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Eurasian Society of Educational Research

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INFORMATION

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How to publish in this journal

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SCOPE

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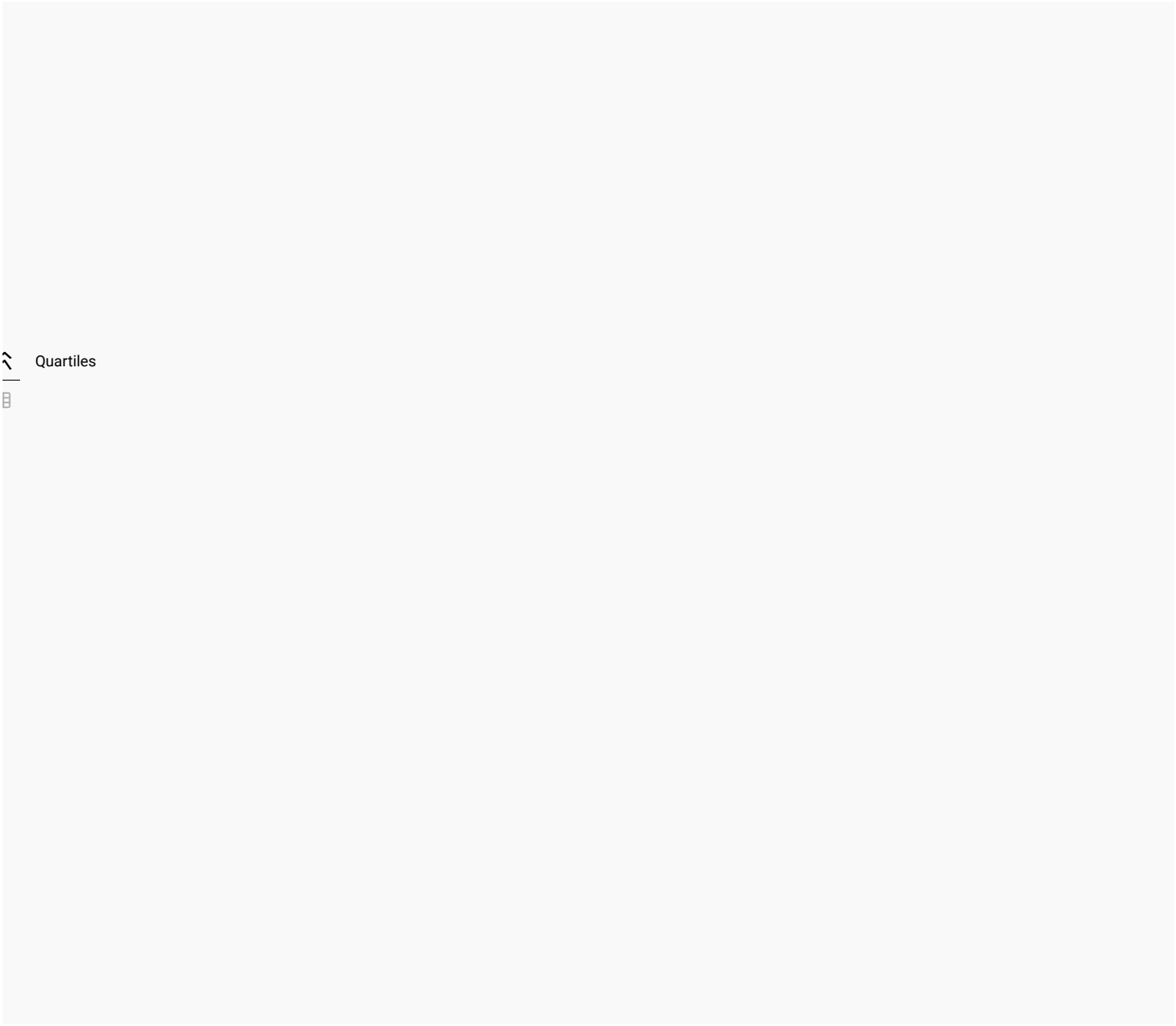

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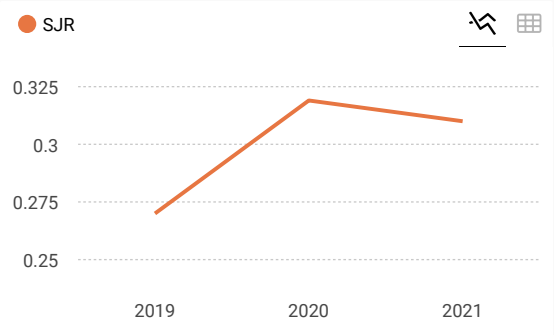

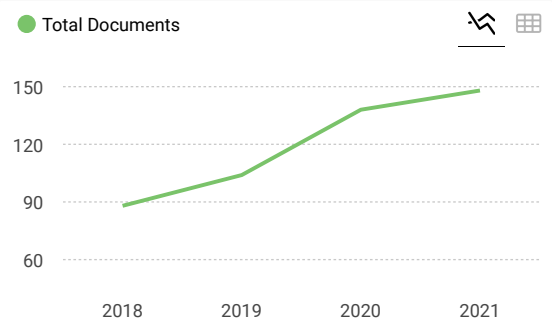

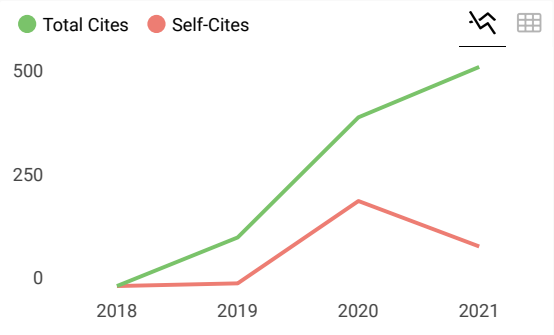

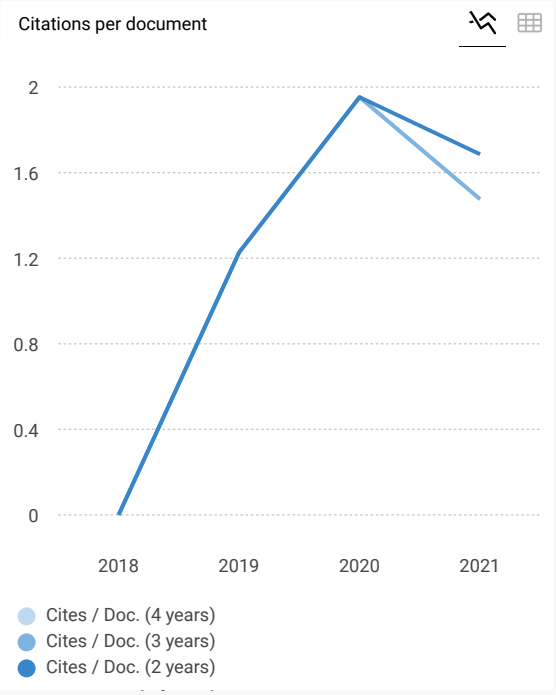

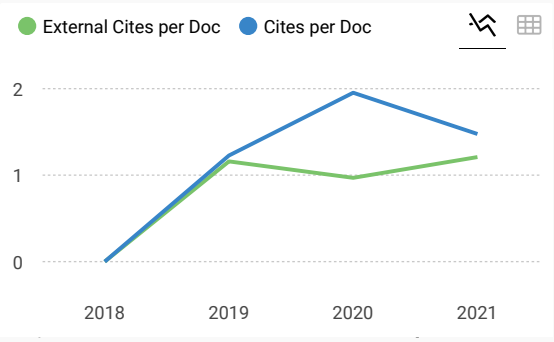

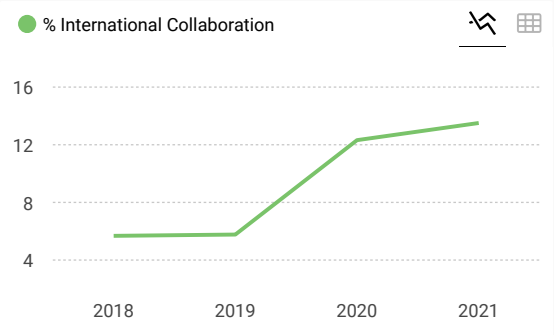

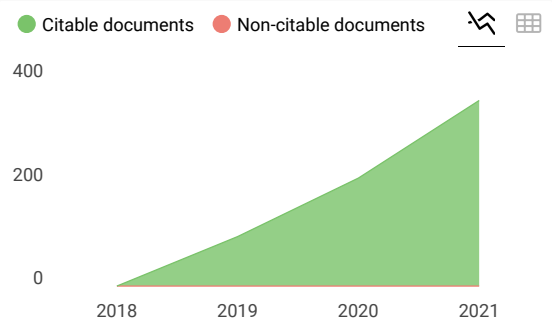

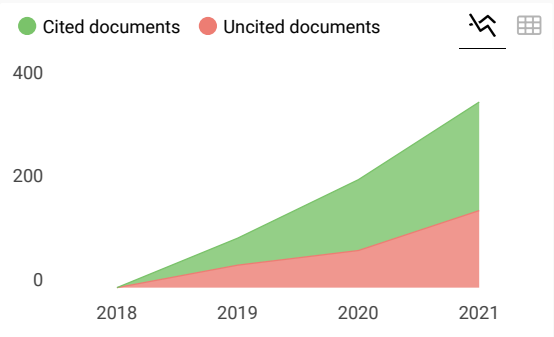

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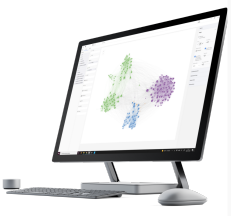

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R **Ratri** 4 months ago

Is the European Journal of Educational Research (Eu-jer) still in Quartile 3?
On Scimagojr and Eu-jer's web page it still says Q3.
Is there no Quartile update from Eu-jer because if I check the site score rank on web Scopus, Eu-jer's percentile has reached 65th (including Q2).
We ask the Scimago team to be able to update the Eu-jer quartile journal.

reply

SCImago Team

Melanie Ortiz 4 months ago

Dear Ratri,
Thank you for contacting us. Our data come from Scopus, they annually send us an update of the data. This update is sent to us around April / May every year. The SJR for 2021 was released on 11 May 2022. Therefore, the indicators for 2022 will be available in May/June 2023 and before that date we can´t know what will happen with this journal.
Best Regards, SCImago Team

S **SUKAINAH HASAN SALEH** 8 months ago

How long does it take to review a paper in the journal for acceptance or rejection?

reply

SCImago Team

Melanie Ortiz 7 months ago

Dear Sukainah,
Thank you for contacting us.
We suggest you visit the journal's homepage or contact the journal's editorial staff , so they could inform you more deeply.

Best Regards, SCImago Team

P **Puji** 8 months ago

May I submit article about Biology education?

reply

SCImago Team

Melanie Ortiz 8 months ago

Dear Puji, thank you very much for your comment, we suggest you look for the author's instructions/submission guidelines in the journal's website. Best Regards, SCImago Team

A **Ambica Vishwakarma** 1 year ago

What is acceptance rate?

reply

SCImago Team

Melanie Ortiz 1 year ago

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I **iness** 2 years ago

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reply

SCImago Team

Melanie Ortiz 2 years ago

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Best Regards, SCImago Team

W **wid** 3 years ago

Dear Scimagojr Teamn,

Many rumors says that this journal become predatory now. is that true? I am interest to publish my paper here, but im confused with the rumors. thank you in advance

reply

SCImago Team

Melanie Ortiz 3 years ago

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Best regards, SCImago Team

N **Nirmal Dhungana** 3 years ago

Hello this is me Nirmal Dhungana from Nepal
I want to publish my article in this Journal. Please provide the necessary information for me.

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SCImago Team

Melanie Ortiz 3 years ago

Dear Nirmal, thank you very much for your comment, we suggest you look for author's instructions/submission guidelines in the journal's website. Best Regards, SCImago Team

Dorji S 3 years ago

What is the process for publishing papers in this journal?

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SCImago Team

Melanie Ortiz 3 years ago

Dear Dorji, thank you very much for your comment, we suggest you look for author's instructions/submission guidelines in the journal's website. Best Regards, SCImago Team

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The Mastery of Technological, Pedagogical, and Content Knowledge among Indonesian Biology Teachers

Paidi* Yogyakarta State University, INDONESIA
Bambang Subali Yogyakarta State University, INDONESIA
Luisa Diana Handoyo Sanata Dharma University, INDONESIA

Received: December 6, 2020 ▪ Revised: February 18, 2021 ▪ Accepted: April 17, 2021

Abstract: The mastery of Technological Pedagogical Content Knowledge (TPACK) is very important for teachers in order to achieve qualified learning. Analyzing the mastery of TPACK by teachers in Indonesia seems to be imperative to provide baseline data to Indonesian government. This study aimed to examine the mastery of TPACK, in particular among biology teachers in terms of their teacher certification status, educational level, and academic background. This research involved 68 biology teachers obtained through proportional random sampling in five districts of Yogyakarta Special Region, Indonesia. The data collection was conducted through a multiple-choice test consisting of 33 items. The results showed that although the teacher's mastery of TPACK was categorized as fair (60.13), it does not meet the work performance standards as a good teacher in Indonesia which has a minimum score of 76.00. Using Mann Whitney U and Kruskal Wallis Tests ($p < 0.05$), the evidence revealed that the mastery of TPACK among biology teachers is likely influenced by the academic background, educational level, and teacher certification status.

Keywords: *Biology teachers, Indonesia, TPACK mastery.*

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Introduction

In an educational context, Information and Communication Technology (ICT) has become a foundation in improving the performance and learning outcomes of students. The integration of technology in the classroom is undoubtedly an important aspect in the success of teaching (Almekhlafi & Almeqdadi, 2010). The advancement of ICT influences the teaching method by refining traditional learning (Lee, 2009), such as the use of student-centered learning method such as problem-based learning and project-based learning which allow students to learn how to collaborate (Rotherham & Willingham, 2009). ICT-based learning enables students to transfer their skills in a different context, reflect on their thinking, train to cope with their misunderstandings, and collaborate with their peers (Saavedra & Opfer, 2012).

The 21st century learning has been directed to have more student involvement in collaborative work and real-world problem-solving using effective ICT (Koh et al., 2016). ICT-based learning is founded on the use of computer technology as the media to create interaction and build student motivation in learning. The media can be in the form of offline animation projected through LCD or website-based online learning (e-learning). Various technological devices, both hardware and software, are beneficial in making the teaching-learning process more interesting. The use of technology might affect students' learning, as well as improve the education product and process (Bhakta & Dutta, 2016; Kriek & Coetzee, 2016). Also, as stated by Flogie et al., (2018) and Lazarević et al., (2018), the use of ICT in biology class can improve student's learning achievement.

ICT-based learning not only demands teachers to adapt ICT, but also even more importantly, how teachers create a learning model with their own creativity and innovation. To create a modern e-learning, teachers must fulfill the three strategies, namely a well-structured learning content with organized meta-data system, inclusion of cognitive, affective and psychomotor domains of learning, as well as to develop instructional design for each learning course according to their specifications (Opara, 2014). Teachers are one of the most important factors in education. They are the students' role models, and thus their figure has a great impact in affecting the students' academic achievements, personality

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developments, and attitudes toward science and nature. Teachers also have a significant impact on influencing students' opinions and perspectives on science, especially biology (Dikmenli & Cardak, 2018).

The biology learning materials are not only concerned with scientific facts on concrete natural phenomena, but also abstract things or objects, such as chemical metabolism inside the body, hormone system, coordination system, etc. Therefore, the subject matters of biology require certain procedures and methods to study. The materials studied in biology are also varied, for example in terms of size, (macroscopic, microscopic), distance (polar ecosystem, desert, tundra, etc.), health (pathological bacteria/virus), and language (the use of Latin in scientific name) (Sudarisman, 2015). Therefore, teachers must use the appropriate technology (learning media) to support the biology learning process. The use of technology in learning will allow students to understand abstract biology materials. The use of ICT in learning will help students in understanding the concepts easily (Raja & Nagasubramani, 2018).

In relation to this, professional and competent teachers are required to possess pedagogical and didactic knowledge on the subjects relevant to the professional practices in the digital era. Therefore, teachers must be able to master and integrate ICT into learning, starting from the planning, organization, implementation, and evaluation of the teaching in order to support the students' learning and development (Kelentrić et al., 2017). Teachers need to learn how to use ICT to help students to learn the 21st-century competencies (Lambert & Cuper, 2008). They need to understand how ICT and pedagogy interact to facilitate the 21st-century competency development to their students (Voogt et al., 2013). Although the government has organized various ICT training for teachers, they are often about how to use the hardware and software, and not on what, why, and how the technology can be used in the teaching-learning process (Bosco & Gil, 2016).

The importance of mastering ICT knowledge for teachers prompts Mishra and Koehler (2006) to develop Shulman's PCK framework (1986). Technological Pedagogical Content Knowledge (TPACK) is the integration between ICT, pedagogy, and content applied in accordance with the context in the learning process (Koehler & Mishra, 2009). According to Suryawati et al., (2014), TPACK is the integration between technological, pedagogical, and content knowledge that a teacher must master. The framework of TPACK consisting of the new three knowledge with the technological elements, namely Technological Knowledge (TK), Technological Content Knowledge (TCK), and Technological Pedagogical Knowledge (TPK) (Mishra & Koehler, 2006).

TPACK is important for teachers because it affects the way they deliver learning materials. The mastery of TPACK in the learning process can improve the students' learning achievements. This is in accordance with a study by Irmita and Atun (2018) who found that the implementation of TPACK approach in learning has a significant impact on the students' science literacy and social skills.

TPACK is defined as an understanding on how technology can be used creatively to fulfill pedagogical needs in delivering certain subjects (Chai et al., 2013; Koehler et al., 2013; Mishra & Koehler, 2006; Niess, 2014; Schmidt et al., 2009). Niess (2014) points out that TPACK details teacher's knowledge in designing and applying the curriculum, as well as assisting students to think and learn using digital technology.

The development of the TPACK framework has intrigued many researchers to explain how teachers integrate ICT into learning. The latest research shows that there is a significant relationship between the teacher's TPACK mastery and confidence in technological, pedagogical, and content knowledge (Kola & Sunday, 2015; Lee & Tsai, 2010). Another study explains that the TPACK framework helps teacher's self-efficacy in integrating technology in classroom learning effectively, as well as teacher's professional and competency development in integrating technology (Boschman et al., 2015; Doering et al., 2009; Heitink et al., 2016; Koh et al., 2016; Saudelli & Ciampa, 2014; Yeh et al., 2014).

Although there have been many evaluations on teacher's TPACK mastery, they mostly use data generated from survey-based research instrument. In fact, TPACK's mastery will be more accurate if a test is used as the research instrument. There are also still many variables that have not been covered in the evaluation of teacher's TPACK mastery, such as teacher's background (i.e. certification status, educational level, and academic background). Up until now, the only teacher evaluation conducted by the Indonesian government is the *UKG* (Teacher Competency Test).

According to the data by the Ministry of Education and Culture of the Republic of Indonesia, Yogyakarta Special Region is the province with the highest score of *UKG* in 2015, with an average score of 62.58, while the national average score was 53.02 (Nugroho, 2015). It must be noted that the pedagogical and content knowledge are still dominant in the test material. In fact, the Yogyakarta teacher's score achievement for the *UKG* particularly shows that most teachers have above average score for content and pedagogical knowledge of 76.00. Therefore, there needs to be a measurement for other knowledge to develop quality learning such as ICT knowledge.

The results of this study provide information on mastery abilities of PK, CK, TK, PCK, TCK, TPK, and TPCK of the biology teachers so that they can be used to improve learning quality. In addition, the results of the study can also provide consideration in determining education policies, related to the type of material, learning experience, or abilities that need to be developed in the curriculum, as well as methods and technologies of education and learning that should be accommodated in the implementation of education.

Methodology

This study was a descriptive-quantitative research aimed to investigate, analyze, and describe the phenomenon of teachers TPACK mastery in an area in relation to some variables. This research was conducted in the Special Region of Yogyakarta, which is the best region of Indonesia in education. The aim of this study was to analyze the mastery of TPACK among biology teachers by looking at several psychometric variables including teacher academic background, education level, and teacher certification status. Biology was chosen as the focus of research, because it is one of the fields that have an influence on the development of civilization and various innovations today. Thus, information on the profile of mastery of the TPACK by high school biology teachers in Yogyakarta was urgent, because it would be able to provide referred information for biology learning in other regions in Indonesia.

Description of the Sample

This research involved 68 biology teachers that were obtained through proportional random sampling of around 173 biology teachers spread across 69 Public Senior High Schools in 5 regencies or districts of the Yogyakarta Special Region. The sample size of 68 biology teachers is considered to have a good effect size. In this study, the criteria for significance were $p < 0.05$, two-sided, and with power $(1-\beta)$ of 0.80. According to the calculation of Cohen (1988) with the criteria of the significance of 0.05, two-tailed, and a power of 0.8, a minimum random sample size of 64 subjects is required. Of the 68 biology teachers, a number of 53 teachers were certified and 15 teachers were uncertified. Based on the educational level variable, 12 teachers were Master's graduates and 56 teachers were Bachelor's graduates. Based on the academic background, 53 teachers came from biology education department, 10 teachers from the biology department, and 5 teachers came from other departments (e.g. agriculture, social sciences).

Measuring Instrument

This descriptive research accommodated quantitative testing method. The instrument used in the research was a test. The test instrument consisted of 33 multiple choice questions. The test instruments included 7 TPACK components whose framework was developed by Mishra and Koehler (2006), namely components of PK (Padagogical Knowledge), CK (Content Knowledge), TK (Technological Knowledge), PCK (Pedagogical Content Knowledge), TCK (Technological Content Knowledge), TPK (Technological Content Knowledge), and TPCK (Technological Pedagogical Content Knowledge). The TPACK mastery instrument consisted of 14 indicators and 33 measurement items. The value of empirical validity and reliability of the instrument used previously had been identified so that it was valid and reliable to use. The in-fit value of the MNSQ test is 1.00 with a standard deviation of 0.16, while the reliability value of the multiple-choice test items is 0.57. Measurement indicators of the TPACK mastery by the biology teacher are presented in Table 1.

Table 1. Measurement indicators of TPACK mastery of biology teachers

TPACK Components	Measurement Indicators
PK	a. Teacher's understanding of the students' characters b. Teacher's understanding of learning theories c. Teacher's understanding of learning models d. Teacher understanding of learning plans
CK	Teacher's understanding of various biology materials
TK	Teacher's understanding of technology, including ICT, i.e. search engine and various websites
PCK	a. Teacher's understanding of how to adapt materials based on learning media b. Teacher's understanding of how to adapt materials based on the approaches, models, and learning methods c. Teacher's understanding of how to adapt materials based on the students' characteristics d. Teacher's understanding of how to adapt materials based on the learning model e. Teacher's understanding of how to adapt materials based on the assessment
TCK	Teacher's understanding of how to adapt materials based on the ICT facilities
TPK	Teacher's understanding of how to adapt materials based on learning methods and media
TPCK	Teacher's understanding of how to adapt ICT, materials, approaches, models, methods, and learning media based on the students' characteristics

The data obtained were then analyzed descriptively and inferentially. The descriptive analysis was done by converting scores on each TPACK component into percent, using the formula:

$$\text{Score} = \frac{\text{Obtained score}}{\text{Maximum score}} \times 100$$

The score obtained was then categorized to find out how the biology teacher's TPACK mastery was. The criteria used were proposed by Arikunto (2011) which can be seen in Table 2.

Table 2. Criteria of teacher's TPACK mastery

Score	Criteria
84 % – 100	Excellent
68 % – 83	Good
52 % – 67	Fair
36 % – 51	Poor
≤35	Very poor

The inferential analysis used the Mann Whitney-U and Kruskal Wallis Tests after it was known that one of the requirements for the parametric tests, namely the normality of the data distribution, was not fulfilled. These tests were chosen to test the differences in biology teacher's TPACK mastery based on certification status, academic level, and academic background. If the probability of significance (p) value is smaller than 0.05 ($p<0.05$), it indicates there was significant differences in biology teacher's TPACK mastery on several variables accommodated. For the data analysis, the SPSS version 22.0 and JASP were used as a tool for analysis.

Results

The measurement of teacher's TPACK mastery was done per component of the TPACK namely PK, CK, TK, PCK, TCK, TPK, and TPCK. The data on the general profile of the teacher's TPACK mastery could be seen in Table 3 below.

Table 3. A General profile of the TPACK mastery of biology teachers in Yogyakarta special region

TPACK Component	Min.	Max.	Mean	SD	Criteria
PK	16.67	100	72.06	17.14	Good
CK	50	100	75	11.78	Good
TK	0	100	51.47	25.14	Poor
PCK	16.67	100	54.9	18.45	Fair
TCK	0	80	53.82	17.71	Fair
TPK	40	100	62.94	17.02	Fair
TPCK	0	100	50.74	23.65	Poor
Average	17.62	97.14	60.13	18.7	**Fair**

Min.: minimum; Max.: maximum; SD: Standard Deviation

Biology teachers have mastered PK and CK well, but the TK of the teachers was found to be in the Poor category. This showed that teachers lack the mastery of ICT basic knowledge. The low mastery of ICT knowledge could be seen in other TPACK components involving technological elements (T), namely TCK, TPK, and TPCK. In this component, the score obtained still had not reached a *Good* category, especially in the TPCK component of teachers who were in the *Poor* category. Nonetheless, the average TPACK mastery of the teachers was in the *Fair* category with a score of 60.13.

The teacher's TPACK mastery was also differentiated based on teacher certification status (TCS). The sample was divided into two groups, namely certified and uncertified teacher. Furthermore, this data were analyzed using the Independent-Samples Mann-Whitney U Test, to test the Null Hypothesis: The distribution of a component of TPACK is the same across categories of TCS. The results of the analysis are presented in Table 4.

Table 4. Hypothesis test summary of the biology teacher's TPACK mastery based on the teacher certification status

Component of TPACK	Mean Rank on categories of TCS		Sig.	Decision
	Certified Teacher	Uncertified Teacher		
PK	35.80	34.13	.762	Retain the null hypothesis.
CK	34.88	33.17	.758	Retain the null hypothesis.
TK	31.69	44.43	.021	Reject the null hypothesis.
PCK	37.33	24.50	.021	Reject the null hypothesis.
TCK	34.49	34.53	.994	Retain the null hypothesis.
TPK	33.33	38.63	.329	Retain the null hypothesis.
TPCK	34.93	32.97	.720	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Table 4 shows that teachers who are certified had a higher level in the mastery of the PK, CK, PCK, and TPCK components. However, the teachers who are uncertified were better at mastering the components of TK, TCK, and TPK than the certified teachers. The Mann Whitney U Test results showed that there was only significant difference in the TK and PCK components between certified and non-certified teachers ($p<0.05$). It showed that, although there was a tendency that the certified teachers were better in most of the components of the TPACK compared to those uncertified teachers, it was only on the PCK components that the certified teachers were actually better than the uncertified teachers. and unfortunately, the certified teachers' mastery of TPACK is significantly lower than that of uncertified teachers in the TK component.

Further analysis was carried out on teacher's TPACK mastery based on the differences in the teacher educational level. The sample was grouped into two, namely teachers with Bachelor and teachers with a Master degree. Furthermore, this data were analyzed using the Independent Samples Mann-Whitney U Test, to test the Null Hypothesis: *The distribution of a component of TPACK is the same across categories of the education level*. The results of the analysis can be seen in Table 5 below.

Table 5. Hypothesis test summary of the biology teacher's TPACK mastery based on the educational level

Component of TPACK	Mean Rank on categories of Education Level		Sig.	Decision
	Bachelor	Master		
PK	34.82	32.00	.762	Retain the null hypothesis.
CK	35.42	30.21	.389	Retain the null hypothesis.
TK	33.75	38.00	.478	Retain the null hypothesis.
PCK	34.16	36.08	.751	Retain the null hypothesis.
TCK	34.10	36.38	.700	Retain the null hypothesis.
TPK	32.14	45.50	.024	Reject the null hypothesis.
TPCK	34.04	36.67	.659	Retain the null hypothesis.

Table 5 shows that the education level of the biology teachers affected the mastery of TPACK in almost all components of TPACK. It was clearly seen that teachers with master's degrees tend to be more knowledgeable about PK, CK, TK, PCK, TPK, and TPCK components than teachers with bachelor's degrees. However, after being analyzed inferentially using the Mann Whitney U test, a significant difference was found only in the TPK component, with $p<0.05$. Teachers with master's degrees have mean rank scores on the TPK component of 45.50 which is much higher than teachers with bachelor's degrees (with a score of 32.14). It indicated that the mastery of TPACK, especially in the basic knowledge of technology component, was likely influenced by the level of teacher education.

If then analyzed based on the academic background variable, the mastery of TPACK by the biology teachers showed other interesting results. The teacher's academic background was classified into three groups according to the academic background, namely biology education, biology, and other study programs, i.e., agriculture and social sciences, except biology education and biology. Furthermore, this data were analyzed using Kruskal Wallis test, to test the Null Hypothesis: *The distribution of a component of TPACK is the same across categories of the academic background*. The results of the analysis are presented in Table 6 below.

Table 6. Hypothesis test summary of the TPACK mastery based on teacher's academic background

Component of TPACK	Mean Rank on categories of Academic Background			Sig.	Decision
	Biology Education	Biology	Other(s)		
PK	42.55	13.25	34.58	.003	Reject the null hypothesis.
CK	34.26	40.20	23.50	.325	Retain the null hypothesis.
TK	36.04	31.70	20.75	.261	Retain the null hypothesis.
PCK	35.96	26.65	34.38	.365	Retain the null hypothesis.
TCK	34.58	42.55	13.25	.029	Reject the null hypothesis.
TPK	35.61	29.60	31.75	.614	Retain the null hypothesis.
TPCK	35.17	29.90	37.00	.692	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Table 6 shows that teachers with an academic background of biology education tend to have a better mastery of TPACK for most components of the TPACK. The ANOVA test showed that there was a significant difference only in the components of PK and TCK ($p<0.05$). In table 6 it was seen that biology teachers with an academic background of biology education had a better TPACK mastery of the PK component than those who have other academic backgrounds.

Likewise, for the TCK component, the biology teachers with an academic background in biology education are better at mastering TPACK than those who have other academic backgrounds.

Discussion

The results of this study (Table 3) indicate that the mastery of TPACK biology teachers in the TPACK components is in the *Fair* category, except for the basic components CK and PK which is categorized as Good. The basic component of TK and the combination component of TPCK also fall in the *Poor* category.

This means that in general, the teacher's ability to teach biology is inadequate. A good biology teacher should not only understand the contents of biological materials, teaching methods, and media separately but more than that, how to choose relevant methods and media so that students understand these biological contents more easily. This is in accordance with and confirms the results of the teacher's ability measurement through UKG (Nugroho, 2015), which states that the average teacher's ability to master subject matter and learning methods is still in a *Fair* category. This is also perhaps one of the causes of low quality of education in Indonesia, seen from various international assessment programs. The latest result of measurements by PISA in 2018 puts Indonesia in the bottom rank (Schleicher, 2018).

The results presented in Table 3 also show that the mastery of TPACK by biology teachers on the components of TK and TPCK are in *Poor* category which shows that the Science teachers lack mastery of TK and TPCK. This indicates that Science teachers lack the confidence of their technological knowledge as well as technology integration with learning content and pedagogics (Bas & Senturk, 2018; Jang & Tsai, 2013). The teacher's lack of confidence may be caused by their limited knowledge of technology (Balanskat et al., 2006). This influences teacher's decisions on the ICT integration in learning since they would be reluctant to integrate technology in learning if they do not master the knowledge about it.

The data in Table 4 show that the certified biology teachers have a tendency to excel in mastering of TPACK, on components of PK, CK, PCK, and TPCK. This excellent is clearer in the PCK component, where the certified teachers mastered it significantly better. On the other hand, there is a tendency that the certified teachers are weak in mastering TPACK on the TK, TCK, and TPK components, especially in the TK component, where the uncertified teachers mastered it significantly better than those of the certified teachers. This means that certified teachers tend to have deficit competency in the technological aspect.

It is understandable that the certified teachers, who are generally older or more senior than uncertified teachers, have better mastery of pedagogical aspects of TPACK. However, it is very interesting to analyse how the certified teachers have less mastery of the technological aspects of TPACK than the uncertified teachers.

The experience requirements of teachers to take part in the certification program as Harris and Hofer's (2011) research conclusions, proved to be more effective in mastering pedagogy, and not for other elements, namely subject matter knowledge (CK) and knowledge of technology. This is also in accordance to the research conducted by Schäffer (2007). Schäffer (2007) stated that it needs a different method between junior and senior age in literacy technology. A research conducted by Kurniawan (2011) also showed that there was no significant difference in the mastery of subject matter between teachers who have been certified and those who have not been certified while Widodo (2016) similarly found that most certified teachers had sufficient ability in opening lessons, but were poor in terms of using ICT in the lesson.

In Indonesia and in some countries, such as in United Stated, England, and Singapore, the teacher certification program is based on the requirement fulfillment in the form of teacher's experience, and completion of all institutional courses. It means that the certification candidate has taken specific education based on his/her field of study (Bautista et al., 2015; Harris & Hofer, 2011). A candidate for certification must first meet the specified certification requirements. Certification candidates must have attained a bachelor's degree, completed at least three full years of teaching or counseling before obtaining the degree, and have valid teaching or counseling certificate during the period (Elliott et al*.,* 2008). Furthermore, Frankhart (2018) explains that, in United State, certification must be taken by holding a bachelor's degree from regional favorite universities, with majors relevant to the field of teaching. Referring to the results of the research shown in Table 4, it means that the experience requirements for participating in the teacher certification program have proven effective in demanding a certified teacher to have a good mastery in PCK.

According to Lehane and Bertram (2015) and Shulman (1986), in biology education, PCK is described as an amalgamation between knowledge of content and pedagogy allowing for more effective teaching of a particular concept of biology. This means that PCK is interpreted as knowledge of the use of pedagogical principles for learning on various characteristics of subject matter. This pedagogical principle is related to the selection and use of learning strategies, methods media and other pedagogical methods based on the characteristics of the subject matter. The field of biology studies includes objects plants, animals, protists, fungi, and monera and studying them from the molecular, cellular, to biome levels (Engleman, 2001; Milani et al., 1987). The scope of those objects varies from micro meters to thousands of kilometers; from very small objects (invisible to the naked eyes) to very large objects. With the large diversity of living things different ways and tools are required to teach these materials to students. Not to mention, biology subject matter also covers a variety of problem themes, from diversity-unity, structure-function, genetics, and evolution.

Data in the Table 5 clearly shows that the education level of biology teachers tends to influence TPACK mastery. In almost all components of TPACK, teachers with a master's degree in biology education have better TPACK mastery scores compared to teachers who have a bachelor's level of education. Especially for the TPK component, teachers with a master's degree have significantly better TPACK abilities in the TPK aspect than teachers who have a bachelor's level of education. This means that additional formal education in form of master's programs can increase TPACK mastery. Increasing the ability of teachers with magister education in mastering TPACK can be understood because of the focus of education on master's programs in Indonesia as well as in other countries uses media and technology to make innovation in education.

According to the results shown in Table 5, teacher's TPACK mastery depends on their academic qualifications, namely the educational level. The analysis of TPACK mastery based on the teacher's educational level shows that teacher's TPK mastery differs significantly based on their educational level. The teachers having master's degrees obtained higher scores than the teachers with bachelor's degrees. These results are in accordance with the study by Cubos (2018) who showed that there were significant differences among teachers with bachelor's, master's, and doctoral degrees in terms of technological knowledge in which the highest score of mastery is possessed by the teachers with a doctoral degree. Meanwhile, the teachers having master's degree have the lowest score. This result indicates that the higher the level of education, the better TK mastery. APJII surveyed internet users in 2017 and the results showed that the percentage of internet users with master's or doctoral degrees was 88.24%, while 79.23% of the internet users had bachelor's degree, 70.54% of them were high school graduates, 25.1% of them were elementary school graduates, and 5.45% of them had no degree (Anonim, 2017). The survey concluded that people with a higher level of education use technology more frequently.

Although on almost all components of TPACK, teachers with a master's degree in biology education have better TPACK mastery compared to teachers who have a bachelor's, significant difference was found only on the component of TPK between the two groups. This result is a little different from Khine's study (2015), which explains that the educational level is one of the factors that are related to TPACK mastery. Overall, Khine (2015) concluded that the higher the level of teacher education, the higher the TPACK mastery. It is shown that the TPACK mastery score for teachers with a master's degree has an overall better result. Another study conducted by Cubos (2018) reveals that there are significant differences regarding science knowledge (CK), PK, TPK, and TPCK based on someone's educational level. It was found that doctoral graduates had the highest scores followed by master's degree graduates, and the bachelor graduates received the lowest score except for TPCK component. However, the TCK component does not differ based on the level of education even though, on average, doctoral degree graduates obtained higher scores than the master's and bachelor's degree graduates.

The excellence of master-educated teachers in mastering TPACK, especially in the component of TPK can be understood. Analysis on results of several educational master program curriculums showed that one of the focuses of education was on increasing the understanding of master's students in the field of ICT, at least so that they are able to develop ICT that is beneficial and prohibits harm (Organisation for Economic Co-operation and Development [OECD], 2016). Through this education, the students undertaking a master's degree also need to be equipped with competencies in the field of ICT for their own professional development.

Research results shown in Table 6 indicate that academic background tends to influence the mastery of TPACK, especially in the PK and TCK components. Biology teachers with an academic background in biology education were able to master TPACK better in almost all of TPACK components with pedagogical aspects, especially PK and PCK. On the other hand, Biology teachers with an academic background in biology were able to master TPACK better in almost all of TPACK components with content (biology) aspect specifically in the TCK and CK components.

The excellence in mastering TPACK shown by biology teachers who have a background in biology education (Table 6) shows that an academic background of biology education has prepared a prospective biology teacher to become a better teacher. but still faces a weak point in the mastery of biological material. Weaknesses in the mastery of content/biology. This is in accordance with the results of the Indonesian teacher's ability measurement through UKG (Nugroho, 2015), which states that the average teacher's ability to master the subject matter and learning methods is still in a Fair category. This result may be contributed by biology teachers who have a background in biology education. Chavan (2016) also found the lack of optimism for biology teachers with a background in biology education through his research on a number of science teachers in Kolhapur City, India. Chavan (2016) found that science teachers have difficulties with Comprehension of Biology Concepts. This difficulty is assumed by the teacher to be lacking in conducting a content analysis of the biology textbook.

A similar thing was also found by Kolbe and Jorgenson (2018) and the University of Vermont research team (2018) that teachers who were most likely to use inquiry-based teaching were those with both education and science degrees, and teachers with graduate-level degrees in science were most likely to teach this way. This means that to become a good biology teacher, it is not enough to master pedagogical knowledge, but also content/biology. Biology teachers who have a background in biology education may be less proficient in biology because, during college, the intensity of learning

biology knowledge was less because at the same time they had to study pedagogical knowledge and its application, doe to the curriculum.

Conclusion

In sum, the mean scores of the biology teachers in this research showed that they have not mastered TPACK and does not meet the standard of performance as a good teacher in the country where they resided, Indonesia, especially on component of technological knowledge and its combinations. The results of the analysis showed that TPACK mastery of biology teachers is likely influenced by teacher certification status, educational level, and teacher's academic background, even though it only affects several components of the TPACK.

The certified teachers showed better mastery of TPACK, however a significant difference was only observed on components PK and PCK. Related to variable of educational level, the biology teachers who have a master's degree tend to be better in mastering the TPACK on almost of components of the TPACK, although a significant difference was only seen on TK components. Related to academic background, overall, biology teachers who were graduated from biology education have a better mastery of the TPACK than teachers who were graduated from biology and other academic backgrounds. However, biology teachers who had degree from biology education showed lower mastering of TPACK on the component of subject matter and technological knowledge. This means it is necessary to increase the mastery of TPACK comprehensively, both basic components and combinations between components of the TPACK, especially components of technological knowledge.

The teacher certification program in the country needs to be continued by strengthening TPACK mastery, especially on the content and technological knowledge components. Providing additional educational programs, degree and non-degree, for the existing biology teachers is important and can be done by strengthening the mastery of technological knowledge for learning innovation. Formal education programs, such as the magister program, have proven to be very effective in increasing the mastery of teacher TPACK, especially in the technology components.

Recommendations

These conclusions are in particular directed to the government of Indonesia (or other similar countries) as policy makers in order to make the right policy in improving their mastery on the TPACK and in recruiting new teachers with the potential in mastering the TPACK. In recruitment programs for biology teachers, the policy makers need to pay attention to the academic background of the prospective teachers, by prioritizing those who have an academic background in biology education. Additionally, further research is needed to make confirmation for the conclusion. Further research is needed to examine other factors that might affect TPACK mastery among the teachers, such as by involving the factors of gender, age, and duration of teaching. It would be important as well that future research investigates the application of TPACK in the learning process on various students, biology topics, and schools.

Limitations

This research may be limited to the knowledge aspects of biology teachers which are: the biological/content knowledge (CK), pedagogical knowledge (PK), technological knowledge (TK), biology-related pedagogical knowledge (PCK), knowledge of biology-related technology (TCK), biology-related technological knowledge (TPK), as well as knowledge of TPACK principles. This research has not discussed the aspect of their implementation in a real class. The implementation of the TPACK principle in a real class will have an impact on the quality of student learning. Although it is known that theoretical knowledge contributes to practice/implementation in many fields, including in the field of education (Andrews et al., 2019; Pangalo et al., 2020; Zhuo, 2017). Therefore, research on the implementation of the TPACK principle in the classroom by biology teachers needs to be done.

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Authorship Contribution Statement

Paidi: Conceptualization and design, data acquisition, data analysis and interpretation, drafting manuscript. Subali: concept and design of research methodology and instrument. Handoyo: Drafting manuscript, critical revision of manuscript, editing/reviewing.

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