Analysis of technological pedagogical content knowledge (TPACK) of biology teachers in classification of living things learning

A R A Putri*, T Hidayat and W Purwianingsih
Program Studi Pendidikan Biologi, Sekolah Pascasarjana, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No. 229, Bandung 40154, Indonesia

*Corresponding author’s email: amalianneisha@gmail.com

Abstract. Technological Pedagogical Content Knowledge (TPACK) is defined as a competence in integrating knowledge of content, pedagogy, and technology into a learning practice that needs to be possessed by teachers to face the era of 21st century education. TPACK competence is inseparable from specific content that is going to be taught, in this case is classification of living things, a distinctive content on biology learning. This study was aimed at analyzing TPACK competence of biology teachers in classification of living things learning. The study was set as a descriptive study and involved five biology teachers from senior high school level, grade X. The data about teachers’ TPACK was gained from CoReS, and teachers’ perspective on TPACK in classification of living things learning was gained from teachers’ responses toward questionnaires. As the result, analysis of CoRes reveals that all (100%) of biology teachers’ TPACK is on the pre TPACK category. The study eventually shows that biology teachers still face some difficulties in integrating content knowledge, pedagogy, and technology in teaching classification of living things that discusses numerical taxonomy to the students.

1. Introduction
The development of digital technology in education has reached the stage where the school curriculum began to integrate technology in learning activities, nowadays teachers and students are expected to be able to integrate it in order to improve the ability and quality of learning and develop 21st century skills. The application of technology ought to be supported by teachers’ knowledge of technology and the ability of teachers to integrate technology into their learning practices, both in the pedagogic and content knowledge of the teacher, it became the basis for the development of pedagogic and content knowledge or pedagogical content knowledge (PCK) which later changes to be technology, pedagogic, and content knowledge (TPACK) [1]. TPACK is defined as a competence in integrating knowledge of content, pedagogy, and technology into a learning practice that needs to be possessed by teachers to face the era of 21st century education. A teacher needs to understand thoroughly the material to be taught (content knowledge), determine the appropriate instructions (pedagogical knowledge), and utilize appropriate technology in planning active learning (technological knowledge), and integrate that three aspects in learning (TPACK), therefore professional teachers are required [2].

TPACK competence is inseparable from specific content that is going to be taught, biology learning is one of which has a distinctive content, namely the classification of living things. The concept of classification of living things has a typical discussion that is about numerical taxonomy...
(phenetics and cladistics). Cladistics or phylogenetic is a part of numerical taxonomy which is discussed in the material of classification of living things in senior high school biology curriculum. Cladistics is a system of classification of living things be based entirely on evolutionary relationships and that’s represented into cladogram or phylogenetic tree [3]. However, numerical taxonomy is still considered as a difficult content among students as well as university students and even Biology teachers [4]. Biology teachers confirmed that cladogram had become a deep misunderstanding and still difficult to fix it [5], it can be happened because of the lack of instruction given by teachers, so students still find it’s difficult in understanding the content [6]. So, we need to know how teachers giving the instructions to student in class and how they integrate knowledge of content, pedagogy, and technology (TPACK) in teaching the material of classification of living things. Based on the explanation, this study was aimed at analyzing TPACK competence of Biology teachers in classification of living things learning. Analyzing Teacher's TPACK competence on a material or concept can be processed by using CoRes (Content Representations) [7] which has already integrated the technological aspects in it.

2. Methods

This research was a descriptive study that will provide an overview of the Biology teachers’ TPACK competence in living thing classification learning. The research subjects were five Biology teachers from senior high school level, grade X from different schools in Bandung. The Biology teachers’ TPACK competency is assessed from the results of teachers’ answers toward CoReS that adapted and modified [8] related to the concept of classification of living things. The CoRes document used consists of 11 questions related to TPACK, which are (1) What do you intend the students to learn about this idea or concept? (2) Why was it important for students to know this concept? (3) What is other topic related that you do not intend students to know yet? (4) What are the difficulties/limitations connected with teaching this idea? (5) What are errors of understanding or students misconceptions that is common in the concept? (6) What factors are likely to influence your teaching of this concept to the students? (7) What are your teaching procedures or the order of teaching the concept? (8) How do you use/utilize the technology in teaching this concept? (9) What are your goals for using technology in teaching this concept? (10) How are you going to deal with the absence of technology at school in order to attain your goals? (11) How do you know that students already understand or not the concepts?

According to the teachers’ answers toward CoRes, the teacher’s TPACK ability can be analyzed and categorized into Pre TPACK, Growing TPACK, and Maturing TPACK for each aspect related TPACK using a modified rubric from Anwar [7]. Based on the rubric, there are five aspect related TPACK, were are (1) Objective aspect consist indicator of teacher's competency to identify and formulate the learning objectives, (2) Concept aspect consist indicator of teacher's competency to determine the important concept, breadth and depth of material, and identify misconceptions, (3) Pedagogy consist indicator of teacher's competency to determine teaching consideration, teaching strategies and material presentation arrangement, (4) Technology consist indicator of teacher's competency to utilize technology in learning, determine the purposes of technology using in learning, and deal with the technology unavailability, last (5) Evaluation about assess students’ understanding. The questionnaire regarding teachers’ perspective of TPACK in classification of living things learning was analyzed descriptively.

3. Result and Discussion

3.1 Analysis TPACK of Biology Teachers Based on CoRes

CoRes is the instrument developed by Loughran which represents how teachers think about the ways to teach a particular topic. CoRes can give an overview of several aspects related to TPACK for it consists of aspects related TPACK that can reflect the integration of knowledge of content, pedagogy, and technology. The teachers’ TPACK category in each aspect based on rubric TPACK category [9] can be showed at Table 1. The result showed that the ability of each teacher in each aspects is
dominant in Pre category, then overall the five teachers are in Pre TPACK category. It means that teachers are still in the early stages of interaction between pedagogy, content, and technology. There is one indicator that is dominant in the growing category, namely teacher’s ability to determine teaching considerations. Teacher’s ability for each indicator is described below:

Table 1. Category of Biology teachers’ TPACK

| No | Aspect | Indicator | Teacher A | Teacher B | Teacher C | Teacher D | Teacher E |
|----|--------|-----------|-----------|-----------|-----------|-----------|-----------|
| 1  | Objective | Objectives Identification | Pre | Pre | Growing | Pre | Pre | Pre |
|    |         | Objectives Formulation | Pre | Pre | Pre | Pre | Pre | Pre |
|    |         | Important Concept | Pre | Pre | Pre | Pre | Pre | Pre |
|    |         | The breadth and depth of material | Growing | Growing | Growing | Growing | Pre | Growing |
|    |         | Misconception identification | Pre | Pre | Pre | Pre | Pre | Pre |
|    |         | Teaching consideration | Growing | Growing | Growing | Growing | Pre | Growing |
| 2  | Concept | Teaching strategy | Pre | Pre | Pre | Pre | Pre | Pre |
|    |         | Material Presentation | Pre | Pre | Pre | Pre | Pre | Pre |
|    |         | Arrangement | Pre | Pre | Pre | Pre | Pre | Pre |
|    |         | Technology Utilization | Pre | Pre | Pre | Pre | Pre | Pre |
|    |         | Purpose | Pre | Pre | Pre | Pre | Pre | Pre |
|    |         | Dealing the Technology Unavailability | Pre | Pre | Pre | Pre | Pre | Pre |
| 3  | Pedagogy | Students Understanding | Pre | Pre | Pre | Pre | Pre | Pre |
|    |         | Assessment | Pre | Pre | Pre | Pre | Pre | Pre |

3.1.1. Teacher’s competency in identifying the learning objectives. The ability of teacher A, B, C, and D in identifying learning objectives is in the pre category due to the teachers’ consideration in identifying the objectives is still limited and not in accordance with the standards set in the curriculum. Moreover, they still consider daily life and didn’t consider the interconnection between materials which causes their lack of ability in formulating learning objectives [10]. Teacher C explained that his consideration in identifying the learning objectives are as a base for knowledge or the prerequisite material for related concepts, and students’ difficulties in making the key determination and cladograms yet. Teacher C had considered the material characteristics and demands of the curriculum, teacher C is in the growing category.

3.1.2. Teacher’s competency in formulating learning objectives. Learning Objectives must be formulated accordingly and based on competencies to be achieved in the curriculum. The competencies in classification of living things material are necessary to achieve are 3.3. Describing principles of the classification of living things in five kingdoms and 4.3. Arranging cladogram based on the principles of classification of living things. Teacher B, C, D, E are included in the pre category, because they had not described accurately the formulation of learning objectives to achieve the expected competencies in the curriculum. This is because in the process of formulating the learning objectives, teachers lacked analyzing competencies in the curriculum. Teacher A is in the growing category because she has started to formulate the learning objectives accurately.

3.1.3. Teacher’s Competency in Determining the Important Concept. In accordance with analysis of 2013 revised curriculum, there are several important ideas/concepts that should be raised by the teachers, among of those are the principle of classification of living things, the basic of classification of living things (five kingdoms), taxon levels and binomial nomenclature, key determinations,
cladograms (cladistics). Based on teacher's answers toward CoRes, the five teachers are in the pre category. The teachers could not bring up all the important concepts related to classification of living things material. Despite teacher A and D have raised all the important concepts needed, but those important concepts are still not relevant to the material being taught, and there are still important concepts which are attributes of other concepts. It is because teachers are accustomed to looking at the book in determining the core concepts without analysis the curriculum. They are still having trouble to determine which concepts are big ideas and concepts that are attributes of other concepts. It was caused by teacher's lack of understanding the concepts. The ability to determine important concepts were influenced by teacher's understanding of content to be taught and analysis of curriculum and material [11].

3.1.4. **Teacher's competency in determining the breadth and depth of material.** The teacher's competency in determine the breadth and depth of learning material reflects the ability to recognize the core values of material grounded on basic competencies to be achieved. Knowledge of concepts that are not allowed yet to be learned by students can be an illustration of how the breadth of material is going to be delivered. Five Teachers are in the pre category for this ability because they were still referring to general concepts then the breadth and depth for each core concept are not clear. Teachers usually have difficulty in determining the breadth and depth of material because they only refers to the general concepts contained in the student’s handbook, whereas teachers who have good knowledge in recognizing core values will not oversimplify the content but still maintain the complexity in order to improve student understanding.

3.1.5. **Teacher's competency in identifying misconception.** In this competency, the five teachers are in the pre category. The teachers have begun to identify misconceptions that occur in learning though has not anticipated. In this topic each teacher has never taught about cladograms so they have not been able to determine misconceptions, teacher’s ability to identify misconceptions is related to teacher knowledge and experience in teaching certain topic. Students’ prior knowledge is an important factor in determining misconceptions and anticipate it, but teacher still has not considered this.

3.1.6. **Teacher’s competency in determining learning consideration.** Teachers A, B, C, E are in the growing category in this point because their teaching consideration is not only based on material, but has begun to consider students’ prior knowledge, curriculum, students’ condition, and other supporting facilities. Teachers' experience and knowledge about class and school were the reasons that teachers could consider various aspects that influence their teaching process [12], so they revealed all aspects and it becomes their consideration in planning and determining learning strategies. This indicator has the best result because the dominant is in growing.

3.1.7. **Teacher's competency in determining teaching strategy.** In this ability the five teachers are in the pre category, they were still lack in analyzing curriculum and material, so they haven't been able to determine teaching strategies wich accordance with the goals [10], it cause teachers used teaching strategies that are common to all taught important concepts and it has not been adapted with the characteristic of the concept. Although there were teachers (Teacher C and D) who determined a different strategy for each important concept, they have not been able to reach the expected competencies. The ability to choose teaching procedure that matched with the expected learning outcome (achieved competence), also knowing how and why they use a procedure in learning are important elements, but teachers were still find difficulty to do it. This can be occurred because of the limited availability of technology and learning media that influence the limitations of teacher teaching strategy.

3.1.8. **Teacher’s competency in determining material presentation arrangement.** Teacher’s ability to determine the order of material presentation haven’t considered the characteristics of materials (from simple to complex). The order of material presentation which showed was still related to the order of material presentation of the book and the important concept that is raised only, some teachers have linked it with teaching method but have not been specific and there was no link between each concept, so the five teachers are in the pre category.
3.1.9. **Teacher's competency to utilize technology.** Description of technology used by each teacher, that were Teacher A used video, search engines, and Plantnet app, Teacher B utilized powerpoint and Kahoot, Teacher C utilized tutorial video and powerpoint, Teacher D utilized powerpoint, tutorial video, and charta. Teacher E utilized powerpoint and website. The selection of used technology was quite varied but teachers were less in associating it with the characteristics of important concepts and didn’t explain the role and how to utilize them in learning and has not been linked to learning strategy so that the five teachers are in the pre category. There are factors that influence the implementation of technology by teachers in the classroom including teacher’s pedagogic, learning effectiveness, habitual use of technology, and the adjustment of integration with material content [13]. Some teachers stated that they could not determine the right technology according to material characteristics. The limited use of technology in learning can occur due to a lack of teacher knowledge of ICT.

3.1.10. **Teacher competency in determining the purpose of technology using.** In the learning process, technology is used as a supporting tool to achieve the expected learning outcomes. It is crucial for a teacher to understand the reasons and roles for using technology in learning process. Teachers A, C, D, E are in the pre category because the purpose of using the technology were still not specific and is only intended to represent material content, the use of technology by teachers is still limited to finding and expanding their content knowledge about biology concept rather than developing their teaching strategy and technological knowledge. Teacher B used technology to present material content with power point, and as an evaluation technique by identifying student’s knowledge using Kahoot's online quiz portal, so teacher B did not only consider the use of it to present content only, but also has developed it for other purposes. The role of technology integration in learning is the central theme of the development of TPACK which consists of technology as a learning strategy, technology for content representation, and technology to identify students knowledge (evaluation) [13].

3.1.11. **Teacher’s competency in dealing with technology unavailability.** The alternative strategy which posited by the five teachers in dealing with technology unavailability has not been specific to the related concept and only put forward one kind of strategy, so that the five teachers are in pre category.

3.1.12. **Teacher’s competency in assessing students’ understanding.** The five teachers are in the pre category for this competency. The evaluation tools using of teachers A, C, D, E were still limited to written tests, teacher B has started to use technology as an evaluation technique on all important concepts but has not considered the characteristics of raised important concepts. The competency to assess students' understanding is interrelated to assessment techniques which should consider the concepts, students’ characteristics, and learning objectives. The evaluation techniques used by teachers are still limited. Teachers were accustomed to using written test and haven't yet explored other techniques. The teacher's belief in their teaching style makes them reluctant to apply other techniques, and their limitations knowledge of technology causing a lack of variation in evaluation techniques.

3.2 **Teacher's Perspective Regarding TPACK in Classification of Living Things Learning**

In general, teachers told that during their teaching experience, they had already integrated technology in teaching a particular biology learning content. It shows that every teacher has applied TPACK in the learning process. Notwithstanding, there are some difficulties faced by the teacher, among others, Teacher A, Teacher B, Teacher D, and Teacher E are difficult to decide the appropriate technology for certain material content, it is caused by the lack of their technology knowledge. Although TPACK integration was considered capable to improve students’ understanding, it was not always achieved because of the lack of implementation skills of technological knowledge in teaching and learning process by teachers [14].

Overall, the five teachers have integrated technology in teaching classification of living things material generally with as media and presenting content. But the teacher stated that they had difficulties in teaching important concepts of numerical taxonomy that is cladistics (cladogram). Teacher A, B, D, and E mentioned that during their teaching experience, they had never taught numerical taxonomy to students, teachers believe that the important concept of numerical taxonomy, cladistics/cladograms, on learning classification of living things is a difficult content to understand,
therefore it is also the reason why teachers are difficult to determine suitable learning strategy. Teachers who do not have an understanding of the content will experience difficulties and misrepresent the material to students. Teachers also have difficulties in determining what technology is appropriate for teaching the classification of the living things, especially on important concept cladistics/cladogram. A different case was found in teacher C who stated that he had taught numerical taxonomy to students but still found it difficult to determine appropriate learning and he did not know what type of technology could be used to teach that concepts. The explanation shows that teachers had difficulties in integrating content, pedagogical, and technological knowledge that is appropriate in teaching classification of living things, especially on cladogram, and it affects to the way they in teaching the concept to students [14].

4. Conclusion
Based on the result, it can be concluded that overall the TPACK's competency of five biology teachers are in the pre category (100%), it can be seen from each TPACK teacher's indicator which is dominant in the pre category. These results can show that the teacher's TPACK competency is still lack. Biology teachers have difficulty in integrating the content, pedagogic, and right technology in teaching the classification of living things to students, especially on the important concepts of the cladogram. To overcome these matters, coaching or training is needed to improve the TPACK competency of biology teacher to teach the classification of living things, especially in the concept of numerical taxonomy which discusses about cladogram. Suggestions from researchers is to conduct training for biology teachers regarding TPACK and numerical taxonomy content (phenetic and cladistic) to support teachers to overcome their difficulties in teaching numerical taxonomy to students so that teachers have the confidence to teach that concept.

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