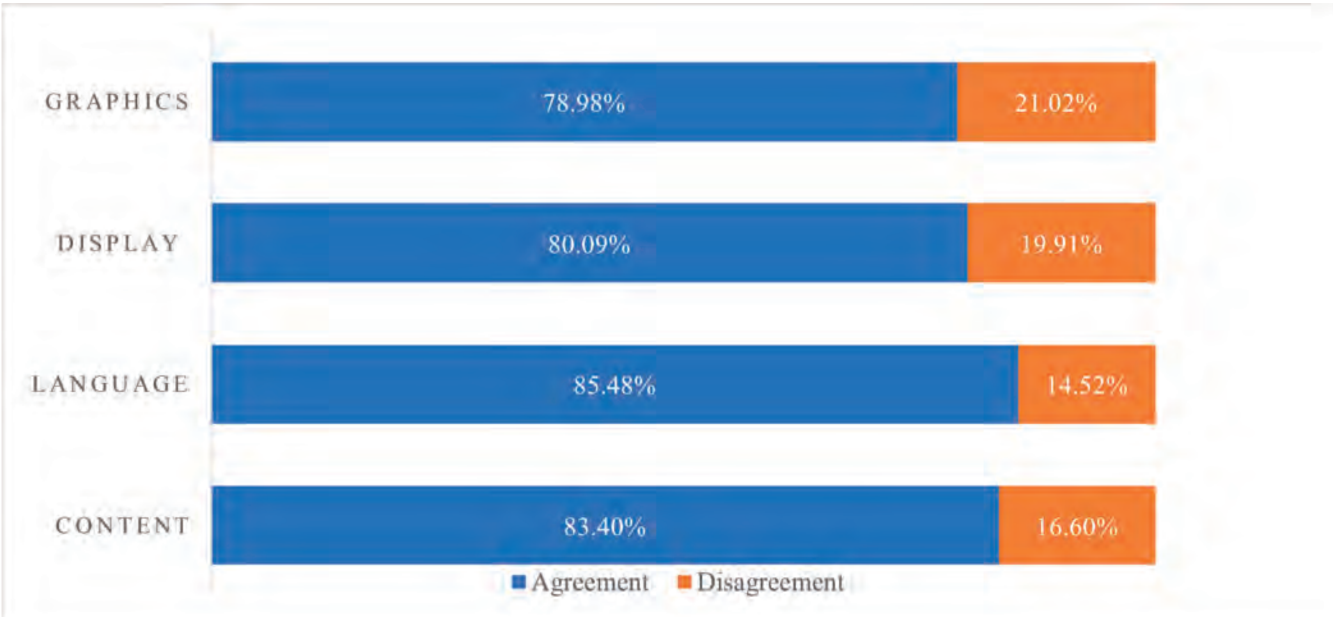
The web is easy to use, but users need guidelines to help preservice teachers get a clear picture of the goal of their learning and provide them with necessary information about the web. (Participant B, 12 February 2021)

In my opinion, it needs to add examples of integrating technology in chemistry learning to provide preservice chemistry teachers with practical experience to create their lesson plans. (Participant C, 12 February 2021)

Based on the TAP result, participants gave some suggestions for website improvement, such as adding an Instruction button to the menu that will provide guidelines for preservice chemistry teachers using the website for TPACK learning (Koh, 2019). The guideline provides users with information to understand more easily the objectives and learning flow when working with this website. Learning activities on the TPACK activity menu are grouped according to the sequence of scaffolding strategy steps. One improvement is to create buttons for each TPACK activity in service-learning for on-the-job learning and for service-learning. Each section will provide learning activities, assignments, and projects related to integrating TPACK into chemistry learning. Another improvement is to group integrated TPACK lesson plans in chemistry learning according to grade levels in high school, which will make it easier for preservice chemistry teachers to find chemistry topics according to grade. In addition, integrated TPACK lesson plans can be used as a reference for preservice teachers designing their lesson plans (Koh, 2019; Poitras et al., 2019).

Web applications provide friendly user interfaces and various functionalities (Lin & Jou, 2012).

Figure 4.
Response of Preservice Chemistry Teachers to Feasability of TPACK Scaffolding



Cycle 2

We used student reflection in Cycle 2 to evaluate the feasibility of web-based TPACK scaffolding. Participants gave responses regarding content, language, display, and graphics. The results of these responses are presented in Figure 4.

Figure 4 shows that the participants found the content, language, display, and graphics of web-based TPACK scaffolding to be feasilble (above 75%), which means this website meets the feasibility test. In the content aspect, preservice chemistry teachers agreed that the content regarding the integration of TPACK in chemistry learning on this website was well explained and easy to understand. They agreed that this website's content was appropriate as a scaffold to help them develop their TPACK skills. They found that aspect language, display, and graphics were well designed, but several parts were lacking. The language in the website used communicative sentences so that preservice teachers could easily understand it. Display and graphics on this website used colors, shapes, and sizes of objects that are proportional and do not interfere with the understanding of preservice teachers. Web-based TPACK scaffolding will be used to promote the TPACK learning of preservice chemistry teachers so that the development carried out considers their comfort and understanding as users.

The technology context synthesizes the student experience when engaged in a web application-supported learning environment (Lin & Jou, 2012, 2013; Mertz & Neiles, 2020). Web-based TPACK scaffolding provides references related to TPACK and TPACK activities that preservice teachers can use as scaffolds to synthesize their understanding and experience of the integration of TPACK in chemistry learning. The various types of scaffolding provided in online learning through the web-based TPACK scaffolding can be used to support preservice chemistry teachers in developing their TPACK skills (Ryan & Reid, 2016).

Implementatian and Reflection

Cycle 3 aimed to implement and reflect on the revised TPACK scaffolding for chemistry preservice teachers after Cycle 2. This stage involved 74 preservice teacher students, and an ANOVA test was conducted after analyzing the factors in Table 4. At the end of the cycle, each preservice teacher was given a TPACK mastery test to assess their understanding of TPACK. The results are summarized in Table 5.

Table 5.
Homogeneity, Normality and t-test Comparison Test Results

Group	SD	N	Sig (p)	
			Homogeneity	Normality
Control	3.60	37	0.63	0.200
Experimental	2.93	37		

Before conducting an ANOVA analysis, it is important to ensure that certain prerequisites are met. These prerequisites involve checking for the normality of data distribution and homogeneity of variance. Normality pertains to the requirement that data follow a normal distribution, which can be assessed through a normality test, such as the Shapiro-Wilk test. Homogeneity of variance pertains to the requirement that the variances of the groups being compared are roughly the same, which can be evaluated using Levene's test. Fulfilling these prerequisites is crucial to guaranteeing the reliability and precision of the ANOVA findings.

Table 6.
TPACK Understanding Test Results on Preservice Chemistry Teachers

Variance of Source	Sum of Squares	df	Mean Square	F	Sig
Between Groups	39.405	1	39.405	15.057	0.000
Group	188.432	72	2.617		

The use of the web-based TPACK scaffolding for online learning is considered an effective approach to enhance preservice teachers' TPACK skills in the field of chemistry. This approach is based on the TPACK theory, which incorporates technology, pedagogy, and content knowledge to create an ideal learning setting. According to the TPACK theory, teachers should possess integrated knowledge of technology, pedagogy, and content to facilitate the development of students' TPACK skills (Cetin-Dindar et al., 2018; Rap et al., 2020). Therefore, the web-based TPACK scaffolding is designed to provide relevant guidance and support to preservice teachers to develop students' TPACK skills during the learning process. The scaffolding approach utilized in this method helps preservice teachers to gradually develop their TPACK skills, starting with the basics of TPACK and moving to more advanced concepts, with appropriate support and guidance provided at each stage (Tomczyk, 2020; Valtonen et al., 2018).

The web-based TPACK scaffolding method for online learning offers an innovative solution to improve preservice teachers' TPACK skills in chemistry and address the challenges of 21st-century education. With the increased emphasis on digital literacy and technology integration, preservice teachers must have a solid foundation in TPACK (Koh et al., 2018; Valtonen et al., 2017). This method allows them to develop these skills using relevant technology and chemistry learning materials in several stages. First, preservice teachers develop their understanding and experience using technology in chemistry learning, starting with general chemistry learning materials and the relevant technology. Then, more advanced TPACK development is achieved through experience and support for integrating technology and chemistry learning content (Bergeson & Beschorner, 2020; Kul et al., 2019).

Online learning through the web-based TPACK scaffolding provides a structured approach to help preservice teachers develop their TPACK skills in chemistry through Web 2.0 technology. This approach begins with an initial stage where preservice teachers gain an understanding of technology and its role in chemistry learning (Otrel-cass et al., 2012). Then, to build their foundational knowledge, they are introduced to general chemistry learning materials and relevant technologies, such as online simulations and digital resources. In the next stage, preservice teachers integrate technology and pedagogy through online collaborative discourse with peers and instructors (Cetin-Dindar et al., 2018; Tan et al., 2019; Valtonen et al., 2017). This collaboration allows for sharing ideas and experiences, which helps participants develop a deeper understanding of TPACK concepts. Web-based TPACK scaffolding for online learning offers a platform for preservice teachers to engage in meaningful discussions about integrating technology and pedagogy in chemistry learning. As preservice teachers become more proficient in using technology and pedagogy to support chemistry learning, they move to the final stage of TPACK development. They are encouraged to design and implement technology-based learning activities that teach specific chemistry content. This hands-on experience provides a practical application of TPACK principles and allows preservice teachers to gain confidence in integrating technology and pedagogy effectively (Polly & Byker, 2020; Zhang et al., 2019).

Web-based TPACK scaffolding for online learning is a comprehensive approach that effectively enhances preservice teachers' TPACK skills by integrating technology, pedagogy, and content knowledge (Yamtinah et al., 2019). By using this method, preservice teachers can develop their digital literacy skills by learning how to use technology effectively in teaching and learning. They can also develop their pedagogical knowledge by learning how to design and deliver engaging learning experiences that promote student learning. Additionally, they can develop their content knowledge by deepening their understanding of the subject matter (Fahmina et al., 2019). Web-based TPACK scaffolding for online learning is crucial to 21st-century education as it addresses the needs of the ever-evolving education landscape. Preservice teachers who learn this method are equipped with essential skills for effective teaching and learning in preparing students for the digital age. In addition, this approach helps preservice teachers meet the demands of 21st-century students who are tech-savvy and expect engaging and effective learning experiences. Ultimately, this method ensures that preservice teachers are well-prepared to excel in their profession and contribute to the development of the education sector (Koh et al., 2018).

The web-based TPACK scaffolding for online learning method is a systematic approach designed to enhance the TPACK skills of preservice teachers. It involves several stages, introducing general chemistry learning materials and relevant technology to develop preservice teachers' digital literacy skills (Chai & Koh, 2017; Gawrisch et al., 2020; Mertz & Neiles, 2020). As they progress, the method supports integrating technology and content knowledge by developing pedagogical knowledge through designing and delivering engaging learning experiences that promote student learning. Additionally, preservice teachers deepen their understanding of the subject matter and improve their content knowledge. By integrating technology, pedagogy, and content knowledge, preservice teachers can comprehensively understand effective teaching practices in the digital age (Koh et al., 2018; Poitras et al., 2019). This method is particularly relevant in 21st-century education, because it emphasizes digital literacy and technology integration. Preservice teachers who undergo this method learn essential skills for effective teaching and learning in preparing students for the digital age (Huwer et al., 2018; Luo et al., 2020). This approach also meets the demands of tech-savvy 21st-century students who expect engaging and effective learning experiences. Ultimately, this method ensures that preservice teachers are well-prepared to excel in their profession and contribute to the development of the education sector.

CONCLUSION

The study aimed to develop a web-based TPACK scaffolding for online learning to enhance the TPACK skills of preservice chemistry teachers. The tool comprised five menus: Home, Instructions, Teaching Materials, TPACK Activity, and Evaluation. In Cycle 1 we evaluated the readability and comprehensibility of the tool using TAP. Participants suggested adding instructions, grouping learning activities, and grouping integrated TPACK lesson plans according to grade levels in high school. In Cycle 2 we evaluated the feasibility of the tool using student reflection. Participants found the tool easy to use and understand and considered it helpful for TPACK learning. The study demonstrated that web-based TPACK scaffolding is a potential new way to engage students in meaningful teaching and learning activities.The teaching materials on the website use various types of scaffolding to enhance preservice chemistry teachers' TPACK skills. The TPACK integrated syllabus and lesson plan provide examples of learning designs for some chemistry subject matter that integrate each component of TPACK appropriately. The TPACK integration matrix contains descriptions and examples for each TPACK component integrated into designed learning. In addition, teaching materials equipped with videos about technology-integrated chemistry learning provide an overview of the ideal interaction of technology, pedagogy, and content in the classroom. The TPACK Activity section on the website contains TPACK learning activities for preservice teachers that provide experience, develope skills, and improve understanding of the integration of TPACK into chemistry learning. In addition, the Evaluation menu consists of an assignment for preservice chemistry teachers to reflect on the process and outcomes of TPACK learning.

Web-based TPACK scaffolding is a helpful tool for preservice chemistry teachers to integrate TPACK into chemistry learning. This study highlights the importance of providing guidelines and clear learning objectives for preservice teachers using the website. The study also suggests that grouping learning activities according to the sequence of scaffolding strategy steps and according to grade levels in high school can improve the website's usability. Web applications provide friendly user interfaces and various functionalities. Therefore, teachers must have sensible rationales when considering how to implement the web application to assist them in managing classroom learning activities. The web-based TPACK scaffolding development is intended to meet the needs of preservice chemistry teachers, and their suggestions for improvement are important to consider. Overall, the study demonstrated the potential of web-based TPACK scaffolding for enhancing preservice chemistry teachers' TPACK skills and improving chemistry learning.

References

Abdallah, M. M. S., & Wegerif, P. R. B. (2014). Design-Based Research (DBR) in educational enquiry and technological studies: A version for PhD students targeting the integration of new technologies and literacies into educational contexts (EDS46471). ERIC. https://files.eric.ed.gov/fulltext/ED546471.pdf

Angeli, C., & Valanides, N. (2009). Epistemological and methodological issues for the conceptualization, development, and assessment of ICT-TPCK: Advances in technological pedagogical content knowledge (TPCK). Computers and Education, 52(1), 154–168. https://doi.org/10.1016/j.compedu.2008.07.006

Anilan, B., & Berber, A. (2019). Effect of conversion factor on problem solving and experience of teacher candidates. International Journal of Research in Education and Science, 5(1), 118–133.

Baddock, M., & Bucat, R. (2008). Effectiveness of a classroom chemistry demonstration using the cognitive conflict strategy. International Journal of Science Education, 30(8), 1115–1128. https://doi.org/10.1080/09500690701528824

Bergeson, K., & Beschorner, B. (2020). Modeling and scaffolding the technology integration planning cycle for pre-service teachers: A case study. International Journal of Education in Mathematics, Science and Technology, 8(4), 330–341. https://doi.org/10.46328/ijemst.v8i4.1031

Bustamante, C. (2020). TPACK-based professional development on web 2.0 for Spanish teachers: A case study. Computer Assisted Language Learning, 33(4), 327–352. https://doi.org/10.1080/09588221.2018.1564333

Cetin-Dindar, A., Boz, Y., Yildiran Sonmez, D., & Demirci Celep, N. (2018). Development of pre-service chemistry teachers' technological pedagogical content knowledge. Chemistry Education Research and Practice, 19(1), 167–183. https://doi.org/10.1039/C7RP00175D

Chai, C. S., & Koh, J. H. L. (2017). Changing teachers' TPACK and design beliefs through the Scaffolded TPACK Lesson Design Model (STLDM). Learning: Research and Practice, 3(2), 114–129. https://doi.org/10.1080/23735082.2017.1360506

Chayati, N., Masykuri, M., & Utomo, S. B. (2020). Development learning cycle 5E module integrated with science, technology, engineering, and mathematics (STEM) in thermochemistry. JKPK (Jurnal Kimia Dan Pendidikan Kimia), 5(3), 282. https://doi.org/10.20961/jkpk.v5i3.38938

Chen, S. Y., & Liu, S. Y. (2020). Using augmented reality to experiment with elements in a chemistry course. Computers in Human Behavior, 111, 106418. https://doi.org/10.1016/j.chb.2020.106418

Chiu, M.-H., Chou, C.-C., Chen, Y.-H., Hung, T., Tang, W.-T., Hsu, J.-W., Liaw, H. L., & Tsai, M.-K. (2019). Model-based learning about structures and properties of chemical elements and compounds via the use of augmented realities. Chemistry Teacher International, 1(1), 20180002. https://doi.org/10.1515/cti-2018-0002

Deng, F., Chai, C. S., So, H. J., Qian, Y., & Chen, L. (2017). Examining the validity of the technological pedagogical content knowledge (TPACK) framework for preservice chemistry teachers. Australasian Journal of Educational Technology, 33(3), 1–14. https://doi.org/10.14742/ajet.3508

Erna, M., Elfizar, E., & Dewi, C. A. (2021). The development of e-worksheet using Kvisoft Flipbook maker software based on lesson study to improve teacher's critical thinking ability. International Journal of Interactive Mobile Technologies, 15(1), 39–55. https://doi.org/10.3991/IJIM.V15I01.15679

Fahmina, S. S., Masykuri, M., Ramadhani, D. G., & Yamtinah, S. (2019). Content validity uses Rasch model on computerized testlet instrument to measure chemical literacy capabilities. AIP Conference Proceedings, 2194(1), 020023. https://doi.org/10.1063/1.5139755

Fonteyn, M. E., Kuipers, B., & Grobe, S. J. (1993). A description of think aloud method and protocol analysis. Qualitative Health Research, 3(4), 430–441. https://doi.org/10.1177/104973239300300403

Fujiwara, D., Kellar, K., Humer, I., Pietroszek, K., & Eckhardt, C. (2020). VSEPR Theory, an interactive and immersive virtual reality. In Proceedings of 6th International Conference of the Immersive Learning Research Network, (ILRN) San Luis Obispo, CA, USA 2020 (pp. 140–146). https://doi.org/10.23919/iLRN47897.2020.9155185

Fung, F. M., Choo, W. Y., Ardisara, A., Zimmermann, C. D., Watts, S., Koscielniak, T., Blanc, E., Coumoul, X., & Dumke, R. (2019). Applying a virtual reality platform in environmental chemistry education to conduct a field trip to an overseas site. Journal of Chemical Education, 96(2), 382–386. https://doi.org/10.1021/acs.jchemed.8b00728

Gawrisch, D. P., Richards, K. A. R., & Killian, C. M. (2020). Integrating technology in physical education teacher education: A socialization perspective. Quest, 72(3), 260–277. https://doi.org/10.1080/00336297.2019.1685554

Huwer, J., Lauer, L., Seibert, J., Thyssen, C., Dörrenbächer-Ulrich, L., & Perels, F. (2018). Re-experiencing chemistry with augmented reality: New possibilities for individual support. World Journal of Chemical Education, 6(5), 212–217. https://doi.org/10.12691/wjce-6-5-2

Kapici, H. O., & Akcay, H. (2023). Improving student teachers' TPACK self-efficacy through lesson planning practice in the virtual platform. Educational Studies, 49(1), 76–98. https://doi.

org/10.1080/03055698.2020.1835610

Koh, J. H. L. (2019). TPACK design scaffolds for supporting teacher pedagogical change. Educational Technology Research and Development, 67(3), 577–595. https://doi.org/10.1007/s11423-018-9627-5

Koh, J. H. L, Chai, C. S., & Natarajan, U. (2018). Developing Indonesia teachers' technological pedagogical content knowledge for 21st century learning (TPACK-21CL) through a multi-prong approach. Journal of International Education and Business, 3(1), 11–33. http://crie.org.nz/journal/vol3no1/Koh%20et%20al%20TPACK_indonesia.pdf

Kul, U., Aksu, Z., & Birisci, S. (2019). The relationship between technological pedagogical content knowledge and Web 2.0 self-efficacy beliefs. International Online Journal of Educational Sciences, 11(1), 198–213. https://doi.org/10.15345/iojes.2019.01.014

Kumala Dewi, R., Wardani, S., Wijayati, N., & Sumarni, W. (2019). Demand of ICT-based chemistry learning media in the disruptive era. International Journal of Evaluation and Research in Education, 8(2), 265–270. https://doi.org/10.11591/ijere.v8i2.17107

Lazem, S. (2019). On designing blended learning environments for resource-challenged communities. International Journal of Emerging Technologies in Learning, 14(12), 183–192. https://doi.org/10.3991/ijet.v14i12.10320

Lin, Y.-T., & Jou, M. (2012). A web application supported learning environment for enhancing classroom teaching and learning experiences. Procedia—Social and Behavioral Sciences, 64, 1–11. https://doi.org/10.1016/j.sbspro.2012.11.001

Lin, Y.-T., & Jou, M. (2013). Integrating popular web applications in classroom learning environments and its effects on teaching, student learning motivation and performance. Turkish Online Journal of Educational Technology, 12(2), 157–165.

Luo, X., Wei, B., Shi, M., & Xiao, X. (2020). Exploring the impact of the reasoning flow scaffold (RFS) on students' scientific argumentation: Based on the structure of observed learning outcomes (SOLO) taxonomy. Chemistry Education Research and Practice, 21(4), 1083–1094. https://doi.org/10.1039/c9rp00269c

Mertz, P. S., & Neiles, K. Y. (2020). Scaffolding career skills into the undergraduate curriculum utilizing a backward design approach. In K. Y. Neiles, P. S. Mertz, & J. Fair (Eds.), Integrating professional skills into undergraduate chemistry curricula (pp. 43–55). American Chemical Society. https://doi.org/10.1021/bk-2020-1365.ch004

Otrel-cass, K., Khoo, E., & Cowie, B. (2012). Scaffolding with and through videos: An example of ICT-TPACK. Contemporary Issues in Technology and Teacher Education, 12, 369–390.

Poitras, E., Mayne, Z., Huang, L., Udy, L., & Lajoie, S. (2019). Scaffolding student teachers' information-seeking behaviours with a network-based tutoring system. Journal of Computer Assisted Learning, 35(6), 731–746. https://doi.org/10.1111/jcal.12380

Polly, D., & Byker, E. (2020). Considering the role of zone of proximal development and constructivism in supporting teachers' TPACK and effective use of technology. Revista de Educación a Distancia, 20(64). https://doi.org/10.6018/RED.408661

Polly, D., Mims, C., Shepherd, C. E., & Inan, F. (2010). Evidence of impact: Transforming teacher education with preparing tomorrow's teachers to teach with technology (PT3) grants. Teaching and Teacher Education, 26(4), 863–870. https://doi.org/10.1016/j.tate.2009.10.024

Rap, S., Feldman-Maggor, Y., Aviran, E., Shvarts-Serebro, I., Easa, E., Yonai, E., Waldman, R., & Blonder, R. (2020). An applied research-based approach to support chemistry teachers during the COVID-19 pandemic. Journal of Chemical Education, 97(9), 3278–3284. https://doi.org/10.1021/acs.jchemed.0c00687

Ryan, M. D., & Reid, S. A. (2016). Impact of the flipped classroom on student performance and retention: A parallel controlled study in general chemistry. Journal of Chemical Education, 93(1), 13–23. https://doi.org/10.1021/acs.jchemed.5b00717

Saefi, M., Fauzi, A., Kristiana, E., Adi, W. C., Muchson, M., Setiawan, M. E., Islami, N. N., Fitria Ningrum, D. E. A., Ikhsan, M. A., & Ramadhani, M. (2020). Validating of knowledge, attitudes, and practices questionnaire for prevention of COVID-19 infections among undergraduate students: A RASCH and factor analysis. Eurasia Journal of Mathematics, Science and Technology Education, 16(12), em1926. https://doi.org/10.29333/ejmste/9352

Siripongdee, K., Pimdee, P., & Tuntiwongwanich, S. (2020). A blended learning model with IoT-based technology: Effectively used when the COVID-19 pandemic? Journal for the Education of Gifted Young Scientists, 8(2), 905–917. https://doi.org/10.17478/JEGYS.698869

Tan, L., Chai, C. S., Deng, F., Zheng, C. P., & Drajati, N. A. (2019). Examining pre-service teachers' knowledge of teaching multimodal literacies: A validation of a TPACK survey. Educational Media International, 56(4), 285–299. https://doi.org/10.1080/09523987.2019.1681110

Tomczyk, L. (2020). Attitude to ICT and self-evaluation of fluency in using new digital devices, websites and software among pre-service teachers. International Journal of Emerging Technologies in Learning, 15(19), 200–212. https://doi.org/10.3991/ijet.v15i19.16657

Valtonen, T., Kukkonen, J., Kontkanen, S., Mäkitalo-Siegl, K., & Sointu, E. (2018). Differences in pre-service teachers' knowledge and readiness to use ICT in education. Journal of Computer Assisted Learning, 34(2), 174–182. https://doi.org/10.1111/jcal.12225

Valtonen, T., Sointu, E., Kukkonen, J., Kontkanen, S., Lambert, M. C., & Mäkitalo-Siegl, K. (2017). TPACK updated to measure pre-service teachers' twenty-first century skills. Australasian Journal of Educational Technology, 33(3), 15–31. https://doi.org/10.14742/ajet.3518

Yamtinah, S., Saputro, S., Mulyani, S., Ulfa, M., Lutviana, E., & Shidiq, A. S. (2019). Do students have enough scientific literacy? A computerized testlet instrument for measuring students' scientific literacy. AIP Conference Proceedings, 2194, 020143. https://doi.org/10.1063/1.5139875

Yu, Z. (2021). The effects of gender, educational level, and personality on online learning outcomes during the COVID-19 pandemic. International Journal of Educational Technology in Higher Education, 18(1), 14. https://doi.org/10.1186/s41239-021-00252-3

Yuriev, E., Naidu, S., Schembri, L. S., & Short, J. L. (2017). Scaffolding the development of problem-solving skills in chemistry: Guiding novice students out of dead ends and false starts. Chemistry Education Research and Practice, 18(3), 486–504. https://doi.org/10.1039/c7rp00009j

Zhang, S., Liu, Q., & Cai, Z. (2019). Exploring primary school teachers' technological pedagogical content knowledge (TPACK) in online collaborative discourse: An epistemic network analysis. British Journal of Educational Technology, 50(6), 3437–3455. https://doi.org/10.1111/bjet.12751