Analysing Technological Pedagogical and Content Knowledge (TPACK) of Pre-Service Science Teachers

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Abstract. In 21st century learning, it is important for science teachers to have good knowledge in integrating technology into learning which is known as the Technological Pedagogical Content Knowledge (TPACK) framework. This study aims to analyze the TPACK of pre-service science teachers. The method used was quantitative research with surveys. The research subjects were students at Science Education Study Program, Universitas Negeri Semarang as pre-service science teachers. The instrument was developed based on the aspects of PK, CK, TK, PCK, TPK, TCK, and TPCK. The results showed that overall the pre-service science teacher TPACK obtained quite good criteria, then if it was categorized the results were 14.75% less good, 70.43% quite good, and 14.75% good. This research can be a reference in the development and improvement of TPACK for future pre-service science teachers.

Key words: tpack; pre-service science teachers; 21st century learning; science learning; technology integration.

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INTRODUCTION

The world is currently in the era of revolution 4.0 where the development of Information and Communication Technology (ICT) can change all aspects of life, one of which is Education [1]. One form of change in the educational aspect is the need for learning for 21st century students. Today's students are highly dependent on technology especially when they are studying [2-3]. Partnership for 21st Century Skills [4-5] states that important competencies in entering 21st century life include critical thinking skills, problem solving, communication, collaboration, mathematical skills, creativity, and fluency in ICT. For that, teachers must be able to have teaching skills that will help students face global challenges in the 21st century [1].

One of the subjects in the 21st century is science, especially closely related to the theme of health literacy and environmental literacy. The role of science teachers is to facilitate students to follow technological developments and get various kinds of learning resources that are increasingly varied [6]. Therefore, science teachers today must be aware of the demands of 21st century learning, so that teaching methods in the classroom must also adjust to 21st century learning indicators [1]. The latest technologies such as robotics, artificial intelligence, and the internet of things (IoT) will replace some human jobs in the future, therefore it is very important for today's students to have skills that cannot be replaced by technology. It is this reason that shows that 21st century skills are indispensable. Science teachers and educators must train them with 21st century skills. However, students will not be able to develop these skills if the teacher himself has less knowledge in training these skills to students [1].

The 21st century learning requires science teachers to have good knowledge of integrating technology into teaching. Therefore, they need to have knowledge of technology, as proposed by Mishra and Koehler [7] as a framework for Technological Pedagogical and Content Knowledge (TPACK). Teaching in the 21st century is no longer the same, because teaching priorities have shifted. To ensure that students are able to develop, practice, and apply 21st century skills, science teachers must have the knowledge and competence in teaching and training students 21st century skills.

TPACK is a theoretical framework in understanding teacher knowledge required for effective technology integration by introducing the relationship and complexity between the three basic components of knowledge (technology, pedagogy, and content) [7-9]. TPACK describes the knowledge that is important for teachers in the millennial era to integrate technology in their teaching process [10-14]. TPACK is an important part of learning achievement and science learning achievement in the 21st century, this can be achieved by students in various domains that cannot be separated from the learning process

carried out [15]. The TPACK framework to answer the challenges of 21st century learning also applies to the field of education. In response to this mandate, science educators have renewed their efforts to promote the integration of learning technologies and inquiry-based practices into their teaching to increase students' understanding of science and also to better prepare them for the 21st century workforce [13].

The need of TPACK for science teachers must be prepared since they become pre-service science teachers [16]. When pre-service science teachers graduate their bachelor's degrees, they should already have good TPACK. This study will focus on analyzing the TPACK possessed by pre-service science teachers. The TPACK analysis of pre-service science teachers is very important as an initial study to find out how prepared pre-service science teachers are in implementing 21st century learning which focuses a lot on technology integration in learning. The TPACK analysis of pre-service science teachers is also very important as an evaluation and basis for educational policies for pre-service science teachers that are in line with 21st century learning needs.

METHODS

The research approach used was quantitative research. In this study, TPACK was analyzed for prospective science teachers. To analyze it, it was done by giving a survey to pre-service science teachers using a questionnaire. The research subjects were 61 students of the Science Education study program at the Universitas Negeri Semarang as pre-service science teachers. Respondents were selected using purposive sampling technic namely students who have completed all courses in the Science Education study program except final thesis.

The survey instrument was developed based on all aspects contained in TPACK, namely Content Knowledge (CK). Pedagogical Knowledge (PK), Technological Knowledge (TK), Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and Technological Pedagogical Content Knowledge (TPCK) [17]. Each aspect is described in several positive statements that must be responded to by respondents so that in total there are 35 statements. The item for each aspect are described in Table 1.

Table 1. Items of all aspects of TPACK on survey instruments

Aspects	Items
CK	(1) Understand science concepts, laws, and theories; (2) follow developments related to science; (3) design and implement science experiments for learning and research purposes; (4) use the latest sources (such as books, journals) to add to the treasury of science knowledge; (4) attend seminars or activities related to the science field
PK	(1) Assess student performance in class; (2) use a variety of assessment methods and techniques; (3) implement a variety of learning strategies strategi; (4) be aware of possible misconceptions and student learning difficulties; (5) manage and control the class well; (6) reflective take action to improve the quality of learning.
TK	(1) Know how to solve technical problems on the computer; (2) easy to learn to use technology; (3) keep up with the latest technological developments; (4) understand the basic components of a computer; (5) use a word processing program; (6) use a number processing program; ((7) use a presentation processing program; (8) use printers, scanners, projectors and cameras (9) storing data on digital media; (10) use the internet as a medium of communication
PCK	(1) Choose approaches and learning strategies that are in accordance with the science material; (2) prepare a lesson plan in advance; (3) make difficult science materials easy for students to understand; (4) create questions to measure students' understanding of science material
TCK	(1) Use technology to help understand science concepts, laws, and theories; (2) know computer applications related to technology; (3) develop student activities and assignments that involve the use of technology
TPK	(1) Use computer applications in learning, (2) choose the appropriate technology with the approach and learning strategy in the classroom; (3) use internet facilities (such as social media, blogs) to communicate with students
TPCK	(1) Choose learning strategies and technology that are in accordance with the science material presented in classroom learning activities; (2) Integrate science knowledge, pedagogic knowledge, and technological knowledge possessed to realize effective learning; (3) help my colleagues to understand how to integrate science knowledge, pedagogic knowledge, and technological knowledge; (4) apply different learning strategies and using various computer applications in the implementation of science learning

For each statement, the respondent provides an appropriate response in the form of rating numbers 1 to 4 (integers) according to the

indicators in each aspect of the respondent's TPACK. The survey data were analyzed using a Likert scale based on the respondents' answers to the questionnaire. The total score of respondents (X) is then converted in percentage (P) according to equation 1 [18]. N is the maximum score.

$$P = \frac{\sum X}{N} \times 100\% \qquad (1)$$

From the survey questionnaire data obtained, it was then transformed into qualitative criteria as a way of interpreting the research results (Table 2).

Table 2. Interpretation criteria for survey results related to TPACK

Percentage Ranges	Criteria
20 – 40	Less Good
41 – 60	Quite good
61 – 80	Good
81 - 100	Very Good

RESULTS AND DISCUSSIONS

The results of TPACK for prospective science teachers are classically based on indicators in all aspects of TPACK shown in Figure 1. Based on Figure 1, the TPACK of prospective science teachers on average in all aspects is included in the fairly good category, namely in the percentage range of 50.41% - 57.27 %. The highest knowledge is obtained in the PCK aspect. So those respondents can be said to have prominent knowledge on choosing of approaches and learning strategies that are in accordance with the science material, making of lesson plans in advance, making easy of difficult science materials for students to understand, and creating of questions to measure students' understanding of science materials [19-20].

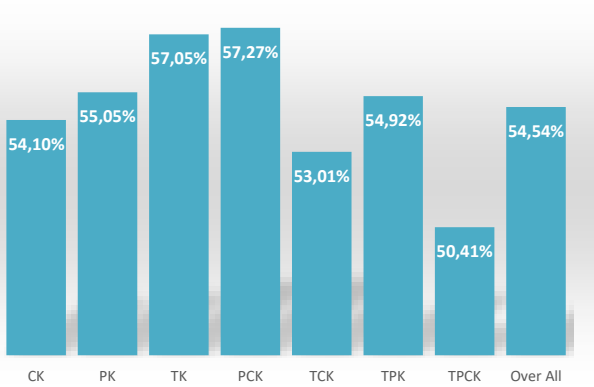

Figure 1. TPACK Result for all aspect.

In addition, the TPCK aspect gets the lowest percentage compared to other aspects. Furthermore, classical data is also displayed in the percentage of respondents on each TPACK criteria (see Figure 2). Based on Figure 2, the TPACK of pre-service science teachers is mostly quite good. There are no respondents who get the TPACK category very well. The results for each aspect will be explained separately.

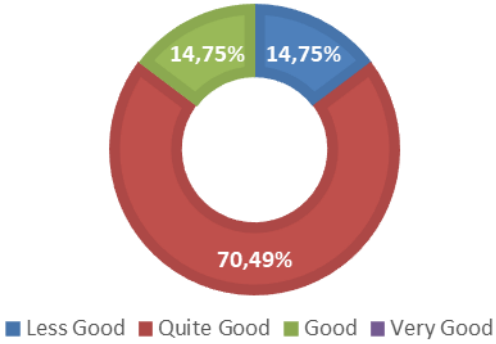

Figure 2. Distribution of respondents' TPACK percentages based on TPACK criteria

Content Knowledge (CK)

CK that must be mastered by science teachers include basic science concepts, science experiments, using science reference sources to increase literacy, and being active in science forums. The results of CK based on these indicators are shown in Figure 3. All indicators show quite good criteria. The highest percentage is on the indicator of active participation in science forums. The results of further analysis show that the era of ICT development allows pre-service science teachers to participate in many sciences forums such as seminars, workshops, and training because they are available online [21].

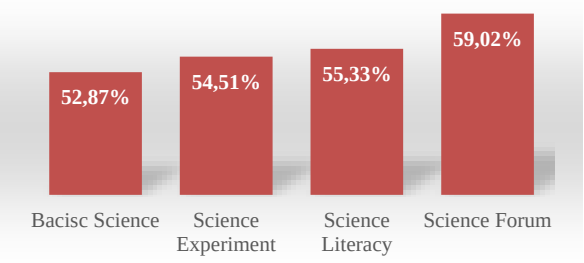

Figure 3. CK result of pre-service science teacher for each indicator

Pedagogical Knowledge (PK)

PK that must be mastered by science teachers include learning designs and strategies, assessment of learning, knowledge of misconceptions, classroom management, and

reflection on the quality of learning. PK results based on these indicators are shown in Figure 4. Design indicators and learning strategies get the highest percentage in the good category. The lowest percentage is in the classroom management indicator. This is reasonable because pre-service science teachers have not much experience in managing a real class [22].

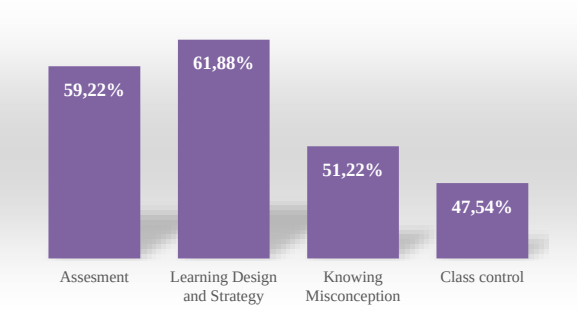

Figure 4. PK result of pre-service science teacher for each indicator

Technological Knowledge (TK)

TK that must be mastered by science teachers include computer technical problem, learning technology, update technological developments, basic components of a computer; word processing, number processing, presentation processing, standard hardware, storing data on digital media; internet as a medium of communication. PK results based on these indicators are shown in Figure 5.

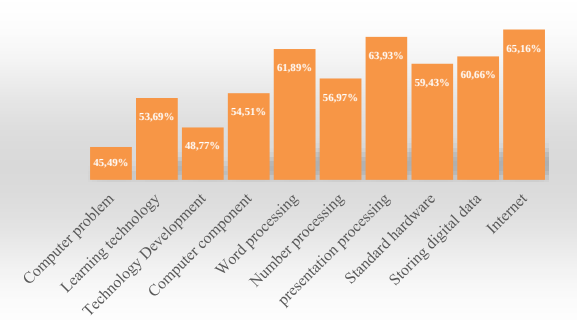

Figure 5. TK result of pre-service science teacher for each indicator

Indicators for word processing, presentation processing, and internet get the good criteria and the others are quite good. The internet indicator gets the highest percentage because respondents are included in the digital native generation, namely the generation that lives in the digital era where the internet is part of their daily life [23].

Pedagogical Content Knowledge (PCK)

The indicators of PCK are learning strategies and approach for science material; lesson plan of science material; makes student easy to understand science material, questions to measure students' understanding of science material. PCK results based on these indicators are shown in Figure 6. Indicator for science lesson plan gets the good criteria and the others are quite good. Based on further analysis, it was found that pre-service science teachers gained knowledge about lesson plans for various courses so that their knowledge results were in the highest aspect.

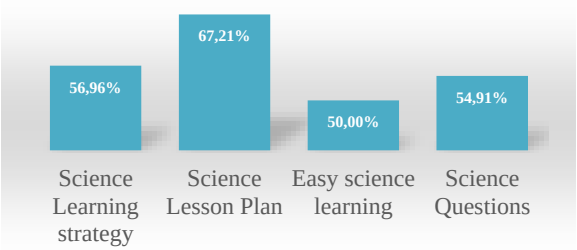

Figure 6. PCK result of pre-service science teacher for each indicator

Technological Content Knowledge (TCK)

The indicators of TCK are technology to help understand science; computer applications related to technology; student activities and assignments that is using technology. Figure 7 shows the results of respondents' TCK for each indicator.

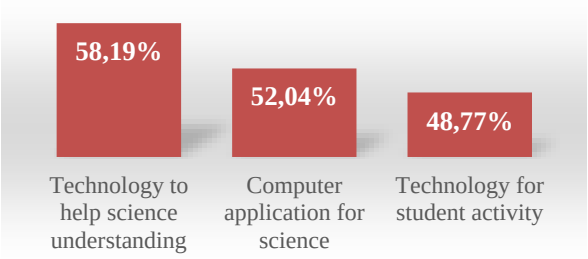

Figure 7. TCK result of pre-service science teacher for each indicator

All indicators show quite good criteria. Pre-service science teachers already quite understand the importance of using technology in science learning, especially in the current pandemic era [24]. They have usually used technology for assignments to students such as Quizizz, Kahoot, and others [25].

Technological Pedagogical Knowledge (TPK)

TPK that must be mastered by science teachers include computer applications in learning, technology for the learning strategy and approach,

internet facilities for communication with students. TPK results based on these indicators are shown in Figure 8. All indicators show quite good criteria. The indicator of technology for the learning strategy and approach obtained the highest percentage.

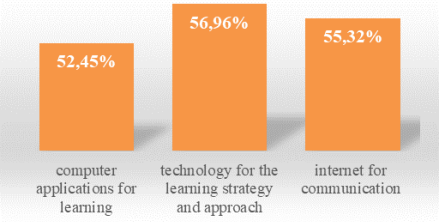

Figure 8. TPK result of pre-service science teacher for each indicator

Technological Pedagogical Content Knowledge (TPACK)

The indicators of TPCK are learning strategies and technology for teaching science materials; integration of TK, PK, and TK for learning, peer assistance for CK, PK, and TK integration; various computer applications in the implementation of science learning. Figure 9 shows the results of respondents' TPCK for each indicator. All indicators show quite good criteria. Pre-service science teachers already quite understand the importance of using learning strategy and technology in science learning [25].

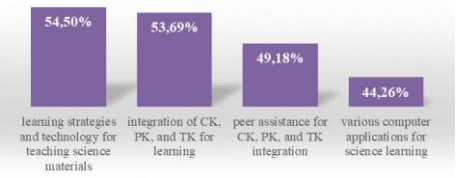

Figure 9. TPCK result of pre-service science teacher for each indicator

CONCLUSION

The results of the pre-service science teacher TPACK analysis overall obtained a quite good category with the details of the distribution being 14.75% less good, 70.43% quite good, and 14.75% good. So there are still a few students who get good criteria, and none even get very good criteria. The PCK aspect got the highest score with a score percentage of 57.27% and the TPACK aspect got the lowest score with a score percentage of 50.41%. These results indicate that the TPACK of pre-service science teachers still needs to be improved so that in the future it will equip them as science teachers who support 21st century learning.

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