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Analysis of Technological Pedagogical Content Knowledge (TPACK) Ability for Prospective Chemistry Teacher Students and Chemistry Teachers: A Literature Review

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Abstract: Mastering ICT is a prerequisite for teachers in the 21st century, and this is consistent with the TPACK framework that a teacher or aspiring teacher needs to be equipped with. Technological, pedagogical, and content knowledge (TPACK) is a conceptual framework that combines components that include three types of knowledge that teachers need to master, namely technological, pedagogical, and content knowledge. TPACK is a framework that seeks understanding the relationship between pedagogical and technological knowledge. In TPACK, teachers' knowledge of integrating technology into learning makes learning effective and efficient. This study aimed to observe the Technological Pedagogical Content Knowledge (TPACK) ability of prospective chemistry teachers and chemistry teachers. The research method used a literature study in the form of an analysis of various literature derived from national and international articles in accordance with the research objectives, namely 33 articles on the ability of Technological Pedagogical Content Knowledge (TPACK) of prospective chemistry teachers and chemistry teachers. The results showed that the components of TK, PK, TPK, TCK, and TPACK owned by prospective chemistry teachers and chemistry teachers were in the sufficient category. The TPACK abilities of chemistry teacher candidates and chemistry teachers still need to be improved in several aspects of content mastery, pedagogy, and technology. Developing TPACK abilities requires a long process to acquire new sources of skills and knowledge needed to form professional teachers.

Keywords: Chemistry Education; Prospective Teachers; TPACK; University Students.

Introduction

Technology, which is rapidly developing, is an inseparable part of human life, including education. Technology assists the learning process and educational administration. Learning processes involving technology can increase students' effectiveness and understanding of the material [1]. Several research results have shown that ICT-based learning processes in education, especially science, can make learning more active, improve student cognition, support constructive learning, and encourage conceptual change and scientific inquiry [2].

In learning science, especially chemistry concepts, students often need help understanding abstract and microscopic concepts [2]. Therefore, technology such as video, animation, or simulation can help students visualize or represent the chemical concepts they are studying to make learning more innovative, creative, and effective [3]. Therefore, teachers and prospective teachers must be able to master technology to support teaching in the classroom.

ICT mastery is a prerequisite for 21st-century teachers; this aligns with the TPACK framework, which a teacher or prospective teacher must possess [4]. Technological, Pedagogical, and Content Knowledge (TPACK) is a conceptual framework combining components including three knowledge teachers must master: technology, pedagogy, and content knowledge. The TPACK component relationships were developed by Mishra and Koehler based on Lee Shulman's conceptual framework Pedagogical Content Knowledge (PCK), integrating technological literacy skills into it [4]. TPACK learning needs to be mastered by teachers so that learning activities can run effectively and efficiently.

Research Methods

This research was conducted using the literature study method. The literature study research method is a research approach that involves collecting and analyzing information from various literature sources that are relevant to the research topic. Literature studies can be used to observe the technological pedagogical content knowledge (TPACK) abilities of prospective chemistry teacher students and teachers. The literature study research method can provide in-depth insight into developments and trends in the TPACK domain. It can be the basis for developing more effective teaching strategies in chemistry contexts.

Journal searches were carried out using the keywords "TPACK student chemistry teacher candidates" and "TPACK chemistry teacher" on the Google Scholar site in the 2018-2023 period. The total number of articles is 33, of which 15 (7 international and eight national) cover the TPACK abilities of prospective chemistry teacher students, and 18 (6 international and 12 national) cover chemistry teachers' TPACK abilities.

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Results And Discussion

TPACK is a framework that attempts to understand the relationship between knowledge about teaching (pedagogical knowledge) and the use of technology (technology knowledge) [5]. In TPACK, teachers' knowledge of integrating technology in learning makes learning effective and efficient [5]. Technology integration is considered a closely related teaching component and is included in PCK [5].

TPACK ability can be used as an indicator of a professional teacher because TPACK consists of two main teacher competencies, namely, in the realm of professional teacher competence, pedagogical competence, and professional competence (mastery of learning material) [6].

The central components of TPACK emerge from integrating other teacher knowledge components and are thus related to each of these domains [7]. The high level of TPCK will be based on the high level of TPK, TCK, PCK, TK, PK, and CK [7]. In contrast, the transformative view describes the intersection of knowledge components to produce a unique body of knowledge that is more than just a combination of core components [7]. In other words, according to the transformative perspective, TPCK cannot only be explained by adding up all the other TPACK components, but TPCK is a separate form of knowledge that transforms beyond its basic components [7]. In this view, TPCK will be influenced by TPK, TCK, and PCK but not directly by TK, PK, and CK [7].

Technological Knowledge (TK) is teachers' knowledge about current technology [8]. Teachers must be aware of technological developments that exist in society today, including prospective teachers [8]. Pedagogical Knowledge (PK) is knowledge about the process and practices or teaching-learning methods to achieve educational goals [8]. Pedagogical knowledge also contains knowledge for assessing student academic achievement and the methods used [9]. The way to assess the three can also be different, through written tests, observations, or questionnaires for self-assessment. This item is also related to student understanding and misconceptions [9]. Prospective teachers and teachers must know the abilities of students in class, whether students understand or whether there are misconceptions in capturing the material given by the teacher. If misconceptions occur, students' understanding must be immediately straightened out to follow the existing material [9].

Content Knowledge (CK), especially chemistry content knowledge, has an important role in the fluency of prospective chemistry teachers in delivering teaching materials [9]. Every prospective chemistry teacher expects chemistry mastery to avoid misconceptions in learning [9].

Pedagogical Content Knowledge (PCK) is related to the ability to evaluate student performance in a lesson [9]. This activity is carried out at the end of the learning process, where evaluation is useful for analyzing learning deficiencies and weaknesses, which are then used as a reflection for the next meeting [9]. This component is also related to the ability of prospective teachers to connect with everyday life with appropriate learning methods. Prospective teachers must also be able to prepare lesson plans according to the latest curriculum to achieve the desired learning objectives [9].

Technological Content Knowledge (TCK) is related to combining technology and chemical content mastered [9]. Prospective teachers must learn the latest technology to explain chemical concepts, for example, virtual laboratories as a substitute for practical work, augmented reality molecules to visualize molecular shapes, etc. [9].

Technological Pedagogical Knowledge (TPK) relates to prospective chemistry teachers' knowledge about technology and good pedagogy to apply in learning [9]. Prospective teachers should have the ability to provide innovation in applying learning technology [9]. The technology, pedagogy, and content knowledge (TPACK) component is related to selecting technology that can improve the quality of chemistry content in classroom learning [9]. Prospective teachers must use broad thinking and be able to develop chemical content in learning. Teachers should use strategies combined with chemical content, technology, and learning approaches [9].

TPACK Prospective Chemistry Teacher

A prospective teacher must be equipped with various competencies before entering the world of education directly [5]. These competencies include content knowledge, education, and technology [5]. Therefore, several universities provide practical field experience (PPL) and PLP activities for one semester, which aim to implement the knowledge gained during the learning process in lectures and identify real problems in the classroom [5].

Research [8] shows that students' TPACK abilities are quite good. After conducting the analysis, the researchers found that the TPACK profile of prospective teachers received the largest score, namely 51% in the pedagogical knowledge (PK) and content knowledge (CK) sections [8]. PCK has the greatest influence on TPACK [8]. The PCK component is in the medium category, so pedagogical knowledge follows the content taught [8].

The research results [6] show a significant relationship between PCK and TPCK, CK and PCK, PK and TPK, and PK and PCK. It means that the components of content knowledge (CK), pedagogical knowledge (PK), and pedagogical content knowledge (PCK) contribute to the formation of teacher knowledge in schools [6]. The results of this research provide information that teachers already have CK, PK, and PCK abilities, which contribute directly and indirectly to the formation of their TPACK. However, they still need attention and guidance in increasing their technological knowledge (TK) [6].

Prospective chemistry teacher students showed the highest level of self-confidence in pedagogical knowledge [9]. On the other hand, all participants had the lowest scores in technological knowledge. In short, they are more knowledgeable in pedagogy and content than in technology [9].

It aligns with the research results [4] that most prospective chemistry teachers already use PowerPoint in the teaching technology component. However, specific integration between technology, pedagogy, and specific content has yet to be seen in teaching planning [4]. It means that prospective chemistry teachers' TPACK abilities in teaching still need to be improved. Although TPACK may not be directly related to teaching practice, this ability can improve the quality of teaching practice when teaching later in school [4].

Chemistry Education students who were the subjects of research [10] stated that they had known some educational technology before the course but still needed help connecting educational technology with chemistry teaching and were worried about how to use it to teach chemistry subjects effectively [10]. After the course was given, they stated they were able to explain the basics of effective teaching with technology [10].

Research results [11] found that 69% of prospective chemistry teacher students' TPACK abilities were in a good category, 13% were in the very good category, and 18% were in the sufficient category. TPACK has been integrated with ASEAN countries' curricula [11]. Technology is not the main component, but teachers need to be able to design instructional learning [11].

The results found in research [1] show that the technological knowledge (TK) of prospective teachers currently has the highest score. Pedagogical knowledge (PK), content knowledge (CK), pedagogical technology knowledge (TPK), pedagogical content knowledge (PCK), and technological content knowledge (TCK) are in a good category [1]. However, the components of technology, pedagogy, and content knowledge (TPACK), applied simultaneously in chemistry learning, are still considered sufficient because this component is the most complex in applying technology, pedagogy, and chemistry in classroom learning [1].

It is in line with research [12] that the TPACK competency of prospective teachers is quite good in the aspects of content knowledge, pedagogy, and technology only in several indicators, such as understanding chemistry in general, understanding effective strategies in learning chemistry, and being able to use technology. However, there are still areas for improvement in indicators of understanding chemical content and technology [12].

Research [13] also states that the abilities of prospective TPACK Chemistry teachers still need to be improved in several aspects of content mastery, pedagogy, and technology. Developing TPACK capabilities requires a long process to obtain new sources of skills and knowledge needed to form professional teachers [13]. The problem that generally arises for prospective teachers who are just starting to carry out learning in the classroom is effective classroom management [13]. Prospective teachers can also not utilize media in learning optimally. They have yet to create active interaction between students and the media [13].

Based on the results of several studies, the TPACK abilities of prospective chemistry teachers are still in the sufficient category and are not evenly distributed. It shows that there is an urgent need in teacher training programs to learn not only about pedagogy (PK) but also how to use technology (TK) to support content (CK) and how to integrate these three pieces of knowledge effectively into the curriculum [9].

Technology in chemistry learning still needs to be improved using PPT, videos, simulations, and other applications such as Kahoot, Quizizz, Padlet, etc. Technological knowledge in the TPACK framework is an important component that unites content knowledge and pedagogy [12].

For this reason, systematic efforts are needed to facilitate the improvement of teachers' TPACK abilities. Thus, it is hoped that prospective chemistry teachers can integrate all components of teaching practice [4]. All TPACK components must be balanced to create a more meaningful learning experience and help students be better prepared to face various real challenges and the world of work [4]. To know technology, especially the technology used in teaching, teachers, especially chemistry teachers in the 2nd century, had to study it [12].

By conducting training, prospective teachers' TPACK abilities will increase. It is based on research [14], which shows a statistically significant increase in pretest and posttest after the training program. Therefore, educational institutions need to integrate technology into training to improve the development of TPACK skills among teachers and prospective teachers [14].

The development and expansion of prospective teachers' PCK require time, a process of reflection, and validation of practice, which leads to the construction of new knowledge about teaching and learning, students, content, teaching strategies, context, content management, and classroom and activity management [15].

The research results [3] show a significant impact of knowledge, including TK, CK, and PK, on TPACK. This dimension directly influences TPACK, thus greatly supporting its development [3]. In particular, TK emerged as the most influential source, as evidenced by its large path coefficient, indicating its most important impact on the formation of TPACK [3]. In addition, research results show that TK and PK directly affect teachers' TPK performance, while TK and CK directly impact teachers' TCK [3]. Furthermore, PK has a direct impact on teacher TPK. It is important to note that these findings explain the interrelationships between three single-dimensional knowledge factors (CK, PK, and TK) [3].

Orientation towards science learning is closely related to teachers' views about science and science learning objectives [16]. Prospective teachers with high CK are more aware of the possibility of misconceptions than teachers who have low CK [16]. If teachers have scientifically incorrect concepts about a particular topic, they can identify fewer student misconceptions [16]. Because if prospective teachers' CK knowledge is low, prospective teachers will have difficulty recognizing students' misconceptions, perhaps because they have similar misconceptions [16].

TPACK Chemistry Teacher

Research conducted by Anci et al. developing the TPACK abilities of chemistry teachers at SMAN 1 Bantarujeg and SMAN 1 Talaga on electrolyte and non-electrolyte solutions through activities Lesson study [17]. The research was conducted qualitatively in three stages, namely (1) creating a learning plan that is integrated with TPACK components, then (2) implementing the learning plan in class and observing the learning process, and finally stage, (3) reflecting on learning activities [17]. Before carrying out activities for the Lesson Study, chemistry teachers at SMAN 1 Bantarujeg and SMAN 1 Talaga still need to understand TPACK. ActivityLesson Study is considered effective for developing chemistry teachers' TPACK abilities. It is proven by the development of chemistry teachers' understanding of TPACK at SMAN 1 Bantarujeg and SMAN 1 Talaga in the first and second cycles [17].

Pedagogical Content Knowledge (PCK) is a combination of content Knowledge (CK) and pedagogical Knowledge (PK) that teachers should develop with time and their teaching experience [18]. Research [18] analyzed PK, CK, and abilitiesPedagogical Content Knowledge (PCK) teachers registered in the MGMP Chemistry Vocational School in Semarang. The research results show that SMK Chemistry teachers in Semarang have above average PK skills and very good CK, then PCK scores vary: 2 teachers are very good, 17 teachers are developing, and three are fair. However, this score cannot guarantee they can implement an effective teaching and learning process [18].

Research conducted by Erlina and Ulfah [19] aimed to determine the TPACK ability level of 42 chemistry teachers from 42 different schools in West Kalimantan. Data collection using the TPACK Assessment modified Likert scale [19]. Based on the results of data analysis, the scores for the TK, CK, PCK, PCK, TCK, TPK, and TPACK components were in a good category. High school chemistry teachers in West Kalimantan are considered to have good TPACK skills to organize technology, information, and communication (ICT) based learning [19].

Research [20] was conducted to analyze the PCK abilities of 2 prospective teachers taking the Chemistry Learning Planning (PPK) course and two chemistry teachers in Semarang. PCK capability is analyzed from the filling results of Content Representation (CoRe) and how to plan the RPP (Learning Implementation Plan) and make LKS (Student Worksheets) [20]. Comparing lesson plans and worksheets made by participants, it was found that prospective teachers paid more attention to the relationship between the depth of material and learning strategies in the writing aspect of learning activities [20]. Prospective teachers pay more attention to the apperception and constructivist aspects visible from the worksheet and learning practice results. However, all research participants [20] still needed to pay more attention to the derivation of the Buffer equation and the Buffer working mechanism in writing worksheets. Some of the challenges faced by prospective teachers and teachers include busy teachers, weak mastery of concepts, and the need to be used to writing reflections on activities [20].

Research [21] developed an integrated 4D model learning tool, TPACK, on colloidal materials, which is expected to improve the capabilities of higher-order Order Thinking Skills (HOTS) students. The 4D model is described in several stages: definition, designing learning device prototypes, development and validation, and then dissemination of learning devices [21]. The research results show that learning tools developed based on the TPACK framework can make learning activities more effective and improve students' HOTS abilities [21].

Research [22] aims to describe and analyze the pedagogical content knowledge abilities of 3 high school teachers in Semarang using PCK components on the pentagon model. The PCK components in the pentagon model include K1 (orientation in teaching chemistry), K2 (knowledge of student understanding in chemistry), K3 (knowledge of the chemistry curriculum), K4 (knowledge of learning strategies and representations for teaching chemistry), and K5 (knowledge of assessment) [22]. Variations are found in K2, K3, K4, and K5, while in K1, the three teachers showed results that tended to be the same [22].

Learning tools developed using the TPACK approach can also increase students' scientific literacy [23]. Learning tools include lesson plans and worksheets. Research [23] was carried out in three stages, namely definition (initial study), design (determination of indicators, learning objectives, and material analysis), and then the steps for learning activities in the Lesson plan and student worksheet were developed. The lesson plans and worksheets were developed to increase scientific literacy, including aspects of science context, science content, and science process [23]. The research results [23] state that the learning tool uses the TPACK approach with model discovery learning to increase scientific literacy in reaction rate material, which has good feasibility.

Research [24] was conducted to identify the TPACK capabilities of 109 chemistry teachers in Java when conducting distance learning during the Covid-19 pandemic. Data was collected using an online questionnaire, which was analyzed quantitatively with factor analysis and qualitatively based on participants' opinions regarding distance learning during Covid-19 [24]. The questionnaire contains 36 closed-ended statements on a Likert scale and ten open-ended questions to identify challenges and possibilities for implementing distance chemistry learning. The questionnaire results showed that the participants' chemistry teachers tried to adapt their teaching methods and use different diverse technologies for conducting assessments [24]. Participants' TPACK abilities tend to be positive; however, training in technology and improving teachers' TPACK abilities are needed to make distance chemistry learning effective [24].

Good teacher understanding regarding technology, pedagogy, and content (TPACK) will provide self-confidence in integrating technology into learning. It will facilitate the achievement of learning goals, so teachers need to have it [25]. Research [25] was conducted to (1) determine and describe the level of understanding of TPACK and Technology Integration Self-Efficacy (TISE) SMA/MA Mathematics and

Natural Sciences teachers in Kroya and Binangun Districts and (2) know the relationship between the level of understanding of TPACK and TISE. Participants were SMA/MA Mathematics and Natural Sciences teachers in Kroya and Binangun Districts, totaling 30 teachers. Primary data was collected using the TPACK and TISE questionnaires, while secondary data was obtained from observations and interviews, which were used to confirm the questionnaire results [25].

Based on the results of data analysis [25], SMA/MA Mathematics and Natural Sciences teachers in Kroya and Binangun Districts have a good understanding of all TPACK components overall. It states that teachers have been able to combine technology well into learning activities. These results still need to be improved because there are deficiencies in the aspects of using a variety of technologies and the effectiveness of using technology to improve students' understanding, and they tend not to be diverse in the use of learning technology [25].

These results are supported by a good level of understanding of TISE, so it can be concluded that teachers have been able to implement technology into learning confidently and adapt technology to learning strategies and the characteristics of the material to be taught [25]. Teachers also demonstrate the ability to evaluate students' work using a variety of platform technology [25]. The relationship between TPACK and TISE is shown in technology, pedagogy, and content knowledge. These three components are an important basis for teachers' self-confidence (self-efficacy), which is good for implementing technology in learning [25].

Research [26] aims to describe the TPACK abilities of 32 chemistry teachers in East Nusa Tenggara, carried out quantitatively descriptively with the TPACK questionnaire. The research results show that participants' TPACK abilities can generally be categorized as good, so chemistry teachers in NTT understand how to implement learning, including planning, process, and evaluation [26]. PK, TPK, TCK, and TPCK components significantly affect chemistry teachers' TPACK abilities [26]. Research [26] states that gender and teaching experience do not significantly affect TPACK ability.

TPACK-based learning tools on colligative properties of solutions have been developed to improve student's critical thinking skills [27]. Learning tools include lesson plans and worksheets in the form of flip-page ebooks. The research was designed using a 4D model development design [27]. The data obtained includes data on students' science activities, students' responses to learning with TPACK, and data on improving students' critical thinking skills [27]. Student activity increased from the first to the third meeting; students seemed enthusiastic about participating in learning activities. However, at the fourth to sixth meetings, there was a decrease in student activity; this was indicated by the group of students who did not report the results of their experiments. In general, students' responses to the learning that had been implemented were very good and good, then as many as four students gave adequate responses, and one student gave inadequate responses [27]. On average, students feel happy and motivated and are helped to understand concepts and solve problems using TPACK learning activities [27]. Students who gave adequate responses were accustomed to using technology in learning; they preferred learning using the lecture method using whiteboards and regular textbooks [27]. With TPACK-based learning activities, students' critical thinking abilities are also relatively good but can still be improved [27]. Critical thinking skills must be trained in every learning activity to prepare students to become critical and responsible thinkers [27].

Research [28] aims to improve the chemistry learning outcomes of vocational school students by implementing problem-based Learning (PBL) integrated TPACK on the mole concept material. The research was conducted qualitatively as classroom action research (PTK), which included planning, treatment, observation, and consideration in cycles I and II [28]. There were 18 students in the class. The research results [28] stated that there was an increase in learning outcomes and student activity in the vocational school chemistry learning process using TPACK-integrated PBL.

Research [29] conducted an analysis of the TPACK profile of chemistry teachers in one school in Jakarta. Participants are professional teachers who have taught for more than 20 years. The research was conducted in a qualitative descriptive manner [29]. Data collection was carried out using the TPACK questionnaire, analysis of learning plans, observation of the learning process, and interviews [29]. Chemistry teachers at this school are able to apply various learning methods at each meeting, adapted to the characteristics of the acid-base material. Participants can also utilize technology, information, and communication (ICT)-based learning media to simplify and summarize material delivery. The research results [29] concluded that the teacher had integrated all TPACK components in acid-base learning; this could be categorized as an action level (Action Level/An) at the TPACK competency level. The next level of TPACK competency is conception (Cn) and perception (Pn) [29]. The level of conception is shown by understanding TPACK theories and how they are implemented through learning. Perception level if the teacher only understands the TPACK component theories [29].

In subsequent research [29], the TPACK profiles of 3 experienced chemistry teachers in Jakarta were analyzed through activities and Lesson study. Descriptive qualitative data collection was obtained from the TPACK questionnaire, learning plan assessment (RPP), content assessment, observation of the learning process, and reflective journals [29]. The research stages started with training on developing RPPs, which were integrated with TPACK components, and then implementing RPPs in the learning process, observation, and reflection activities. The research results found that all participants could create and use interactive videos and presentations in the learning process regarding chemical and acid-base equilibria. Teachers' TPACK abilities can be developed during learning, from perception to conception, through activities Lesson Study [29].

Research conducted by [30] analyzed the ability of high school chemistry teachers in North Sumatra to integrate TPACK into learning. The research results showed that participants could integrate all TPACK components [30].

Other results were shown by research [31]. This research analyzes the TPACK abilities of SMA/MA chemistry teachers in Kuantan Singingi Regency and Pekanbaru City from August to December 2022. The number of participants was 123 people. TPACK ability is reviewed from several aspects, namely gender, certification status, work location, and length of service [31].

Based on gender, there is no significant difference in participants' TPACK abilities; this is based on the perception that male and female teachers have the same rights and opportunities to master all TPACK components [31]. Based on certification status, it was found that some teachers with longer tenure were less motivated to utilize technology in learning activities, thereby affecting their work effectiveness [31]. The TPACK ability of chemistry teachers in Pekanbaru City is better than chemistry teachers in Kuantan Singingi Regency; this can be influenced by educational background and the factor of openness of information that can be accessed by all teachers [31]. Chemistry teachers with less than ten years of tenure show high scores on the TK, TPK, and TCK components. Chemistry teachers with between 10 and 20 years of service scored the highest TPACK component scores. Chemistry teachers with more than 20 years of service received the highest PK, CK, and TPK scores. Teachers with less than ten years of service still have high motivation to use technology in the learning process but still need more experience. Teachers with more than 20 years of work experience have quite a long teaching experience and mastery of the material repeatedly. Still, they are found to have decreased motivation or a low tendency to learn new things, especially those related to technology [31].

Research [32] is a descriptive study that describes the need for TPACK-based learning tools in chemistry learning. Participants were 33 state high school students majoring in Mathematics and Natural Sciences in Jambi City. Data collection was obtained by distributing online questionnaires to students and interviewing chemistry teachers. 93.9% of the students' questionnaire results stated that they had difficulty understanding chemistry lessons. As many as 57.6% needed help understanding the concept, and 72.7% had difficulty working on questions on the chemistry material provided. A need for more teacher innovation in the learning process causes it. This innovation is very important to make the learning process more interesting and enjoyable for students [32].

Learning designed by integrating TPACK fosters 21st-century skills in chemistry learning, such as problem-solving skills, critical thinking, creative thinking, scientific literacy, and scientific process skills. In chemistry learning, teachers can design and develop a learning model that can encourage students to learn and solve problems faced by students. One model that can be applied is the problem-based learning model. In its implementation, this model exposes students to problems related to problems in everyday life so that it can develop students' critical thinking skills and creative thinking abilities [32].

Teachers need to increase innovation in integrating pedagogy and technology in chemistry material. Technology is one component of TPACK that cannot be separated. Technology and learning materials (TCK) can help and influence other components. Likewise, the use of technology and pedagogy (models, approaches, strategies, and methods) (TPK) can support active learning. Technology can also make teaching and learning activities easier for teachers [32].

A TPACK-based learning tool on salt hydrolysis material has been developed in research [33]. The learning tools developed include lesson plans and TPACK-based electronic modules. This device is connected and mutually supportive between all TPACK components and can improve students' problem-solving skills in salt hydrolysis material at SMAN 5 Merangin, Jambi City. The tool was validated by several validators, including lesson plan validation, material expert validation, media expert validation, and design expert validation [33].

Problem-solving ability is one of the learning outcomes obtained by students through active student activities in seeking knowledge and concepts regarding a given problem. These problem-solving skills must be trained and provided to all students, especially when facing complicated problems in learning chemistry. Critical thinking skills precede this process and develop into a weighty opinion that can be combined with a credible theory. The teacher's role is as a planner, organizer of the learning environment, and facilitator who is obliged to develop educational goals into operational plans. Teachers need a response in developing learning tools because they are more experienced and better understand the characteristics and real school learning conditions [33].

Conclusion

The results show that the TK, PK, TPK, TCK, and TPACK components possessed by prospective chemistry teacher students and teachers are in a good category. The abilities of prospective chemistry teachers and chemistry teachers in TPACK still need to be improved in several aspects of content mastery, pedagogy, and technology. Developing TPACK capabilities requires a long process to obtain new sources of skills and knowledge needed to form professional teachers.

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