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Demographic factors affecting technological pedagogical content knowledge in Generation-Z preservice biology teachers

Ahmad Kamal Sudrajat[1,2], Ibrohim[1], Herawati Susilo[1]
[1]Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Malang, Indonesia
[2]Department of Biology Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Yogyakarta, Yogyakarta, Indonesia

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ABSTRACT

Generation-Z dominating preservice biology teachers in this era. Teachers' TPACK is influenced by factors such as demography. Technological, pedagogical and content knowledge (TPACK) is a framework used in teacher competence in Indonesia. This research will contribute to the training process of Generation-Z preservice biology teachers who have special characteristics. This study aims to determine the effect of demographic factors on the TPACK of Generation-Z preservice biology teachers. A total of 652 Generation Z preservice biology teachers from biggest ten Indonesian educational universities participated in this survey. The research results show that only gender has a relationship with TPACK in every aspect. Motivation to become a teacher influences TPACK, except for the technological knowledge (TK) aspect. In contrast, other aspects do not influence TPACK. Gender and motivation to become a teacher are factors that need attention in the training process for prospective biology teachers. Universities and the government can use these results to formulate suitable training programs for preservice biology teachers in Indonesia.

Corresponding Author:

Ibrohim
Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang
Cakrawala street no.5, Sumbersari, Lowokwaru, Malang, Indonesia
Email: ibrohim.fmipa@um.ac.id

1. INTRODUCTION

Technological, pedagogical and content knowledge (TPACK) is a framework for teacher competency in pre-service and in-service [1]. TPACK consists of several components as a professionalism framework: pedagogical knowledge (PK), content knowledge (CK), technological knowledge (TK), pedagogical content knowledge (PCK), technological pedagogical knowledge (TPK), technological content knowledge (TCK), and TPACK. TPACK includes three main interconnected components: technology, pedagogy, and content. TPACK is dynamic and follows rapidly changing technology, pedagogy, and subject matter developments [2]. TPACK is important to develop since teachers are in the preservice teacher stage [3]. Current teacher candidates are Generation-Z and have a high affinity for and accessibility to technology. However, they must be able to utilize their TK in a learning context [4].

The content aspect needs attention in TPACK. As part of science, biology has scientific characteristics such as problem-solving, hypothesis generation, scientific research, conducting experiments, evaluating evidence, and formulating conclusions [5]. Jang and Chen [6] explain that developing learning models for preservice science teachers requires different characteristics. Biology teachers need strong instructional strategies to teach abstract topics in science and technology. In addition, they need to replace conventional learning media with technology as part of TPACK and reflect it in their learning design. Teacher collaboration

as part of pedagogical competence also significantly influences the quality of learning conducted by teachers [7]. Although Moynihan *et al.* [8] do not classify teacher actions into specific competencies, they can serve as studies that list such comprehensible components in learning.

In science or biology learning, integrating technology into PCK has been initiated by several researchers [9]–[11]. In more detail, Kotzebue [9] analyzed and compared the internal relationship between the four dimensions of technology (TCK, TK, TPK, and TPACK) in the two instruments (self-report measure and performance assessment) and found evidence of whether the data supports an integrative or transformative view [9]. Research by Muhaimin *et al.* [12] examined TPACK on specific subjects and the perceptions of science teachers on technology integration related to TPACK. It showed that most teachers felt the benefits of using technology to improve the quality of their learning. Meanwhile, Thohir [13] also conducted a case study on three physics teachers and Rochintaniawati *et al.* [14] on three biology teachers from the two studies and showed that technology integration in learning needs to pay attention to a specific subject (for example, specific for science, language learning, and social studies).

This study aimed to identify the effect of demographic factors on the TPACK of Generation Z preservice teachers on specific biology content. This research is important so that preservice teacher training can be carried out more effectively by considering their demographic characteristics. The demographic factors studied were gender, year of study, motivation to become a teacher, and the hometowns of preservice teacher students. This aspect was chosen because it represents the condition of preservice teachers demographic factor. For example, the year of study is chosen not only because of sufficient knowledge, but also because it is related to their age. The motivation to become a biology teacher is also interesting to study because in Indonesia, the choice to take teacher candidate education is the last choice due to competition which is not too tight when selecting to enter university [15], [16]. In several conditions, motivation to be a teacher related to student's hometown, factors such as family, environment, and career opportunities in the area contribute to this relationship [17].

2. LITERATURE REVIEW

2.1. Technological, pedagogical and content knowledge in Generation-Z preservice teacher

Generation-Z has a high friendliness towards technology because they have used it since childhood [18]. However, being comfortable with technology does not necessarily translate into the ability to use it effectively in the teaching and learning process. TPACK helps prospective teachers bridge the gap between their general understanding of technology and the specific ways technology can improve teaching. The use of technology in learning can attract students' interest, visualize abstract material, make learning interactive, and others so that the quality of learning will increase [19], [20].

Generation-Z prospective teachers should be provided with examples and case studies that illustrate the effective use of technology in teaching and learning [21]. They must be able to design technology-rich lesson plans, integrate digital tools, and assess their impact on student learning. Generation-Z tends to be collaborative and connected through technology [22]. Teacher education programs can use this by promoting collaborative learning experiences where teacher candidates share their TPACK insights, strategies, and lesson plans [23], [24]. Prospective Generation-Z teachers must be able to critically evaluate technology use in the classroom. This condition includes considering issues such as accessibility, equity, and the impact of technology on diverse learners. In short, integrating TPACK into future Generation-Z teachers' education and professional development involves recognizing their familiarity with technology, providing targeted training on effective integration, and cultivating a mindset of continuous learning and adaptation to new technologies.

2.2. Factor affecting technological, pedagogical and content knowledge

Factors related to technology that can affect the effectiveness of teacher competency development can be influenced by demographic factors. Several studies show that the demographic factor of gender has an influence or relationship with TPACK [25]. Other demographic factors, such as teaching experience, also affect TPACK [26]. Other demographic factors such as year of study, student hometown, and motivation to become a teacher are infrequently studied. These factors play an essential role in the success of the preservice teacher education process. We still use gender in our research because the distribution of gender in the teaching profession, especially science teachers, tends to be uneven [27]. More females are interested in becoming a teacher than males [28]. Motivational factors are another important factor in the preservice teacher student training process. Motivation has a role in success, including in the training process [29]. However, studies regarding the influence of motivation on preservice teachers' TPACK are important to identify.

The teacher's TPACK may differ due to different student conditions and contexts of the subject [3]. Most studies have also recommended subject-matter-specific observations to explore the TPACK context in greater detail [30], [31]. TPACK must focus on specific subjects to create a better framework [32]. The study of TPACK for certain specific materials remains important because it can explain the barriers and potential use of specific technology for certain learning materials [2]. The lack of material specificity in TPACK allows for

the low validity of the TPACK measurement [33]. Referring to the importance of specific subject TPACK studies, this research focuses on the TPACK of preservice biology teachers.

3. METHOD

3.1. Research design

This study used a cross-sectional survey design [34], [35]. The cross-sectional survey aimed to measure the TPACK of preservice biology teacher students. The cross-sectional survey design was chosen because the sample obtained has good generalization, and the survey can be carried out quickly [36]. Several previous studies have also used cross-sectional surveys to measure the relationship between demographic factors and a person's knowledge or behavior [37], [38].

3.2. Participants

The participants in that study were preservice biology teachers in Indonesia. The study used random sampling, with respondents being preservice biology teacher students in their third or fourth year. Third- and fourth-year students were selected because they already had sufficient PK from the courses they had previously taken during their training. The survey included six hundred and fifty-two preservice biology teachers from Indonesia's ten oldest and biggest educational universities. The university was chosen because it had sufficient experience training preservice teachers and had the best accreditation in Indonesia. The survey was conducted in September-November 2022.

This survey's respondents were dominated by females, with 86% of the respondents being female. There are more third-year students than fourth-year students, at about 68%. The respondents mainly involved had the motivation to become teachers (65%), and they mostly came from rural areas (61%). In more detail, the demographics of the respondents involved in this survey can be seen in Table 1.

Table 1. Demographics of the respondent

Criteria	Group	Total	Percentage (%)
Gender	Male	92	14.11
	Female	560	85.89
Year of study	3rd year	442	67.79
	4th year	210	32.21
Motivate to be a teacher	Yes	430	65.95
	Maybe	174	26.69
	No	48	7.36
Domicile	Rural	396	60.74
	Urban	70	10.74
	Big city	186	28.52

3.3. Instrument and data collection

The instrument used in this research is a questionnaire. The questionnaire consists of two parts. The first part contains information about the demographics of the respondents, and the second part contains a survey to measure the TPACK of preservice biology teachers. The questionnaire developed in this research was adapted to the characteristics of biology subjects [39].

Before use, the questionnaire was translated into Indonesian by English language experts. The questionnaire aims to determine the demographic and TPACK of preservice biology teacher students. The questionnaire consists of 44 questions, six questions for TK, seven questions for CK, eight questions for PK, six questions for PCK, seven questions for TCK, five questions for TPK, and five questions for TPACK. Before use, we conducted validity and reliability tests. We tested the validity using the corrected item discrimination (r), while reliability used Cronbach's alpha (α). Cronbach's alpha was chosen because it is the best way to measure the reliability of an instrument. An instrument is reliable if it scores above 0.8 [40]. The results of the validity and reliability tests are shown in Table 2.

A valid questionnaire was then entered into the Google Form to be distributed to respondents. Researchers distributed questionnaires through coordinators at each university. Coordinators at each university then distributed the questionnaires to preservice biology teacher students. Biology teacher candidate students could disseminate the questionnaire information to other students. The time required to fill out the questionnaire was approximately 10 minutes. As an ethical consideration, preservice biology teacher students were free not to participate in that survey. The survey was conducted anonymously so that the researcher's subjectivity could be avoided, and the confidentiality of the respondent's data was maintained.

3.4. Data analysis

The researcher took data from Google Forms. Then, the researcher sorted and discarded data that was double and outside the specified criteria. Data analysis was performed using descriptive and inferential statistics. The descriptive analysis calculated the percentage and average of the data obtained. The inferential analysis used was the Mann-Whitney and Kruskal-Wallis tests. This test was chosen to determine the effect of demographic factors on the TPACK of preservice biology teachers. The Mann-Whitney test was used to determine the mean differences between the two groups of demographic factors (gender and year of study). The Kruskal-Wallis's test was used to determine the mean differences between the three groups of demographic factors (motivation to be a teacher and hometown).

Table 2. Summary result of validity and reliability test

Dimension	∑ item	Validity (r)	Reliability (α)
TK	6	0.75-0.79	0.87
PK	8	0.75-0.83	0.91
CK	7	0.76-0.86	0.91
PCK	6	0.83-0.87	0.92
TCK	7	0.74-0.87	0.92
TPK	5	0.76-0.85	0.88
TPACK	5	0.85-0.89	0.91

4. RESULTS

The results obtained indicate that there is an influence between gender and TPACK in each of its aspects. Years of study and hometown do not affect TPACK in all aspects. Meanwhile, the motivation to become a teacher has a TPACK effect on every aspect except the TK aspect. More details will be described.

4.1. The effect of gender on technological, pedagogical and content knowledge

Gender influences TPACK in every aspect. Gender influences all factors in TPACK. Male teacher candidates have a higher score of TPACK in every aspect than female teacher candidates. The highest score difference is in the TK aspect, and the lowest is in the TPACK aspect. Male have the highest score on the PK aspect and the lowest on the TCK aspect, while women have the highest score on the PK aspect and the lowest on the CK aspect. The results of the analysis of the influence of gender on TPACK are shown in Table 3.

Table 3. Results of analysis of the effect of gender on the TPACK of preservice biology teachers in each aspect

Variable		TK		PK		CK		PCK		TCK		TPK		TPACK	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Gender	Male	4.203	0.498	4.260	0.652	4.065	0.689	4.156	0.727	4.000	0.638	4.148	0.611	4.096	0.730
	Female	3.814	0.624	3.997	0.565	3.763	0.585	3.947	0.603	3.748	0.613	3.944	0.564	3.879	0.623
z score		-5.157		-4.617		-4.764		-3.703		-3.632		-3.548		-2.770	
Sig.		0.000		0.000		0.000		0.003		0.000		0.000		0.006	

4.2. The effect of year of study on technological, pedagogical and content knowledge

Based on the results of the analysis, the preservice teacher student's year of study does not have the influence of TPACK on every aspect. Third-year students score the highest on the PK aspect and the lowest on the CK aspect. Fourth-year preservice teacher students have the highest scores on the PK aspect while the lowest on the TCK aspect. The highest mean difference lies in the TK aspects, where third-year preservice teacher students have higher scores than fourth-year students. The results of the analysis of the effect of the year of study on TPACK are shown in Table 4.

Table 4. Results of analysis of the effect of year of study on the TPACK of preservice biology teachers in each aspect

Variable	TK		PK		CK		PCK		TCK		TPK		TPACK	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Year of study														
3rd year	3.886	0.612	4.028	0.583	3.800	0.609	3.979	0.626	3.805	0.626	3.985	0.570	3.926	0.634
4th year	3.835	0.644	4.047	0.588	3.817	0.611	3.972	0.629	3.738	0.614	3.949	0.585	3.874	0.661
z score	-1.096		-0.725		-0.883		-0.142		-1.044		-0.734		-0.938	
Sig.	0.273		0.468		0.377		0.887		0.296		0.463		0.348	

4.3. The effect of motivation to become a teacher on technological, pedagogical and content knowledge

Motivation to become a teacher influences the TPACK score of preservice biology teachers in every aspect except for the TK aspect. Students motivated to become teachers have higher TPACK scores on each influential aspect. The PK aspect has the highest score for motivated preservice teacher students to become teachers. In the TK aspect that had no effect, both students who were motivated to become teachers, who were not motivated, and who were doubtful had almost identical scores. However, preservice teacher students who are motivated to become teachers have higher scores. The results of the analysis of the influence of motivation to become a teacher on the TPACK score are shown in Table 5.

Table 5. Results of analysis of the effect of motivation to become a teacher on the TPACK of preservice biology teachers in each aspect

Variable	TK		PK		CK		PCK		TCK		TPK		TPACK	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Motivation to be teacher														
Yes	3.885	0.607	4.110	0.539	3.882	0.610	4.043	0.609	3.852	0.604	4.026	0.546	3.979	0.620
Maybe	3.826	0.654	3.940	0.617	3.678	0.589	3.891	0.618	3.649	0.606	3.908	0.569	3.839	0.626
No	3.883	0.649	3.695	0.692	3.589	0.550	3.688	0.700	3.655	0.749	3.733	0.753	3.542	0.753
Kruskal-Wallis H	0.331		20.709		21.147		14.289		14.305		9.419		19.564	
Sig.	0.848		0.000		0.000		0.001		0.001		0.009		0.000	

4.4. The effect of student's hometown on technological, pedagogical and content knowledge

Based on the analysis results, there is no influence between preservice teacher student origin domicile on the TPACK of preservice biology teachers. Student teacher candidates who come from cities have the highest scores on the CK aspect. Student teacher candidates from urban areas have the highest scores on the PCK spec. Preservice teacher students from rural areas have the highest scores on the CK aspect. The influence analysis results between hometown and TPACK are shown in Table 6.

Table 6. Results of analysis of the effect of preservice teacher student's hometown on TPACK in each aspect

Variable	TK		PK		CK		PCK		TCK		TPK		TPACK	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Preservice teacher student's domicile														
Rural	3.914	0.579	3.749	0.614	4.017	0.640	3.921	0.667	3.830	0.645	3.974	0.592	3.884	0.680
Urban	3.829	0.687	3.870	0.564	3.966	0.535	4.014	0.494	3.795	0.560	3.994	0.618	3.903	0.627
Big city	3.856	0.631	3.821	0.614	4.054	0.566	3.996	0.627	3.759	0.623	3.969	0.560	3.922	.0629
Kruskal-Wallis H	0.905		3.841		1.503		2.611		1.119		0.005		0.654	
Sig.	0.636		0.147		0.472		0.271		0.571		0.998		0.721	

5. DISCUSSION

This study aims to determine the effect of demographic factors on the TPACK of Generation Z preservice biology teachers. Demographic factors are proven to have a relationship or influence on the motivation and effectiveness of training [41]. The research results can be used to develop suitable training curricula for preservice biology teachers. The results of the study show that gender has an influence on TPACK in every aspect. The motivation to become a teacher influences every aspect of TPACK except for the TK aspect. Meanwhile, the length of time in college and the preservice teacher student's domicile have no relationship with TPACK in every aspect.

5.1. The effect of gender on technological, pedagogical and content knowledge

The study results show that gender affects TPACK of preservice biology teachers in every aspect (PK, CK, TK, TPK, TCK, PCK, and TPACK). Research on the relationship or influence of gender in TPACK has previously been studied several times [42]. For example, research by Erdogan and Sahin [43] on 137 preservice mathematics teachers in Turkey showed that gender correlated with several components in TPACK, including TK, TPK, TCK, PCK, and TPACK. In another study by Lin *et al.* [44], science teachers in Singapore show that gender is related to teachers' TPACK perceptions regarding technology. However, studies also show that gender only has a relationship with pedagogical factors in TPACK [45]. Research by Ibrohim *et al.* [26] on science teachers shows that gender is related to science teachers' TPACK perceptions; male teachers have higher scores than female teachers. The research results on preservice biology teachers can provide insight into how males and females in Indonesia have significantly different TPACK scores in every aspect.

The higher TPACK scores of male biology teacher candidates were related to their technology perception and skills. The Technology component in TPACK has relationships with other components in TPACK [46], so it can affect the scores of other components. Self-efficacy, in general, influences instructional quality. In another sense, self-efficacy in using technology is related to the pedagogical aspect. This link between gender and technology perceptions and skills is consistent with several studies showing that male have higher self-confidence, positive attitudes, and perceptions of technology use [47]. Research by Teo *et al.* [48] shows that female teacher candidates are more challenged to use technology than male teacher candidates in South-East Asian countries. In addition, male teacher candidates have higher self-efficacy in using technology than female teacher candidates [49]. In real life, self-efficacy gaps can reveal differences in teachers' intentions and actions when using technology [50].

5.2. The effect of year of study on technological, pedagogical and content knowledge

The year of study in preservice biology teachers does not affect their TPACK in all aspects. The results of exploring this factor are important for providing general information about the effectiveness of training and improving the TPACK of prospective biology teachers. However, research conducted by Cetin-Berber and Erdem [51] showed a relationship between the year of study and the PCK and TCK components. This difference is due to differences in teacher education curricula in a country. Differences in the curriculum will also affect the training results [52]. The study length has a bearing on the amount of knowledge about technology, pedagogy, and content that preservice teachers have acquired. However, the knowledge they acquire is still partial, so they require a higher level of thinking to integrate it into the TPACK framework [53]. Studies in PCK have found that preservice teachers can less consider the relationship between content and pedagogy when imagining their teaching experiences [54], [55].

The experience factor of learning at real school has a possible effect on TPACK. Based on research conducted by Ibrohim *et al.* [26] the experience possessed by the teacher has a relationship with several aspects of TPACK (TK, TCK, TPK, and TPACK). Another study by Cheng [56] shows that the experience of teachers teaching in schools has a relationship with CK, PCK, and TPK. A similar result was found by Liu *et al.* [45] a survey of teachers in China showed that teaching experience was related to all aspects of TPACK except PCK. Some experts state that teaching experience will affect the quality of learning [57], [58], the quality of learning will be related to PK [46]. Experience teaching preservice biology teachers about field conditions in schools is minimal, so it does not affect their TPACK [51].

5.3. The effect of motivation to become a teacher on technological, pedagogical and content knowledge

Motivation to become a teacher influences the TPACK of preservice biology teachers in every aspect except for the TK aspect. Motivation relates to preservice biology teachers' enthusiasm to continue learning and developing their skills and knowledge. Motivation is also associated with student self-regulation [59]. Motivation also plays a role in student achievement regarding their pedagogy [60]. Motivated students are encouraged to master the training content, believe they can control their learning, value what they learn, and demonstrate confidence in their learning and performance [61].

Several studies have shown that the motivation of preservice teachers to choose teaching as their career choice is related to their future professionalism [62]. A similar study examining the relationship between the motivation to be a teacher as a career choice was conducted by Saito [63] on preservice teachers in Japan. The results of this study indicate that intrinsic motivation has a positive correlation, while extrinsic motivation has a negative correlation with the preservice teacher's PK. Self-development of preservice teachers during training will be maintained when they become teachers [64].

Even though many Generation Z students in this survey have the motivation to become teachers, more than a third of them are not sure and are not motivated to have a profession as a teacher. Several factors identified as influencing why Generation-Z is not interested in having a teaching profession are changes in values [65], job expectations [66], and environmental demands [67]. To overcome this challenge, there needs to be efforts from the government, educational institutions, and society to increase the attractiveness of the teaching profession, improve the education system, and provide appropriate incentives for those who choose a career as educators. Additionally, it is important to listen to the aspirations and needs of Generation Z and provide appropriate support so that they see the value and satisfaction in choosing the teaching profession.

5.4. The effect of student's hometown on technological, pedagogical and content knowledge

Based on the results, student's hometown does not affect the TPACK of preservice biology teachers. In this student's hometown, we took three categories: city, urban, and village. The hometown of preservice biology teacher candidates has no effect because students in higher education are students of choice [68]. They were selected through strict selection and eliminated several competitors to enter the program. High-intelligence students will more readily accept what they learn during training [69]. This acceptance will later affect their mastery of content, pedagogy, and technology.

Students participating in this study belong to Z-Generation, so their mastery of technology is quite good [70]. The ability to master technology does not differ between people who live in villages or cities. Good mastery of technology makes it easier for them to use it in a learning context [71]. The ability to use technology will affect the teacher's TPACK self-efficacy [72]. This statement is supported by research Ibrohim *et al.* [26] on science teachers in Indonesia, which shows that junior teachers with 0-5 years of teaching experience have higher technology-related TPACK component scores than teachers in other groups. Similar research by Nazari *et al.* [73] showed that senior teachers scored higher on the pedagogy-related component and lower on the technology-related component. Based on these results, preservice teacher mastery of technology is sufficient. Integrating the mastered technology into pedagogical and content aspects needs to be considered. This problem can be solved by providing training on learning management systems and integrating augmented reality (AR)/virtual reality (VR) in learning, virtual simulations, and other areas. These results can be used by universities that hometown is a factor that can be ignored in their recruitment of preservice teacher students.

5.5. Research implication

This research has implications for aligning the preservice teacher education training curriculum. The education of preservice teachers must pay attention to the participants' demographics because each region has different economic, social, and cultural characteristics. Choosing the suitable training model based on the findings of demographic factors in this research will help create Generation Z preservice biology teachers who are collaborative, solution-oriented, and able to develop the potential of their region.

In addition, universities must pay attention to gender distribution when accepting biology teacher candidates. Gender influences the TPACK score in every aspect. Based on this, preservice female biology teachers need more support related to technology. This support can be provided by providing courses on more technology use at universities. Training conducted by preservice teachers, both independently and at universities, can potentially increase self-efficacy.

It is necessary to extract initial data on motivation to become a teacher when preservice teachers enter the university because motivation is significant in their TPACK score. Universities need to select students who are highly motivated to become teachers. Questionnaires related to motivation can be explored in their selection program.

6. CONCLUSION

The research provides an overview of the TPACK of Generation Z preservice biology teachers from the ten largest and oldest universities in Indonesia, which focus on forming preservice biology teachers. The results of this research generally show that certain demographic factors influence Generation Z prospective biology teachers. This study shows four main results: i) gender influences the TPACK of preservice biology teachers in all aspects. Male teacher candidates have higher scores than female teacher candidates in every aspect; ii) year of study of preservice biology teacher students does not affect TPACK in all aspects; iii) the motivation to become a teacher has an influence on the TPACK scores of preservice biology teachers in all aspects except for the TK aspect. Students motivated to become teachers have the highest TPACK scores for each component; and iv) domicile of preservice biology teacher students does not affect the TPACK score in each aspect. Based on the results of this study, gender and motivation factors need more attention in the training of Generation-Z preservice biology teachers because these two factors have a significant influence on TPACK in most aspects. Generation Z has a special character where they are more familiar with technology and expressive, so these characteristics are important to pay attention to in the training of preservice biology teachers. The results of this research can also be used to design training models that suit the characteristics of Generation-Z preservice teacher. It is important to carry out further research on the opinions of in-service teachers regarding their training needs so that there is harmony between conditions at school and training at educational universities.

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BIOGRAPHIES OF AUTHORS

Ahmad Kamal Sudrajat is an assistant professor in the field of biology education at Universitas Negeri Yogyakarta. His research focuses on the professional development of science teachers and prospective teachers. However, he also researches the development of students' 21st-century skills. He is also a reviewer in several reputable journals indexed by Scopus and Web of Sciences. Currently he is a member of the Indonesian Lesson Study Association (ALSI) and the World Association of Lesson Study (WALS). He can be contacted at email: kamalsudrajat@uny.ac.id.

Ibrohim is a professor in the field of professional development for science teachers at Universitas Negeri Malang. Currently, he is the head of the biology education doctoral study program. He is also an assessor for quality assurance of higher education in Indonesia. The research he carries out focuses on developing the professionalism of teachers and prospective teachers. Apart from that, he also focuses on curriculum development in higher education. He is also a reviewer in several reputable journals indexed by Scopus and Web of Sciences. He can be contacted at email: ibrohim.fmipa@um.ac.id.

Herawati Susilo is a professor in the field of biology education at Universitas Negeri Malang. Her research focuses on the development of 21st-century skills for biology teachers and prospective teachers. She has also conducted several studies on the theme of innovative learning development. Currently, she serves as a reviewer for several reputable international and national journals. She can be contacted at: herawati.susilo.fmipa@um.ac.id.