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A Case Study: Technological Pedagogical and Content Knowledge (TPACK) of Pre-service Physics Teacher to Enhance the 4C's Skills During Online Learning

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Abstract: Technological Pedagogical and Content Knowledge (TPACK) framework aims to provide an overview of teaching and learning that is integrated with technology to improve students' knowledge which supports 21st century skills. According to curriculum 2013 is expected to provide learning that develops students' learning skills (critical thinking, creativity, collaboration, and communication) to face the world in the 21st century. The study is aimed to expose TPACK competence of pre-service teacher to enhance 10th grade students' 21st century skills in physics learning. The method used descriptive qualitative, and data obtained from mentor's feedback, teacher's reflection in five meetings. As a result, TPACK component of pre-service teacher during five meetings of physics, was able to use technology to guide students well (TK1, TCK1, TPK1, and TPK2) and guide students to share ideas and knowledge (PK 3 and PCK3), discuss (PK4 and PCK4). The disadvantages of pre-service teachers which are still low is the content knowledge components and needs to be improved before becoming a professional teacher, so the teacher can integrate learning using technology properly. However, this study needs to be further developing the strategies to observed pre-service teacher.

Keywords: 21st century skills; TPACK competence; students' learning skills

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Introduction

The education system in various countries is affected by the spread of Corona virus disease 2019 (Covid-19). The same goes for Indonesia, where several provinces deciding to close schools. Traditional learning with interactions between teachers and students in the classroom turns into online learning. This attempt is to prevent the spread of Covid-19. The Ministry of Education and Culture (MOEC) collaborates with seven online learning platforms for public and free online learning facilities, namely Google Indonesia, Smart Classroom, Microsoft, Quipper, Ruangguru, Sekolahmu, and Zenius (Churiyah, et al., 2020). All of activities in every school will go into hybrid learning system in digital era.

Online learning has the understanding as a learning activity either in thoroughly or partially run through the internet (Meylani, et al., 2015). Distance learning is one example of the application of learning activities that are fully conducting through the internet. Ideal online learning includes several things, among others: supporting student learning types, supplying students to be flexible, supplying scaffolding for online learning, being able to supply face-to-face interaction in online learning, supporting cooperative learning, and so on (Meylani, et al., 2015).

Based on research from Lie, et al. (2020), there are five factors that need to be considered in online learning, namely students, teachers' understanding of online learning, teachers' ability in technology and teaching, and the support system. The change of learning system in Indonesia into online learning

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encourages teachers to integrate learning using technology and must master digital technology (Putri, et al., 2020). According to Alrwaished, et al. (2017), integrating technology into mathematics and science learning requires teachers who need to understand the content in depth, decide learning methods that can support different students' abilities, and find the right technology tools and can support in learning.

Mishra & Koehler (2006) see that an effectively integrated learning framework with technology is the best way for teachers. Technological Pedagogical and Content Knowledge (TPACK) framework aims to provide an overview of teaching and learning that is integrated with technology to improve students' learning understanding (Purwaningsih, et al., 2019). This framework, building on Shulman's theory that teachers who master pedagogy and content very well will be able to provide effective and meaningful learning (Cahyani, et al., 2021; Juanda, et al., 2021). TPACK is also a framework that can help teachers to provide learning that supports 21st century skills (Chai, et al., 2019). TPACK framework has three core parts that teachers need to master, namely technology, pedagogy, and content, as shown below:

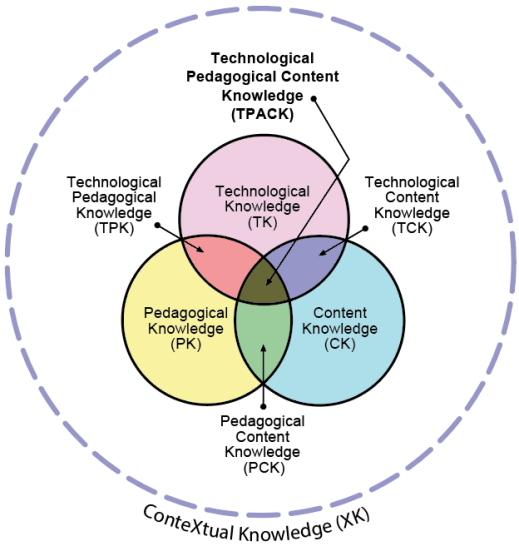

Figure 1. Technological Pedagogical Content Knowledge (TPACK) Framework (Mishra, 2018)

The definition of the three section of Schmid et al. (2020) is as follows: content knowledge which is the main lesson central concepts, theories, procedures) that teachers must master to teach; pedagogy knowledge is about the process and practice of implementation the methods of teaching (encompasses the purpose, values, and aims of education), and technology knowledge as a teacher's skill in mastering communication and information technology, mastery of technology from low tech (books and chalkboards) to digital technologies such as Internet, software programs, digital literacy, and so on The three sections have four intertwining, namely pedagogy and content knowledge (PCK), technology and pedagogy knowledge (TPK), technology and content knowledge (TCK), and technological pedagogical and content knowledge (TPACK).

From these three sections and four intertwining as a base framework, expected that teachers can found a new way of thinking in learning and improve their skills to help students learning well in this age, using and adapt digital technologies in effective way. Learning experience that is prepared according to curriculum 2013 is expected to provide learning that develops children's learning skills to face the world of the 21st century. Learning skills that need to be developed include critical thinking, creativity, collaboration, and communication (4C). There are four categories based on Assessment and Teaching of 21st Century Skills or ATC21S (Griffin, et al., 2012), namely ways of thinking, ways of working, tools for working, and ways of living in the world; which are related to the 4C. Critical thinking skills and creativity belong to the category of skills that show the way of thinking. As for collaboration and communication skills, they are included in the skills required during learning activities (way of working).

According to Miterianifa, et al. (2021), one of the indicators from critical thinking skills when students get a chance to discuss is being able to express opinions from different points of view. The improvement of students' critical thinking skills will be seen in the communication skills that students have (Mursidah, et al., 2019). Communication skills are seen when students can clearly share information they have learned (articulate thoughts) orally (Ichsan, et al., 2020). The relationship between these two skills is the communication ability of students when they are sharing ideas in discussions describing their ability to think critically.

Student creativity as the one of learning skill, can be seen when students are able to complete tasks which the problems have never been found using ideas or information they have and are able to analyze problems by using technology (van Laar, et al., 2020; Bakhshaei, et al., 2018). Student also need to develop their collaborating skill that can be seen from their ability to work effectively and appreciate group friends, show a desire to improve themselves and their group to achieve common goals, as well as appreciate the contributions of each group member (Redhana, 2019).

In this study will be focused to sees how teacher implementing the knowledge of TPACK while teaching in virtual class from teacher's reflection. It is aimed to expose TPACK competence of pre-service teacher to

enhance students' 21st century skills in physics learning. Based on research of TPACK has been done and can be grouped into five parts, namely the relationship between TPACK and other variables, TPACK instrument development, strategies to develop TPACK, identify TPACK, and how teachers adopt TPACK (Setiawan, et al., 2019; Yulisman, et al., 2019). Based on earlier study on how to measure TPACK summarized by Setiawan, et al. (2019), it shows that there are two basics focuses; which are self-reports and performance. Self-report focuses on a certain context or based on experience implementing TPACK while teaching, whereas performance observes how teachers develop lesson plans that implement TPACK, research while teachers are teaching, and measuring TPACK skills from teacher's reflection. Research on TPACK's competence of pre-service teachers is necessary to see their readiness to become teachers (Jang & Chen, 2010; Fuad, et al., 2020; Lie, et al., 2020).

Method

This study was conducted during online learning in five meetings when pre-service teacher teaching the topic 'Measurement' for 10th grade at one of Cikarang High School. This research uses descriptive qualitative method with case study technique. The goal is to know in depth the TPACK's ability of pre-service physics teachers when teaching Physics. This research takes five meetings with the detail timelines would be provided in this following table (Table 1).

Table 1. Action Timelines (1)

Date	Implementing Plan in Virtual Class (Actions)	Data Sources and Code
6 August 2020	Enhance student's communication and collaboration skills in group discussion.	Feedback from In-service teacher (FIT 1), pre-service teacher diary (PTD 1)
12 August 2020	Enhance student's critical thinking, communication, and collaboration skills in class discussion.	Feedback from In-service teacher (FIT 2), pre-service teacher diary (PTD 2)
13 August 2020	Open discussion in meeting to enhance student's critical thinking, communication, and collaboration skills	Feedback from In-service teacher (FIT 3), pre-service teacher diary (PTD 3)

Table 2. Action Timelines (2)

Date	Implementing Plan in Virtual Class (Actions)	Data Sources and Code
19 August 2020	Open discussion in meeting to enhance student's critical thinking, communication, and collaboration skills	Feedback from In-service teacher (FIT 4), pre-service teacher diary (PTD 4)
26 August 2020	Formative assessment using Microsoft Form	Feedback from In-service teacher (FIT 5), pre-service teacher diary (PTD 5)

Validity of data obtained from mentor's feedback and teacher's reflection. The first data is mentor's feedback from a professional physics teacher as an observer who provides feedback during five meetings of physics learning when pre-service physics taught. The mentor provides feedbacks in descriptive form in word documents (Feedback from In-service Teacher). The second data was obtained from the teacher's journal when observing professional physics teacher and journal while teaching. The codes for observation journals from pre-service teachers are Observation Teacher Diary and Pre-service Teacher Diary.

Furthermore, to find out the ability of pre-service teachers in mastering TPACK in 21-century learning skills (the 4Cs), it uses instruments from Valtonen, et al. (2017) adapted from Schimdt, et al. (2009). This instrument was used for several previous studies, such as Valtonen, et al. (2019); Yulisman, et al. (2019); and Revilla, et al. (2020). This study adapted the instruments used by Yulisman, et al. (2019) for science learning. The instrument is shown in Table 2.

Table 1. Instrument of Technological Pedagogical Content Knowledge (TPACK) for 21st Century Learning Skills for pre-service teacher

TPACK Components	Indicator	Code
Content Knowledge	Understand concepts, laws, theories, and applications in physics lessons	CK1
	Able to develop material of physics lessons	CK2
Technological Knowledge	Using technology effectively	TK 1
	Following the new technology	TK2

Table 2. Instrument of Technological Pedagogical Content Knowledge (TPACK) for 21st Century Learning Skills for pre-service teacher

TPACK Components	Indicator	Code
Pedagogical Knowledge: *Supporting students' …/ Guiding students to …*	critical thinking	PK1
	creativity	PK2
	share ideas and knowledge	PK3
	discussion with their study group (2-5 students)	PK4
	reflective thinking	PK5
Pedagogical Content Knowledge: *In physics lesson, I know how to be supporting students' …/ Guiding students to …*	critical thinking	PCK1
	creativity	PCK2
	share ideas and knowledge	PCK3
	discussion with their study group (2-5 students)	PCK4
	reflective thinking	PCK5
Technological Content Knowledge: *I am able to use technology to …*	teaching physics lesson	TCK1
	develop physics materials	TCK2
Technological Pedagogical Knowledge: *I am able to use technology to …*	support learning activities	TPK1
	support students to communicate and collaborate	TPK2
	support students critical thinking and creative thinking	TPK3
TPACK	I am able to use technology as the basis for every physics learning activity effectively	TPACK1
	I am able to develop and share information productively with learning which integrates with technology	TPACK2

Result and Discussion

Based on qualitative analysis from the feedback from professional physics teachers in five meetings, the summarize is shown in Table 2. The result shows that the lowest pre-service teacher capability is Content Knowledge. Based on the indicator-CK1, teacher can master some materials well and can provide contextual applications to students but has not mastered the concept of physics in depth. For five meetings, pre-service teachers have not been able to master the indicator-CK2, which is developing physics subject matter. Then for technological knowledge aspect shows that pre-service teacher can run and use technology effectively (TK1). Based on indicator-TK2 which is the ability to keep up with technological developments, in this class learning cannot be seen directly by professional physics teachers.

Table 3. Result of pre-service physics teacher' TPACK ability

No	Code	FIT 1	FIT 2	FIT 3	FIT 4	FIT 5
1	CK1	√	*)	*)	**)	**)
2	CK2					
3	TK1	√	√	√	√	√
4	TK2					
5	PK1		√			
6	PK2					
7	PK3			√	√	√
8	PK4	√	√	√		
9	PK5					√
10	PCK1		√			
11	PCK2					
12	PCK3			√	√	√
13	PCK4	√	√	√		
14	PCK5					√
15	TCK1	√	√	√	√	√
16	TCK2					
17	TPK1	√	√	√	√	√
18	TPK2	√	√	√	√	√
19	TPK3					
20	TPACK1				√	
21	TPACK2				√	√

*) applicative, but lack of concept
**) lack of concept

The ability of pre-service physics teachers to develop 21st century skills in students is seen in PK, PCK, and TPK components. When teaching physics for 10th grade students, PK and PCK's most prominent skills are to be able to guide students to share ideas and knowledge (PK3 and PCK3), discuss (PK4 and PCK4). PK1 and PCK1 indicators of pre-service teacher ability to guide critical thinking students can only be found at the second meeting. Also, the ability of pre-service teachers to guide students to think (PK5 and PCK5) can only be found at the fifth meeting. Considering the result from FIT in five meetings, PK2 and PCK2 indicators on students' ability to develop creative thinking have not been observed (PK2 and PCK2).

Pre-service teacher who has not mastered yet in concepts and theories (physics content) deeply influence their mastery of technological, pedagogical, and content to guide students to develop critical thinking and creative thinking skills. The development of critical thinking skills is carried out by pre-service teachers with discussion interactions in the classroom. As a result, students can also develop their communication skills as well as being invited to think, so that learning time can be used efficiently through an active attitude to ask and answer (PTD 2).

During online learning, teachers must have the ability to use technology well to teach. In the Technological Content Knowledge component, based on mentor's feedback shows the TCK1 indicator was met during five meetings when delivering physics material online. Based on Technological Pedagogy Knowledge component, TPK1 and TPK2 are indicators that have been fulfilled; which can use technology to support online learning activities and able to use technology to support students to communicate and collaborate. TPK3 indicator, which can use technology to support students critical thinking and creative thinking cannot be seen.

TPK3 indicator is closely related to PCK1 and PCK2 indicators where teachers have not been able to guide students to critical thinking and creative thinking during learning. PCK1 and PCK2 indicators also have something to do with the ability of CK (Content Knowledge) teachers who have not mastered physics content in depth. This data was also found by research that has been done by Agustin, et al. (2019) on pre-service science teachers' TPACK ability with quantitative method shows the highest capability results are technological knowledge (95.24) and the lowest value in content knowledge (20.24).

In the core integration aspect of TPACK, pre-service teachers showed that the ability to use technology as the basis for each physics learning activity effectively (TPACK1) can only be fulfilled in the fourth meeting. TPACK 2 indicator, which can develop and share information productively with learning integrated with technology is only fulfilled at the fourth and fifth meeting, with mentor description: *Able to organize online learning, classes are managed and conducive.* (FIT 4 and FIT 5).

Exertion's Pre-Service Physics Teacher to Enhance 21st Century Skills

The ability of pre-service teachers in designing learning has initial knowledge obtained from observations of professional teachers who have experience teaching physics in online learning. Based on observation reflection (OD), pre-service teachers learn how to teach online, such as the following quote. *"My mentor has competence as a professional teacher in the field of Physics with the first competency that stands out in him is mastering physics in depth. The second competency is the knowledge of media platform technology used by schools, namely the Office 365. The third competency is excellent teaching ability, mastering the learning methods used, and being able to develop learning methods for each topic with creative ideas. These three competencies are often referred to as TPACK Learning and are seen in every learning I take part in in every Physics class."* (Observation Teacher Diary).

Based on the experience of attending online classes, pre-service teachers have the confidence to develop learning using the TPACK framework which can support students with 21st century skills.

The experience of teaching online for five meetings of physics for 10th grade students was the first conducted in field experience. Pre-service teachers get the opportunity to receive input when drafting the Lesson Plan in the 'Measurement' chapter. Written data on PTD1 as follows: "*I completed the complete Lesson Plan and then gave it to the mentor teacher to be given an input especially in the preparation of questions on the Lesson Plan*" (PTD1, 6th August 2020).

In the first meeting, the pre-service teacher provides students with the opportunity to have communication skills as follows: "*I try to bring each student to remember the experience of measuring in their daily lives.*" (PTD 1, 6th August 2020). In addition to practice communication skills, pre-service teachers also provide opportunities for students to discuss, with data on PTD as follows: "*I direct students to take advantage of learning opportunities to develop discussion and communication skills with classmates.*" (PTD 1, 6th August 2020).

As a result, almost all students use the opportunity to share their experiences both orally and in writing via chat clearly. Students were also given the opportunity to practice their collaborating skills by discussing 7 guide questions answered using sources from You Tube that have been provided by the teacher.

Discussions is held with two or three friends in the study group. Some students were unsure whether they would be able to complete the discussion or not during the teaching.

"The response of some students also complained that they were unable to finish watching the video as digital literacy because it was too much." (PTD 1, 6th August 2020).

In the second meeting, the teacher gave the opportunity for each study group to share the results of the discussion with other groups. As a result, some students showed the development of skills in communicating on indicators using learning time efficiently by actively responding during learning, learning to listen effectively, and being able to share the results of their thinking clearly.

The dynamics of students in this class are much more active and quicker in responding. Each group gets a chance to deliver the results of one number answer. (PTD 2, 12th August 2020).

In the critical thinking skills aspect, some students show a willing attitude to try the critical thinking seen when sharing information in discussions. In the collaboration aspect, students' attitudes show that they can see their group friends and help each other. The conversation of one group of students when sharing a discussion can be seen in the following PTD2.

- *Student 1: "Ms. my group member is consisting of: me, student 2, and student 3."*
- *Student 2: "I think that 1-meter is my one foot, Ms." (This student responded well because I asked: "What does a 1-meter do you think? Try explaining it in your own language". However, student 2 misinterpreted the meaning of 'Try to explain in your own language', so I tried to give a chance for his friend to make sure the answer to student 2 was correct.)*
- *Student 3: "I tried to answer Ms. that 1-meter as a standard unit of measurement length used for the universe." (Student 3 begins to understand that her friend is good at trying to answer using his own language, but the answer is wrong so that student 3 tries to justify it. The answer of student 3 has almost right, so I gave one chance to be able to answer again.)*
- *Student 1: "Lah, my friend (students 2) ... yesterday we had a discussion and had answer it."*
- *Student 2: "Ms. Lidya said that we must to try to explain in your own language, then I answered like that."*
- *Student 1: "I will try Ms, if we thought 1-meter was the length of the trajectory traveled by light in a vacuum for 1/299.792.458 seconds. A meter is a unit of Length that has been figured out with certainty. Meter is a unit for measuring, meters are used as a standard measurement."*

(PTD 2, 12th August 2020).

Based on PTD 3 in the third meeting, it was found that the student's response in learning was slow. The same thing is also seen by professional teachers during observing what is written in FIT 3.

I give students the opportunity to think equally when giving examples to understand significant number's rules with learning media using PPT. ***The response and energy of the students in today's session decreased.*** (PTD 3, 13th August 2020).

The activities cannot run well as like as the time in Lesson plan because of some things like slow student response. (FIT 3).

In the third meeting, there was only one session held for 45 minutes. The pre-service teacher plan to give a formative test through Microsoft Form cannot be implemented because there is one subtopic that has not been taught.

Based on the data in the fourth meeting, the teacher gave the students opportunity to practice communication, one of which gave the students an earlier learning review. The results found are as follows: *"One of the students tried to deliver a review, although she still read the significant number's rules exactly as written in my PPT media while teaching at the previous meeting."* (PTD 4, 19th August 2020).

Pre-service teacher teaching with interactive discussions when delivering materials using PPT media using videos and images that can involve students thinking (Figures 2 and Figures 3). Video in the form of weighing wafers with zero-point errors on the scales (as a systematic error) and correct wafer measurement videos. The images help students to convey this material by viewing from three different points of view when looking at the mass scale of objects. It is expected that, students can feel the difference in reading scales from three different points of view and can find the right point of view in measuring the mass of an object.

The engagement of the students at this meeting seen from their initiative and willingness to convey ideas. In addition, students also want to try critical thinking by looking for the accuracy of their thinking that can be seen in the act of asking back to the teacher the part that is not yet understood and requesting an initiative re-explanation. This data is taken from PTD4 as follows: *"Some students began to try to actively convey ideas in an initiative, willing to convey parts that were not yet understood, and asked to re-explain the missing part."* (PTD 4, 19th August 2020).

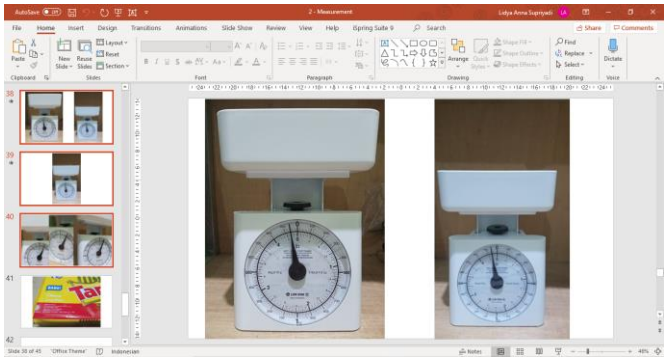

Figure 2. Video about zero-point errors on the scales (as a systematic error) and how to set the scale at zero-point

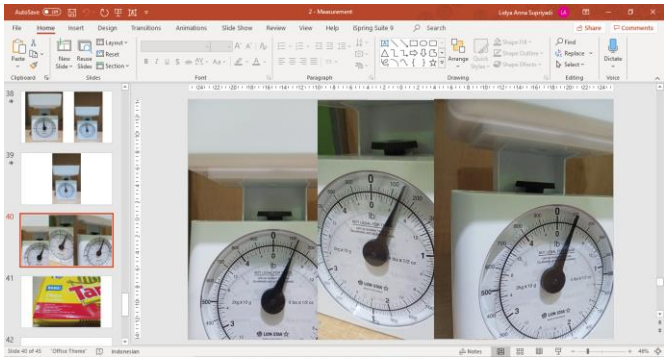

Figure 3. Images to help students learning how to read the right of scale of mass from three different points of view

In the fifth meeting, the pre-service teacher gave students the opportunity to share the results of reflection orally after formative test to practice critical thinking, reflective thinking, and communication skills. In critical thinking and reflective thinking aspects, students learn to seek accuracy in their thinking through questions about elusive parts of the material. Communication skills can be seen when students speak to ask for a re-explanation in a missing section.

"I give students the opportunity to using the raise hand feature in meeting rooms in Microsoft Teams to tell the missing part according to the result of formative test. The chance to provide feedback for students helped me to be able to build relationships with them well. The opportunity to interact with each student's personal for researchers as a teacher can be a time to supply support, motivation, get to know the condition of students, and share physics and soft skills (communication, collaboration, creativity)." (PTD 5, 26th August 2020).

The ability of pre-service teachers in mastering content knowledge, pedagogical knowledge, technological knowledge, and integration must be fulfilled in a balanced manner. In fact, pre-service teachers have not been able to master in a balanced manner, in the CK component, pre-service teachers have not been able to master the concept of physics in depth (CK1) and the development of physics material has not been seen (CK2). In Technological Knowledge (TK) components, pre-service teachers can use them effectively during learning. In the PK component, the most prominent mastery from pre-service teacher to develop students have 21st century skills while studying physics, is being able to guide students to share ideas and knowledge (PK3 and PCK3), discuss (PK4 and PCK4).

The fundamental knowledge required by teachers while teaching in the 21st century is need to understanding to formulate lesson that tare integrated with technology which supports learning with the seven TPACK construction (Hernawati & Jailani, 2019). When teachers are not able to master basic skills well, will also be difficult then to develop physics materials and improve the skills of the 21st century in students. Research conducted by Mishra & Mehta (2017) shows that teachers consider the development of 4C skills more important than proficiency in basic skills (the fundamental knowledge). This problem was also found in a study of pre-service science teachers' TPACK to develop STEM learning conducted by Chai, et al. (2020). The results showed that the challenge in integrating STEM-TPACK to be effective is the need for teachers' ability to master content knowledge (exploring basic principles and understanding their relation to daily life). Overall, in online learning, it is not only technology skills that need to be considered. The content knowledge (CK) as known the ability to share content with students, being expert to guide students have 4C skills, and being able to use digital technology effectively must be mastered equally.

Conclusion

The pre-service teacher ability of the seven components of TPACK during five meetings of physics, was able to use technology to guide students enhance their communication skills and collaborate well (TK1, TCK1, TPK1, and TPK2). Pre-service teacher efforts to develop 21st century skills in 10th grade students while teaching physics are seen from PK and PCK components which the most prominent component is to be able to guide students to share ideas and knowledge (PK 3 and PCK3), discuss (PK4 and PCK4). The disadvantages of pre-service teachers which are still low is the content knowledge components, the teacher can master some materials well and can provide contextual applications to students but has not mastered the concept of physics in depth (CK1). Also, pre-service teachers have not been able developing physics subject matter (CK2). This CK-component of pre-service teacher needs to be improved before becoming a professional teacher, so the teacher can integrate learning using technology properly. However,

this study needs to be further developing the strategies to observed pre-service teacher.

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