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# Strengthening Chemistry Teachers' Technological Pedagogical Content Knowledge through the Introduction of Augmented Reality and Learning Management Systems

**Muhamad Imaduddin[1]*, Andari Puji Astuti[2]**
[1]*Institut Agama Islam Negeri Kudus, Indonesia*
[2]*Universitas Muhammadiyah Semarang, Indonesia*

imad@iainkudus.ac.id*

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**Abstract**

Strengthening of Technological Pedagogical Content Knowledge (TPACK) needs to be done as an effort to present chemistry learning that is following the times. The purpose of this activity is to identify the TPACK conditions of chemistry teachers, as well as to seek initial activities to strengthen teachers' TPACK through the introduction of augmented reality technology according to chemical content, as well as classroom management based on a learning management system platform. The implementation method included Focus Group Discussion (FGD) activities, lectures, and implementation practices. Participants in this activity consisted of chemistry teachers who were active members of the Chemistry Teacher Groups of Kudus Regency, as many as 17 teachers. This community service activity is in the form of a series of activities that include (1) identification of difficult chemistry materials, most of which show microscopic concepts as one of the difficult materials, (2) identification of the condition of the teacher's level of mastery of technology which is generally still at a moderate level, (3) introduce the potential use of technology in the chemistry learning process in the form of Augmented Reality, namely RAppChemistry, and (4) the use of a learning management system in the form of the Google Classroom platform that can be used in electronic-based teaching and learning processes. Further partnerships need to be implemented to implement the technology on a classroom scale. Activities that may be carried out are lesson study activities to optimize the integration of technology in chemistry learning.

**Keywords**: Pedagogical Content Knowledge, Augmented Reality, Learning Management System

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## INTRODUCTION

Technology is the most influential factor that shapes the world of education today. Integrating technology into the classroom will optimize 21st-century skills in the aspect of technology mastery (Hidayah et al., 2020). In the future, students will certainly need technology both as a workforce and in their daily lives (Brown et al., 2018). Many educational institutions have shown their support in increasing the use of technology in the classroom by providing software such as tablets and computers, improving internet connectivity, and various training to improve technology mastery for teachers and students. Internet, YouTube, Facebook, WhatsApp, and many new technologies have become inseparable from their daily lives (Szeto et al., 2015).

Teachers have the task of being interactive and innovative by internalizing the use of technology in the teaching and learning process following the development of the digital era (Chen et al., 2011). Professional educators need not only mastery of content and pedagogical skills (L. Shulman, 1987; LS Shulman, 1987), but also relevant technical knowledge to optimize teaching strategies according to student needs (Ottenbreit-Leftwich et al., 2010). Although teachers recognize that technology can be used to improve the quality of education, teachers also often find that implementing it in the learning process is a formidable challenge (Johnson et al., 2016).

The challenges of implementing technology in teaching are still common in Indonesia. This also happened to the teacher group, in this case, the chemistry teacher in Kudus regency. The implementation of technology in chemistry teaching is needed to create active chemistry learning, both in terms of providing a comfortable feel in the chemistry learning process as well as concretizing and increasing understanding of chemical concepts (Hidayah et al., 2020). Technology is especially needed to optimize the content of microscopic chemical concepts (Hidayah et al., 2020). The submicroscopic level is a world that cannot be observed and can only be accessed by imagination (Bucat & Mocerino, 2009; Imaduddin & Haryani, 2019). Visual representation is very important in the learning and teaching of chemistry (Alkan & Koçak Altundağ, 2015).

Strengthening of Technological Pedagogical Content Knowledge (TPACK) needs to be done as an effort to present chemistry learning following the times. TPACK is a widely used framework for understanding and preparing teachers' pedagogical knowledge related to the use of technology. TPACK emphasizes that teacher knowledge covers subjects, content, and specific contexts in integrating technological knowledge in classroom teaching (Szeto & Cheng, 2017). Improving the quality of chemistry learning has been attempted in various ways by educators starting from the planning level to evaluating its implementation through technology integration. Therefore, in this community service activity, the service team seeks to contribute to improving the quality of education through a partnership program with the Kudus district Chemical MGMP group. The purpose of this activity is to try to identify the TPACK conditions of chemistry teachers, as well as to seek initial activities to strengthen TPACK owned by teachers through the introduction of augmented reality technology according to chemical content, as well as classroom management based on a platform learning management system.

## METHOD

The method of implementing this activity included Focus Group Discussion (FGD) activities, lectures, and implementation practices. Participants in this activity consisted of chemistry teachers who were active members of the Kudus Regency Chemistry MGMP, as many as 17 teachers. The characteristics of a teacher's experience as a chemistry teacher vary from 6-30 years. This community service activity consists of three main stages (Figure 1) which include: (1) Identification of chemistry teachers' TPACK; (2) Introduction of technology in learning chemistry; and (3) Introduction of the Learning Management System, as shown in Figure 1. The details of data collection and data analysis in this activity are shown in Table 1.

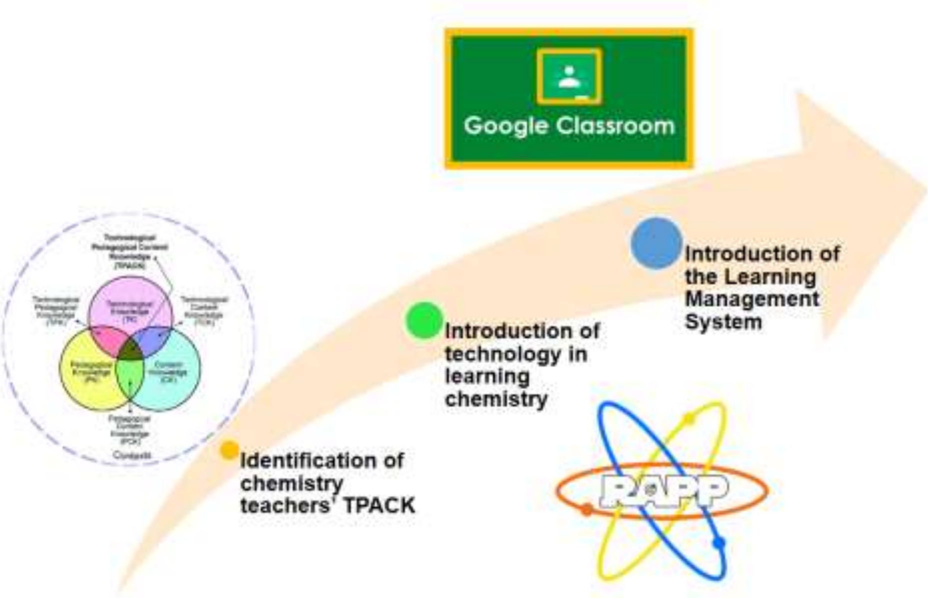



**Figure 1.** The process in the stages of implementing PKM TPACK strengthening

**Table 1.** Details of the stages of community service

| No. | Stages | Description of activities | Objectives | Data collection Data | analysis |
|---|---|---|---|---|---|
| 1 | Identification of Chemistry Teacher TPACK | Data collection related to chemical materials that are difficult for teachers to understand and difficult to teach to students, as well as the TPACK level of chemistry teachers | Obtained information related to chemical materials that can be used as a basis for selecting technology. Information was obtained on how the TPACK conditions for chemistry teachers were | Questionnaire related to TPACK modified from Schmidt et al., (2009) | a. Descriptive Statistics<br>b. Category teacher TPACK level (average score per item)<br>1.0 – 2.0 = Low<br>2.1–3,0 = Medium<br>3.1 – 4.0 = High |
| 2 | Introduction of technology in chemistry learning | Introduction of technology that can be used for learning chemistry | Teachers gain information and understanding of the potential use of Augmented Reality in chemistry learning that is difficult to teach | Qualitative observations, interviews, and documentation | Descriptive narrative |
| 3 | Introduction to *Learning Management System* | Introduction of technology for online classroom management | teacher obtains information and understands the potential use of LMS | Qualitative observations, interviews, and documentation | Descriptive narrative |

## RESULTS AND DISCUSSION

### Identification of Chemistry Teacher TPACK

At this stage, the team conducts data collection related to the learning conditions carried out by the teacher (Figure 2 .). In this case, the chemistry teacher feels still difficult to learn, as well as material that is difficult to be taught by the teacher. This relates to the types of technology options that teachers might be able to take advantage of. Thus, the support of existing facilities at the teacher's institution, personal facilities, and student accessibility also affect. This condition is tried to be explored indirectly through the condition of the TPACK level owned by the teacher.

**Figure 2.** Data Networking Process Related to teacher TPACK

**Table 1**. Identification of the material that is difficult to understand and difficult to teach by the teacher

| No | Concept | The chemical level that dominates in learning The | number of responses that appear | |
|---|---|---|---|---|
| | | | Content that is considered difficult to understand | Content that is difficult to teach |
| 1 | Intermolecular force | Mic & Sim | 2 | 1 |
| 2 | Molecular shape | Mic & Sim | 3 | 4 |
| 3 | Stoichiometry | Mic & Sim | 2 | 1 |
| 4 | Organic Chemistry | Mk & Sim | 5 | 6 |
| 5 | Elemental Chemistry | Mk & Sim | 4 | 6 |
| 6 | Analytical Chemistry M | & Symbol | 2 | 3 |
| 7 | Solubility and Solubility Products | Mak, Mic, & Sim | 2 | 4 |
| 8 | Redox Reactions and Electrolysis | Mak, Mik, & Sim | 2 | 1 |
| 9 | Physical chemistry | Mak, Mik, & Sim | 1 | |
| 10 | Macromolecules | Mak & Sim | 4 | |
| 11 | Colloids | Mak, Mik, and Sim | 2 | |
| 12 | Hybridization | Mic & Sim | 1 | |
| 13 | Polymers | Mak, Mic, & Sim | 3 | |
| 14 | Equilibrium in aqueous solution | Mak, Mik, & Sim | | 5 |
| 15 | Thermochemistry | Mak, Mik, & Sim | | 1 |
| 16 | Reaction Rates | Mak, Mik, and Sim | | 1 |

Description: Mak = Macroscopic, Mik = Miskoroscopic; Sim= symbolic

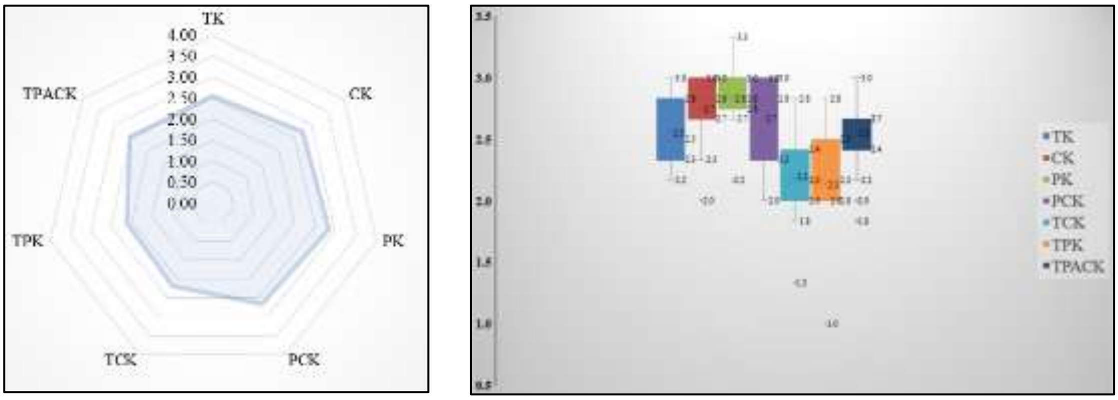
Table 1 shows the chemical materials that still need to be optimized for the learning process. The use of technology is expected to be able to improve understanding and can make it easier for teachers to teach chemistry content. Based on the material presented, the type of technology that will be introduced to the teacher is selected. Difficult chemistry concepts vary at the macroscopic, microscopic, and symbolic levels. Technology can be used as an effort to help chemistry learning that demands mastery and association at each level of representation. Macroscopic representation describes the condition of real phenomena that can be seen through everyday experience. An example is the observation of changes in the properties of matter such as color changes, foaming, gas formation, and precipitation in chemical reactions. Microscopic representations describe the explanation of the particulate level. This level is real and consists of micro levels that are used to describe the movements of electrons, molecules, particles, and atoms. Matter in chemistry is described as an arrangement of atoms, molecules, and ions. Symbolic representations show the involvement of chemical symbols, formulas and equations, pictures of molecular structures, diagrams, pictorial representations, algebra, and computational forms of submicroscopic representations (Chandrasegaran et al., 2007; Chittleborough, 2014; Devetak et al., 2007; Imaduddin, 2018b).

The TPACK framework emphasizes connections, interactions, capabilities, and boundaries between content, pedagogy, and technology. In the widely proposed framework model, knowledge of content (C), pedagogy (P), and technology (T) are central to the development of good teaching. Seven things need to be understood concerning this framework (Cox & Graham, 2009; Mishra & Koehler, 2006; LS Shulman, 1986):

1) Technology Knowledge (TK) is the knowledge of educators on variations of technology that can be used to organize the learning process. For example, the use of software, animation, and internet access. Therefore, even though they teach chemistry, teachers also need to master information and communication technology.
2) Content Knowledge (CK), which in this case is the teacher's knowledge related to the content that will be taught to students. The material content includes a variety of knowledge in the form of concepts, theories, ideas, frameworks, scientific methods, as well as various applications in everyday life. For example acid-base theory, solution pH, use of acid-base concepts in waste treatment.
3) Pedagogy Knowledge (PK) shows knowledge of the depth of theory and practice of teaching and learning which includes objectives, processes, assessment learning methods, strategies, and others. Teachers are also expected to understand how students understand and construct knowledge, attitudes, and skills (Koehler & Mishra, 2005) through various approaches, methods, and learning models.
4) Pedagogy Content Knowledge (PCK) includes a wedge between pedagogy (P) and content being taught (C). PCK is a concept about learning certain material content following the applicable curriculum and the assessment process (Koehler et al., 2014). Example: The guided inquiry approach with the learning model is Discovery Learning implemented in learning related to natural indicators.
5) Technology Content Knowledge (TCK) leads to understanding technology and subject matter that can support the learning process and influence other components (Mishra & Koehler, 2006). The teacher's basic knowledge of technology, the teacher's understanding of the content of the material, are integrated to support the process of transferring the content of the teaching material.
6) Technology Pedagogy Knowledge (TPK) is knowledge of how technology can be functioned properly to support the teaching process. Knowledge of the benefits, advantages, disadvantages, and weaknesses of technology to be utilized in learning (Schmidt et al., 2009).
7) Technology Pedagogy Content Knowledge (TPACK) summarizes a series of learning that combines mastery of technology that is inseparable from its constituent

components (C), (P), and (K). TPACK requires multi-interaction and a combination of components, namely subject matter, pedagogy, and technology.

The results of the seven components are shown in Figure 3. The general condition shows that the majority of teachers have abilities at a moderate level (2.1-3.0), although some teachers show abilities at a low level (1.0-2.0) and high ( 3,1-4,0) at each component level. The component that shows the highest level is the PCK component. This means that teachers with various experiences can integrate their content knowledge with their pedagogical abilities. As for the TCK and TPK components, there are still teachers who have low-level abilities.




TK = Technological Knowledge; CK = Content Knowledge; PK = Pedagogical Knowledge; PCK= Pedagogical Content Knowledge; TCK = Technological Content Knowledge; TPK = Technological Pedagogical Knowledge; TPACK= Technological Pedagogical Content Knowledge.

**Figure 3.** Conditions of TPACK Chemistry Teachers

**Introduction of Technology in Chemistry Learning**

At this stage, one of the uses of technology is introduced, namely Augmented Reality (AR), which is a further development of Virtual Reality (VR). Unlike traditional VR, AR combines the real world and the virtual world so that users can interact with virtual objects inserted in the real world around them and get the most natural and authentic human-computer interaction experience (Salve et al., 2017). In line with the participatory design approach, previous research has shown that the smartphone GeoSciTeachapp supports awareness about integrating geospatial ideas into science (Price et al., 2014). Mobility, combined with other features emerging in augmented reality, can help facilitate contextual learning experiences. Educators can find that the application of augmented reality in the classroom significantly improves the quality of learning and teaching in pedagogical and technical terms (Rizov & Rizova, 2015). At this introduction stage, the teacher shows interest in Augmented Reality and is willing to explore various AR applications that can be used for the learning process.

Figure 4 shows one application, namely RAppChemistry that can be used by teachers. This application can be downloaded for free via https://play.google.com/store/apps/details?id=com.CreatingWare.RAp&hl=en.


**Figure 4.** An example of one marker and the results of visualization Augmented Reality (Plata & Muñoz, 2017)

At this stage, the teacher is introduced and discussed its potential use in classroom learning. Several other applications of augmented reality are also shown their use through videos (Figure 5). There are several advantages shown by the RAppChemistry application based on the results of the Focus Group Discussion (FGD), namely: this application is interesting and can show how to model atoms and electrons in each element. Implementation of this application can be used on the material atomic structure, chemical bonds, the periodic system of elements, elemental chemistry. The obstacles in implementing this application according to the teachers are: (1) there are rules in several schools relating to the prohibition on students to bring smartphones to school; (2) lack of support for using applications on certain smartphone specifications.

**Figure 5**. Introduction of Augmented Reality technology to chemistry teachers using the RAppChemistry application: AR

**Introduction to Learning Management System**

The Learning Management System (LMS) is a web-based application for electronic learning program activities (Imaduddin, 2018a). At this stage, teachers are introduced to the use of a learning management system, namely Google Classroom (https://classroom.google.com/) which can be used by teachers for learning management. Google Classroom is a free online service for institutions such as schools, non-profit organizations, or others who have a Google account. This application can make it easier for educators and students to stay connected both inside and outside the classroom. At this stage, teachers can use their smartphones or apply them to their laptops as shown in Figure 6.

**Figure 6.** Introduction of the Learning Management System to chemistry teachers

As with the use of AR, several teachers explained school policy policies regarding the use of smartphones in the school learning environment. In addition, some teachers with low abilities Technological Knowledge (TK) showed a lack of interest in using this LMS application. This is considered to require a lot of preparation and patience in its management. The use of this LMS can actually be optimized with the class flow as shown in Figure 7.

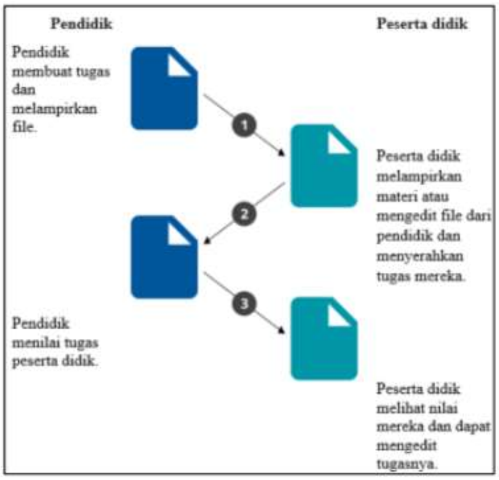



**Figure 7.** Class Flow on the use of Google Classroom (Imaduddin, 2018a)

From a series of activities that have been carried out, it is known the condition of the TPACK owned by the chemistry teacher, as well as an overview of activities for strengthening. This community service activity is a partnership activity which is the initial stage of strengthening TPACK activities for chemistry teachers. Therefore, it is necessary to carry out a further mentoring process related to the implementation of the use of technology in the learning process.

The main findings from this mentoring process indicate the need for continued mentoring for teachers in the implementation of chemistry learning to strengthen teachers' pedagogic abilities. Chemistry teachers need further training in the management of technology-based learning as well as in the use of applications related to chemical concepts such as augmented reality.

Various kinds of mentoring activities for teachers have also been carried out to improve the quality of teachers, in this case, the chemistry teacher. Many pieces of training for chemistry teachers have been carried out including Computational Chemistry training (Ananto et al., 2020), the creation of E-magazines (Rahmasari et al., 2020), the production of Chemsketch-based learning media (Indriyanti et al., 2020), the creation of e-mails. learning modules and videos (Hardeli et al., 2020), as well as the use of Chemistry Board

Games (Subagyono et al., 2021). The training that has been given to chemistry teachers is expected to improve their pedagogic skills. This assistance is carried out to strengthen the concept of teachers in microscopic aspects by utilizing technology, as well as managerial aspects of chemistry teacher classes through the use of learning management systems based on learning technology.

This TPACK strengthening program contributes to the implementation of better chemistry learning, especially by utilizing various technologies. The teachers involved become more aware of several alternative technologies that can be used in learning, especially by utilizing smartphone devices owned by teachers and students. This positive form of smartphone utilization is later expected to also have an impact on policies for its use in school learning. Thus, in the future, learning technology can be used optimally and wisely by chemistry teachers, both to manage classroom teaching or transfer abstract and microscopic chemistry.

## CONCLUSION

This program is a partnership activity carried out by a service team with a group of chemistry teachers to strengthen teacher TPACK. This activity was carried out in several steps, starting from (1) identifying difficult chemistry materials, most of which showed microscopic concepts as one of the difficult materials, (2) the condition of the teacher's level of mastery of technology which was generally still at a moderate level, (3) introducing the potential use of technology. in the chemistry learning process in the form of Augmented Reality, namely RAppChemistry, and (4) Introduction to the use of the learning management system in the form of the Google Classroom platform which can be used in electronic-based teaching and learning processes. Further partnerships need to be implemented to implement the technology on a classroom scale. Activities that may be carried out are activities lesson study to optimize the integration of technology in chemistry learning.

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