KnE Social Sciences
ICMScE
International Conference On Mathematics And Science Education
Volume 2024

Research Article

TPACK Profile of Biology Teachers During Their Learning Process After Participating in Numerical Taxonomy and its Training Program

Topik Hidayat[1]*, Amalianneisha Rafadewi A. Putri[2], Widi Purwaningsih[1]

[1]*Study Program Biology, Faculty of Mathematics and Science Education, Universitas Pendidikan Indonesia, Jalan Dr. Setiabudi 229 Bandung, Indonesia*
[2]*Education Consultant and Tutoring Iwa K, Jalan Karawitan 71 Bandung, Indonesia*

ORCID
Topik Hidayat: https://orcid.org/0000-0002-4589-8059
Amalianneisha Rafadewi A. Putri: https://orcid.org/0000-0003-0986-852X
Widi Purwaningsih: https://orcid.org/0000-0001-9748-0183

Abstract.
This study aimed to analyze the TPACK (Technological Pedagogical Content Knowledge) profiles of biology teachers in their learning process after participating in numerical taxonomy and its training program. TPACK is a construction of knowledge that must be possessed by teachers in the 21st century. Numerical taxonomy and its training aim to develop biology teachers' TPACK in the classification of living things. This training equips biology teachers with the knowledge needed to integrate TPACK components into the learning process, including contents related to TPACK and to the classification of living things, especially numerical taxonomy, learning technology, learning strategies, and methods to integrate TPACK into the learning process. This research is a descriptive study in which the data of biology teachers' TPACK during the learning process were obtained from PaP-eRs and the results of the learning performance assessment. The results showed that biology teachers' TPACK during the learning process after numerical taxonomy training had good results, and there has been an interactive phase between the TPACK components in the learning process. This is proven by teachers' ability to develop good PaP-eRs and teachers' performance based on the learning assessment results. It was further found that the use of technology in the learning process has been optimally applied by teachers. Meanwhile, the delivery of motivation and misconception were less developed by the teachers during the implementation of the TPACK learning process.

Keywords: TPACK, numerical taxonomy, training program, biology teachers

Corresponding Author: Topik Hidayat; email: topikhidayat@upi.edu

Published: 26 April 2024

Publishing services provided by Knowledge E

Selection and Peer-review under the responsibility of the ICMScE Conference Committee.

1. INTRODUCTION

Integration of technology in the learning process has been recognized as one of the significant factors that can determine the quality of learning in the classroom and improve students' learning abilities. Accordingly, to face technological developments in the 21st century, knowledge to integrate technology in the learning process is needed by teachers. Technology integration must be supported by teachers' knowledge about

technology and how to integrate the technology into their learning practices, in both content and pedagogical aspects. A conceptual framework that integrates technological knowledge, pedagogy knowledge, and content knowledge was proposed by Mishra & Koehler called Technological Pedagogical Content Knowledge (TPACK) [1]. TPACK is a form of Pedagogical Content Knowledge (PCK) development formulated by Shulman [2]. The addition of the technology concept to PCK was then developed to emphasize that technology should not be studied separately but along with pedagogical and content knowledge, this is the basis for TPACK. TPACK describes the knowledge needed by teachers to use technology in teaching effectively, and for doing so, teachers must be competent in the three TPACK domains which include technological, pedagogy, and content knowledge [3].

The central point of TPACK is how this type of knowledge is given in the context of specific content rather than in more general content [4, 5], thus, TPACK is related to the more specific contents to be taught. Biology learning has various specific contents, one of them is classification of living things that further has a unique content dealing with numerical taxonomies (phenetic and cladistic/phylogenetic). Based on the 2013 curriculum, in high school, cladistics is one of the concepts contained in the classification of living things that must be well acknowledged by students. Unluckily, numerical taxonomy is still considered difficult by both students and even biology teachers [6, 7]. Some high school teachers also confirm that cladistic material has become a deep misunderstanding that is difficult to correct [8]. This may occur due to inaccurate instructions given by the teacher so that students have difficulties in understanding the materials [6, 7, 9]. Thus, it becomes important to know how teachers instruct the learning process and how they integrate content, pedagogical, and technological knowledge in teaching the concept of classification of living things in the classroom.

In a learning context, TPACK is a unique construction that must be supported by its development [10] as a good comprehension of TPACK will be useful to develop appropriate strategies suiting the context so as to conduct a good quality of teaching. However, previous research has shown that most teachers' development programs often fail to support and develop the identity of educators as good users of technology in the teaching process since there are still development programs that separate the three TPACK areas (technological knowledge, pedagogical knowledge, and knowledge content). This condition leads to failure in teaching [11]. Therefore, a good strategy is needed to develop teacher knowledge of complex relationships between technology, pedagogy, and content. One of the attempts is by conducting a training program for teachers who use the TPACK framework as a reference as research shows that

training programs with this approach is able to develop teachers' knowledge on the seven components of TPACK and it is also able to make teachers possess a higher understanding of PCK, TPK, TCK, and TPACK [12].

To facilitate this issue, there needs to be a follow up action to improve and develop TPACK of biology teachers, especially in the context of biology learning related to the classification of living things. One of the strategies used in this research is to conduct a numerical taxonomy and its learning training program. Numerical taxonomy and its learning training, in this case,is a program that aims to develop biology teachers' TPACK in learning specific content that is the classification of living things. This training program is needed since it equips teachers with the knowledge needed in integrating TPACK, focusing on knowledge of content related to TPACK and knowledge of content related to the classification of living things especially numerical taxonomy, technology in learning, learning strategies, as well as how to integrate TPACK into the learning process. The numerical taxonomy training program is expected to be an effective strategy in an attempt to change and develop biology teachers TPACK in the classification of living things. PCK development of biology teachers through technology-based training programs and discuss PCK on evolutionary content and natural selection, as well as various aspects of teaching, both in content, pedagogical and classroom management issues [13]. To find out how the training program can develop the TPACK of biology teachers, it is necessary to analyze the biology teachers' TPACK profile after the numerical taxonomy of its learning program by looking at their practice of teaching and learning process in the real setting.

2. RESEARCH METHOD

This research was set as a descriptive study that gives an overview of TPACK of biology teachers in the learning process on the concept of classification of living things. Five biology teachers (Table 1) were involved to be the subjects of the current study. The teachers were teachers who teach 10th graders students from five different schools in Bandung. The research subjects were selected based on a purposive sampling technique with the criteria of a biology teacher of 10th grades, never attend a training on numerical taxonomy, and having good availability and access to the use of technology at school.

Before observing how teachers integrate TPACK in the learning process, numerical taxonomy training and learning were conducted to prepare teachers for the knowledge needed in integrating TPACK into the learning process including information related to

TABLE 1: Teachers' profile.

Name	Gender	Teaching Experience	Educational Background
Teacher A	Female	5-10 years	Bachelor of Biology Education (S1)
Teacher B	Female	2-5 years	Bachelor of Biology Education (S1)
TeacherC	Male	5-10 years	Bachelor of Biology Education (S1)
Teacher D	Female	2-5 years	Bachelor of Biology Education (S1)
Teacher E	Female	>10 years	Bachelor of Biology Education (S1)

TPACK and numerical taxonomy, technology in learning, and how to develop learning strategies in concept of classification of living things. This training program discussed the development of content and learning strategies, as well as its technology.It is expected that it will contribute to the development of professionalism of biology teachers. Training programs focusing on strategies that support and seek content will contribute to the development of professional teachers [14]. In the training process, teachers were given materials related to the TPACK components that included aspects of Content Knowledge, Pedagogical Knowledge, and Technology.

After training, the teachers' teaching process in the classroom, particularly on how the TPACK is applied was observed. This step was conducted to get a comprehensive picture of how the teachers integrate technological knowledge, pedagogy, and content in the learning process.

After being observed, the teachers were asked to prepare the PaP-eRs which will be explained in the next section. Besides, the teachers were also interviewed to follow up data gained from the PaP-eRs and the observation results. In the interview session, the teachers were asked to explain their teaching procedures in the class related to the teaching phases, strategies use in teaching and reason of choosing particular strategy, instruction in learning, students' responses toward the instructions, limitations and difficulties encountered during the learning learning process, and details relating to the aspects of TPACK. Interviews were conducted to uncover things that might not have been revealed by the teachers in the PaP-eRs that had been prepared.

Pedagogical and Professional-experience Repertoires (PaP-eRs) developed by Loughran *et al*. was used in describing the components of teacher professional knowledge regarding content knowledge and pedagogy (PCK) [15]. After the teaching practice, the teachers were asked to create PaP-eRs, a narrative of the learning situation that describes introduction activities, main activities, and closing activities, which further describes all teacher' and students' activities, classroom interactions, students' responses and follow up actions made by the teacher toward it. The PaP-eRs were analyzed based on the PaP-eRs components contained in the PaP-eRs

assessment rubric which were modified into 19 components that are made in the form of Likert scale of 0-3 for each component with a maximum score of 57. In addition, the learning performance assessment sheet was used as a data collection instrument while observing the learning process carried out by the teachers. The learning performance assessment was employed to see the teachers' teaching process in the class, how the teachers integrate the TPACK components, and the numerical taxonomy learning in the classroom setting.

3. result and discussion

Teacher's TPACK profile in the learning process is obtained based on the results of the PaP-eRs and assessment of the implementation of the learning process. The PaP-eRs were aimed to describe the actual activities that occur in the classroom to reflect the teachers' professional performance after teaching since the PaP-eRs reflect the ability of teachers in teaching practices on how to teach class related to introduction activities, main activities, and closing activities, including teachers' and students' activities, classroom interactions showing students' responses and follow ups made by teachers about it [15–17]. The assessment towards the PaP-eRs shows that biology teachers' performance is classified into a good category with an average value of 72. The results of PaP-eRs assessment result can be seen in Table 2.

TABLE 2: PaP-eRs assessment results.

No.	Name	Score	Category
	Teacher A	79	Good
	Teacher B	74	Good
	Teacher C	77	Good
	Teacher D	72	Good
	Teacher E	60	Adequate
	Average	72	Good

The ability of teachers to develop PaP-eRs has reached a good category.Teachers develop PaP-eRS quite well and there are no teachers who fail in developing PaP-eRs [16]. The teachers can describe the process of introductions activities, main activities, and closing activities well. In the current study, Teacher A has the highest ability to develop PaP-eRs in the good category with a score 79, while teacher E who has the lowest score of 60 is classified into the adequate category. The PaP-eRs analysis in this study highlights the most prominent aspects or components of the PaP-ers that teachers have developed regarding TPACK in their teaching process. The following descriptions

explain some of the components that are best developed and underdeveloped by teachers in PaP-eRs.

Based on the PaP-eRs compiled by the teachers, it can be seen how the compatibility between the learning ideas by teachers and the TPACK components. There is a component that is best narrated in the PaP-eRs by the five teachers, namely the aspect of conveying the use of technology in learning. For example, Teacher A gave detailed explanation about her learning activities, as follows: the teacher instructs students to prepare laptops and clustalX and treeview applications to be used in the preparation of cladograms using technology. Further, Teacher A instructed students to read instructions and understand what is instructed in the student worksheet (LKPD). In LKPD, there are pictures of several species of living things including gymnosperms, monocots, dicots, mosses, ferns, and algae. The students were asked to identify the characteristics of each species using the determination keys, and to create a characteristic table to compile phylogenetic/ cladogram trees, both manually and by using software. The teacher then gave instructions for each step in using the software to be followed by the students. In this section, the teacher also described how students' responses to the usage of technology in learning activities showed that students look so enthusiastic, amazed, and curious about the usage of software. Each group of students were found enthusiastic while observing the process of preparing a cladogram by using technology.

In addition, the teachers also described how they respond to students' questions. For instance, when the students asked whether the software can be used to compile a cladogram with large number of living things and a large number of characters, the teacher responded to students' questions by explaining that the application is very useful to make students' easier in compiling cladogram and in finding the evolutionary relationships of many species and many characters, while manual cladogram compilation is less possible. In the PaP-eRs, the teacher explained that the TPACK integration to learning made a more fun learning atmosphere that can contribute to encouraging students' involvement and enthusiasm to the learning activities. The teacher further stated that these activities develop students' creativity, curiosity, and ability to formulate questions to form their critical thinking needed for their future life and their long-life learning.

Meanwhile, the PaP-eRS assessment also reveals less developed aspects by the teachers in their learning practice. Those aspects include aspects of delivering motivation and aspects of addressing cognitive misconceptions at the apperception stage that may illustrate the teacher's knowledge of content and pedagogy.Based on Teacher D and Teacher E analysis, it was revealed that teachers apperception activities only convey

an introduction to the material without conveying the benefits of studying the material related to the daily life concepts, as well as the reasons behind the importance of the concept that actually can motivate students and invite their enthusiasm to learn.

Teacher C, D, and E did not explain the learning obstacles that occurred at the apperception stage in detail. The teacher stated that misconception towards the materials may appear due to the lack of intensity of questions and answers made at the apperception stage between teacher and students, and due to the lack of teachers' exploration of students' initial knowledge at the beginning of learning. This is in line with other research finding that the lack of ability to narrate misconceptions on PaPeRs can be caused by the implementation of teacher learning not carrying out these activities. Misunderstanding can occur because each student has an initial conception of an event or phenomenon that is sometimes in conflict with the concept. Therefore, the teachers are required to find out the students' initial conception in learning and clarify if there is a misunderstanding to fit the science concept [16].

Evaluation on the learning process is the result of observation regarding the ability of teachers to integrate TPACK in the learning process. The implementation of learning was assessed in three learning phases, namely introduction activities, main activities, and closing activities. Table 3 shows that the implementation of learning carried out by the five teachers has an average score of 78 that is classified into a good category, where Teacher A has the highest score (83) in the very well category, while the lowest grade belongs to Teacher E (69) in the good category.

Table 3: Results of learning outcomes assessment.

No.	Name	Score	Category
	Teacher A	83	Very well
	Teacher B	79	Good
	Teacher C	82	Very well
	Teacher D	77	Good
	Teacher E	69	Good
	Average	**78**	**Good**

The ability of teachers to integrate TPACK into the learning process has reached a good category. This is possible because during training and before observation of learning implementation, teachers were given guidance in preparing lesson plans, planning strategies, learning materials, and technology that will be used in learning, so that in the implementation of learning all components can be carried out as planned by the teacher. Other research found that after training, teachers will find it sufficient to teach content more effectively to students because efforts to improve individual

components through training, in general, can improve teacher teaching [13]. In other words, after having trained, teachers can systematize all the learning instructions. In addition to that, new insights and understanding of the whole teaching and learning process obtained by the teacher will improve the ability to teach the same topic in the future [18].

In the introduction activities, each teacher has implemented apperception associated with the content and learning objectives that are in accordance with curriculum standards. However, one significant aspect remains undeveloped by the teacher in which teachers haven't implemented the delivery of motivation to students. This can also be identified based on the PaP-eRs made by the teachers where the component of delivery of motivation is a component that is not delivered by the teacher in the PaP-eRs. Delivery of motivation relates to how the teacher conveys the importance of a concept to be learned that is associated with contextual matters in the students' daily lives and subsequent material that is useful to improve students' motivation to learn the material being discussed. In addition, delivery of motivation also relates to the importance of concepts being conveyed so that students obtain a more meaningful learning material [15].

In the main activities, aspects of the use of technology in learning that shows how teachers integrate TPACK into learning are best developed by teachers. This is also consistent with the results of the teachers' PaP-eRs where the teachers explain the use of learning technology in PaP-eRs well. In the implementation of the learning, the five teachers used a variety of technologies including clustalX and treeview to construct cladogram trees, quizizz and kahoot to identify students' initial knowledge, quizzes in learning and homework to evaluate students' understanding, PlanNet to make plants identification, and also other forms of technological feature such as school web platforms, powerpoints and learning videos. At this stage, it can be seen how the teacher has optimally applied technological aspects that have been introduced during the previous training into their classroom practice. This also shows that the teachers' insight and knowledge about technology is increasing. This finding is in accordance with previous studies results that knowledge of technology influences teachers' decisions about the use of educational technology to be more precise and prudent and the use of technology in their learning activities becomes more "conscious, strategic, and diverse" [19, 20].

Another significant finding of the study is related to the good ability of teachers in implementing the use of technology to teach numerical taxonomic subconcepts, in this case cladograms which are one of the important concepts in learning the classification of

living things to students. The technological touch to the learning can be seen when the teachers employed clustalX and treeview computer programs to arrange cladograms by involving students along the process. The results from observation and the PaP-eRs show similar results showing that students looked so enthusiastic when the teacher used technology in teaching cladogram. It was even described that when the results of the cladogram tree were displayed, some students applauded. At this stage, it can be seen that ICT (information and computer technology)positively contributes to the teaching and learning process. As technology is used in an integrated pedagogical interest in the learning framework, it can provide an active role for students so that a more active and meaningful learning is formed [21, 22].

In addition, in terms of the selection of procedures and learning strategies, each teacher used a different strategy whose learning activities are still in accordance with learning objectives demanded by the curriculum. For example, Teacher A used some methods namely lecture, discussion, questions and answer, observation, with the cooperative learning model of STAD and Discovery learning. During the learning process, the teacher engages students in observation activities, plant identification, the use of technology, as well as in question and answer activities and presentation of the results of discussions. These activities and strategies used contribute to foster active student participation and that is supported by teachers' good responses toward the students' participation. This is considered as good teaching, as a situation where students can make connections and interact directly with teachers, so teachers can assess student understanding through questions or provide opportunities for students to explain what they understand [23]. However, some teachers did not consider the time allocation during the implementation of learning, for example, teacher A did not do reflection activities because of insufficient learning time.

In delivering material (content), the teachers have shown a good mastery of the material in terms of its systematic aspects. However, not all teachers show good mastery of the material in conveying concepts related to the cladogram. For example, the cladogram preparation activities, Teacher E has explained steps of preparing the cladogram manually or using technology but she has not explained how to interpret the cladogram tree related to the evolutionary relationship and kinship between taxa, or evolutionary characters. This occurs because the teacher is not yet familiar with the content due to her lack of experience in teaching cladogram materials to the students. Yet, the teaching experience factor is one of the factors that can determine how teachers teach [24].

In the closing activity, it can be concluded that, in general, the teachers have had the ability to reflect on their learning and to conclude learning activities quite well by involving students.This is a good finding since reflection is the main focus in post-active assignments, here, the teacher reflects on the lesson and also the student's response with the aim of improving further teaching [18]. This is also expected to be a material for teachers to make evaluation and reflection for their future learning to support their TPACK competence better.

4. CONCLUSION

Based on the results of the study, it can be concluded that the TPACK profile of biology teachers in the learning process after numerical taxonomy and its learning training are considered good. This was proven by their ability to develop a good category of PaP-eRs which illustrate how their TPACK competence in reflecting their own learning related to the concept of classification of living things. The teacher is able to explain introduction activities, main activities, and closing activities well, where it was found that the use of technology becomes the most significant aspect developed by the teachers, meanwhile the delivery of motivation and misconception become underdeveloped components. In addition, the results of the assessment on teaching implementation has shown that teachers ability is also classified into a good category since they have been able to conduct an interactive teaching and learning phases that integrates TPACK components in terms of technology, pedagogy, and content during the learning process, from the introduction activities, main activities, to closing activities. A relatively similar result was also found from assessment of PaP-eRs that show aspects that are best and less developed by the teachers during the learning process. The less developed aspect is related to the delivery of motivation at the apperception stage in the introduction activity, meanwhile the best developed aspect is related to the use of technology in learning activities.

ACKNOWLEDGMENTS

Acknowledgements go to School of Postgraduate Study of UPI which provides the fund to conduct this research.

References

[1] Mishra P, Koehler M. Technological pedagogical content knowledge: a framework for teacher knowledge. Teach Coll Rec. 2006;108(6):1017–54.

[2] Shulman L. Those who understand: knowledge growth in teaching. 1986;15(2):4–14.

[3] Koseoglu P. Hacettepe university prospective biology teachers' self-confidence in terms of technological pedagogical content. Procedia Soc Behav Sci. 2012;46:931–4.

[4] Angeli C, Valanides N, Ioannou I. Developing computer science teachers' technological pedagogical content knowledge. Presented at the (2015).

[5] Getenet ST. Adapting technological pedagogical content knowledge framework to teach mathematics. Educ Inf Technol. 2017;22(5):2629–44.

[6] Catley KM, Phillips BC, Novick LR. Snakes and eels and dogs! oh, my! evaluating high school students' tree-thinking skills: an entry point to understanding evolution. Res Sci Educ. 2013;43(6):2327–48.

[7] Dees J, Momsen JL, Niemi J, Montplaisir L. Student interpretations of phylogenetic trees in an introductory biology course. CBE Life Sci Educ. 2014;13(4):666–76.

[8] Baum DA, Offner S. Phylogenies & tree-thinking. Am Biol Teach. 2008;70(4):222–9.

[9] Sa'adah S, Hidayat T, Sudargo F. Identifikasi miskonsepsi mahasiswa pendidikan biologi dalam memahami pohon filogenetika. Prosiding Seminar Nasional Sains dan Teknologi. Bandung: UIN Sunan Gunung Djati; 2015. pp. 337–42.

[10] Koehler M, Mishra P, Kereluik K, Shin T, Graham C. Handbook of research on educational communications and technology. In: Spector JM, Merrill MD, Elen J, Bishop MJ, editors. Handbook of Research on Educational Communications and Technology. 4th ed. 2014. pp. 101–11.

[11] Janssen N, Lazonder AW. Implementing innovative technologies through lesson plans: what kind of support do teachers prefer? J Sci Educ Technol. 2015;24(6):910–20.

[12] Koehler MJ, Mishra P. What happens when teachers design educational technology? the development of technological pedagogical content knowledge. J Educ Comput Res. 2005;32(2):131–52.

[13] Stasinakis PK, Kalogiannnakis M. Analysis of a moodle-based training program about the pedagogical content knowledge of evolution theory and natural selection. World Journal of Education. 2017;7(1):14.

[14] Paik S, Zhang M, Lundeberg MA, Eberhardt J, Shin TS, Zhang T. Supporting science teachers in alignment with state curriculum standards through professional

development: teachers' preparedness, expectations and their fulfillment. J Sci Educ Technol. 2011;20(4):422–34.

[15] Loughran J, Berry A, Mulhall P, editors. Professional Learning. New York: Springer; 2012.

[16] Purwaningsih W, Mardiyah A. Analysis of Pedagogical Content Knowledge (PCK) ability of science teachers in planning and reflecting on environmental pollution content. J Phys Conf Ser. 2018;1013(1):12076.

[17] Bertram A. 'CoRes and PaP-eRs as a strategy for helping beginning primary teachers develop their pedagogical content knowledge. Educ Quím. 2014;25(3):292–303.

[18] Shing CL, Saat RM, Loke SH. The knowledge of teaching- Pedagogical Content Knowledge (PCK). The Malaysian Online Journal of Educational Sciences. 2015;3(3):40–55.

[19] Harris JB, Hofer MJ. Technological Pedagogical Content Knowledge (TPACK) in action. J Res Technol Educ. 2011;43(3):211–29.

[20] Tsai HC. A senior teacher's implementation of technology integration. Int Educ Stud. 2015;8(6):151–61.

[21] Jimoyiannis A. Designing and implementing an integrated technological pedagogical science knowledge framework for science teachers professional development. Comput Educ. 2010;55(3):1259–69.

[22] Mikropoulos TA, Natsis A. Educational virtual environments: a ten-year review of empirical research (1999–2009). Comput Educ. 2011;56(3):769–80.

[23] Estes TH, Mintz SL, Gunter MA. Instruction: a model approach. 3rd ed. London: Pearson Education; 2015.

[24] Rochintaniawati D, Widodo A, Riandi R, Herlina L. Pedagogical content knowledge development of science prospective teachers in professional practice programs. Unnes Science Education Journal. 2018;7(2):119–28.