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## Chemistry Teachers' TPACK Competence: Teacher Perception and Lesson Plan Analysis

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**Abstract.** This descriptive study aims to describe chemistry teachers' Technological Pedagogical Content Knowledge (TPACK) competence based on teacher perception and lesson plan analysis. Chemistry teachers' perceptions were obtained through the TPACK questionnaire, which was developed based on components in the TPACK framework. Meanwhile, the lesson plan analysis is carried out through a rubric developed based on the TPACK indicator for the lesson plan. The respondent was 86 chemistry teachers who teach in one Indonesian province. Sampling for the analysis of teacher perceptions was carried out through purposive sampling, and the sample lesson plans were selected from several respondents who filled out the TPACK questionnaire. Both data sets were analyzed descriptively. The results of the TPACK perception analysis of chemistry teachers on the components of TK, PK, and PCK show that they have sufficient ability. These results align with the analysis of the lesson plans they made, which are in the good category. In the CK and TPK components, chemistry teachers' perception shows they have sufficient ability. It is not in line with the results of the analysis of lesson plans which are in the poor category. In TCK component, chemistry teachers' perception shows they have less ability. These results are quite in line with the analysis of lesson plans which are in the very poor category. Finally, the results of the analysis on TPACK component show that chemistry teachers are unsure or doubtful about their abilities, while the results of the analysis of lesson plans are in the very poor category.

**Keywords.** chemistry teachers, lesson plan analysis, perception analysis, TPACK

### 1. Introduction

Chemistry is one of the most difficult subjects to learn because it is abstract and often causes many students to have misconceptions [1]. Chemical concepts generally relate to microscopic representations, so students have difficulty understanding and visualizing concepts such as atoms, molecules, or chemical reactions [2]. Most of the students' test scores were in the moderate to the poor category and needed improvement [3]. Many studies on misconceptions evidence the urgency of misconceptions in chemistry learning. [4] analyzed research trends in chemistry education from 650 articles and found that between 2004 – 2013, 7.7% of the research works discussed concept mastery, concept change, and misconceptions.

That study proves that chemistry is a difficult subject and full of misconceptions.

To teach material that is full of misconceptions, such as chemistry, the learning designers tried to improve teaching and learning through chemistry education research with a study base on the view of obstacles to learning chemistry, the nature of chemistry, three representations of material, laboratory practice, and mastery of concepts. As a result, conventional chemistry knowledge taught in lectures has been complemented by laboratory experiments intended to provide opportunities for students to experience chemistry as an inquiry [5]. Currently, chemistry learning has been helped by technologies such as HyperChem for molecular modeling, PhET Interactive Simulations for simulations, scientific webs such as PubChem and ChEMBL, augmented reality for chemistry learning, and many more. In addition, instruments and computers can visualize the progress of science in understanding phenomena [6].

The presence of various chemistry learning innovations designed by designers and innovators in the fields of education and technology to support the understanding of chemical concepts is not in line with the implementation of teaching and learning by teachers in the classroom. Teachers have an important role in shaping students to be more competitive in 21<sup>st</sup> century. The teacher's task is not only to give lessons but also to package the experience to be more interesting to make students easy to understand the lesson [7]. However, teachers sometimes fail to integrate technology into their teaching due to a lack of pedagogical knowledge [2]. Teacher competencies are considered a key factor not only for the actual use of Information and Communications Technology (ICT) but also for the effectiveness of its application. The teacher self-assessment survey shows that their digital literacy is continuously improving. However, the successful use of educational technology is highly dependent on efficacy and positive self-confidence [8].

Shulman, in 1986 introduced subject-specific teacher professional knowledge known as Pedagogical Content Knowledge (PCK). PCK consists of two aspects, Content Knowledge (CK) which includes knowledge of concepts, theories, ideas, frameworks, and proof methods, and Pedagogical Knowledge (PK) which includes class management, assignments, lesson plans, and the concept of teaching and learning [9]. Teachers not only need to understand CK, but they also need to understand specific knowledge to teaching and learning. The knowledge includes how to interpret the content, problems, problems that have been constructed according to the interests and abilities of students, and how they are presented in the teaching and learning process. In the current situation, technology and information are developing rapidly. The movement to the digital era has not only impacted the social system but also the education system. [10] stated that technology is an important component of teaching. The use of technology in the classroom is in line with indicators of pedagogic competence and professional competence. The technology used in the classroom has also been developed into the teacher's PCK, now known as Technological Pedagogical Content Knowledge (TPACK).

Mishra and Koehler's formulation of the TPACK framework extends Shulman's knowledge characterization to explicitly consider the role that knowledge of technology can play in effective teaching. Technology-supported instruction enhances student learning and understanding [2]. However, technological knowledge is insufficient for effectively integrating technology in teaching. Teachers must have other types of knowledge, namely content and pedagogical, and the ability to integrate these types of knowledge. All teachers who wish to integrate technology into their subjects must understand TPACK [11]. In addition, schools are required to equip students with the necessary technological competencies. Future community technology literacy standards have been proposed, and related elements are being integrated into school curricula worldwide. As a result, teachers must possess appropriate technological

literacy and adequate pedagogical competencies to teach students the necessary knowledge and skills [12].

According to [13], the TPACK framework can be used to see which components of knowledge affect technology integration effectively. TPACK can be used as an indicator of professional teacher competence because the TPACK component consists of two competencies in the realm of teacher professional competence, namely pedagogic competence and professional competence. Technology offers various ways to engage students in the development of knowledge and skills. We must be mindful of the impact of technology and focus not only on what technology has to offer but on what pedagogy requires. Integrating technology in learning requires teachers to have TPACK competencies. Therefore, this study aims to analyze TPACK competencies of chemistry teachers based on their perceptions and lesson plans.

## **2. Method**

This descriptive study aims to describe the TPACK competence of chemistry teachers based on their perception and lesson plan analysis. The respondent was 86 chemistry teachers who teach in one Indonesian province. The data collection method used is mix method. [14] defines the mixed method as a research approach using both quantitative and qualitative data sets related to problem situations and taking advantage of these two data sets. The mix method consists of six designs that differ in time to collect data. A sequential descriptive design was used in this study. In this design, quantitative data is collected first, then qualitative data is collected to strengthen the quantitative data. Data analysis is often interrelated and combined at the data interpretation or discussion stage [14].

Quantitative data collection on TPACK competencies was carried out through teacher perception survey. The sampling technique is purposive sampling. Purposive sampling is a sampling technique with certain considerations. The instrument used is the TPACK questionnaire which was adapted from [15]. The questionnaire consists of 45 statements that are part of the seven types of knowledge in the TPACK framework. The answer choices use a 5-point Likert Scale starting from Strongly Disagree (1) to Strongly Agree (5). The data collected was then analyzed descriptively. Descriptive analysis is used to determine the trend in the data.

Besides survey, quantitative data collection on TPACK competencies is also carried out through lesson plan analysis. The lesson plan sample was selected from several respondents who filled out the TPACK questionnaire. Lesson plan was analyzed descriptively using a rubric developed based on indicators of lesson plan analysis with the TPACK component adapted from [8], [16]. A rubric can be expressed as a set of display criteria (performance) that shows mastery of certain competencies. Therefore, the rubric is suitable for assessing teacher TPACK competencies. Through the analysis of the lesson plan, qualitative data was also collected. Qualitative data collection was used to strengthen quantitative data findings. The learning steps written by the respondents in the lesson plans are categorized based on the TPACK components. They are presented in the discussion section to strengthen quantitative data findings.

## **3. Results**

The results of the study are (1) the description results of the analysis of the perception of chemistry teachers about their TPACK competencies and (2) the description results of the analysis of the lesson plans used by chemistry teachers in teaching based on the components of the TPACK. Furthermore, the results of the two analyzes were compared to determine the TPACK competence of the chemistry teachers who were the samples in this study.

3.1. *Teacher Perception Analysis of Their TPACK Competence.* Perception analysis of chemistry teachers was conducted to determine their TPACK competence based on self-assessment. The method that can use to determine the respondents' self-assessment of their TPACK competence is through a questionnaire. This can be done by submitting relevant statements about respondents who tend to have an informed opinion. Therefore, the research data for this perception analysis was obtained through a questionnaire. The response of chemistry teachers to the questionnaire are presented in Table 1.

**Table 1.** Percentage of chemistry teachers' perceptions about their TPACK competence

No	Components	Responses (%)				
		STS	TS	R	S	SS
1	Technological Knowledge (TK)	1%	6%	33%	41%	19%
2	Content Knowledge (CK)	1%	10%	24%	53%	11%
3	Pedagogical Knowledge (PK)	3%	4%	21%	55%	17%
4	Pedagogical Content Knowledge (PCK)	1%	11%	34%	44%	11%
5	Technological Content Knowledge (TCK)	0%	55%	37%	5%	3%
6	Technological Pedagogical Knowledge (TPK)	3%	5%	29%	49%	15%
7	Technological Pedagogical Content Knowledge (TPACK)	6%	40%	45%	7%	2%

3.2. *Lesson Plan Analysis.* Lesson plan analysis was conducted to determine the chemistry teacher's TPACK competence based on their document, namely the lesson plan. Document analysis can be used as a data source to help researchers understand the phenomenon [14]. In addition, documents have the advantage that they are ready to be analyzed directly without transcription as required for data from observations and interviews. Therefore, in addition to surveys, research data was obtained for TPACK competence analysis for chemistry teachers through lesson plan analysis. The results of the lesson plan analysis are presented in Table 2.

**Table 2.** The results of the lesson plan analysis

No	Components	Average Score	Criteria
1	Technological Knowledge (TK)	2.95	Enough
2	Content Knowledge (CK)	1.82	Less
3	Pedagogical Knowledge (PK)	3.09	Enough
4	Pedagogical Content Knowledge (PCK)	3.18	Enough
5	Technological Content Knowledge (TCK)	1.00	Very Less
6	Technological Pedagogical Knowledge (TPK)	2.36	Less
7	Technological Pedagogical Content Knowledge (TPACK)	0.91	Very Less

3.3. *Software in Teaching and Learning.* When discussing TPACK, the discussion cannot be separated from the use of ICT. ICT in the TPACK framework is contained in the TK, TCK, TPK, and TPACK components. Specifically, the ICT referred to this study is software that can support the teaching and learning process, namely Google Classroom, Google Meet, Google Site, Youtube, Zoom, Whatsapp, Whatsapp Video, Hyperchem, Avogadro, Chems sketch, Chemdraw, PhET Colorado, and Chemlab. The percentage of chemistry teachers' respond

toward the use of this software in supporting teaching and learning is presented in Figure.

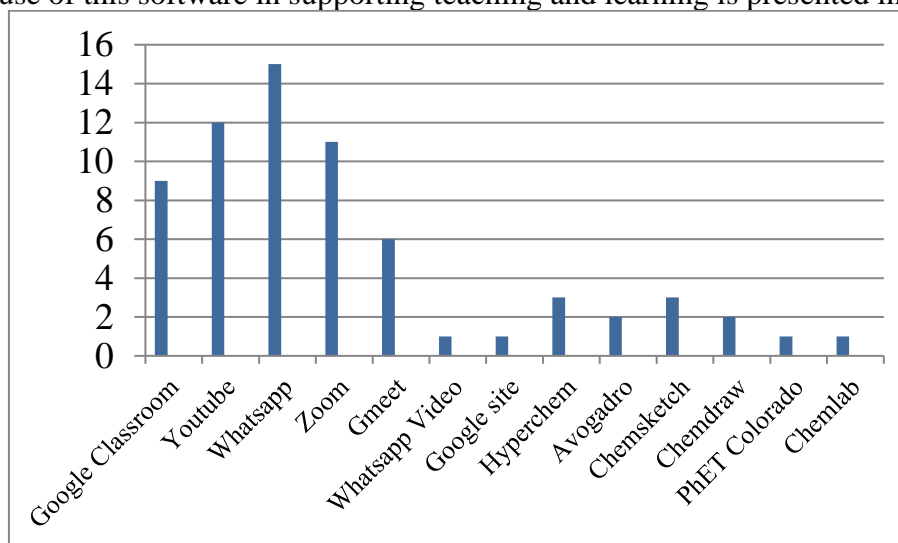


Figure. The percentage of chemistry teachers' respond toward the use software in supporting teaching and learning

#### 4. Discussion

4.1. *Technological Knowledge (TK)*. TK is related to teachers' knowledge of using technology in general. The TK concept used in the TPACK framework is similar to the technology concept from the Committee of Information Technology Literacy of the National Research Council [10]. They state that TK requires a person to understand ICT more broadly to apply it productively in the workplace and everyday life. Based on the survey results of chemistry teachers' perceptions of their TK, it was found that most of the respondents (41%) believed that they had sufficient TK competence. This is in line with the results of the lesson plan analysis, which shows that the competence of TK in the lesson plan is in a good category.

In the lesson plans, the chemistry teacher writes down the general use of technology as a learning media, such as Microsoft PowerPoint, textbooks, e-books, whiteboards, markers, and others. The learning steps section contains a description of the teacher in using the technology, such as:

LP 2 : *The teacher gives the material briefly using PowerPoint media.*

LP 3 : *The teacher conveys the learning objectives by writing them on the blackboard.*

LP 5 : *The teacher asks students first to study the learning material delivered next week in the available textbooks or e-books.*

This statement strengthens the quantitative findings based on the TPACK perception survey of chemistry teachers and lesson plan analysis, which shows that respondents have TK competence in the good category. Teachers in digital era need TK competence because the rapid growth of ICT. Using ICT in the classroom based on knowledge and understanding by the teacher is very important to give students experience in preparing themselves for the future [17].

4.2. *Pedagogical Knowledge (PK)*. In Indonesia, PK is closely related to the pedagogical competence that teachers must have according to UU No. 14 Tahun 2005, which means that pedagogic competence is the ability to manage to learn. Pedagogy is any conscious activity that a person, in this case, the teacher, does to improve the learning process. PK is knowledge of teaching and learning processes and practices or methods [10]. The results of the TPACK perception survey for chemistry teachers showed that the respondents felt they had sufficient in PK, in line with the results of the analysis of the lesson plans sample. In lesson plans, teachers

present various approaches, models, methods, and assessments needed in the learning process, such as scientific approaches, laboratory approaches, Project-based Learning model, Problem-based Learning model, Guided Inquiry models, methods of teaching, and others. In addition, the teacher also presents various assessments to determine student abilities, such as questions of concept mastery, attitude observation sheets, product assessment sheets, and others. Learning steps that describe the teacher's pedagogic knowledge such as:

- LP 2 : *Students must have curiosity, responsibility, and cooperation to solve problems.*
- LP 2 : *The teacher helps students reflect and evaluate the problem-solving process.*
- LP 3 : *Checking the attendance of students as a disciplined attitude.*
- LP 6 : *The teacher opens the lesson by greeting and instructing students to pray (religiously)*

The statements in LP 2, LP 3, and LP 6 show the teacher's plan to develop students' affective aspects. Positive learning experiences can result when teachers are in touch with the affective characteristics of the students. In another study, PK is described through collaborative activities and efforts to facilitate students' problem-solving skills in the environment. [18] confirm that using varied learning strategies in chemistry education effectively increases student achievement.

4.3. *Content Knowledge (CK)*. CK is closely related to mastery of the learning material to be delivered. In lesson plans, very few teachers write about the aspects included in the CK components, such as descriptions of facts and theories in chemistry, the process of chemical compound reactions, and detailed structures of elements and chemical compounds. Some lesson plan containing chemical content such as:

- LP 7 : *Fact: Coconut milk, milk, and glue are examples of colloids.*  
*Concept: Some typical colloid properties are the Tyndall effect, Brown Motion, adsorption, coagulation, colloid stability, and lyophilic and lyophobic colloids.*  
*Principle: Colloids are dispersion systems with particle sizes larger than solutions but smaller than suspensions.*

By putting aside the scientific truth of the facts, concepts, and principles presented, authors suspect there is no detailed description of CK in the lesson plans because the teacher thinks CK is already found in teaching materials and textbooks. However, science textbooks support teacher preparation for teaching by providing detailed explanations of lesson content [19]. This is what makes the survey results not in line with the results of the lesson plan analysis. The survey results show the chemistry teachers' perceptions of their CK components are in a good category. In contrast, the results of the RPP analysis show their CK components are in the less category.

4.4. *Pedagogical Content Knowledge (PCK)*. PCK is defined as transforming content knowledge possessed by teachers as pure intrinsic value into knowledge used for teaching. The survey results show that the PCK competency level of the chemistry teachers who were respondents in this study is in line with the results of the PCK component analysis in the lesson plans. Most research results show teacher confidence only in PCK, not TPACK [11]. PCK is considered a basic competency that must be possessed by a teacher [9]. The description of the learning steps in the sample lesson plans which are included in the PCK such as:

- LP 1 : *The teacher asks students to write down the important concepts contained in the solubility topic*

- LP 4 : *The teacher guides students to make a summary/conclusion of the lesson and encourages students to be grateful in life.*
- LP 8 : *The teacher outlines the material coverage of acid-base solutions.*
- LP 8 : *The screen presented the pictures of shampoo and oranges. Then teacher asks "What do the fruits and shampoos in the pictures taste? (macroscopic representation, acid-base).*

LP 1 and LP 8 show the teacher's technique in applying the PCK aspect, namely the concept formulation. In LP 1, the teacher asks students to formulate important concepts, while in LP 8, the teacher has formulated the concept, and the formulation results are presented to students. In LP 4, the teacher uses the content taught as a form of gratitude to the creator. This includes the form of content transformation wrapped in pedagogic science. Pedagogic aspects and actions supported by a knowledge base are very important in supporting professionalism as a teacher. The second statement in LP 8 shows the representative aspect of PCK. The teacher displays macroscopic representations in chemistry through examples of shampoo and oranges to represent acidic and basic compounds. Connecting aspects of representation in chemistry can form a complete understanding of chemical concepts.

4.5. *Technological Content Knowledge (TCK)*. The results of the TCK survey show that respondents consider their TCK to be in the poor category. This result is quite in line with the analysis of the RPP sample, which shows that the teacher's TCK is in the very poor category. Another supporting fact is the choice of software used by teachers in learning. Based on the choice of software (Figure 1), only a few teachers admitted to using software in the TCK category, such as Hyperchem, Avogadro, Chems sketch, Chemdraw, and PhET Colorado, and Chemlab. These softwares develop visual representations that support communication in chemical content [6]. The description of the learning steps in the sample lesson plans which are included in the TCK category are:

- LP 9 : *The teacher guides each group to do the practicum and ensures that each group carries out the practicum according to the tools and work procedures in the worksheet.*
- LP 3 : *The teacher asks students to look for answers to problems on the internet or other sources.*

In LP 9, the teacher uses practical technology in the laboratory to convey chemical content through experimental activities. In addition, LP 3 shows the use of the internet to answer chemistry problems. The use of technology that supports lesson content is still limited compared to the technology that supports learning pedagogy. Nevertheless, this technology is important to introduce future chemists to the technology they will encounter [6]. In other fields, such as mathematics, the use of the GeoGebra application has a positive effect on the self-efficacy of teachers and prospective teachers in the TCK component. The efficacy scores of prospective teachers who take GeoGebra-supported micro-teaching are significantly higher than those of prospective teachers who only follow Micro Teaching [20].

TCK involves understanding how technology and content are interrelated. Technology presents newer and more varied representations of science. This type of knowledge requires the teacher to know how the subject matter is changed by applying technology. Technological advances in medicine, such as Roentgen's discovery of X-rays, prove that the presence of technology and medical science is interrelated [10]. Instruments and computers can visualize the progress of science in understanding phenomena [6]. Chemical concepts generally relate to the microscopic level. Students have difficulty understanding and visualizing concepts such as atoms, molecules, or chemical reactions. Educational technologies such as animation and simulation are quite helpful in visualizing these concepts [2].

4.6. *Technological Pedagogical Knowledge (TPK)*. Similar to CK, the results of the TPK survey are not in line with the results of the lesson plan analysis. Respondents felt that they had sufficient TPK but based on the analyzed lesson plan sample, their TPK was in the poor category. This fact is not supported by an additional survey conducted by researchers on software in teaching and learning. In the survey, the distribution of software selection by respondents was mostly focused on using software that requires TPK capabilities. Even the most widely used software by respondents is Whatsapp, where Whatsapp is a software/application that requires sufficient TPK. This means that respondents have sufficient TPK to run the software, as stated in the self-perception survey. This result is in line with [21] which compares the claims of their respondents with the results of a knowledge test about technology integration in learning. Respondents stated they have adequate knowledge, skills, and attitudes to use technology in learning. At the same time, the results of tests indicate that their knowledge and skills in integrating technology for learning are still low. implemented properly

The description of the learning steps in the sample lesson plans which are included in the TPK category such as:

LP 3 : *The teacher informs students to send the worksheet to the Schoology, then do online discussions about the material that has not been understood.*

LP 7 : *The teacher asks students to collect information through discussion and literature study (Library Literacy) or learning resources from the internet (Digital Literacy).*

The results of the analysis of the technology-based TPACK components in this study, such as the TPK and TCK components, are in line with the claims of science teachers in the study from [22], who stated that they considered the ability of the technology-based TPACK component to be lower than the ability of the non-TPACK component such as PCK. The teacher self-assessment survey shows that their digital literacy is continuously improving. However, the successful use of educational technology is highly dependent on efficacy and positive self-confidence [8]. Future citizen media literacy standards have been proposed, and related elements are being integrated into school curricula worldwide [12]. The technology used can be developed to suit the characteristics of students [7]. The pedagogic component comes over as an important predictor of the process of integrating ICT by teachers.

4.7. *Technological Pedagogical Content Knowledge (TPACK)*. TPACK is the main component that emerges from the interaction of the previous components. The interaction between technology, content, and pedagogy is very important. Improperly carrying out these interactions or using irrelevant or inappropriate technology for this component can lead to several negative effects [21]. All teachers who wish to integrate technology into their subjects must understand TPACK [11], [23]. Formal training in computer software for chemistry education is required but is not currently offered in many programs [24]. Factors that influence the development of teacher TPACK: (1) the results of discussions with experts during lesson study activities; (2) recommendations from observers; and (3) the result of self-reflection [7].

TPACK is the basis of the use of technology for teaching and learning in effective way, the use of technology to teach content constructively, the use of technology to address learning problems, and the use of technology to develop learning [10]. For the TPACK component, the responses of chemistry teachers in the perception survey showed they were unsure or doubtful toward their TPACK. Different results were obtained from [25] through a survey of the TPACK component in the biology teacher. Most biology teachers felt that their TPACK was in the poor category, and some were in the very poor category. The doubtful attitude of the respondents in this study can be confirmed through the analysis of lesson plans. In fact, through the lesson plan analysis, it was found that the respondent's TPACK component was in the very poor category.

Description of the learning steps in the sample lesson plans that fall into the TPACK category such as:

LP 8 : *Through learning using a guided inquiry model combined with PhET (Physics Education Technology) simulation media, students are expected to be able to explain the concepts of acids and bases, analyze the differences between strong acids and weak acids and strong bases with a weak base, and can calculate the pH value. Students can also collect information about acid-base solutions based on the results of virtual experiments in groups with collaboration.*

The TPACK category of respondents in the lesson plan analysis is in the category of very less making limitations in presenting qualitative data, lesson plan which presents qualitative data is just LP 8. Teachers use PhET simulation media as additional software in the guided inquiry learning model. PhET is a simulation software that can visualize this software integrated with appropriate learning models and can improve the quality of learning. Using various applications in learning with various combinations can increase the TPACK of teachers. The research from [16] illustrate that using screencast applications as a concept strengthening tool in mathematics makes teachers more creative in presenting learning videos.

## 5. Conclusion

The results of the study revealed a match and discrepancy between the perceptions of chemistry teachers regarding their TPACK competence and the lesson plan documents they made. Improvements in learning plans are needed, especially for the TPACK component, which is in the "less" and "very less" categories, so that technology integration in classroom learning becomes more systematic. Teachers need to understand better the importance of the TPACK framework in learning that integrates technology to apply it in the classroom. Especially in the field of chemistry, learning in schools must be balanced with technological advances related to chemical content, such as molecular visualization, reaction simulation, and others. This study suggests teachers and prospective teachers pay attention to TPACK competencies so that improving the quality of learning can occur through technology integration. In addition, efforts from various parties such as the government and Lembaga Pendidikan Tenaga Kependidikan (LPTK) are also needed to improve the TPACK competence of chemistry teachers.

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