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Impact of digital interventions on the development of TPACK: Interviews, reports, and video simulation among pre-service teachers

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Abstract
It is a truth of today's world that there is a growing investment in advancing technological opportunities in education. The literature contains a substantial quantity of research on the integration of digital educational settings that contribute to the development of higher education institutions. However, actual data linking key factors like TPACK (technological pedagogical content knowledge) level and ideas of teaching and learning science is still lacking in the literature. For this purpose, the study was designed to find out how a digital environment affects the development of TPACK. Twenty pre-service chemistry teachers (PCHTs) were chosen for this investigation using the convenience sampling methodology. Mixing qualitative and quantitative methods to collect, analyse, and evaluate data was used in this study. The study's results showed that digital intervention had an impact on how PCHTs used their digital abilities and instructional techniques. It was also found that TPACK scores predicted the association of PCHTs' technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK), which eliminated deficiencies in these areas of knowledge as well as in the understanding of TPACK in favor of the synch group. Because of synchronous instruction, students seemed to talk to each other more and build learning experiences that helped each other. Synchronous meetings helped more PCHTs and TPACKs grow. The synch environment helped to develop the relationship between TK, PK, and CK and PCK. In this study, it is recommended that PCHTs have a basic understanding of what digital tools are. Also, the findings of this study are expected to theoretically and practically contribute to the integration of TPACK in online sync and async systems.

Keywords Interviews · Reports, video simulation · Technological knowledge · Content knowledge · Pedagogical knowledge · Pre-service teachers

Extended author information available on the last page of the article

1 Introduction

In the spring of 2020, schools around the country were faced with an unprecedented challenge: keeping students in the classroom despite their absence (Minkos & Gelbar, 2020). As never before, radical changes in education are required. While remote training had been on the rise for some time, it was still the exception rather than the rule. All of that changed with the COVID-19 pandemic (Barton, 2020).

According to studies, even when technology was readily available for instructional purposes, teachers and students were not enthusiastic about using it in the classroom (Bayaga et al., 2021). Lack of basic expertise and confidence, as well as typical issues such as a lack of suitable technological tools, could explain the low frequency and poor usage of technology in classrooms. (Jen et al., 2016). However, the interruptions to the education system during the first few months of the pandemic resulted in instructional approaches that did not necessarily match the body of research on teaching and learning (Johnson et al., 2020). For example, 88 percent of teachers said their students spent less time on science through remote learning than they did in the classroom, and just 38 percent said their students had participated in experiments or investigations through remote learning (Watson & Rockinson-Szapkiw, 2021; West, 2018, 652).

The relevance of considering the digital education environment as a tool to increase learning is emphasized in this study. Although there is debate about whether technology can improve student accomplishment (Decuypere & Landri, 2020), effective use of digital technology in the classroom may improve learning by encouraging more creative processes and serving as a cognitive aid (Singh, 2021). However, the effective use of digital technology as a cognitive tool is contingent on the adequate pedagogical preparation of potential instructors that extends beyond the acquisition of technical abilities (Sargent, 2018).

Research on the use of digital technologies in chemistry education is particularly significant for identifying trends in theoretical frameworks and technology applications in educational practice (Erduran & Akış, 2023). It is surprising that there does not seem to be enough research on these problems in university chemistry curricula, given the significance of digital learning technology in chemistry education (Pilcher et al., 2023).

Chemistry demands both observable facts and intellectual concepts (Wan et al., 2023). It is well known that students frequently struggle to successfully integrate these perspectives, especially when experimental evidence defies model-based explanations (Cooper et al., 2022). One example of this is when students interpret chemical equilibrium as a dynamic process despite observing a static system with no discernible changes. Through digital media, possibilities that may not have been accessible to this degree before are now available. Nevertheless, we do not know enough about how much these media tools support learning processes while simultaneously having the potential to harm them (Gumasing & Castro, 2023).

To fully understand chemical phenomena, like chemical reactions, one must know about them on three levels: the macroscopic (one can see and touch them), the representational (chemical equations and formulas), and the submicroscopic (atoms and molecules). It is also necessary to know how these three levels affect each other (Kumar et al., 2020). Instructors only focus merely on the macroscopic and visual aspects, ignoring and failing to examine the microscopic elements (Pecha et al., 2019). Because of this, students often struggle to comprehend and visualise microscopic concepts like atoms, molecules, or chemical reactions (Slapničar et al., 2018). For instance, when studying the subject of electrolyte and non-electrolyte solutions, students find it difficult to comprehend how the ions in a solution can move freely and conduct electric currents. The use of a digital learning environment such as digital platforms or blended spaces can considerably improve students' comprehension of chemical principles, theories, and molecular structures (Penn & Ramnarain, 2019). As a result, technology can be used to help students understand chemical ideas, which is a starting point for learning.

To prepare teachers to use digital technology in the classroom (DTC) effectively in online synchronous and asynchronous environments, opportunities for meaningful use of technology as a learning aid must be provided. "To a considerable extent, a teacher's capacity to integrate technology into the classroom depends on the classroom experience that person received as a pre-service teacher," Elstub et al. (2021) write. Modeling pedagogical methods must take place in the context of their current reality, resulting in skill development, information transfer, and self-expression (Vongkulluksn et al., 2018). Furthermore, beyond developing technical abilities, pre-service teachers must establish a clear vision of how to integrate technology into their teaching (Claro et al., 2018; Dahlstrom-Hakki et al., 2020; Karaseva et al., 2018).

Synchronous learning environments include aspects such as instructor lectures, collaborative activities, and student inquiries (Mellati et al., 2018). For each class meeting, all students in the course are logged on at the same time. In asynchronous learning environments, students participate in exercises regardless of the lecturer or other students (Carruana Martín et al., 2021). Asynchronous settings include reviewing a pre-created learning module, threaded discussion boards, and/or email interaction with the instructor or classmates (Roseth et al., 2013). A hybrid course can take many different forms and sizes. Some classes meet at the same time, while others meet separately or asynchronously. The element of education supplied to students who are not near traditional, brick-and-mortar instruction is the most significant factor for students from remote regions, regardless of course synchronization (Raes, 2022).

According to Jesson et al. (2018), "almost 70% of teachers report not feeling well equipped to use the Internet in their teaching." To encourage technology-using teachers in pre-service training, Sampson et al. (2018) offer the "finding the self" approach. Pre-service teachers, according to Sampson et al., should perceive digital technology as a useful instrument that aids them in their current lives and as a means of self-expression. As a result, to improve pre-service teachers' abilities to integrate digital technology into their teaching, new ways must be taught (Amin & Sundari, 2020; Backfisch et al., 2021).

As students' exposure to online learning settings has grown, their perceptions have shifted (Bond & Bedenlier, 2019). According to students, both synchronous and asynchronous environments have advantages. Students report that they comprehend more and perform better when they participate in synchronous environments (Bell et al., 2014). Students in asynchronous classrooms, on the other hand, have the freedom to work at their own pace.

1.1 Digital didactic design in teaching chemistry

Digital technology could be utilized to promote dialogic and emancipatory behaviors. Students participate in dialogic activities that promote learning by taking an active, engaged, and empowered role in the conversation (Theelen & van Breukelen, 2022). For instance, learners using a molecular modeling application can begin to talk about what they see on a computer screen without relying on vocabulary they may not be familiar with (look at ’that,’ what happens if you do "this?"). As the project progresses, the teacher can incorporate the appropriate terminology into the discourse (Pirhadi et al., 2016).

Chemistry is taught as a subject or academic discipline and includes both theoretical and practical aspects. This implies that it requires both material and human resources, such as classroom space and qualified instructors. Lawrie (2021) lists a number of issues with teaching chemistry, including teacher and student attitudes, non-professionalism, time constraints, workshops, class size, working atmosphere, laboratory suitability, and dubious test procedures. Some of the most important issues in teaching chemistry in the digital age are listed below. Tiemann and Annaggar, (2023), who explored these concerns in terms of the factors impacting students’ academic performance in chemistry, stressed the significance of digital learning technologies in the teaching of chemistry.

Both the availability of instructional materials and a teacher’s technical proficiency in using them can have an impact on the aforementioned chemistry-related teaching challenges. Naturally, this has no influence on the teacher’s ingenuity and inventiveness in making sure that learning based on digital technology goes hand in hand with subject-matter competence.

It is vital to do research in chemistry teaching using digital technologies to discover trends in theoretical approaches and technology employed in educational practice (Walan, 2020). Despite the importance of digital learning technologies in chemistry education, reviews of digital learning technologies in university chemistry education appear to be lacking in the literature. These evaluations summarize and arrange the extant literature, highlighting the technologies and educational approaches used. Therefore, they can provide significant insights into the present state of the area, assisting researchers in identifying study topics that are still relevant (Pagliaro, 2018).

One of these new approaches used by successful chemistry teachers in today’s era of the technological and cognitive revolution to employ technology in teaching scientific content in a thoughtful educational manner is TPACK (see Mishra, 2019). The TPACK model is a professional teacher preparation model that enables educators to develop instruction to meet the diverse needs of students (Lachner et al., 2021).

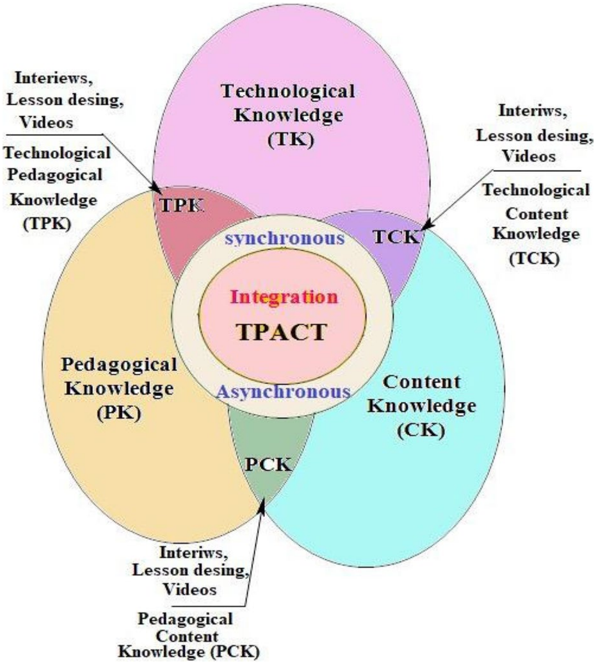


Fig. 1 The components of the TPACK model with digital teaching

This suggestion was offered in Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge by Mishra & Koehler, (2006) (see Mishra, 2019). Their results build on the Pedagogical Content Knowledge (PCK) framework that Shulman first talked about in his 1986 book, Those Who Understand: Knowledge Growth in Teaching. Shulman's original view of the PCK model focused on the educational context and the content context (see Fig. 1) (Rets et al., 2023).

Researchers define TPACK as a seven-dimensional model of different types of knowledge that includes technological knowledge (TK), content knowledge (CK), and pedagogical knowledge (PK), as well as the intersection of these three types of knowledge (TPK, TCK, and PCK) (Mishra, 2019).

After examining studies conducted on TPACK during the early years, it was observed that researchers concentrated on establishing the ideas of TPACK (Swallow & Olofson, 2017) and determining the relationships between the concepts (Mishra, 2019). Later, researchers used existing measurement methods and developed new ones to determine pre-service chemistry teachers' (PCHTs') attitudes and competencies about TPACK (Miguel-Revilla et al., 2020). As a result, determining the TPACK growth of PCHTs by focusing on a specific topic, technology, or teaching technique does not produce practical results. As a result, focusing on the TPACK integration of PCHTs across a broad range of subjects, technologies, and instructional techniques will produce more precise results (Li et al., 2022).

When all the methods used in studies to improve the TPACK parts of PCHTs were looked at together, it was TPACK-based lessons that showed that planning lessons with technology (Deng et al., 2017), giving presentations (Kiray, 2016), and training with digital tools were the ones that helped PCHTs' TPACK integration the most. When these strategies are looked at separately, it is clear that PCHTs learn how to use TPACK principles in technology-enhanced lesson plans, but they cannot make up for the fact that they are not good at getting their ideas across (Cetin-Dindar et al., 2018). When PCHTs offer TPACK-based lessons to their peers, it is also not enough to gain experience in a genuine classroom setting.

1.2 Research question

A positive relationship exists between TPACK levels and the desired role of educators, technology usage in education knowledge, lesson planning, peer collaboration, practical classroom experience, video simulation, and continuing feedback. With consideration for the advantages of the methods used in earlier studies, we propose using a TPACK Development Course that combines interviews, reports, and video simulation in a digital setting to raise the TPACK and application levels of PCHTs. The study seeks to investigate the effect of these interventions on the levels of TPACK and its associated applications. Therefore, the following inquiries helped to determine the issue of the study:

1. Do digital interventions in the synch and asynch environments have an effect on TPACK integration?
2. Are there differences between the synch and asynch environments in TPACK integration?

For the purpose of this study, the research hypotheses are listed below:

H1. Digital interventions in synch and asynch environments have an effect on the integration of TPACk elements.
H2. There will be no significant differences between a sync or async online environment on TPACK integration.

2 Methods

2.1 Research model

This study was carried out as a case study with an in-depth research design that mostly uses qualitative techniques but also occasionally includes quantitative methodologies (Feagin et al., 2016) and lasted three months during the first semester of the academic year 2021–2022. Using mixed methodologies is a research methodology, according to Creswell and Clark (2017). A mixed-procedures research design has its own philosophical assumptions and inquiry methods. It uses philosophical assumptions to guide data collection and analysis from numerous sources in a single study. This study depends on a sequential exploratory design. This design begins with qualitative data collection to examine experiences, perceptions, and meaning

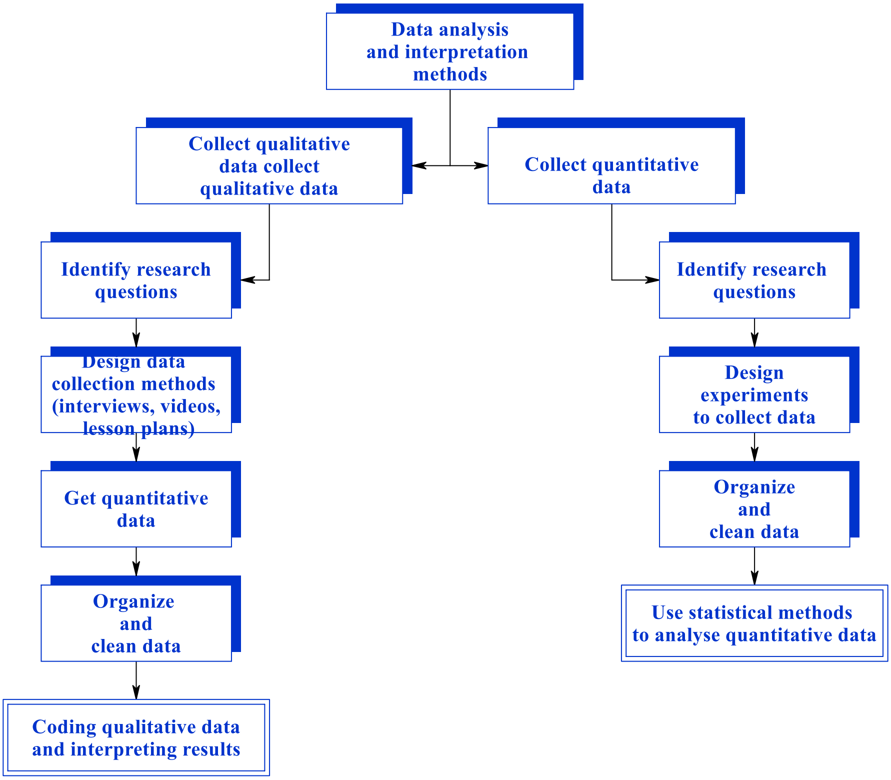


Fig. 2 Data analysis and interpretation mothode

using observations, interviews, cross-validation, and analysis, followed by quantitative data collection and analysis. The qualitative findings help inform the development of quantitative measures, which are collected from numerical data and statistical analyses performed using surveys and experiments, and provide a deeper understanding of the research question (Fig. 2). It looks into the TPACK integration of PCHTs from a variety of data sources, including interviews, lesson designs, and instructional video recordings. This study was done in the fourth year of the Department of Chemistry in Higher Education, using discussion, scientific explanations, virtual labs, and guided inquiry in online synchronous and asynchronous environments.

2.2 Participants

Twenty PCHTs were used in this study; ten PCHTs (6 females and 4 males) were placed in the synchronous group, while ten PCHTs (6 females and 4 males) were placed in the asynchronous group (see Fig. 2). The convenience sampling approach was used to choose them. To increase the reliability of the study, convenience sampling, a sort of nonprobability sampling, is used to gather data from people who are easily available. The convenience sample was chosen from a group of students who are easy to reach or locate, regardless of whether they are a representative sample of the entire student body. Because chemistry is one of the main barriers to teaching and understanding science in a classroom, researchers choose to engage with chemistry pre-service teachers to educate them on the best ways to use the concepts and methods learned in chemistry classes, produce chemical formulas, and train students. This study must ascertain the amount of technical, pedagogical, and subject knowledge-related teaching and learning that pre-service chemistry instructors now possess in order to make recommendations for future university-level chemistry teacher education and research. All PCHTs were given a demographic information questionnaire before the trial began. Two more skilled in PK (PCHT-3, PCHT-6, PCHT-8), two in TK (PCHT-2, PCHT-9), and five in CK were determined based on the findings of the questionnaire (PCHT-1, PCHT-4, PCHT-5, PCHT-7, PCHT-10). For instance, PCHT-3 in the synchronous group demonstrated how simple technology is to learn, and PCHT-6 in the synchronous group discussed his proficiency with many forms of technology. The average age of these ten PCHTs, who ranged in age from 19 to 21, was 20. Throughout earlier stages of teacher training, they took a variety of courses for CK, including chemistry and pedagogy; science curriculum, teaching methods, and material development; and computer courses for TK. The PCHTs have three to ten years of experience with office software like Word, PowerPoint, and the Internet. They only took part in a couple of lesson presentations. When it comes to CK, PK, and TK, PCHTs can be said to have a basic understanding. They, on the other hand, do not have a thorough understanding of simulations and lesson presentations (Aktaş & Özmen, 2020) (Fig. 3).

2.3 Data sources

In this study, the growth of PCHTs that used Microsoft Teams was tracked using synchronous and asynchronous interviews, lesson design reports, and videos of lesson presentations.

2.3.1 Synchronous and asynchronous interviews

Synchronous interviews were done four times: before the meeting, after the training sessions, during the synchronous micro-teaching plan, and during the real-world application. There were also four asynchronous interviews: one before the meeting, one after the training sessions, one after the asynchronous micro-teaching plan, and one after the application in the real world. Synchronous online interviews are most like conventional ones in that they take place in real time. So, everyone takes part in interviews at the same time through an Internet chat room. The interview questions were developed with the phases' goals in mind. The questions were adapted from the literature and theoretical framework of TPACK. These questions focused on comprehending and outlining the types of information that a teacher requires to implement effective pedagogical techniques in a classroom. Examples given to the PCHTs include:

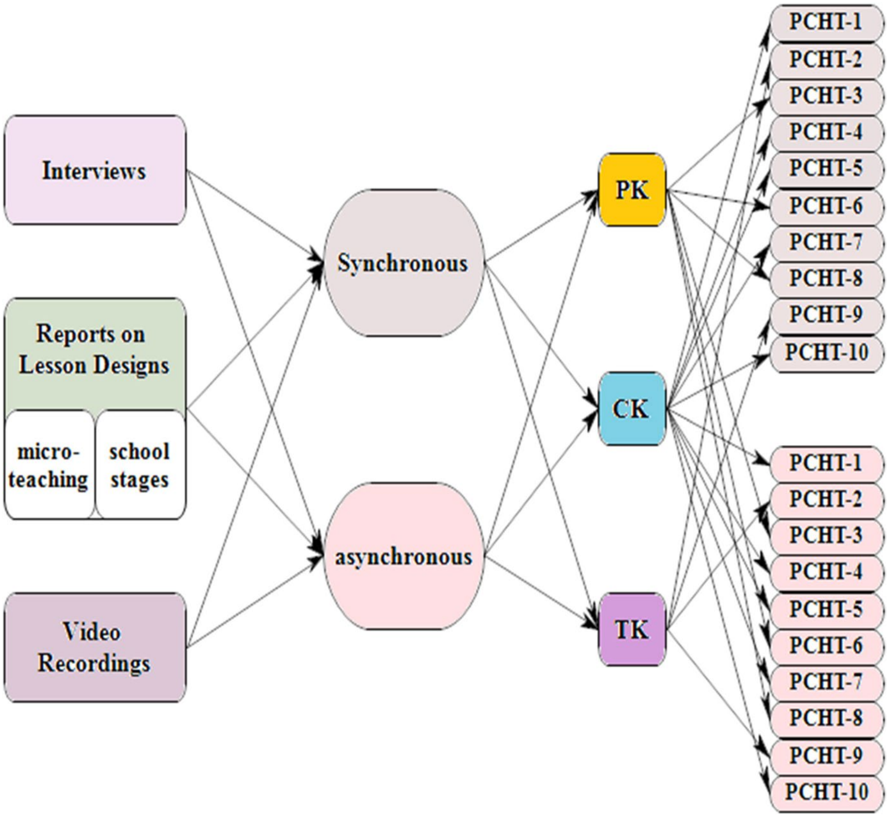


Fig. 3 Research model

Q1: Give an example of a time when you showed or simulated integrated content successfully.
Q2: What role does the teacher play in guiding students' self-learning in class?

The previous two questions are one of the simultaneous interview questions posed to students. An asynchronous interview, as opposed to a live chat, allows PCHTs to view a video with a series of questions and provides them with a certain amount of time to think about and respond. Then, their replies were examined. Examples of questions in an asynchronous interview include:

Q1: Summarize the themes and ideas presented in the video.
Q2: Ask three questions related to the video.

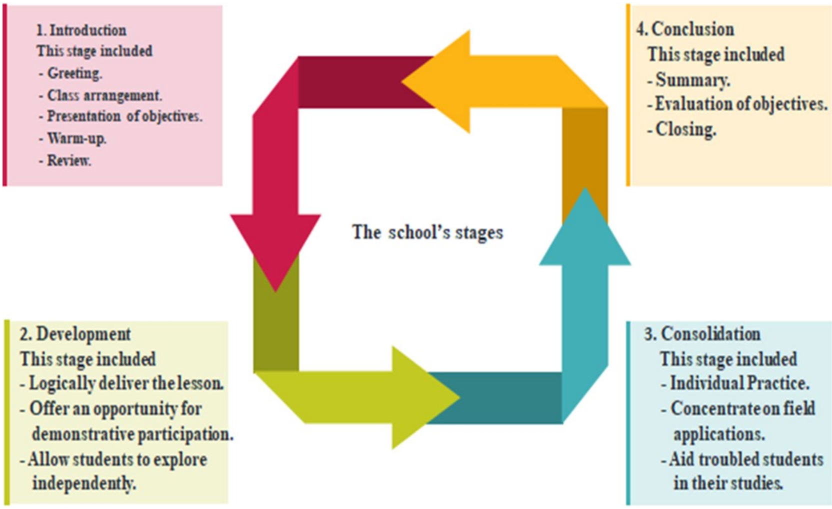


Fig. 4 The structure of school stages

2.3.2 Reports on lesson designs

PCHTs created lesson plans for both the microteaching and school stages. Micro-lessons are short modules that focus on the most important aspects of the messages of a learning topic (Aktaş & Özmen, 2020). Lesson planning plays a huge role in providing students with a stable online classroom environment that best supports their learning. Students respond best to activities in which they are involved and can anticipate what comes next. Figure 4 shows the school stages used in the research and suggested by the researchers.

2.3.3 Video recordings

PCHTs in both synchronous and asynchronous groups could learn a lot more quickly with the help of videos in a course. After their first-class presentations were videotaped, the PCHTs in both synchronous and asynchronous groups were asked to carefully look over the footage and make a second presentation that fixed any mistakes they found. The second presentation of the PCHTs was also videotaped. In the synchronous group, PCHT submits ideas online and converses "face-to-face" in the meeting space. The PCHT in a synchronous group can record their videos whenever and anywhere they like, and they can also divide up how they watch the videos such that they take significant breaks in the middle of the discussion. Figures 5 and 6 show examples of the footage.

Fig. 5 Examples of the video recordings

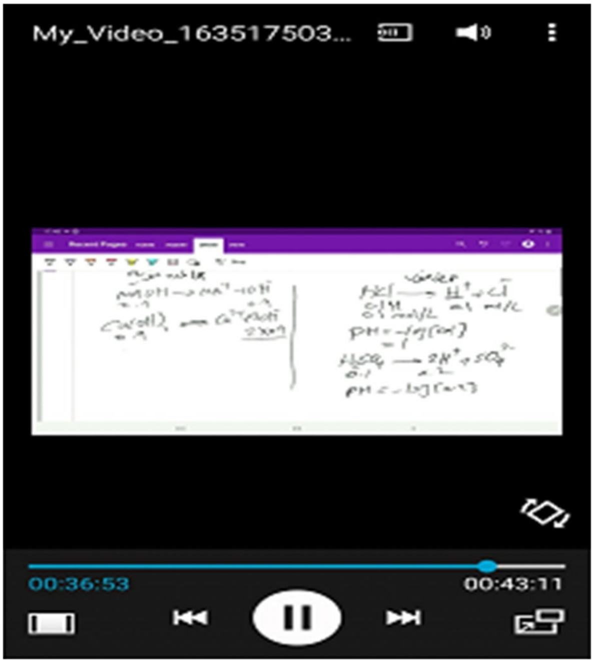
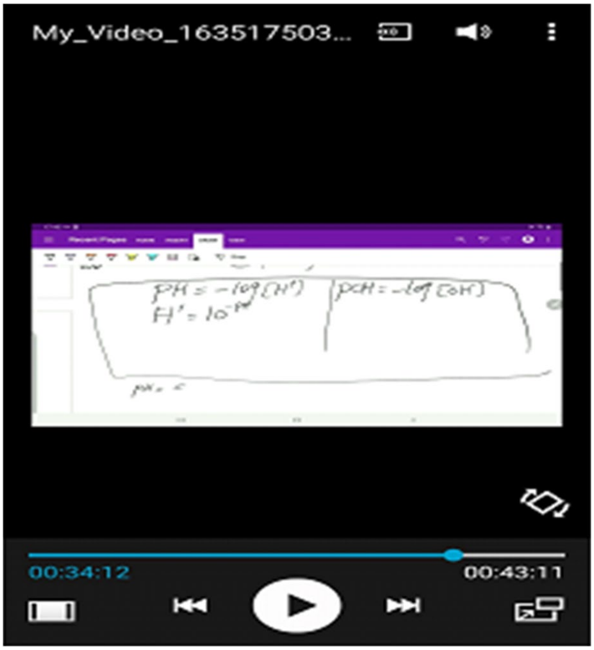


Fig. 6 Examples of the video recordings



2.3.4 Procedure

The Chemistry Teacher Training Programme was implemented in the second semester of the college's fourth year. It took three months to complete. Ten PCHTs took the special teaching methods course provided using Microsoft Teams simultaneously, while ten others attended the course asynchronously. They also attended school lectures at the practice school during the same semester. PCHTs performed their activities and lessons at the practice school either in their classrooms or in the laboratory, depending on the needs of their lesson design.

2.3.5 Ethical issues

The study was done in a way that respected the rights of the people who took part in it at all times. Since this research was done at a public high school and by the faculty of education, they had to give their permission first. Since the people taking part were younger, consent forms were sent to their parents. The parents were also told how the research would be done and asked to sign off on it. All of the students took part in the study because they wanted to, and they all stayed involved the whole time. The participants were assured of the confidentiality of the information. The taught content was selected from among the courses for the academic year. During the interview, researchers sat down with each participant in a comfortable place and asked them to answer the questions. The information recorded is confidential.

2.3.6 Implementation of the experiment

A training course, lesson designs created to be utilized in conjunction with online synchronous and asynchronous micro-teaching, and school activities were all part of the experiment (Ledger & Fischetti, 2020) (see Table 1).

The course includes digital teaching tools for PCHTs like animations, simulations, sending messages and sharing files with Microsoft Teams (https://www.microsoft.com/en-us/microsoft-365/microsoft-teams/group-chatsoftware), improving the skills needed to use the ideas and materials in chemistry lessons, and writing chemical formulas with Chemdraw (https://chemdraw-pro.software.informer.com/8.0/). At this point, the goal is to boost PCHTs' TPACK awareness, increase their TK, and integrate TK, PK, and CK (Jannah et al., 2019). Researchers tell PCHTs how to utilize digital resources effectively in teaching at the start of the course, and then he shows them examples of sample lesson designs. "Physical and chemical properties of acids and alkalis," "classification of solutions as acidic, basic, or neutral," and "pH of solutions" were the topics of his three lesson presentations. In the technology-based workbooks for PCHTs, the trainer used simulation, the Internet, movies, and computers, both synchronously and asynchronously. The researcher also employed a variety of instructional methods, including asynchronous conversation, scientific explanations, guided inquiry, and planning and conducting scientific experiments. PCHTs' success in planning the lesson and presenting was discussed in both synchronous and asynchronous class discussions, as well as what could be done to improve their performance.

Table 1 Shows the tasks of the instructor and PCHTs

	Training course	Group1 (lesson designs involving sync micro-teaching)	Group 2 (lesson designs involving async micro-teaching)	School activities
Aim	To improve understanding of TPACK components To gain the ability to use digital teaching skills	To design effective lesson designs and employ the components of TPACK To clarify the relationship between science, mathematics, and technology To use digital tools such as animation and simulation to provide opportunities for displaying phenomena	To design effective lesson designs and employ the components of TPACK To send messages and exchanging files through the educational platform To use the Internet to search for facts related to a scientific phenomenon	To apply digital skills in school rooms
The tasks of the instructor	Digital teaching skills instructor	Managing synchronous class discussions Evaluating lesson plans and presentations	Managing asynchronous class discussions Evaluating lesson plans and presentations	Evaluating different lessons and presentations
The tasks of the PCHTs	Getting a better understanding of the TPACK components. Raising awareness of the benefits of using digital technology in the classroom	Employing the components of TPACK effective communication between teacher and students Designing presentations	Employing the components of TPACK effective communication between teacher and students Designing presentations	Employing the components of TPACK Designing school activities

School activities present different chemistry subjects in real classrooms (Holstein et al., 2018). At this stage, the PCHTs enable TPACK integration. The PCHT's role was to construct the lesson design, present it in a real school room, and practice applying it with a new plan and presentation. Each PCHT created and presented three lessons in this study. One of the researchers videotaped and collected the lesson presentations.

3 Data analyses

3.1 Interviews

Content analysis was used to examine the interview data. The researchers used the following steps in content analysis: First, they reread the transcripts to understand the interviews. Second, they carried out coding to find study-related words, phrases, and sentences. Units are codes. Two researchers collaborated to conduct a content analysis, in which they sorted the material from Pre-Service Chemistry Teacher-1 into meaningful sections and coded it (PCHT-1). The PCHT synchronous and asynchronous interviews were then coded independently (Jannah et al., 2019). Third, they used a codebook guide for data coding. It includes code definitions, descriptions, and examples for consistency. Fourth, the researchers used code interview data from the codebook. Each data segment has content-based codes. Fifth, they examined code relationships and data-driven concepts. The data was recorded in the synchronous and asynchronous interviews in accordance with the TPACK elements (TK, PK, CK, PCK, TPK, TCK, TPACK) (see Table 2).

Sixth, the researchers' coding was scrutinised for consistency. The amount of coded data that was used face-to-face in the synchronous interview and the data that was analysed at different times in the synchronous interview helped determine the consistency measurement. This was calculated[1] (Marinucci et al., 2020) (see Tables 2 and 3).

3.2 Lesson design and video using a TPACK model

The TPACK rubric was used to compare the synchronous and asynchronous lesson designs and video recordings. Each PCHT delivered three presentations—two in classroom settings and one involving lesson plans that included the use of microteaching activities. Schmidt et al. (2009) established the TPACK rubric, which includes 12 performance criteria and five teaching performance levels. The two researchers graded PCHT-1's lesson design report and presentation. The researchers used TPACK-Rubric to evaluate video recording methods using "agree" to "strongly agree" and "disagree." The researchers contrasted synchronous and asynchronous groups in the TK domain by measuring skill in managing

[1] The measurement of consistency is the amount of the same encoded data divided by the sum of the amounts of the same encoded data and the different encoded data.

Table 2 Illustration of content analysis of TPACK elements

Themes	Codes	Examples
TK	Using scientific books and digital libraries to learn chemistry	Q: What did you gain from studying the course?
	Learning chemistry with graphics and videotapes	A: I was able to use the Internet to understand new different concepts in chemistry
	Knowing how to use Office software (PPT, DOC, etc.)	A: I learned how to use PPT and similar tools to prepare a presentation and create videos, as well as how to present on Microsoft Teams
PK	Knowing new teaching techniques	A: I used a variety of teaching methods in planning lessons, such as discussion, building scientific explanations, and guided inquiry. These were virtually taught to me
CK	Removing barriers to aid in the development of the student	A: I was a little perplexed about the physical and chemical features of acids and alkalis
PCK	Discussing the importance of teaching concepts	A: I first, determined the students' concepts and then we begin to correct them
TPK	Using different techniques to engage students	A: I used Chemdraw to write chemical formulas, as it helped the students learn more effectively
TCK	Referring how knowledge is represented	A: I used a simulation that showed the behavior of acids and alkalis
TPACK	Using suitable tools to understand chemistry courses	A: Since learning is visual in simulation and animation, it allows them to learn about chemistry concepts more effectively

Table 3 The reliability measurement of coded data for synchronous and asynchronous interviews

	PCHT-1	PCHT-2	PCHT-3	PCHT-4	PCHT-5	PCHT-6	PCHT-7	PCHT-8	PCHT-9	PCHT-10
sync interview	0.555	0.529	0.533	0.571	0.588	0.588	0.511	0.602	0.614	0.599
async interview	0.647	0.597	0.641	0.497	0.548	0.687	0.714	0.743	0.475	0.578

video recording tools, applications, and platforms, using suitable settings and features for high-quality recordings, and addressing technological issues.

In the PK domain, the researchers designed video recording activities that align with specific learning objectives and used various instructional strategies and techniques to engage PCHTs in the video recording process and promote active learning and reflection. In the CK domain, the researchers compared the synchronous and asynchronous groups by looking at how well the video recordings show accurate and up-to-date subject knowledge, help students understand by including relevant content knowledge, and match the learning outcomes and standards in the curriculum. The researchers compared synchronous and asynchronous groups in TPACK integration by looking at how well PCHTs and technology knowledge work together to make powerful video recordings. This shows that they have a deep understanding of how video recording helps PCHTs learn and can change how they do it based on formative assessment data and PCHT needs. The majority of respondents agreed that using technology in the classroom encourages participation and learning. According to respondents, technology enhances student involvement and learning.

PCHTs' lesson design practices were assessed using the TPACK survey. The TPACK survey was used to measure confident PCHT in selecting and structuring lesson content and recognising how his/her topic expertise affects his lesson design selections. TPACK examined how well PCHT uses a variety of instructional strategies and students' learning needs and preferences while creating lessons in the PK domain. The TPACK survey examined PCHT's comfort with using technology to enhance his/her teaching and stay current in TK. The TPACK survey assessed lesson design's integration of topic knowledge and pedagogical methodologies and students' PCK domain content issues and misconceptions. The TCK domain TPACK survey assessed technology tools and resources for the material being taught and their suitability and efficacy in supporting content learning goals. The TPK domain's TPACK assessment examined how well he/she integrated technology into his/her classes to increase learning and encourage student participation.

The researchers used the following procedures to apply the TPACK model to a content analysis of a lesson plan: The first is a thorough comprehension of the TPACK structure, its elements, and their interrelationships. Second, to identify the coding categories or themes that are used to analyse the instructional plan, researchers defined coding categories. These categories—technological knowledge, pedagogical knowledge, content knowledge, and their intersections—align with the TPACK paradigm. Third, PCHTs tried to read the lesson plan and carefully code the important parts or passages using the standard coding categories. PCHTs then looked for examples of pedagogical knowledge (the teaching methods used, for instance), content knowledge (for example, the subjects covered), and technological knowledge (such as the technology tools or resources that were used). Fourth, in order to find any patterns, trends, or connections between the various TPACK model components, the researchers examined the coded data and looked for indications in the lesson plan of how the teacher incorporates pedagogical techniques, content knowledge, and technology. Finally, the researchers attempted to make inferences on how well the lesson plan adheres to the TPACK model's tenets.

The two researchers then scored the data from the other PCHTs individually. When examining lesson design, each researcher considered the following factors: (1) student learning objectives; (2) teaching and learning activities; and (3) techniques for judging students' knowledge.

After scoring, Kendall's coefficient of concordance was calculated to examine the consistency of both researchers' scores (Aktaş & Özmen, 2020). The internal consistency of the rubric's items was determined using Cronbach's alpha coefficient (see Table 4).

Two researchers examined the data, and they used the consistency coefficient to determine how accurate the data were. To ensure that the data was triangulated, Jen et al. (2016) used a variety of data gathering sources and lesson design reports. The analysis method is comparable to that of Aktaş and Zmen (2020). The outcomes were discussed. All analyses were conducted using SPSS (Statistical Package for Social Sciences) 29.0 software.

4 Findings

4.1 Findings from interviews

In this study, the information from four PCHT interviews was broken down into seven themes: TK, CK, PK, PCK, TPK, TCK, and TPACK. The number of times each theme's codes appear was counted, and ten PCHTs showed a better understanding of the TPACK (Voogt & McKenney, 2017) (see Table 5).

Table 5 shows that the training course improved PCHTs' baseline knowledge of PK, TK, TPK, and TPACK the most, followed by TCK and TK. With the help of synchronous micro-teaching, the lesson plan developed TCK, TPK, PCK, TPACK, TK, PK, and CK. Following PK, PCK, and CK in terms of where they developed the most were TPACK and TPK. Before the study, few PCHTs recognised the necessity of identifying students' knowledge levels and individual variances and guiding them during instruction. TK taught them Microsoft Office and Internet searching. Few PCHTs used suitable ideas for students' knowledge levels, integrated concepts into daily life, engaged in appropriate attention-grabbing activities, and evaluated misconceptions during learning. Few visual presentations had TPK (Aktaş & Özmen, 2020).

PCHTs chatted online and shared information through written texts, slideshows, links to other websites, and instructional videos during asynchronous training. Because people could not quickly share ideas and comments, these PCHTs did not get any feedback on their lessons. The asynchronous course improved TPK, TCK, and TPACK, then TK and PK, and lastly CK. Asynchronous classes allowed participants to focus more on the instructional scenario because they did not have to interact at a set moment. Namaziandost et al. (2022) state that asynchronous approaches do not give students significant in-class interactions or the flexibility they need to change how they learn in these settings.

Table 4 The results of Kendall's W coefficient in the synchronous/asynchronous lesson designs

Two researchers collaborated on the code	PCHT-1	PCHT-2	PCHT-3	PCHT-4	PCHT-5	PCHT-6	PCHT-7	PCHT-8	PCHT-9	PCHT-10
Kendall's W in sync design	0.824	0.863	0.83	0.851	0.821	0.901	0.801	0.912	0.911	0.874
Kendall's W in async design	0.647	0.529	0.742	0.73	0.548	0.478	0.641	0.71	0.817	0.563

Table 5 The advances in the TPACK levels

TPACK development	Instruction course	Group 2 (sync micro-teaching lessons)	Group1 (async micro-teaching lessons)	School activities
Top-level of knowledge	PK TK TPK TPACK	TCK TPK PCK TPACK	TPK TCK TPACK	TPACK TPK
Moderately developed knowledge	TCK	TK PK	TK PK	PK PCK
Lack of knowledge	TK PK	CK	CK	CK

4.2 The training course's outcome

In synchronous training, PCHTs built TK using simulations, animations, and Microsoft Teams. Considering learners' knowledge levels and adapting teaching techniques to their personalities enhanced PK. CK teaches science. PCK helps choose effective teaching methods, complete assessments, and engage in subject-appropriate attention-getting activities. TPK teaches students how to use technology to study chemistry and engage PCHTs at their level of knowledge. (Jen et al., 2016). TPACK helps children learn about acids and alkalis through technology. PCHT statements:

> PCHT 1(sync): Before the course, I had little information on teaching methods, but *now I know* how to apply them in chemistry lessons.
> PCHT 2(sync): After the course, I learned how teaching methods affect guiding students' thinking and learning in chemistry.

PCHTs developed TK regarding using recorded lessons, audio files, and emails in an asynchronous training course. They created PK according to the students' knowledge levels (Kruit & Bredeweg, 2020), and they created CK to describe how new ideas or discoveries influence scientific and technological knowledge. TPK was intended to teach students how to understand and reinforce information through watching educational videos, as well as the best way to demonstrate phenomena and test scientific theories using digital technologies. They created TPACK to help students learn about acids and alkalis by utilizing appropriate technology. In light of this, the researchers agree to compare synchronous learning activities and their outputs with asynchronous ones. However asynchronous learning does not enable the interaction of learners who receive immediate feedback from peers or teachers. The following are some examples of PCHT statements:

> PCHT 5 (async): I benefited a lot from the course, but I was bored with not communicating with my colleagues directly.
> PCHT 6 (async): After the course, I learned how using educational techniques develops students' creative abilities.

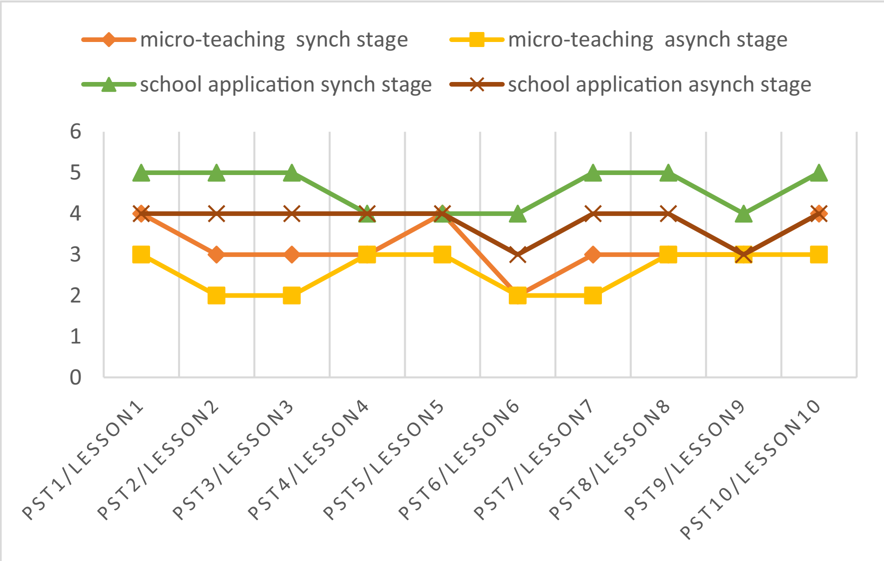


Fig. 7 Class management organization skills

Finally, decide which synchronous or asynchronous method will help create TPACK. There is no winner or loser. The best-designed classes build engaging activities that address course objectives, engage students in a variety of ways, and employ the best tools to meet the goals of the activity and class. In synchronous training, PCHTs built TK using simulations, animations, and Microsoft Teams. Consider learners' knowledge levels and tailor instruction to their personalities to improve PK. CK teaches science. PCK helps teachers choose effective teaching methods, complete assessments, and engage in subject-appropriate attention-getting activities. Also, PCHTs developed TK regarding using recorded lessons, audio files, and emails in an asynchronous training course. They created PK according to the students' knowledge levels. H1 can be accepted because synchronous e-learning better supports personal participation and asynchronous e-learning better supports cognitive participation, and we conclude that the digital interventions will increase PCHTs' application of TPACK in a sync or async online environment. A study by Umutlu (2022) confirmed this.

TPACK integration: each PCHT presented ten instructive lectures. The synchronic setting allowed students to learn with a live online teacher, ask questions in real-time, receive immediate feedback from other students, and maintain a schedule similar to that of a brick-and-mortar school. Figures 7, 8, 9, 10, and 11 show PCHT scores from each presentation in synchronous and asynchronous contexts. Synchronous environments improve students' class management organization, chemistry skill direction, technology skill use, assessment and evaluation, precision in introducing knowledge and learning activities, and leading students to use higher-order thinking skills when learning chemistry subject elements with technology.

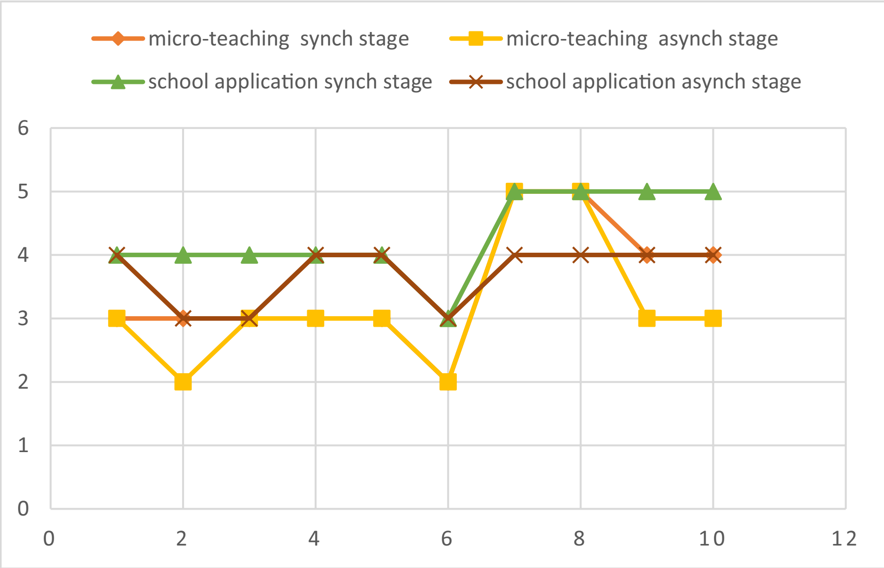


Fig. 8 Directing students' thinking in chemistry skills

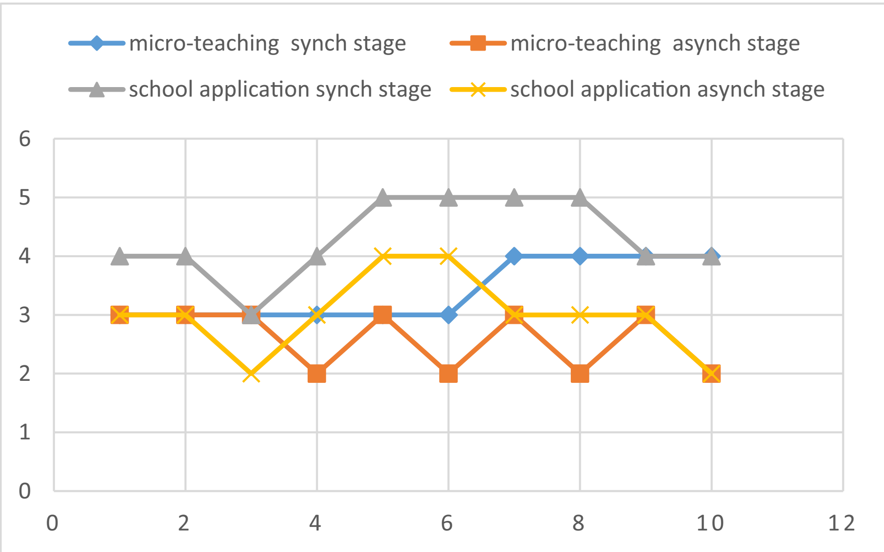


Fig. 9 Using technlogy skills

While PCHTs in synchronous settings attempted to elicit curiosity by asking a few questions about the lesson in the first presentation, after presenting visuals in a PPT presentation and sometimes watching a video in the second presentation,

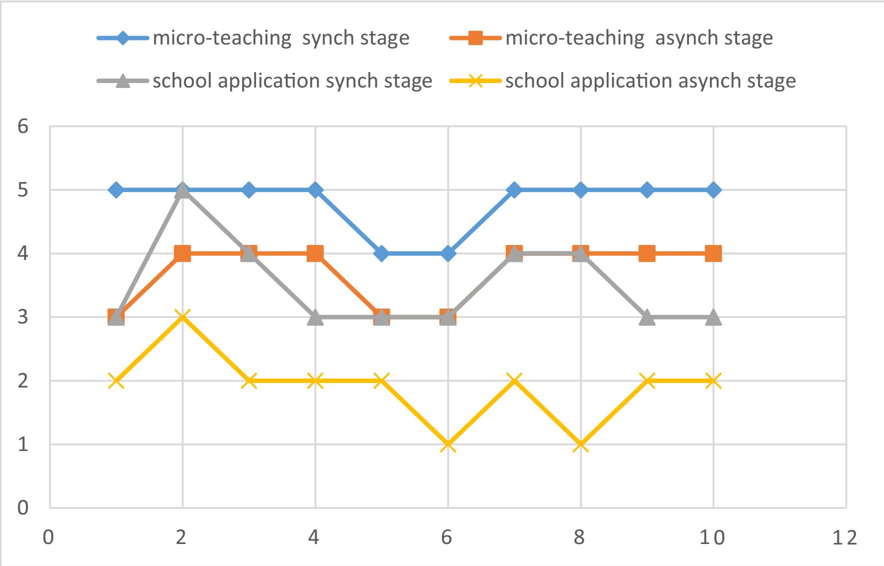


Fig. 10 Assessment skills

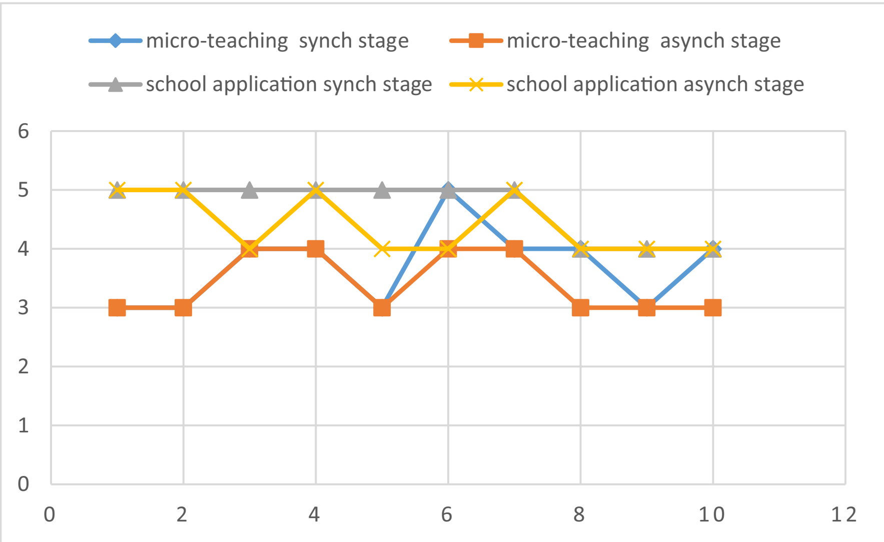


Fig. 11 Scientific thinking skills

they began to attract students' attention with the question-and-answer technique (see Fig. 7).

For the question "Directing students' thinking in chemical abilities" (see Fig. 8), the PCHTs tried to get students involved by using adaptive tests or the

Internet in most synchronous and asynchronous courses during the evaluation step, but not during the beginning step. The amount of time students spent utilizing and interacting with the online learning system had a significant impact on their academic achievement. Furthermore, it has been demonstrated that active participation in both synchronous and asynchronous online learning opportunities results in higher engagement and academic accomplishment than merely attending face-to-face classes.

Synchronous learning has a positive impact on PCHTS' commitment and task motivation when it comes to using technology (see Fig. 9). Active participation in both synchronous and asynchronous online learning has been linked to higher levels of engagement and academic success, as has active participation in both real-time and non-real-time online learning options.

In the second show, the PCHTs did better, to the point where they could do alternative assessments for critical objectives. In the first show, they could only do traditional assessments and evaluations for objectives (see Fig. 10).

The PCHTs developed higher-order thinking abilities when it came to making assessments (see Fig. 11). PCHTs who are skilled analyzers, synthesisers, and synthesizers develop into employees who are better prepared for the issues they will confront in the workplace. In online classes, class discussion is a long-established and well-respected teaching approach that can be synchronous or asynchronous. Synchronous debate occurs in real-time and is frequently conducted using chat or messaging programmes.

The lesson design stage, which included microteaching, had a minimal impact on how students learned, how teachers taught, and how they were encouraged to think deeply. It did not impact how PCHTs did in their initial asynchronous presentations in terms of using the correct technology and taking learners' levels, where they did well, and aiding with class management, where they did poorly. Micro-teaching appears to improve PCHTs' TPACK skills.

It is evident that the PCHTs perform better on some TPACK items than others, such as capturing students' attention, accurately communicating information or concepts, and carrying out assessments and evaluations, when comparing their scores from the lesson plan involving the application of micro-teaching methods stage and the school application stage. The duties of guiding, providing classroom management, and generating assessments and evaluations are perceived as being more favourably impacted by the school apps while teaching science courses utilising technology in either an asynchronous or synchronous environment. As a result, H1 may be accepted, drawing the conclusion that the digital interventions will boost PCHTs' application of TPACK in a sync or async online environment because synchronous e-learning and asynchronous e-learning both enable personal engagement more effectively.

Table 6 illustrates PCHTs' average ranks in micro-teaching and school-based synchronous and asynchronous digital teaching skills. Both groups reported medium-to-high pleasure and high absolute scores for strain and effort. The synchronous PCHTs outperformed the asynchronous group in guiding chemistry students' thinking, employing technology, making assessments, and using scientific reasoning. The synchronous group's enhanced use of PCHTs for teaching and

Table 6 The average rankings in the synchronous / asynchronous digital teaching skills

Skills	Stage	Sync & Async	*N*	Mean rank	Sum of ranks	Percentage
class management organization	micro teaching stage	sync	10	15.00	150.00	64%
		async	10	6.00	60.00	52%
	school application stage	sync	10	15.20	152.00	%92
		async	10	5.80	58.00	%76
Directing students' thinking in chemistry	micro teaching stage	sync	10	15.50	155.00	70%
		async	10	5.50	55.00	64%
	school application stage	sync	10	15.25	152.50	86%
		async	10	5.75	57.50	74%
using technology	micro teaching stage	sync	10	15.50	155.00	68%
		async	10	5.50	55.00	52%
	school application stage	sync	10	15.20	152.00	86%
		async	10	5.80	58.00	60%
assessment	micro teaching stage	sync	10	15.25	152.50	96%
		async	10	5.75	57.50	74%
	school application stage	sync	10	15.20	152.00	70%
		async	10	5.80	58.00	38%
scientific thinking skills	micro teaching stage	sync	10	15.50	155.00	74%
		async	10	5.50	55.00	68%
	school application stage	sync	10	15.15	151.50	94%
		async	10	5.85	58.50	88%

Table 7 The results of the U test for the synchronous / asynchronous digital teaching skills ($N=10$)

Test statistics[a]

Skills	Class management organization		Directing students' thinking in chemistry		Using technology		Assessment		Scientific thinking skills	
	Micro teaching stage	School application stage	Micro teaching stage	School application stage	Micro teaching stage	School application stage	Micro teaching stage	School application stage	Micro teaching stage	School application stage
Mann-Whitney U	5.000	3.000	0.000	2.500	0.000	3.000	2.500	3.000	0.000	3.500
Wilcoxon W	60.000	58.000	55.000	57.500	55.000	58.000	57.500	58.000	55.000	58.500
Z	-3.555-	-3.702-	-3.938-	-3.725-	-3.938-	-3.702-	-3.711-	-3.702-	-3.938-	-3.682-
Asymp. Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Exact Sig. [2* (1-tailed Sig.)]	0.000[b]	0.000[b]	0.000[b]	0.000[b]	0.000[b]	0.000[b]	0.000[b]	0.000[b]	0.000[b]	0.000[b]

[a]Grouping Variable: synchronous & asynchronous

[b]Not corrected for ties

learning with social support led to this result. They learned TPACK, how to use technology, and how to evaluate it using tools suited for the subject matter and student competence.

The researcher used quantitative analysis to describe the significance of the differences between synchronous and asynchronous groups, which was determined using the Mann-Whitney test (see Table 7). The following factors prompted researchers to use non-parametric methods: (1) Data Distribution: Non-parametric methods do not assume data distribution. Thus, they are more flexible and effective when data deviates from parametric test assumptions like normality. Despite skewed or non-normal data, non-parametric tests are reliable. (2) Tiny Sample Sizes: Non-parametric tests may function better with small samples. With fewer data points, non-parametric tests can draw statistical inferences, but parametric tests often need larger sample sizes (Zimmerman & Zumbo, 2014). According to the U test, post-PCHT responses improved in a synchronous setting more than in an asynchronous setting, demonstrating that synchronous activities improved students' ability to manage their classes and organize their work during microteaching ($U = 5.000$, $Sig = 0.000$).

This is due to synchronous and asynchronous situations that enhance social connection. Synchronous settings enable group projects and video conferences, which engage students and professors. Synchronous environments emphasise content, while asynchronous ones encourage student participation. To promote social interaction, online conversations and other asynchronous methods need greater forethought.

Considering these findings, one can conclude that the lesson plan involving the application of micro-teaching methods is effective in improving PCHTs' TPACK application performance.

Tables 6 and 7 demonstrate that synchronous meetings helped more PCHTs and TPACKs grow. Synchronous meetings developed the relationship between TK, PK, and CK, developed PCK for PCHTs, and provided opportunities to display phenomena and test scientific predictions that may have an effect on PCHTs. It is obvious that there are significant differences between the TPACK scores and all subdimensions of TPACK ($P < 0.001$) in favour of the synchronous group. So, H2 is rejected; in other words, it cannot be said that there are any differences between TPACK levels in a sync or async online environment.

4.3 The effect of the school practice on PCHTs

PCHTs studied how to use graphics and technology to help people remember and how to use technology in real-time and asynchronous contexts to make classes more interesting and easier. They practiced integrating technology into chemistry lectures, picking the proper technology for certain challenges, and applying technology to real-world ideas. They learned how to use appropriate technologies to make chemical subjects easier to study, how to use technologies to engage students in class when teaching the subject, and how to choose teaching methodologies and technology by considering pre-learning of subject solutions. PCHT statements:

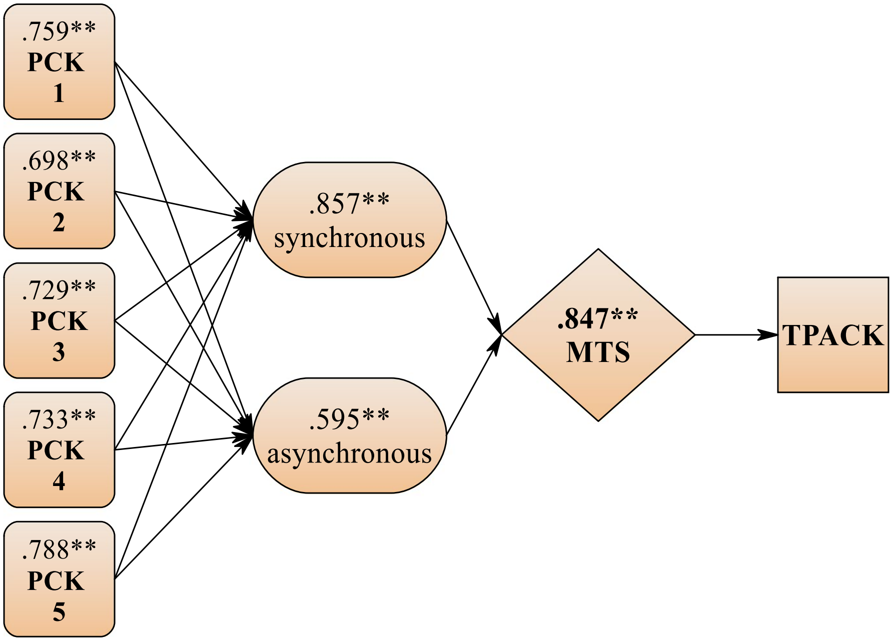


Fig. 12 The extent of PK, CK, PCK, TPACK of the respondents

PCHT 7 (sync group): To achieve the educational goals, I attempted to create an interactive lesson using media from the Internet. (PCK).
PCHT 3 (async group): I tried to show you a set of images of some chemical tools and concepts on Flickr. They attract more attention (TCK).

4.4 Conclude the level of knowledge of the PCHT in TPACK model

Spearman's correlation coefficient was used to find a link between the overall result of the TPACK application and how well digital teaching works. A study was done utilising the six TPACK elements and TPACK as the dependent variable to determine which of the seven criteria made a large impact on how well the PCHT did overall in TPACK. In an asynchronous training session, PCHTs produced PK using simulations, animations, and Microsoft Teams (MTS). TPACK PCHTs presented lessons. Figure 12 illustrates the cumulative TPACK-based learning environment scores for each presentation.

Figure 12 illustrates the respondents' level of pedagogical content knowledge (PCK). According to the data gathered, the PCK of the PCHTs in synchronous training is primarily concerned with selecting effective teaching techniques to guide students' thinking and learning. With a correlation coefficient of 0.759, the statistics indicate that the PCK of the PCHTs is mostly concerned with "misunderstanding of student concepts".

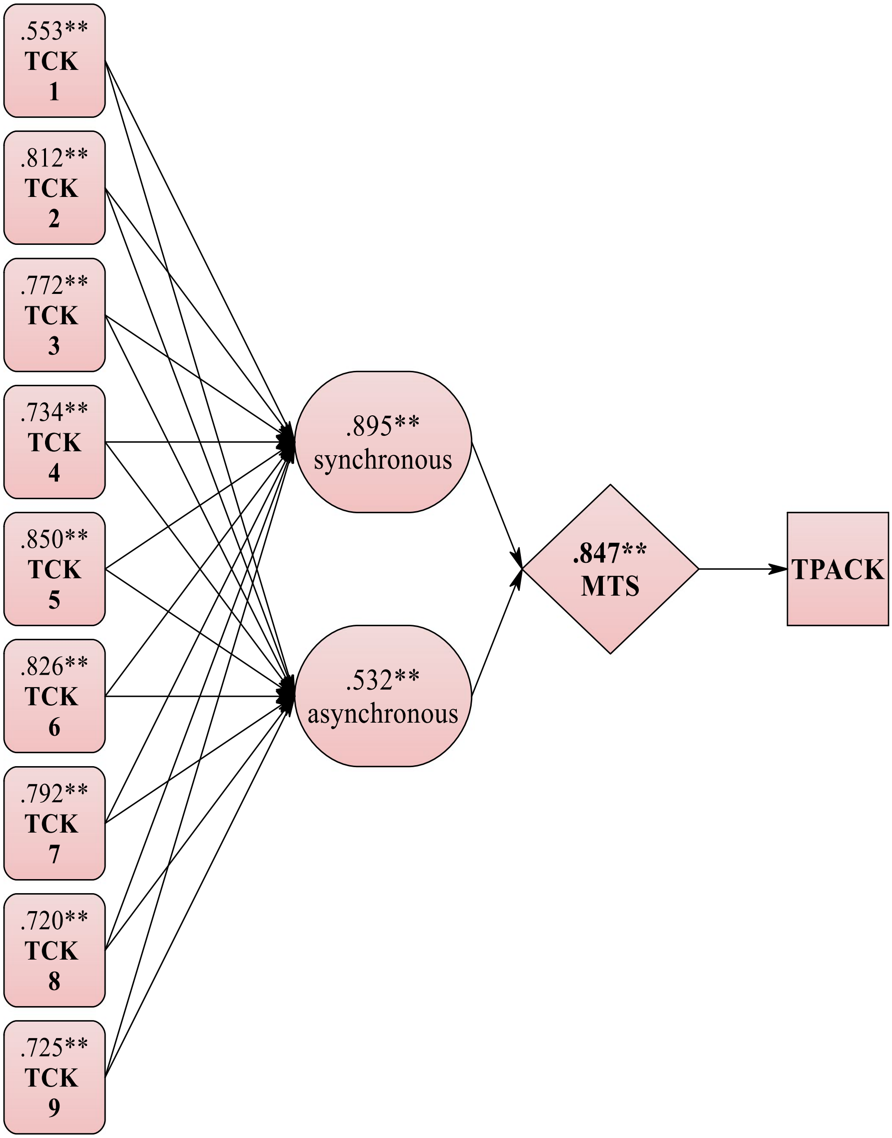


Fig. 13 The extent of TK, CK, TCK, TPACK of the respondents

With a correlation coefficient of 0.857, PCHTs' TPACK pays a lot of attention to making lessons that combine chemistry, math, and different teaching methods in the right way. In asynchronous training, on the other hand, PCHTs' TPACK pays a lot of attention to using the Internet to find facts about a scientific phenomenon.

In training, PCHTs developed TK by using the Internet to learn chemistry and solve technical problems. Each of the PCHTs created videos using Microsoft PowerPoint (PPT) and similar programmes and presented them on Microsoft Teams

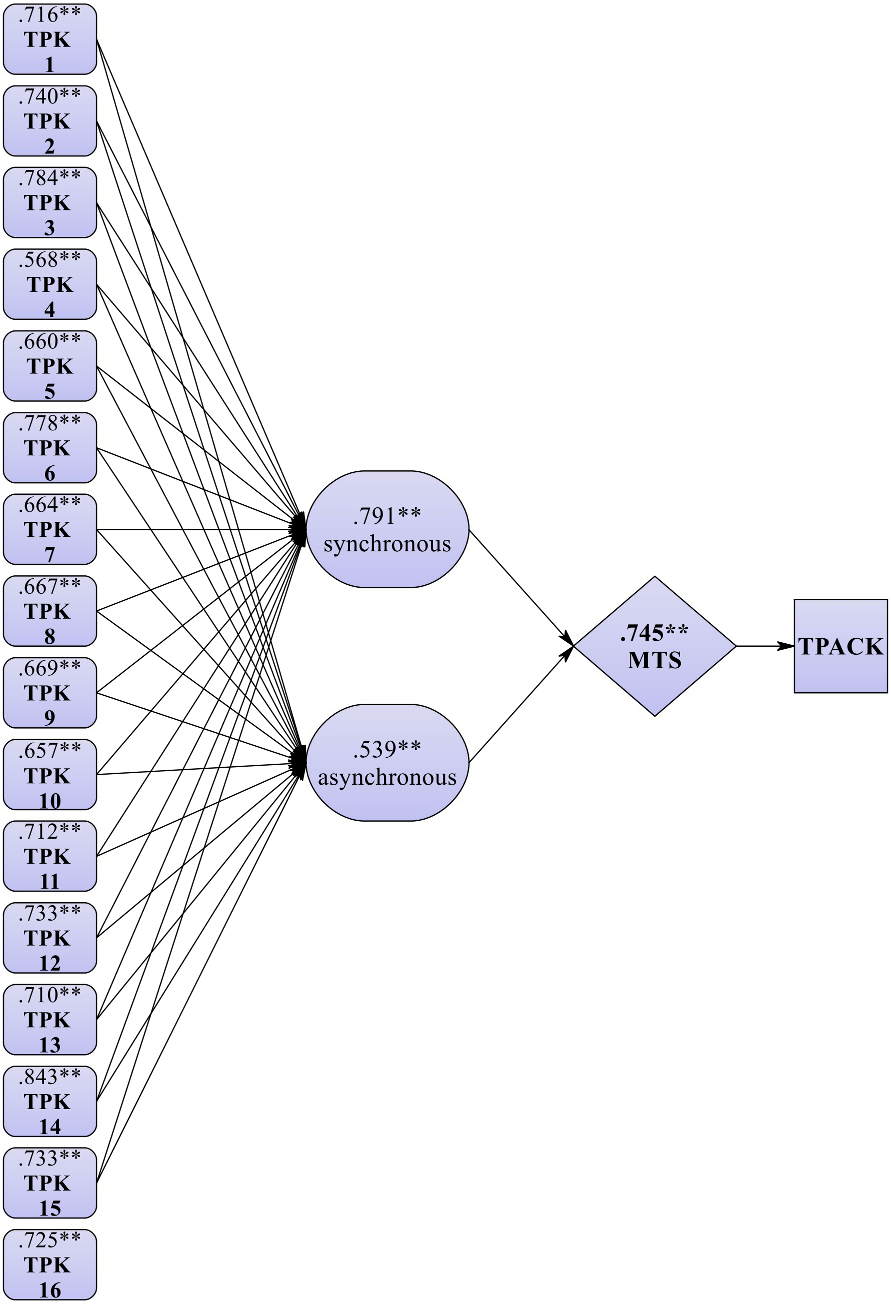


Fig. 14 The extent of PK, TPK, TPACK of the respondents

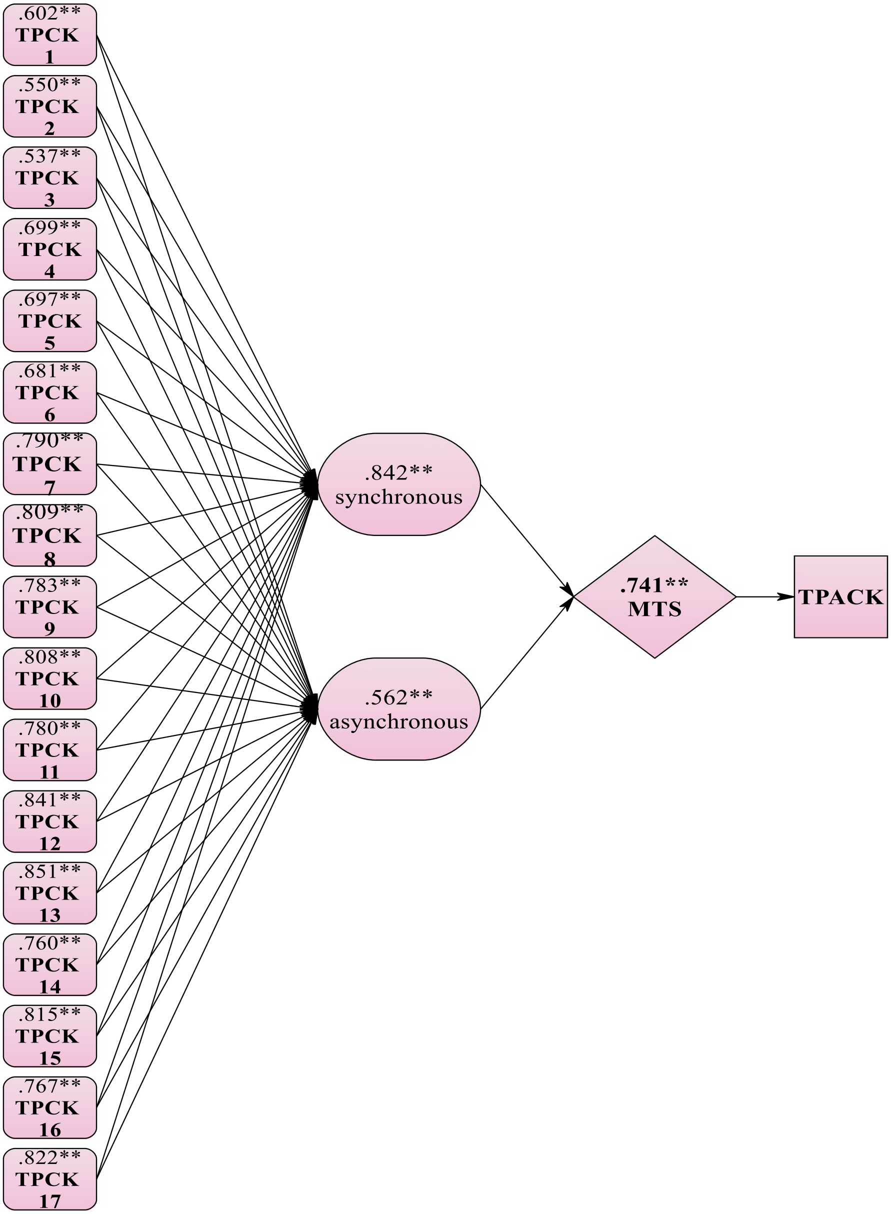


Fig. 15 The exent of TPK, PCK, TCK, TPACK of the respondents

(Listiawan et al., 2018). Figure 13 shows the total scores for each video based on the TPACK-based learning environment's criteria.

In training, PCHTs developed PK by using various teaching methods and strategies to develop an understanding of chemistry, such as discussion, building scientific explanations, virtual labs, and guided inquiry. Each of the PCHTs could create a new lesson

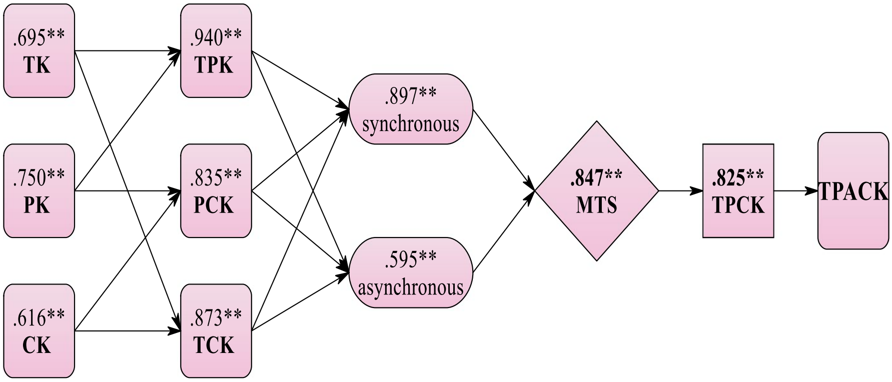


Fig. 16 The respondents extent of TK, Pk, CK, TPK, PCK, TCK, TPCK, and TPACK

design and presentation by applying the micro-teaching method (Holstein et al., 2018). According to the data gathered, the TPK of the PCHTs is primarily concerned with thinking critically about how to use technology in one's classroom (see Fig. 14). With a correlation coefficient of 0.568, the statistics indicate that the TPK of the PCHTs in synchronous training is mostly concerned with "use strategies that combine content, technologies, and teaching approaches".

PCHTs developed TPK, PCK, TCK, TPCK, and TPACK. They developed TPCK using different techniques to teach learners about using the Internet to learn chemistry and solve technical problems (see Fig. 15). With a correlation coefficient of 0.602, the statistics indicate that the TPCK of the PCHTs in synchronous training is mostly concerned with "choosing technologies that enhance the content of a lesson".

Figure 15 illustrates the extent of TPK, PCK, TCK, TPCK, and TPACK among the respondents. In synchronous training, PCHTs' TPACK greatly focuses on designing lessons in which chemistry is integrated with educational techniques and teaching methods, with a correlation coefficient of 0.681. Asynchronous training has a correlation coefficient of 0.767.

The teacher must choose a suitable social media tool that matches the digital content and the strategy used. So, PCHTs developed the relationship between TK, PK, and CK and developed PCK (see Fig. 16).

Figure 16 illustrates the extent of the respondents' TK, PK, CK, TPCK, PCK, TCK, TPCK, and TPACK. In synchronous training, PCHTs' TPACK greatly focuses on taking advantage of digital aid systems such as animation and simulation to provide opportunities to display phenomena and test scientific predictions with a correlation coefficient of 0.897. In asynchronous training, there is a correlation coefficient of 0.595. All models are conducted using RFFlow software (https://rff.com/index.php) as a software programme for drawing flowcharts, charts, and diagrams.

5 Discussion

This study wants to find out how different teaching and learning environments—mostly synchronous and mostly asynchronous—affect students and shed light on what this might mean for digital teaching and learning in higher education. According to the findings, TPACK has many positive benefits for PCHTs' digital teaching. In the beginning, PK was created by employing various teaching approaches and strategies such as discussion, scientific explanation building, virtual labs, and guided inquiry in synchronous training to acquire an understanding of chemistry. Using the micro-teaching method, each PCHT can develop a lesson design and presentation. The findings are consistent with those of Aktaş and Zmen (2020). Both studies agree that TPACK implementation in schools has to be prioritized for effective lesson delivery. Little attention is paid to the knowledge that teachers require to foster early literacy through the use of technology, and teacher educators themselves struggle with the effective use of technology in their own courses through three stages: a training course, a lesson plan, and school applications. Finally, it has enhanced its digital capabilities in areas such as student engagement, the creation of student-centered instructional environments, and the use of appropriate strategies to reduce difficult-to-understand challenges.

These four factors suggest that PCHTs may be getting better at TPACK and digital teaching. The first was that the training course used digital tools, which PCHTs had never seen before in a learning environment. Then, develop a mechanism for delivering a large number of example lessons. PCHTs can share their thoughts more in simultaneous meetings during the class discussions that follow the educational lectures. While the asynchronous environment provided the ability to store scientific content, refer to it, and use it many times, it was not restricted to a specific place or time, as the student could enter the discussion board and view the available questions at any time. Finally, including teaching approaches and school application into lesson design increases the PCHTs' PK (Özgür, 2020).

In the synchronous and asynchronous training course, PCHTs learned for the first time about digital tools like simulations, animations, and the Microsoft Teams platform. Synchronous meetings helped more PCHTs and TPACK grow. They learned more about different chemical topics from a presentation. These factors have an impact on instruction, teacher professional development, and students' science learning. Data from interviews backs them up, demonstrating that PK, TK, TPK, TCK, and TPACK have had the most growth. Previous research findings back up these assertions (Hillmayr et al., 2020; Özgür, 2020; Santos & Castro, 2021; Tseng et al., 2022).

The focus of asynchronous training presentations has shifted from the teacher to the students. These assisted in swiftly compressing a large amount of data in memory and displaying it in a logical order. Results have contradicted the finding of Lee (2021) that PCHTs used materials including PPT presentations, simulations, and video recording in their lesson designs, despite the fact that they intended the teaching process to be student-centered. The goal of this study's student-centered PCHT presentations is to help students learn a lot of material. When PCHTs can communicate with one another and actively participate in their own education, they are more likely to be interested in learning (Santos & Castro, 2021(.

Furthermore, the chemistry simulations utilized by PCHTs are suitable for students to learn from. They are used to illustrate important and complex processes that cannot be examined because of a lack of resources. Students actively participated in this case, which resulted in student-centered environments. Teachers and students both benefit from purposeful technology integration in the classroom because it gives them access to a variety of educational tools that encourage creativity, collaboration, and problem-solving.

The goal of this study is to get chemistry professors to use digital tools in the classroom to teach chemical concepts and to choose good methods and technology for figuring out hard ideas and organizing information. The worksheets in the synchronous environment get the students involved, guide them, and run the classroom. Because of synchronous instruction, students seemed to talk to each other more and build learning experiences that helped each other. The synchronous environment helped to develop the relationship between TK, PK, and CK and developed PCK for PCHTs.

6 Implications of research

This study aims to fill a significant gap in the literature by concentrating on the connections between TPACK components. The study model offers some useful suggestions for pre-service teachers' professional development. In light of the findings of the present study, it is recommended that pre-service teachers have a basic understanding of what digital tools are and how they operate in order to better comprehend the ethical issues they raise. In this regard, the course incorporates digital teaching tools for PCHTs such as animations, simulations, messaging, and file sharing with Microsoft Teams, strengthening the skills required to use the concepts and resources in chemistry lectures and creating chemical formulas with Chemdraw. The pedagogical benefits of digital tools, such as suitability and rapid feedback, might be underlined during the integration process. Because of this, it is more probable that they will use digital tools in their teaching careers because they will be conversant with technological pedagogy. Therefore, as is clearly clear from the results of the current study, encouraging technology content understanding may be appropriate. The use of a digital instrument that is pertinent to their field should then be familiar to chemistry teachers at that point. Researchers can use the TPACK scale to better understand digital instructions by concentrating on extra factors. Research might, for instance, look at how well the TPACK elements predict the quality of teachers' use of digital resources.

The findings of this study are expected to theoretically and practically contribute to the body of material already available on the integration of TPACK in online synchronous and asynchronous systems. The study's most important theoretical contribution is the presentation of a model that takes classroom management skills in technologically enhanced courses into account. In this method, TPACK level more accurately predicts TPACK integration than do digital interventions.

The results demonstrate that digital interventions significantly predict TPACK. As a result, it is conceivable to state that improving pre-service teachers' digital skills could play a significant role in ensuring successful technology integration and classroom management in courses that are technologically advanced. It might be argued that activities for teaching digital skills to improve pre-service teachers' technology integration abilities in educational contexts will have substantial benefits due to the strong association between digital interventions and TPACK.

7 Conclusion

There are both synchronous and asynchronous settings that, in theory, help people connect with each other. Group projects and video chats are made possible by synchronized environments, which naturally promote interaction between students and between students and teachers. Asynchronous environments prioritize promoting student interaction with the learning materials more than synchronous environments, which are more content-focused. Online discussions and other asynchronous approaches that encourage social contact require more thought and careful planning in order to encourage social participation. The deliberate and intentional use of technology to enable flexible and equitable learning possibilities in higher education is still important today. It is essential for educators to properly integrate online resources into their lessons, to create teaching and learning plans with technologies that have a clear purpose, and to make sure that student connections with teachers, with other students, and with content are not neglected. It is concluded that when using asynchronous teaching styles, teachers should make an extra effort to provide students with ample opportunities to engage not only with content knowledge but also with the educator and their peers. Self-paced learning flipped learning, adaptability for individual requirements, collaborative projects like wikis or blogs, and automated evaluations are all possibilities in online teaching and learning environments. Continuous support must be added to all of this, both for technical problems and for efficient online teaching and learning. The resources they require to fully utilize technological breakthroughs must consequently be provided to teachers.

This research shows that PCHTs can improve their understanding of TPACK and its use even without participating in teaching technique courses or getting computer or teaching technique training. Therefore, PCHTs ought to encourage students to take advantage of technology-based opportunities that are pertinent to their field of study and integrate digital tools into their curricula and TPACK planning in line with online synchronous and asynchronous environments. This study also found out that TPACK training would be more effective if all of its components were combined, as opposed to being broken up into classes on technology, pedagogy, and content. So, it has been possible to improve PCHTs' understanding of TPACK and their ability to use it by using lesson plans that use microteaching and real-class experiences to build TPACK.

As a result of the foregoing, PCHT, digital learning according to online synchronous and asynchronous environments, and TPACK integration should be investigated. This would help pre-service chemistry teachers (PCHTs) gain the knowledge they need to choose appropriate teaching approaches using technology to teach the related subject solution, correctly teach the content, apply skills to encourage active collaboration by learners, maintain management of the classroom, and provide suitable guidance while teaching chemistry lessons.

8 Limitations

When analyzing the conclusions of this study, it is important to keep in mind that there are a few caveats. Because the participants were chosen using a suitable sampling procedure, the generalizability of the findings of this study was lower than that of random sampling. The association between digital interventions and TPACK integration can be increased if mixed or quantitative research is conducted with more participants. The findings can be used to demonstrate how the framework for classroom management in these lessons has evolved. There was surprisingly little research comparing synch and async online learning, and we chose not to look at how the professor affected students' involvement decisions.

Since the training, the researchers have encouraged PCHTs to deliver lesson presentations and activities as trainers. The researcher's encouraging position as a trainer might be considered an intervention in the study. Another limitation of this research of this research is the need for more reflective data collection technologies to identify the integration of TPACK in online synchronous and asynchronous systems. This would suggest that the technology available in classrooms is not quite as advanced as pre-service teachers believe. Therefore, depending on the viewpoints of pre-service teachers, research can be done to determine the components involved in online synchronous and asynchronous contexts. This could provide precise information about what affects pre-service teachers' ability to maintain order in the classroom.

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Data availability The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Competing interests The authors declare no competing financial interests.

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