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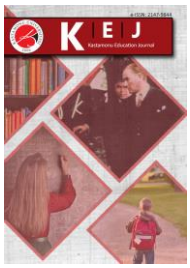

| Research Article /Araştırma Makalesi |

Technological Pedagogical Content Knowledge of Pre-Service Biology Teachers on Protein Synthesis[1]

Biyoloji Öğretmen Adaylarının Protein Sentezi Konusundaki Teknolojik Pedagojik Alan Bilgisi

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Keywords

1. Biology teaching
2. Protein synthesis
3. Technological pedagogical content knowledge
4. Content analysis

Anahtar kelimeler

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Abstract

In this study, it is examined that the Technological Pedagogical Content Knowledge (TPACK) of pre-service biology teachers on protein synthesis. The study was carried out with 8 pre-service biology teachers. This research used a semi-structured interview form, open-ended content knowledge test, lesson plan, and lesson plan evaluation form as data collection tools. Data were analyzed simultaneously within the scope of TPACK components and evaluated together. Data were analyzed with MAXqda, a qualitative data analysis program and evaluated by the content analysis method. As a result of the research, it is defined that pedagogical, technological and technological pedagogical knowledge of pre-service biology teachers is partially sufficient. Also, it is determined that their content knowledge of protein synthesis is insufficient, and there are essential knowledge deficiencies and misconceptions. Since their content knowledge of protein synthesis is insufficient, they could not explain how to use their pedagogical knowledge to teach the topic.

Nonetheless, despite their technological and pedagogical knowledge being sufficient separately, they have difficulty integrating technological knowledge with teaching content. Therefore, it is thought that it would be beneficial to refer more about which technologies, at which stages of the teaching process, for what purposes, and how they can be used in the content of the education courses in the biology teaching program and to enable pre-service teachers to practice on this subject. In addition, there is a need to eliminate the misconceptions of pre-service teachers from secondary education and before and to improve their content knowledge. For this reason, it is recommended to add courses to the teacher education program as applications of the related field courses, in which pre-service teachers will be able to explain the knowledge they have learned in the classroom to their other friends. Thus, it is thought that the information they have learned will be more permanent, and they will be aware of their own and their friends' deficiencies and misconceptions while explaining.

Öz

Çalışmada, biyoloji öğretmen adaylarının protein sentezi konusundaki Teknolojik Pedagojik Alan Bilgisi (TPAB) incelenmiştir. Çalışma, 8 biyoloji öğretmen adayı ile gerçekleştirilmiştir. Araştırmada veri toplama aracı olarak yarı yapılandırılmış görüşme formu, açık uçlu alan bilgisi testi, ders planı ve ders planı değerlendirme formu kullanılmıştır. Veri toplama araçlarından elde edilen veriler, TPAB bileşenleri çerçevesinde eş zamanlı olarak analiz edilip birlikte değerlendirilmiştir. Elde edilen verilerin analizinde bir nitel veri analizi programı olan MAXqda kullanılmıştır. Veriler, nitel içerik analizi yapılarak değerlendirilmiştir. Araştırma sonucunda, öğretmen adaylarının pedagojik bilgi, teknolojik bilgi, teknolojik pedagojik bilgi açısından kısmen yeterli oldukları belirlenmiştir. Protein sentezine ilişkin konu alan bilgilerinin ise yeterli düzeyde olmadığı, önemli bilgi eksiklikleri ve kavram yanılgıları olduğu tespit edilmiştir. Protein sentezine ilişkin alan bilgileri yeterli olmadığından sahip oldukları pedagojik bilgiyi konunun öğretimi bağlamında nasıl kullanacaklarını açıklayamamışlardır. Bununla birlikte teknoloji bilgileri, pedagojik bilgileri tek başlarına iyi olmasına rağmen teknoloji bilgilerini konu alanının öğretimine entegre etmekte zorlanmışlardır. Dolayısıyla biyoloji öğretmenliği programındaki eğitim derslerinin içeriklerinde hangi teknolojilerin, öğretim sürecinin hangi aşamalarında, hangi amaçlarla, nasıl kullanılabileceğine daha fazla değinilmesinin ve öğretmen adaylarının bu konuda pratik yapmalarına imkân sağlanmasının yararlı olacağı düşünülmektedir. Ayrıca öğretmen adaylarının ortaöğretim ve öncesinden getirdikleri kavram yanılgılarının giderilmesi ve konu alanı bilgilerinin geliştirilmesine ihtiyaç olduğu açıktır. Bu nedenle öğretmen yetiştirme programına ilgili alan derslerinin bir uygulaması olarak öğretmen adaylarının öğrendikleri bilgileri sınıf ortamında anlatmalarının sağlanacağı dersler eklenmesi önerilmektedir. Böylece öğrendikleri bilgilerin daha kalıcı olabileceği, anlatırken kendilerinin ve arkadaşlarının eksiklerinin ve kavram yanılgılarının farkına varabilecekleri düşünülmektedir.

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INTRODUCTION

Questions such as what methods and techniques teachers-who have considerable effects on students- teach their students in addition to having content knowledge, to what extent they know their students, and whether they conduct teaching directed to students have gained more and more importance and have been made the subject matter of research. Consequently, research has focused on the issue of what teachers should be competent on, and different descriptions with points common to all have emerged (Grossman, 1990; Hill, Ball, & Schilling, 2008; Shulman, 1987). Teacher training was based on the concept of content knowledge until the period prior to 1980. Thus, the one who had the most content knowledge was considered the best teacher (Shulman, 1986). However, research done in the 1980s suggested that teachers' knowledge of some general pedagogical methods (asking questions, evaluating the performance, Etc.) apart from content knowledge and their use of such methods in teaching had positive effects on students' achievement. Hence, the idea that teachers' pedagogical knowledge besides content knowledge would secure meaningful learning and increase permanence in learning began to dominate (Doyle,1986; Feiman-Nemser & Buchman, 1987; Holmes Group, 1986; Reynolds, 1992; Tobin & Garnet, 1988). The thought was posed for the first time by Lee Shulman (1987) as a "missing paradigm" in educational research. Shulman (1987) claims that the missing component in educational research is "pedagogical content knowledge (PCK)"- which is composed of using content knowledge and pedagogical knowledge in combination and which is a particular area of knowledge independent of pedagogy. In a study conducted in 1986, Shulman argued that teachers' knowledge consisted of three categories of knowledge called content knowledge, knowledge of the curriculum and pedagogical content knowledge. The author referred to the ties between pedagogy and content knowledge with the concept of "pedagogical content knowledge"- which he began to use in the literature, said that it was inadequate for teachers to have the only content knowledge and stated that a particular area of knowledge about how to teach the content knowledge was required. He called the particular area of knowledge "pedagogical content knowledge" and described it as "the knowledge of how to make content knowledge understandable to students" (Shulman, 1986; 1987).

The use of technology became more and more widespread at the beginning of the 21st century- which is directly influential in education. Thus, technology was integrated into instructional processes by the educational policies in Turkey. Several indicators are indicated within the framework of General Competencies for Teaching Profession (MofNE, 2017a) and of Biology Teachers Content Knowledge Competencies (MofNE, 2017b) prepared by the ministry of national education general directorate of teacher training and development that teachers are expected to have an approach of teaching and skills through which they can integrate technology into teaching. Computers, tablet PCs, smart boards and several other technological instruments are available today in classrooms. Teachers' proper use of technology offers convenience in learning differences that stem from individual differences, concretizes concepts challenging to learn, and helps students learn at their own pace according to their capabilities and needs. It also enables kinaesthetic learning as well as cognitive and affective learning. Besides, using specialized materials in education is also quite effective in developing students' active learning, purposeful learning and original learning skills (Crook, 1998). Therefore, it is apparent that it is not sufficient for teachers to have strong content knowledge and pedagogical knowledge only. They also need to have adequate technological knowledge and that they need to be able to use the relevant educational technologies effectively. Setting out from this reality, the concept of "technological knowledge" was added to the concept of pedagogical content knowledge described by Shulman in 1986, and thus the concept of technological pedagogical content knowledge (TPACK) was created (Mishra & Koehler, 2006). TPACK is defined as "teachers' knowledge of how to combine technology with pedagogical strategies while teaching a subject in their area and of the effects of technological instruments and presentations on students' understanding the subject" (Graham et al., 2009).

Technological assistance is significant in the visual presentation of subjects in the course with abstract content such as biology. Well-prepared visuals, three-dimensional models, animations and interactional media help understand a subject more easily. One of the subjects that both students and pre-service teachers have learning and teaching difficulties and misconceptions is the subject of protein synthesis in biology (Fisher, 1985; Gerçek, 2018; Guzman & Barlett, 2012; Gül & Özay Köse, 2018; Koçakoğlu, 2002; Öz Aydin, Şahin, & Sicaker, 2014; Rotbain, Marbach-Ad, & Stavy, 2005; Saygın, 2009; Sinan, Yıldırım, Kocakülah, & Aydın, 2006; Taştan, 2005; Yakışan, 2008). This study was based on the idea that it would be beneficial to know about the efficacies of pre-service biology teachers- who are going to be practicing teachers in the future-in teaching the subject. In this context, the current study considers the concept of TPACK- which is frequently mentioned today in teachers' efficacies (Mishra & Koehler, 2006), and it also investigates pre-service teachers' TPACK and types of knowledge which are the sub-components of TPACK.

The Theoretical Framework

Technological pedagogical content knowledge (TPACK) was built based on the pedagogical content knowledge (PCK) model suggested by Lee Shulman (1986; 1987). Mishra and Koehler (2006) added the component of technology to pedagogical content knowledge, and thus they put forward the concept of technological pedagogical content knowledge (TPACK). The model developed by Koehler and Mishra (2009) to demonstrate the components of TPACK and their interactions is shown in Figure 1.

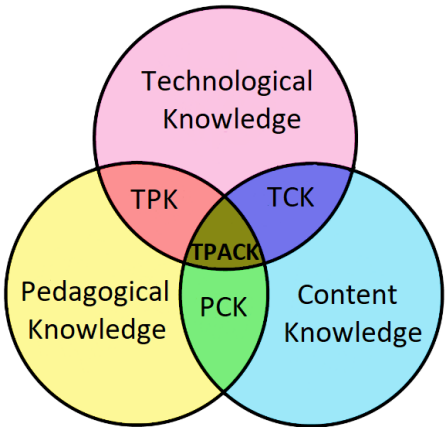

Figure 1. TPACK and the types of Knowledge it contains (Koehler & Mishra, 2009)

The sub-areas of knowledge contained in technological pedagogical content knowledge can be described as in the following (Mishra & Koehler, 2006):

Pedagogical knowledge (PK): It is the knowledge teachers have about using the methods and techniques of teaching. PK consists of how students learn, general classroom management skills, lesson planning and student assessment. A teacher with an accumulation of pedagogical knowledge knows how students will learn and acquire skills.

Pedagogical content knowledge (PCK): It is teachers' knowledge of what methods and techniques of teaching to use in teaching a subject in the best way.

Technological knowledge (TK): Teachers' knowledge of what technology to use in teaching a subject.

Technological pedagogical knowledge (TPK): Teachers' knowledge of the effects of using technology in various ways on teaching and learning.

Technological content knowledge (TCK): Teachers' knowledge of how technological knowledge and content knowledge affect each other.

Content knowledge (CK): It is the scientific knowledge teachers have about the subject they will teach.

Studies concerning TPACK gained momentum with the inclusion of technology in areas of teacher competence and with the revival of integrating it into other areas of competence. Research conducted about TPACK obtained differing results about teacher and pre-service teachers' levels of TPACK. Even though several studies are investigating pre-service teachers' TPACK levels (such as Akarsu & Güven, 2014; Archambault & Crippen, 2009; Avcı & Ateş, 2017; Canbazoğlu Bilici, 2012; Gonzales, 2018; Jordan, 2011; Karakaya, 2012; Karataş, 2014; Kaya, 2010; Kılıç & Kazanç, 2016; Özbek, 2014), the number of studies which have obtained detailed findings of a domain is negligible. The number of studies investigating the TPACK levels in a specific subject in teaching biology, in particular, is limited. Therefore, this current study is thought to contribute to the area in this sense.

METHOD

This is a qualitative study, and it uses the method of case study- which is thought to enable researchers to collect detailed data specific to individuals to determine their TPACK levels in the subject of "protein synthesis. The case study is a descriptive method used commonly in qualitative studies, and it enables researchers to analyze a person, an event or a case in-depth and in holistic approach (Yıldırım & Şimşek, 2006). Case studies do not aim to reach general conclusions. People, cases or phenomena are considered in their original environment, and then they are described in detail and interpreted (Seggie & Bayyurt, 2015).

The Study Group

The study group was composed of pre-service teachers who attended the Biology Teaching Programme of a state university in Turkey. The purposeful sampling method, one of the non-random sampling methods, was used in choosing the participants in this study (Yıldırım & Şimşek, 2006). It was demanded that the pre-service teachers' assumption that they should have the necessary knowledge was met since this paper intended to investigate pre-service teachers' technological pedagogical content knowledge. Therefore, the research was conducted with the participation of randomly chosen 8 students (1 male and 7 female) who had taken the Molecular Biology course -in which the subject of protein synthesis was taught in detail- and the teaching and Learning Theories and Approaches course and the Measurement and Evaluation course- in which pedagogical knowledge on teaching the domain was taught- and who had passed their exams in those courses. Two of the participants were second-year students, whereas six were fourth-year students.

Data Collection

The research data were collected in the Spring semester 2018-2019 academic year. Semi-structured interview forms and the lesson plan preparation method (Van Der Valk & Broekman, 1999) were used in collecting the data. The interviews were recorded with a voice recorder.

The pilot scheme was carryout out with the inclusion of two pre-service teachers, and following the pilot, a scheme decision was made to use the data collection tools without making any changes. The data were collected at two stages for each participant. At stage one, data on the components of TPCK outside content knowledge were collected, and then, the participants were asked to complete the template for the lesson plan and answer the questions in the lesson plan evaluation form during the interviews. At stage two, they were asked to give written answers to the questions about content knowledge.

Data Collection Tools

The TPACK interview forms, content knowledge test, template for lesson plans and lesson plan evaluation forms prepared by the researchers were used in collecting the research data.

TPACK Interview Form

The researchers developed the interview form used to collect the research data by taking the components of TPACK (Koehler & Mishra, 2009). The literature concerning how to arrange questions about the components of TPACK was reviewed, informing the questions in the interview form. Some of the questions were re-stated, in other words, during the interviews when necessary or were skipped. Thus, the participant's knowledge of the components of TPACK was analyzed in detail through problem-based semi-structured interviews, which were held based on the questions in the interview form. The TPACK interview form contained open-ended questions through with the components of TPACK was analyzed under specific headings.

Content Knowledge Test

The content knowledge test on protein synthesis, which the researchers developed, consisted of 22 open-ended questions. The test was developed after examining the misconceptions about protein synthesis reported in the literature, and the achievement tests developed. The scope of the content knowledge test was determined according to literature review, secondary education biology curriculum prepared by the Ministry of National Education (MofNE,2018) and the course content of the biology teaching departments of universities, and open-ended questions were prepared accordingly. Two lecturers with experts in biology education and experienced biology teachers analyzed the questions, and construct validity was attained for the questions.

Lessons Plan and Lesson Plan Evaluation Form

A general template for the lesson plan was given to the pre-service teachers, and they were asked to prepare a lesson plan for protein synthesis using the template. The participants were interviewed through 10 open-ended questions available on the lesson plan evaluation form after they had prepared their lesson plans, and thus, detailed information on the points they had taken into consideration while preparing the lesson plan was obtained.

Data Analysis

The 8 participants were coded as PT1…PT8 (PT: pre-service teacher) before the analyses were referred to by using the codes in the analysis and findings sections of this paper. The exclusive interview content concerning TPACK and lesson plan evaluation- voice recorded- was put to writing word by word. The written answers given to the questions of content knowledge besides the interview content and the lesson plans prepared were also digitalized on the computer, the protocols (the data texts) were obtained, and they were evaluated in the categories distinguished. In this way, the entire content was analyzed synchronically. The protocols prepared were re-arranged in interpreted protocol method (Mayring, 2002).

The data was put to content analysis on MAXQDA 2018 program. The deductive and inductive content analysis methods were used in combination. First, the data was divided into categories in the deductive content analysis method by considering the components of TPACK. The answers in each category were evaluated using the deductive and inductive approaches together, and then the sub-categories were distinguished. The sub-headings used in the interview form (deduction) were considered for some TPACK components by content descriptions available in the literature. At the same time, inferences made from students' answers (induction) were considered for some other components of TPACK. The answers given to the sub-categories were analyzed in an inductive approach, and codes were created- that is to say, the guidelines for coding the sub-categories were described. As a result, the data were analyzed more systematically.

The categories distinguished and the codes created in the content analysis to interpret the pre-service teachers' levels of TPACK in protein synthesis are shown in Table 1.

Table 1. The System of Categorising in Data Analysis

Categories	Sub-categories	Coding (guidelines for coding)
Pedagogical knowledge	Knowledge about students' learning difficulties	The characteristics of age group
		The properties of subjects easy/difficult for them to understand
		Causes of misconceptions
	Knowledge of teaching strategies, methods, techniques, activities and classroom management	Knowledge of classroom management
		Knowledge of strategies, methods, techniques and activities
	Knowledge of measurement and evaluation	How often, at what stages of the course
		Knowledge of measurement and evaluation method
		Giving feedback, determining misconceptions

Pedagogical content knowledge	Knowledge about students' learning difficulties in biology and in protein synthesis	Subjects easy and difficult for students to understand in the biology course Misconceptions about biology Concepts/events about protein synthesis easy and difficult for students to learn Misconceptions about protein synthesis
	Knowledge of strategies, methods, techniques activities in relation to teaching biology and protein synthesis and knowledge of classroom management	Strategies, methods, techniques and activities they plan to use in their classes Knowledge of classroom management in teaching protein synthesis Strategies, methods, techniques and activities they plan to use while teaching protein synthesis Preventing, determining and removing the misconceptions about protein synthesis
	Knowledge of curriculum and materials in relation to teaching biology and protein synthesis	The specific goals of biology curriculum The distribution of subjects according to years in biology curriculum Knowledge of materials in relation to teaching biology The place of protein synthesis (the scope and time allocated) in the programme The extent to which protein synthesis is associated with other subjects Students' gains in the subject of protein synthesis The way protein synthesis is presented in course books
	Knowledge of measurement and evaluation in relation to teaching biology and protein synthesis	Measurement and evaluation methods they plan to use/what is the object of measurement in the biology course
Technological knowledge	Knowledge of the concept of technology and the use of technology	Definition of the concept of technology What technologies they use and how often they use them Adapting into new technologies The purpose and length of using the internet
	Knowledge of computers	Knowledge of using computers For what purpose and how often they use computers
Technological pedagogical knowledge	The use of technology in teaching	The effects of using technology on the process of teaching (from the aspect of teachers) The effects of using technology on the process of teaching (from the aspect of students) Technologies planned to be used in teaching
	Competence in using technology in the teaching process	The choice of right technologies and implementing them in the process of teaching
Technological content knowledge	Knowledge of technology related to biological studies	Knowledge of technological instruments specific to the area of biology Knowledge of internet sites with content of biology Following technological developments related to biology Technologies scientists use in biology
	Knowledge of technology related to protein synthesis	Knowledge of internet sites related to protein synthesis Knowledge of technologies explaining protein synthesis
Technological pedagogical content knowledge	Knowledge of technological equipment and materials in relation to teaching protein synthesis	Technological equipment and materials they plan to use in teaching protein synthesis and reason for using them
	Knowledge of technology-supported teaching strategies, methods and techniques that can be used in teaching protein synthesis	Technology-supported teaching strategies, methods and techniques they plan to use in teaching protein synthesis and reasons for using them
	Using technology in determining and removing the misconceptions and learning difficulties in protein synthesis	Technological support they plan to use in determining and removing the misconceptions and learning difficulties in protein synthesis

	Using technology at the stage of measurement and evaluation in relation to teaching protein synthesis	Technologies they plan to use at the stage of measurement and evaluation in relation to teaching protein synthesis
Content knowledge	General self-perception of their knowledge of protein synthesis	The mark they give to themselves for their content knowledge (over 5) Being able to set up associations between concepts Misconceptions noticed
	Knowledge of protein synthesis	Coding was made as "adequate scientific explanation", "partially scientific explanation" and "non-scientific explanation" for each of the 22 questions according to the answer key prepared

The categories of evaluation that would enable the researchers to interpret the findings were distinguished after distinguishing the categories and sub-categories about the components of TPACK. The data concerning the sub-categories of TPACK were evaluated as "adequate scientific explanation," "partially scientific explanation," and "non-scientific explanation at this stage (Roth & Anderson, 1987). The principle of the coding set for the three categories was similar to the ones used in Kaya (2010) and Karakaya (2012)-as described below:

Adequate scientific explanation: adequate scientific explanation is made, and there are no misconceptions or partial understanding.

Partially scientific explanation: The answer is made partially, or there are missing parts; there are no misconceptions.

Non-scientific explanation: partially scientific information is given, but there are also incorrect and irrelevant answers, there are no answers, or there are misconceptions.

The grading system recommended by Vazquez-Alonso and Manassero-Mass (1999) was used to evaluate content knowledge questions for the three categories. The marking system was based on the idea that the range between points given to students' complete and incomplete answers should not be too narrow. Thus, scientific explanations were given 3.5 points, partially scientific explanations were given 1 point, and non-scientific answers were given 0 points. The average score that the participants received from the content knowledge test of 22 open-ended questions was calculated, and interpretations of their content knowledge were made possible.

Table 2 gives an example of how the questions in the content knowledge test were evaluated.

Table 2. A question in the Content Knowledge Test and the Analysis for it (question: why are the synthesised polypeptides in living creatures have different structures?)

Non-scientific explanation	Partially scientific explanation	Adequately scientific explanation
"That the genetic materials are different (PT8)" (0 Point)	"The sequence of amino acids is different (PT1)" (1 point)	"The differences in the number, sequence and type of amino acids (PT7)" (3.5 points)

Reliability and Validity of Data Analysis

Reliability in case studies means obtaining the same or similar results when another researcher repeats a study in the same way. Two experts in biology education were consulted to test reliability in this study. The experts analyzed the protocols according to the codes created and the categories distinguished by the researchers; then, the results were compared, the agreement was reached on the differences, and the necessary arrangements on the data were made.

The researchers had the opportunity to collect more comprehensive data with the use of more than one data collection tool, and they made efforts to promote construct validity by having variation in data collection (Yıldırım & Şimşek, 2006; Yin, 2003). Besides, the data collection tools were checked by experts prior to the implementation to test construct validity and content validity (Seggie & Bayyurt, 2015). Two lecturers of biology teaching and an experienced biology teacher were consulted at this stage.

FINDINGS

The findings obtained in this study are shown in Table 3 so that the findings for the components of TPACK can be associated and interpreted more easily. The students' attitudes towards biology science and biology course were analyzed by doing independent samples t-test according to gender. The findings for the analysis are shown briefly in Table 3.

Table 3. Findings for the Analysis of the Pre-service Teachers in the Framework of TPACK

Categories and sub-categories		Pre-service teachers							
Categories	Sub-categories	PT1	PT2	PT3	PT4	PT5	PT6	PT7	PT8
Pedagogical knowledge	Knowledge about students' learning difficulties	P	S	P	P	O	P	S	P
	Knowledge of teaching strategies, methods, techniques activities and classroom management	O	S	S	S	P	P	O	P
	Knowledge of measurement and evaluation	P	S	S	O	O	P	P	P
Pedagogical content knowledge	Knowledge about students' learning difficulties in biology and in protein synthesis	P	S	P	S	P	P	P	P
	Knowledge of strategies, methods, techniques, activities and classroom management in relation to teaching biology and protein synthesis	S	S	S	P	P	P	P	O
	Knowledge of curriculum and materials in relation to teaching biology and protein synthesis	O	P	S	O	O	O	O	O
	Knowledge of measurement and evaluation in relation to teaching biology and protein synthesis	O	P	S	P	S	S	S	P
Technological knowledge	Knowledge of the concept of technology and the use of technology/knowledge of computers	S	S	P	P	P	P	P	P
Technological pedagogical knowledge	Use of technology in teaching/competence	S	S	S	P	P	P	P	O
Technological content knowledge	Knowledge of technology related to biological studies and protein synthesis	O	S	P	P	P	P	O	O
Technological pedagogical content knowledge	Knowledge of technological equipment and materials in relation to teaching protein synthesis	S	S	P	P	S	S	S	O
	Knowledge of technology supported teaching strategies, methods and techniques usable in teaching protein synthesis	O	S	S	P	O	P	P	O
	Use of technology in determining and removing the misconceptions about and learning difficulties in protein synthesis	O	S	O	P	P	P	O	O
	Use of technology in teaching protein synthesis at the stage of measurement and evaluation	O	O	O	O	O	O	P	O
Content knowledge	General self-perceptions about their knowledge of protein synthesis **	3	5	3	3	2	3	3	2,5
	Their knowledge of protein synthesis***	19	34,5	25,5	22,5	28	7	18,5	28

* S stands for adequately scientific explanation; P stands for partially scientific explanation, O stands for non-scientific explanation ** The points that pre-service teachers give to their own content knowledge over 5. *** The average score they received from the content knowledge test over 77.

Although PT1 had given 3 points to his/her knowledge of protein synthesis over 5, the average score he/she received from the content knowledge test was 19 over 77. On examining the answers given to the questions in the content knowledge test and the questions in the interview form, it was found that PT1 lacked content knowledge. The participant was inadequate in technological content knowledge- which was a combination of technological knowledge (adequate) and content knowledge (inadequate). The participant's pedagogical knowledge was partially adequate. Technological pedagogical knowledge was considered to be adequate since he/she could integrate technology into his/her pedagogical knowledge. However, it was also found that the deficiency in PT1's content knowledge was reflected in his/her pedagogical content knowledge. The pre-service teacher was found to have

difficulty integrating the three types of knowledge because he/she had partially adequate pedagogical knowledge and adequate technological knowledge but inadequate content knowledge.

Samples from the statements made by PT1 during the interview areas in the following:

"[A misconception] is that it does not exactly mean what it means."

"Every moment of education is evaluation, in my opinion. The way one listens to the teacher, the way one writes…, everything…I will generally give multiple-choice tests or oral exams [when I become a teacher] and do exercises directed to exams. …. Feedback is necessary for students [as a result of evaluation]."

"Students have difficulty mostly understanding the major RNA and the minor RNA in protein production and the synthesis of big sub-division and the small sub-division."

"[In daily life] I usually use phones, televisions and computers. …. I use Facebook and Instagram actively…. I am quite good at computers and the internet."

"Use of technology affects the process of teaching in good ways because students learn better because smart boards are visual and because they make abstract concepts concrete, learning is more permanent. …. Students can think faster and make decisions more quickly due to technology."

PT2 received 34.5 over 77 in the content knowledge test even though he/she had given 5 points to his/her knowledge of protein synthesis over 5. The data demonstrated that he/she had a medium level of content knowledge. The participant also had adequate technological knowledge, and therefore he/she was adequate in technological content knowledge, a combination of the two domains. The pre-service teacher, who had adequate pedagogical content knowledge, was adequate in TPACK since he/she could integrate technology into the component.

Some of the examples for statements made by PT2 during the interview were as in the following:

"[A misconception] is the situation in which there is a difference of meaning between what students envision in their mind and what it means."

"I evaluate at the end of each subject. I cannot make healthy measurements with one single instrument of measurement. … I would summon my students one by one and tell them where they had mistakes, and I would give them Feedback…."

"Code, codon, chromosome genes, reproduction can be given as examples [for misconceptions students commonly have]. They first have difficulty understanding protein synthesis because they face too many unknown concepts. They confuse translation with transcription; they learn the concept of amino acid easily because they study it at grade nine."

"I think the fact that biology is within our life should be taught to children by giving examples from life. The subject of protein synthesis is under the subject of genes. The 12th graders are taught protein synthesis as the sub-subject…. Then, they move on to biotechnology."

"I use my phone continuously and my computer for about 4 hours a day…. I use the internet for things such as reading the news, UpToDate knowledge and articles."

"I use computers, overhead projectors and -if there are any- smart boards [in my classes]. …. [Because] there are too many abstract concepts… learning is retained better in mind by making students watch videos."

PT3 evaluated his/her knowledge of protein synthesis by giving 3 points to himself/herself over 5. The average score he/she received from the content knowledge test was 25.5 over 77. On examining the participant's answers to the questions in the content knowledge test and the questions in the interview form, it was found that he/she had an almost medium level of content knowledge, but it was inferred from his/her repeated statements that he/she had the Misconception that "protein synthesis does not occur unless DNA matches itself." The participant's technological knowledge was partially adequate. Since his/her pedagogical knowledge was adequate, his/her technological pedagogical knowledge was considered sufficient. The pre-service teacher mentioned could integrate technological knowledge into his/her pedagogical knowledge. However, the participant's TPACK component was generally inadequate since he/she could not integrate his/her technological knowledge into teaching protein synthesis even though his/her technological knowledge and pedagogical knowledge each was adequate on its own.

Some of the examples for statements made by PT3 during the interview were as in the following:

"It is necessary to have a good command of all components [of classroom management]. It is necessary to know time management to manage the classroom. … I want to use the discovery method in my classes."

"Students should be evaluated as a whole. Exams on their own are not important. We should look at whether students can use what they learn, whether they can adapt their learning into daily life, whether they participate in classes and whether they can do projects to be able to inculcate in them the skills which we call 21st-century skills."

"I think misconceptions mostly occur in theories, laws and hypotheses… primarily, there is the process in which DNA matches itself prior to protein synthesis, …. In fact, in my opinion, they have difficulty…. Because it is too abstract."

"Models, mock-ups can be prepared, or videos are available because subjects are explained rather abstractly while teaching protein synthesis. In my opinion, visualizing such videos and making students watch them enables students to learn better."

"I always use my phone in daily life. … We also use computers frequently. Furthermore, televisions and radios… the internet is mostly used in social media, but it is also a convenient method to learn what we wonder."

PT4 evaluated his/her knowledge of protein synthesis by giving himself/herself 3 points over 5. The average score he/she received from the content knowledge test was 22.5 over 77. The participant's answers to the questions in the content knowledge test and the questions in the interview form demonstrated that he/she lacked content knowledge. It was also found that the pre-service teacher had difficulty following technological developments specific to the area. Therefore, his/her technological knowledge was considered partially adequate. PT4- because he/she had inadequate knowledge of measurement and evaluation, which was a component of pedagogical knowledge- was partially adequate pedagogical knowledge. In support of this finding, he/she was observed to have partially adequate technological pedagogical knowledge- a combination of technical knowledge and pedagogical knowledge. The participant was inadequate in using technology at the stage of measurement and evaluation in teaching protein synthesis, and he/she generally had difficulty integrating technology into teaching protein synthesis.

Some of the examples for statements made by PT4 during the interview were as in the following:

"[Misconception] is mistaken knowledge of something."

"All students are different. It is difficult to appeal to all. For this reason, managing the classroom is also difficult."

"I think that evaluation should be made frequently because it makes students study hard. … I can use not only oral but also written exams. [The purpose of using different measurement and evaluation instruments] is to measure students' knowledge and motivate them to understand better."

"[I think that students will have difficulty in understanding protein synthesis] because it is also abstract, it is a subject which they need to imagine more."

"I would use the direct method in teaching protein synthesis. Firstly, I need to have a good command of the subject. I would ask questions when I start a lesson, try to reveal the concepts they know, and then teach them what they do not know. I would prepare worksheets for them; I would give them homework."

"Using technology facilitates students' learning. It motivates students because they learn by watching videos and by seeing. For example, teaching protein synthesis by making them watch videos rather than teaching it on the board enables learning in a shorter time and more effectively."

"I use computers (the internet) for researching outside the school, and I play games in the summer…. I believe that I am good at adapting to new technologies."

"Yes [I make use of technology in measurement and evaluation], such as preparing questions on the computer and getting them photocopied…."

PT5 evaluated his/her knowledge of protein synthesis by giving himself 2 points over 5. The average score he/she received from the content knowledge was 28 over 77. He/she almost had a medium level of content knowledge. His technological knowledge was partially adequate. The participant was found to know technological instruments specific to the area, use them, and be generally informed of technological developments related to biology. Thus, he/she was found to have partially adequate technological content knowledge. The fact that the participant had inadequate knowledge of measurement and evaluation and inadequate knowledge of students' learning difficulties, a component of pedagogical knowledge, demonstrated that he/she lacked pedagogical knowledge. In parallel to that, his/her technological pedagogical knowledge was also found to be partially adequate. The participant's knowledge of technology-supported teaching strategies, methods and techniques and of using technology at the stage of measurement and evaluation in teaching protein synthesis was inadequate. He/she could not know what technology-supported strategies, methods and techniques usable in teaching protein synthesis were. In general, it was concluded that the participant had inadequate TPACK because he/she could not integrate technological knowledge with pedagogical and content knowledge.

Samples from the statements made by PT5 during the interview were as in the following:

"[Misconception] means not knowing the definitions of concepts… the reason for it is insufficiency of resources."

"Managing the classroom is easy for me. It is necessary to know the properties of age groups."

"I plan to use written exams or question and answer method when I become a teacher. The purpose of using different measurement and evaluation instruments is to see what children understand from different aspects because every child may not be good at multiple-choice tests or essay type exams."

"[determining and removing students' misconceptions about protein synthesis] I can give them a quiz; I can do a question-and-answer activity. Even an exam can show what a student is lacking."

"I use technology in any area in daily life. My mobile phone is always in my hand. I spend time on the internet usually for communication. I use sources of news".

"I would use videos to show the stages [while teaching protein synthesis] … sound, sight; it would be beneficial to appeal to more than one sense. I would make students watch videos to determine misconceptions about protein synthesis and eliminate them. They would ask questions, or they would understand while watching the videos… I do not think that technology can be available [in the process of evaluation]."

PT6 evaluated his/her knowledge of protein synthesis by giving himself/herself 3 points over 5. The participant's average score from the content knowledge test was 7 over 77. He/she was found to have severe inadequacies in content knowledge. The statement "genetic code is created as a result of protein synthesis" notably strengthened the thought that he/she had inaccurate knowledge and misconceptions about the subject. It was found that the pre-service teacher had partially adequate technological knowledge, did not know what technologies to use about protein synthesis, but that he/she could name the technological instruments specific to biology in general and that he/she knew how to use them. Thus, it became apparent that his/her technological content knowledge was partially adequate. The participants' pedagogical knowledge was partially adequate. He/she could not adequately answer the questions about the effects of using technology on the teaching process. In parallel to that, his/her technological pedagogical knowledge was partially adequate. However, his/her knowledge of curriculum and materials about teaching protein synthesis-a component of pedagogical content knowledge- was inadequate, but the other components were partially adequate. The pre-service teacher was found to have difficulty in associating the three types of knowledge because he/she was inadequate in using technology at the stage of measurement and evaluation in teaching protein synthesis because he/she could associate technological knowledge with pedagogical knowledge but because his/her content knowledge was inadequate.

Samples from the statements made by PT6 during the interview were as in the following:

"Misconception. I can give such an example for it. One has logical reasons because He/he has learned it from somewhere, combining the pieces in his or her way, and he or she interprets it in that way. In my opinion, that person has learned the incorrect knowledge, and so the person has misconceptions."

"I think the subject that students can understand the most easily may be the fundamental properties of living things and the subject that they will have the most difficulty with maybe genetics… they can have difficulty understanding protein synthesis because it has complicated features. They may be confusing it with translation." Transcription in particular.

"[In teaching protein synthesis,] I would prefer the direct method. … However, I would use smart boards, videos, animations and visuals to concrete the subject. I would ask them questions at the beginning to determine misconceptions and to eliminate them. I would evaluate their knowledge and Feedback. Then, I would explain the real knowledge to them."

"Most probably, I would do fill in blanks exercise first to see if they had understood it. Then, I would ask them open-ended questions to see if they had understood the logic of the subject or if they could state it in their own words."

"I use computers, tablet PCs 24 hours a day. I spend time mostly for social media on the internet."

"Using technology affects the teaching process terribly if you are not good at technology. Because it is a waste of time, and students do not take you seriously… If you are competent in technology, I think it affects it positively."

PT7 evaluated his/her knowledge of protein synthesis by giving himself/herself 3 points over 5. The participant's average score from the content knowledge test was 18.5 over 77. It was remarkable that ribosome was a molecule available in the structure of RNA and that rRNA was the place where ribosome was produced. The participant had inaccurate knowledge and deficiencies in content knowledge. The participant was found to have inadequate technological content knowledge because he/she had partially adequate technical knowledge and because he/she could not integrate technology into content knowledge. Apart from inadequate knowledge of teaching strategies, methods, techniques and activities, and classroom management- the components of pedagogical knowledge; PT7 was partially adequate in other components. The participant had difficulty evaluating the effects of technology use on teaching from the aspect of students. Thus, the participant was partially adequate in technological

pedagogical knowledge. He/she was inadequate in the curriculum and material about teaching protein synthesis- a component of pedagogical content knowledge- but partially adequate in the other components. Besides, he/she had inadequate knowledge of using technology to determine misconceptions and eliminate them. In addition to that, he/she had difficulty associating technological knowledge with pedagogical knowledge. It was concluded that participant PT7 had partially adequate TPACK apart from his/her inadequacy in using technology to determine and eliminate misconceptions.

Samples from the statements made by PT7 during the interview were as in the following:

"[Misconception] is the thing that is known incorrectly by a large mass of people. Generalizations can cause it."

"It is generally logical to make evaluations at the end of each unit. There is a program. We should not move on to the next unit until students learn a unit. I would give worksheets, oral tests, open-ended questions… Yes, I would [give Feedback after an evaluation]. I would give worksheets to students. If there were any mistakes, I would explain them. I would ask them if they had any questions."

"I cannot remember the teaching strategies, methods and techniques that I can use in teaching protein synthesis. However, there should be something that will make students active, but it is a difficult subject. The teacher should also be active."

"I have not looked at the course books. I do not know anything about gains about protein synthesis."

"I use my phone and my computer the most. I began to use computers more often when I started university. I watch TV less. I usually spend time researching the internet- 2-3 hours a week. I use Instagram very often. I am concerned with them because I am curious about new technologies."

"Using technology affects the teaching process in terms of length of time. Especially using the smart board…. I think I am good at using the right technology in teaching. Because we know the technologies that students may need."

"Scientists have mostly used microscopes in reaching knowledge related to biology and in researching because they analyze microscopic structures."

PT8 evaluated his/her knowledge of protein synthesis by giving himself/herself 2.5 points over 5. The participant's average score from the content knowledge test was 28 over 77. His/her content knowledge was considered almost at a medium level. The participants' technological knowledge was partially adequate, but he/they did not know what technologies to use in protein synthesis. It became apparent that his/her technological content knowledge was inadequate since he/she could not integrate technology into content knowledge. PT8 had partially adequate pedagogical knowledge. The pre-service teacher could not evaluate the effects of using technology on the teaching process from students and teachers. Despite partial adequacy of his/her technological and pedagogical knowledge, he/she had difficulty associating the two, and his technological pedagogical knowledge was inadequate. The participant's knowledge of curriculum and materials and his/her knowledge of teaching strategies, methods, techniques and materials about teaching biology and protein synthesis was inadequate, but his/her knowledge of the other components was partially adequate. Although his/her technological knowledge, content knowledge and pedagogical knowledge were partially adequate, he/she could not associate the components. Thus, he/she was found to be inadequate in TPACK.

Samples from the statements made by PT8 during the interview were as in the following:

"[Misconception] is the wrong knowledge of a concept. It can stem from teachers. They might have misdescribed concepts."

"Classroom management involves the ability to control the classroom, to attract the attention, to transfer the knowledge and to use the time efficiently… different teaching strategies, methods, techniques and activities are nice in theory but difficult in practice."

"I usually evaluate at the end of classes. Maybe at the end of a unit. I use all of the measurement instruments. How much a student has understood can be found with various questions… Yes, I would explain in what points students have made mistakes as a result of the evaluation."

"Students learn the subject of cells the most easily because they have fundamental knowledge from primary school years. Systems can seem too complex. The misconceptions students commonly have in biology can be in theoretical subjects."

"Using technology can influence students both in positive and negative ways. ıt changes from person to person… Drawings or videos can be used in teaching protein synthesis… quizzes can be given to determine students' misconceptions about protein synthesis, and I would try to teach the right things based on the quizzes."

"I use computers and my phone very often in daily life. I use the internet usually for watching films, but I also use it for research."

An examination of the answers given to the content knowledge test indicated that the pre-service teachers had significant knowledge deficiencies and misconceptions. They were found to have difficulty in answering the questions in that a codon encoded only one amino acid. However, an amino acid could be encoded by more than one codon, that one type of tRNA carried only one type of amino acid, but a type of amino acid could carry more than one type of tRNA, in the frequency of replication, transcription and translation events and in the way DNA spring unravels in replication.

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

The findings of the components of TPACK are interpreted under separate headings in this section, and then individual evaluations are made based on the relationships between the components within the theoretical framework of TPACK. The results for individual-based analyses are interpreted, and recommendations are made here.

Pedagogical Knowledge

It was found in this study that pre-service teachers' most remarkable deficiency in pedagogical knowledge was about students' misconceptions. Even though they offered a partially adequate definition of a misconception, they did not know the reasons for students' misconceptions. However, knowing the reasons for misconceptions can provide teachers with essential clues on preventing and eliminating them. Apart from that, the pre-service teachers can have a medium level of pedagogical content knowledge even though that is lacking in some points. The results obtained for pre-service teachers' pedagogical content knowledge are also supported by the ones obtained in other studies. Kaya (2010), for instance, in a study conducted with the participation of pre-service science and technology teachers, found that the participants' knowledge of teaching strategies, methods and techniques was partially adequate. Similarly, Uşak (2005) also reported that pre-service science teachers preferred traditional measurement and evaluation instruments.

It is a requirement that pre-service teachers follow the new practices and approaches in teaching for their professional development. Therefore, course content should be created to enable pre-service teachers to follow contemporary developments. They should be informed of and motivated to update their knowledge of new teaching strategies, methods and activities and alternative measurement and evaluation techniques during their education and professional life. Thus, they will be able to understand better the demands and needs of changing student profiles, and they will be able to have more accurate pedagogical approaches towards students. It is also thought that highlighting misconceptions more during teacher training will be beneficial in preventing and eliminating them. In addition, enriching the content of such courses as "Developmental Psychology" and "Teaching Methods and Techniques- which are offered in undergraduate education- would also be beneficial.

Pedagogical Content Knowledge

The pre-service teachers had partially adequate knowledge about learning difficulties in biology and protein synthesis. In addition to their deficiencies about misconceptions in pedagogical knowledge, they were also found to have inadequate knowledge about students' current misconceptions about protein synthesis. However, teachers need to know about students' misconceptions to make meaningful and permanent learning. Therefore, it is thought that considering the subjects in which secondary education students have difficulty and their probable misconceptions in relevant undergraduate courses would be beneficial. In this way, pre-service teachers would know the probable misconceptions and the difficulties students might have and plan the teaching process accordingly.

This current study found that the pre-service teachers knew of the strategies, methods, techniques and activities they could use for permanent and mastery learning but did not have adequate knowledge about how to use them in teaching biology and protein synthesis. Some of the participants used concepts such as constructivist teaching approach and mastery learning model in their explanations, but they had difficulty giving tangible examples for the strategies, methods and techniques they could use in teaching protein synthesis. However, teachers are expected to know the teaching methods, strategies, techniques, and materials, providing students with gains about the content. Such deficiencies in pedagogical content knowledge stem from inadequate content knowledge because the participants tended to give hesitant and general answers to questions about what stage of teaching and what techniques they could use. However, they knew specific teaching methods and techniques.

The participants were found to have inadequate knowledge of the curriculum and materials about teaching the biology course and protein synthesis. The deficiency might be attributed to continual changes in the biology curriculum.

A close examination of the findings demonstrated that the pre-service teachers were weaker in pedagogical content knowledge than in pedagogical knowledge. Studies in the literature also report teachers' and pre-service teachers' deficiencies in pedagogical content knowledge (such as Polly, 2010; Çelik, 2015; Kartal, 2017). The pre-service teachers included in this current study answered the questions measuring their general pedagogical knowledge better, but they had difficulty when they were required to associate their content knowledge with their pedagogical knowledge. It was thought to stem from inadequate content

knowledge. They were found to have significant lacks in and misconceptions about the subject according to the statements they had made in the interviews and the content knowledge test results.

Pre-service teachers' awareness of the necessity for having adequate and up-to-date knowledge about the structure and content of such courses as Teaching Practice, Curriculum Development and Teaching can be raised, and thus, they can be made to follow the changes in the curriculum. The studies conducted in this respect have shown that the activities done in such courses as School Experience and Teaching Practice are insufficient and that they do not serve their purpose (Aksu & Demirtaş, 2006; Güzel & Oral, 2008; Kaya, Kılıç, & Akdeniz, 2004; Şimşek, 2005; Yiğit & Alev, 2005). It may be recommended that the cooperation between teacher training institutions and the Ministry of National Education in teacher training should be revised so that the deficiencies in this respect can be eliminated and the communication between teachers and university lecturers and the length of practice courses should be increased so that the teachers in schools of teaching practice can offer more practical guidance.

Technological Knowledge

This study also found that the pre-service teachers' technological knowledge was partially adequate. All of them were able to make comments on the concept of technology, but they had difficulty defining it. They were less knowledgeable about technologies they did not need to use but were adequately knowledgeable about the technologies they frequently used in daily life. Thus, the pre-service teachers were found to have an acceptable level of technological knowledge. Considering the studies in the literature (such as Hırça & Şimşek, 2013; Kaya et al., 2011; Şad, Açıkgül, & Delican, 2015) and the results of them, the interpretation that pre-service teachers' technological knowledge is inadequate and that they need improvement in this respect can be made. Therefore, the need for pre-service teachers to improve themselves in using technology should be emphasized, their consciousness should be raised, and they should be motivated to take elective courses and learn to use the technologies they need or may need to use. Even though computers and technology use courses are available in universities, practice is also needed in those courses. It is thought that teachers can behave advantages in catching up with the era if they have experience with applied courses and have more self-confidence in using technology.

Technological Pedagogical Knowledge

The participants said that they would use smart boards to make students watch videos and animations or use microscopes to catch their attention, but they had difficulty associating teaching strategies, methods, and techniques with technology. They could not explain using technology, especially in the measurement and evaluation process. In a similar study, Kılıç (2015) also found that most pre-service teachers did not know what technologies to integrate and how to integrate them at the stage of measurement and evaluation, and therefore they could not assess students' knowledge by using technology. The finding was attributed to the fact that they did not have sufficient knowledge and experience to use technological support in measurement and evaluation during their training. As a result, it may be said that pre-service teachers are partially adequate in integrating technology into the teaching process. Similarly, Meriç (2014) concluded that pre-service science teachers had low self-confidence in technological pedagogical knowledge.

Pre-service teachers need more knowledge and more self-confidence in using technology in teaching. It would be beneficial to consider what technologies to use, at what stages of teaching to use them and for what purposes and how to use them in the content of pedagogy-related courses in the biology teaching programs of universities. The pre-service teachers included in this research had difficulty integrating technology, especially into measurement and evaluation. Therefore, knowledge and practice in using technology in measurement and evaluation could be emphasized more in the relevant course content in undergraduate education.

Technological Content Knowledge

Based on the findings obtained in this paper, it may be stated that pre-service biology teachers have partial knowledge of technological content knowledge. It was remarkable that the participants had inadequate knowledge, especially about what technologies scientists used and how they used them to reach knowledge and research biology. Their responses indicated that they were also lacking in knowledge about the scientific method. The pre-service teachers who were relatively good at technological knowledge had difficulty answering the questions on content knowledge- which was also remarkable. The situation was thought to stem from a lack of content knowledge. Studies with similar and different results are available in the literature. While Polly (2010), for instance, reported that teachers' technological content knowledge about mathematics teaching was quite good, Karakaya (2012) concluded that science teachers' technological content knowledge about global environmental problems was inadequate.

Pre-service teachers should be made to have the correct perceptions primarily about the nature of science. It will be beneficial for this purpose to know the misconceptions they bring from secondary education and from earlier education about the nature of science to deal with them and eliminate them during undergraduate education. Encouraging them to follow technological developments related to the area, allocating more space for biotechnological studies and providing them with more opportunities to use domain-specific technologies are also considered beneficial in inculcating the desired level of technological content

knowledge. Technological equipment and material support for pre-service teachers should be increased in universities, and they should be encouraged to use them. In addition to that, they should also be made to prepare more technological materials in the relevant undergraduate courses under the gains described in the secondary education course curriculum.

Content Knowledge

An examination of the pre-service teachers' scores from the content knowledge test- in which the maximum score receivable was 77- showed that only 3 out of 8 participants answered almost half of the questions accurately. The data from the content knowledge test and the interviews indicated that the pre-service teachers, in general, lacked content knowledge. Besides, they were also found to have misconceptions about the subject according to the answers they had given to the content knowledge test and the statements they had made in the interviews. They will cause misconceptions stemming from teaching if they graduate from university and start teaching without eliminating their misconceptions. Thus, Kaya (2012), in a study conducted with pre-service science teachers, points out that pre-service teachers' misconceptions about the subject and their inadequate conceptual knowledge were the most significant problems in students' mastery and permanent learning. The educational process at university might need revision by taking pre-service teachers' inadequacy of content knowledge and their misconceptions into consideration. It becomes clear on examining the content of programs training teachers that the time allocated to teaching protein synthesis in courses such as general biology, molecular genetics and genetics and molecular biology is much less than the time allocated to the subject in secondary education. Undoubtedly, undergraduate students are different from secondary education students in terms of cognitive levels and terms of readiness and therefore, post-graduate students are expected to understand and learn a more significant amount of knowledge in a shorter time, to reach the knowledge on their own and to be able to control their learning better. However, it is also clear that there are deficiencies in having permanence in learning, setting up cause and effect relationships, and learning the subject meaningfully.

Courses in which pre-service teachers can present their content knowledge in the classroom environment can be included in the teacher training program to apply for the courses in their area (such as genetics, molecular biology, etc.). It is believed that knowledge will be more permanent when they prepare to present a subject and become aware of their own and their classmates' deficiencies and misconceptions while presenting the subject. What is said above is not related only to protein synthesis, but it would be beneficial to have similar practice with all the courses in the domain.

Technological Pedagogical Content Knowledge

There was a general decrease in the participants' explanations on TPACK compared to their explanations on PCK. Considering their answers to all the components of TPACK separately, it was clear that they were knowledgeable about certain subjects but had difficulty associating pedagogical knowledge with content knowledge and technological knowledge. Therefore, more studies should be conducted to ensure they are informed of TPACK and its components. It may be said that considering the developing educational and domain-specific technologies, it would be beneficial to consider all three factors together and plan the teaching process accordingly. There is a need to train pre-service teachers so that they are ready to offer effective teaching by using relevant technologies and having adequate pedagogical and content knowledge in our time. This study, which was conducted with the inclusion of 8 pre-service teachers, could be repeated in a quantitative method with larger samples by developing scales to measure the TPACK and including in-service teachers and pre-service teachers. It would be possible to evaluate the TPACK levels of teachers and pre-service teachers concerning protein synthesis.

Additionally, the study could also be repeated with other subjects known to be difficult for students, and thus, efforts could be made to improve pre-service teachers' levels of TPACK. Raising teachers well equipped in TPACK will increase the efficiency of biology courses in secondary education. Classes will be more enjoyable and instructive through teaching, supported by technology and vital in pedagogical knowledge and content knowledge.

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We hereby declare that the study has not unethical issues and that research and publication ethics have been observed carefully.

Researchers' contribution rate

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Ethics Committee Approval Information

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