Journal of Theoretical Educational Science, 15(4), 907-937, October 2022
Kuramsal Eğitimbilim Dergisi, 15(4), 907-937, Ekim 2022
[Online]: http://dergipark.org.tr/akukeg
DOI number: http://doi.org/10.30831/akukeg.1110596

Examining Science Teachers' Performances at Planning Geology Lesson through TPACK-based Argumentation Practices*

Fen Öğretmenlerinin TPAB temelli Argümantasyon Uygulamalarıyla Jeoloji Dersi Planlama Performanslarının İncelenmesi

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Received: 28 April 2022 **Research Article** **Accepted:** 24 August 2022

ABSTRACT: This study aims to reveal science teachers' performances in designing TPACK-based argumentation practices for teaching geology. This study used a holistic single case study design where thirty-two science teachers participated in a professional development program. All materials such as videos, etc. used by the teachers and the Pedagogical Reasoning Assessment Form (PRAF) were used as data collection tools. Descriptive analysis was conducted through the scoring rubric for lesson plans and content analysis for PRAF. Findings indicated that teachers successfully used TPACK indicators in their lessons. Findings also revealed that although teachers thought that formative assessment could be improved by learning from professional development programs, they did not use technology for assessment in their lesson plans. Related to the argumentation process, teachers tended to construct their arguments with one rebuttal, and they could not use warrants. Moreover, although teachers had high scores in the quality of claim, rebuttal, and backing respectively, they had some problems in presenting data and warrant for the claim. PRAF findings indicated that the TPACK-based Argumentation Practices Professional Development Program (TPACK-bAP PDP) enriched their lesson plans in some aspects.

Keywords: Argumentation, pedagogical reasoning, technological pedagogical content knowledge (TPACK).

ÖZ: Bu çalışma jeoloji öğretiminde TPAB temelli argümantasyon uygulamaları tasarlama konusunda fen bilimleri öğretmenlerinin performanslarını ortaya çıkarmayı amaçlamaktadır. Katılımcılarını mesleki gelişim programına katılan 32 fen bilimleri öğretmeninin oluşturduğu çalışmada bütüncül tekli durum çalışması deseni kullanılmıştır. Öğretmenler tarafından kullanılan video vb. tüm materyaller ile Pedagojik Akıl Yürütme Değerlendirme Formu (PADF) veri toplama aracı olarak kullanılmıştır. Ders planları için puanlama rubriği aracılığıyla betimsel analiz, PDAF için içerik analizi yapılmıştır. Bulgular öğretmenlerin TPAB göstergelerini derslerinde kullanma konusunda başarılı olduklarını göstermiştir. Bulgular ayrıca öğretmenlerin mesleki gelişim programında öğrendikleri ile süreç değerlendirmenin iyileştirilebileceğini düşündüklerini ancak ders planlarında değerlendirme için teknoloji kullanmadıklarını ortaya çıkarmıştır. Argümantasyon süreciyle ilgili olarak, öğretmenlerin argümanlarını tek bir çürütücü ile oluşturmaya eğilimli oldukları ve gerekçe kullanamadıkları bulunmuştur. Bununla birlikte, öğretmenler iddia, çürütücü ve destekleyici kaliteleri bakımından yüksek puanlara sahip olmalarına rağmen, veri sunma ve iddiayı gerekçelendirme konusunda bazı problemler yaşamaktadırlar. PADF bulguları, TPAB temelli argümantasyon uygulamalarının bazı açılardan ders planlarını zenginleştirdiğini göstermiştir.

Anahtar kelimeler: Argümantasyon, pedagojik akıl yürütme, teknolojik pedagojik alan bilgisi (TPAB).

* This study was generated based on the findings from the project, which was supported by the Scientific and Technological Council of Turkey with the project number 117B269.
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Citation Information
Unal-Coban, G., Kocagul, M., Akpinar, E., & Baran, B. (202?). Examining science teachers' performances at planning geology lesson through TPACK-based argumentation practices. *Kuramsal Eğitimbilim Dergisi [Journal of Theoretical Educational Science]*, *15*(4), 907-937.

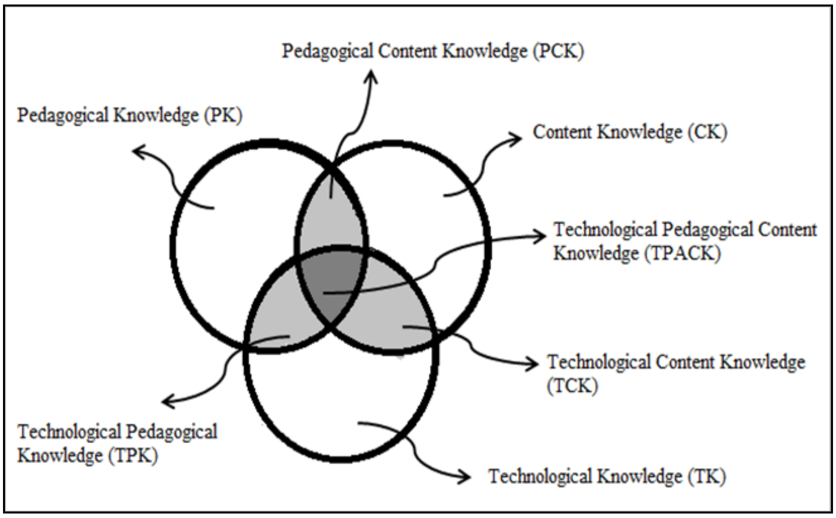
ISSN: 1308-1659

Technological Pedagogical Content Knowledge

Technology is everywhere in our lives. We use technology for banking transactions, ordering food, shopping, etc. It is inevitable that technology increases its impact on our lives day by day and, as a result, affects the learning environment. According to Trust (2018), the aim of technology integration into the learning environment should be the transformation of learning. In other words, technology integration should allow students to have new learning experiences. Here, the greatest role for effective integration of technology belongs to teachers, who are the designers of learning. With the thought of technology integration into the learning process, teachers should have both pedagogy and content knowledge (PCK) (Shulman, 1986) and technology knowledge. The technology integration into PCK constitutes technological, pedagogical content knowledge (TPACK), as Mishra and Koehler (2006) proposed. According to Dietrich (2018), TPACK requires the use of technology for both presenting and teaching the concept, facilitating concept learning, the knowledge about concepts, theories, approaches, etc., the use of technology effectively and productively in daily lives, and choosing appropriate instructional methods for teaching the concept.

Figure 1

Technological Pedagogical Content Knowledge Framework



Note. (Mishra & Koehler, 2006)

Here CK correspondences to teachers' knowledge of learning/teaching subjects. PK is teachers' knowledge of the learning/teaching process while TK is the knowledge of using all technological tools (Koehler & Mishra, 2009). PCK, which is one of the dual interactions in the TPACK framework, correspondences to using appropriate pedagogies for teaching a specific content (Shulman, 1986). Similarly, while TCK is the knowledge about using appropriate technological tools for teaching specific content, TPK is an understanding of how the use of technology affects learning. Since TPACK includes the interactions between three knowledge domains (Figure 1), researchers have investigated its nature. The nature of TPACK can be distinctive (Lee & Kim, 2014), and each knowledge domain can be a significant predictor of TPACK or integrative (Koehler & Mishra, 2009), which TPACK can be developed based on the complex interactions of three knowledge domains or transformative (Angeli & Valanides, 2008) which contextual factors such as teachers' beliefs about school, learner, teaching, etc. besides the knowledge about three domains are effective on TPACK development. We believed that the interactions between three main knowledge domains could cause the development of TPACK, as the integrative view proposed.

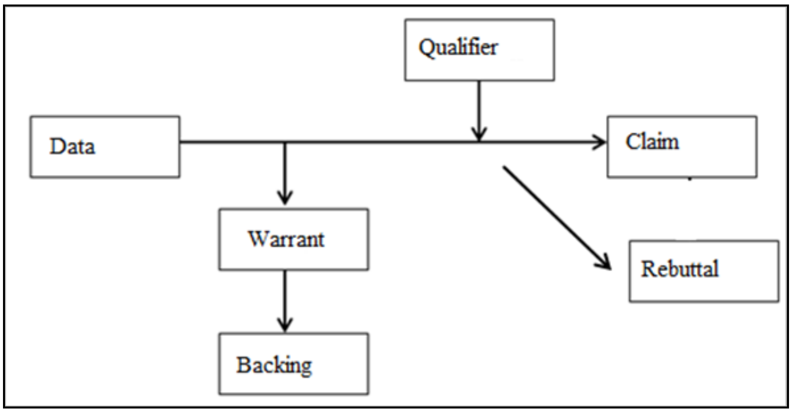
TPACK has been studied for many years and researchers have presented some evidence on the importance of having TPACK. They reported that TPACK has positive effects on concept teaching (Akkoc et al., 2012), selecting appropriate educational activities based on technology (Aktas & Ozmen, 2020), and classroom management (Saritepeci, 2021). Besides, it was reported that training on TPACK affected teachers' design beliefs (Chai & Koh, 2017; Koh et al., 2015). To sum up, TPACK serves as a key for effective technology integration into classes.

Argumentation

Argumentation can be defined as a knowledge justification and persuasion process individually or socially. Argumentation is seen as important, especially in science education. According to Jimenez-Aleixandre and Erduran (2007), argumentation supports the development of communication skills, scientific literacy, reasoning and epistemology, and the use of scientific language when writing and talking. Therefore, curriculums emphasize the integration of argumentation into the learning environment with the desire of promoting informed citizenship for the 21st century. In practicing argumentation, teachers should guide the students' inquiry process and encourage them to justify the knowledge and evaluate the arguments (Jimenez-Aleixandre, 2007). Researchers studying argumentation offered various approaches for practicing or assessing this process (Erduran et al., 2004; Kelly & Takao, 2002; Sandoval & Millwood, 2005; Toulmin, 1958; Zohar & Nemet, 2002). We, in this study, adopted Toulmin's Argument Pattern (TAP). TAP consists of six elements as data, warrant, backing, qualifier, rebuttal, and claim (Figure 2). According to Erduran (2007), a claim is an assertion of the problem at hand. Data and warrants serve as support for the claim. Here, data present facts to support the claim and warrants links between the claim and data. The backing which serves the support for warrants is the scientific generalizations. Rebuttals correspondence to the exceptional circumstances where the claim is not valid while qualifiers correspondence to the degree of reliance.

Figure 2

Toulmin Argument Pattern (TAP)



Note. (Toulmin, 1958)

TAP is used mostly in argumentation studies, but it has some disadvantages. One of the problems with TAP is that the definitions of TAP components (warrant, backing, etc.) are not clear (Kelly et al., 1998) and so analyzing students' argumentation is difficult. The other problem is that TAP could not assess the epistemic status of arguments (Erduran, 2007). Another one is that it allows analyzing the argument structure but does not give an idea about its trustworthiness (Driver et al., 2000). Although TAP has some criticism, we used TAP because it is useful in the short argumentation process (Kelly et al., 1998). It helps teachers to model argumentation and has a solid understanding of it (Simon, 2008). Another reason for choosing TAP is that it allows visualizing the thinking process through argument mapping, as shown in Figure 2. Argument mapping enables individuals to develop critical thinking skills (Dwyer et al., 2013; Kunsch et al., 2014) and their argumentation skills (Buzan & Buzan, 2000).

The results of the studies led us to use argumentation as the PK component of TPACK. The study by Sengul et al. (2020) showed that the increase in PK of argumentation caused the increase in teachers' epistemological belief levels and these teachers tended to use argumentation while teaching. Further, other studies reported that technological tools support and promote argumentation in classes (Bell, 2004; Clark & Sampson, 2007; Ozcinar, 2015; Yeh & She, 2010). With the thought of using the advantages of both technology and argumentation to create effective learning environments, we designed a professional development program (TPACK-bAP) for science teachers that integrate argumentation into the TPACK framework.

Geology Teaching

For our TPACK-bAP, there are some reasons for choosing geology for the CK component of TPACK. One reason is that learning geology is important for dealing with the challenges (global warming, ozone layer, sustainability, etc.) that we may face and taking precautions against them (National Research Council [NRC], 2012). Teaching geology enables students to become well decision makers. Since studying geology requires inference skills and spatial reasoning, it promotes the development of thinking skills (Orion, 2017). The other reason is that although its importance, geology education has not gotten enough attention. For example, in Turkey, geology content is embedded in the science units in middle grades and the geography units in high schools and there is no individual geology course until the university level (Kazanci et al., 2016). The situation seems similar across other countries. According to the results of the study by Kacovsky et al. (2021), the ratio of obligatory learning outcomes regarding geology was 4% in the Czech Republic, 3% in Estonia, and only 1% in Poland and Slovenia. Another reason is that although geology generally has a low number of learning gains, there are many misconceptions regarding geology. Francek (2013) examined the literature and found 502 misconceptions, of which over 40% of them belonged to middle or high school students, regarding geology such as plate tectonics, weathering/erosion, and historical geology.

Geology does not use controlled experiments as in biology or physics rather it draws conclusions based on the existing data and makes inferences from them. In other words, individuals construct geological knowledge by collecting evidence and evaluating them in the light of related theoretical knowledge. From this point of view, argumentation is a well-established context for studying geology besides gaining basic science process skills such as formulating, hypothesizing, observing, making inferences, drawing conclusions, and the nature of science. Moreover, other studies reported that technology integration facilitated geology teaching and learning (Dolphin et al., 2019; Greer & Heaney, 2004; Wallace & Witus, 2013). Considering these points, relationships between geology-technology and geology-argumentation originated this study.

The Need and Originality of the Study

The main components of this study are TPACK, argumentation, and geology teaching. To highlight the need and originality of this study, we firstly presented a general look into the existing literature about TPACK, argumentation, and geology teaching and assessed the trends in them.

Studies about TPACK are heavily focused on determining the current status of students or teachers' TPACK (Archambault & Crippen, 2009; Chai et al., 2013; Schmidt et al., 2009; Yeh et al., 2015), pedagogical knowledge development for TPACK (Harris & Hofer, 2011; Khan, 2011; Wetzel et al., 2008) and technological knowledge development for TPACK (Jamieson-Proctor et al., 2010; Spaulding, 2016; Trainin et al., 2018). These studies pointed out that TPACK development studies mostly adopted the distinctive view of TPACK. Unlike these studies, we adopted the integrative view of TPACK. In our TPACK-bAP professional development program, teachers experienced argumentation as the PK component of TPACK, some technologies as the TK component, geological knowledge as the CK component, and some other activities which were based on PCK or TPK components of TPACK. After that, teachers were asked to design TPACK-bAP in a geology lesson that correspondences to the practice of the integrative nature of TPACK. The study by Ahadi et al. (2021) also reveals the significance of our study. The results of this study indicated that evaluation studies regarding teachers' professional development on technology use mostly reported teachers' new knowledge gain or affective factors and only a few of them analyzed teachers' teaching strategies (3%) and teaching quality (7%) after attending PDP. In our study, we shared the results of teachers' lesson plans to reveal the teachers' practices after attending PDP.

Besides, there are many argumentation studies in the literature. These studies are heavily on determining the effect of argumentation intervention on some variables, developing the argumentation skills, and determining the status of argumentation skills and focused mostly on physics and biology-related subjects (Bag & Calik, 2017). Further, most of them were conducted with students (Kahraman & Kaya, 2021). From the perspective of PK, studying argumentation with teachers and in the context of geology will provide an important response to the need in the relevant field and will especially contribute to the determination of teachers' thoughts in this process and the development and enrichment of geology teaching. From the point of view of TPK, this research will contribute to the elimination of the gap in the literature in terms of showing teachers how to integrate the use of technology into the argumentation process through a different topic. Because most technology-supported argumentation studies used software to support the argumentation process (Bell, 1997; McAlister et al., 2004; Pinkwart et al., 2006; Ranney & Schank, 1998; Schwarz & Glassner, 2007) or technological tools (Gordon et al., 2007; van Gelder, 2003) to visualize this process. We presented different technologies in the TPACK-bAP professional development program rather than using only one software or technological tool to allow teachers to integrate the argumentation process with different technologies. From the TPACK perspective, studying argumentation also has importance. Although technology-supported argumentation studies were widespread, studies on argumentation from the TPACK perspective were rare. The pioneering study was conducted by Unal-Coban et al. (2016). In this study, in-service science teachers experienced TPACK-based argumentation training, which reflects the integrative view of TPACK, and results indicated that TPACK-based argumentation practices significantly affected their TPACK self-efficacy perceptions and views on argument quality.

Further, it was reported that participant teachers declared that they could use TPACK-based argumentation practices in their classes. In another study, Namdar and Salih (2017) investigated pre-service science teachers (PSST)' views about TPACK-based argumentation practices and found that PSSTs saw TPACK-based argumentation as important in terms of effective learning and teaching, generating scientific knowledge, personal development, and classroom management. In Korkmaz's study (2020), which integrates TPACK and argumentation in a mathematical context, pre-service mathematics teachers collected data through GeoGebra and then engaged in the argumentation process for reaching some generalizations in the context of analytic geometry. Although our study seems to share some common points with the study of Unal-Coban et al. (2016) such as participants as in-service science teachers and the use of TPACK-based argumentation practices, this study focuses on the practices of teachers after attending TPACK-bAP rather than evaluating the effectiveness of the professional development program.

Studies about earth science teaching, in which geology is one component of it, are mainly focused on PCK or TCK components of TPACK. In one of the PCK studies for teaching earth science, Folkomer (1981) compared the effectiveness of lecture method, laboratory-based lecture method, and field trips and found that field trips were the most effective method for teaching geology because they enabled students to remember facts. Supporting this, Elkins and Elkins (2007) indicated that field-trip-based geoscience teaching had significant effects on gaining and improving geoscience concepts. In another study, Anderson and Contino (2010) investigated the effect of web diagrams on earth science knowledge which have some common aspects with concept maps, but they begin from a central concept like mind maps and use of phrases or clauses to make radially connections between concepts. They found that web diagrams were effective for increasing students' networking capacity and their fluency in explaining scientific concepts. Besides, students had positive attitudes toward both using web diagrams and their usefulness in learning. Similarly, Apedoe et al. (2006) designed an inquiry-based geology course and they found that this method was successful in developing both inquiry skills and content knowledge. Other PCK studies also used argumentation in the context of earth science (Clayton & Gautier, 2006; Koffman et al., 2017; Short et al., 2020; Takao et al., 2002; Trend, 2009; Yoo et al., 2020). The common point of the studies above was that most of them used argumentation for teaching socio-scientific issues such as global warming in the context of earth science rather than focusing on geology content solely. One of the TCK studies for teaching earth science investigated the effect of technology integration on geology teaching. This study offered virtual field trips comprising images by drone, 2-D photomosaic, and 3-D computer models. Researchers reported some student difficulties, such as having difficulties with the relationship between observation and inference about virtual field trips and they offered to teach the "how" aspect of geology (Dolphin et al., 2019). This study is important because it shows that technology integration into geology teaching should aim to teach not the "what" aspect of geology but also "how" and it emphasizes a well-designed learning environment for technology-supported geology teaching. In another study, software that can be used for organizing geospatial data was introduced (Dobush et al., 2004).

Similarly, another study reported the effectiveness of student response technologies in an introductory earth science course (Greer & Heaney, 2004). In another study, Wallace and Witus (2013) used iPads as an educational tool for teaching geology. They integrated iPads into both field-based and classroom-based courses. iPads served to visualize, display, and share spatial data and note-taking in the field-based course while they were used for digitalizing the materials and also taking notes in classroom-based courses. As seen in these studies, specific technological tools such as iPads or software were used for technology integration into geology teaching. Unlike these studies, we offered different technological tools teachers are already aware of, to use effectively in their lessons.

Other studies use TPACK in geology teaching. For example, Hesthammer et al. (2002) investigated the effectiveness of two technological tools in the context of problem-based learning. In their study, while one group used a field simulator to promote deep geological understanding, the other used a digital camera and PC. It was found that both approaches were effective for enhancing geology learning. In Totten's study (2008), an earth science course was designed for pre-service teachers to teach them how to incorporate earth science content with pedagogy. This course included PowerPoint presentations that aimed to probe pre-service teachers' current understanding, educational games, in-class activities which were based on inquiry method, video-case studies which aimed to show real cases to pre-service teachers, clicker assessments to assess pre-service teachers' understanding during the course period and some other additional resources (journal articles, web sites, etc.). Results of this study showed that pre-service teachers found this course useful, and their content knowledge and instructional practices improved. In a similar study, Doering et al. (2014) designed a TPACK-based professional development program for middle and high school geography teachers. This program consisted of geography for CK, inquiry-based learning for PK, and GeoThentic application for TK. The results of this study indicated that this program was effective on both teachers' TPK development and students' geographic inquiry skills. Another study reported the effectiveness of a one-day professional development program in integrating geographic information systems (GIS) into classes based on the TPACK framework. Middle and high school teachers experienced the use of GIS technically, teaching materials, and GIS for implementing inquiry-based learning (Oda et al., 2020). Studies using the TPACK framework in teaching geology generally focus on problem-based or inquiry-based learning as a PK component. However, Morgan (2006) introduced software, a computer-supported argumentation visualization for geography education. This study seems similar to our study, but we have some differences. Although both studies used argumentation for the

PK component, Morgan's study used only one software for the TK component and focused on teaching geography content. However, we introduced different technologies for integrating them into the argumentation process and focused on geology content, especially principles of geology.

This study is important for some aspects. Firstly, although there are geology learning gains, embedded into other courses such as science or geography, in middle and high school curriculums at the local level, there is not a professional development program for ensuring teachers develop their geological knowledge. Secondly, although there are professional development opportunities, especially for PK development related to inquiry-based learning and there are studies that integrate technology into geology teaching at the global level, there is not any study that uses only argumentation or TPACK and argumentation together in geology teaching. Therefore, this study aims to determine science teachers' performances in designing TPACK-bAP lesson plans for teaching principles of geology content. The research questions are as follows:

RQ1. What is the status of science teachers in designing TPACK-bAP lesson plans?

RQ2. What does science teachers' pedagogical reasoning tell us about TPACK-bAP?

Method

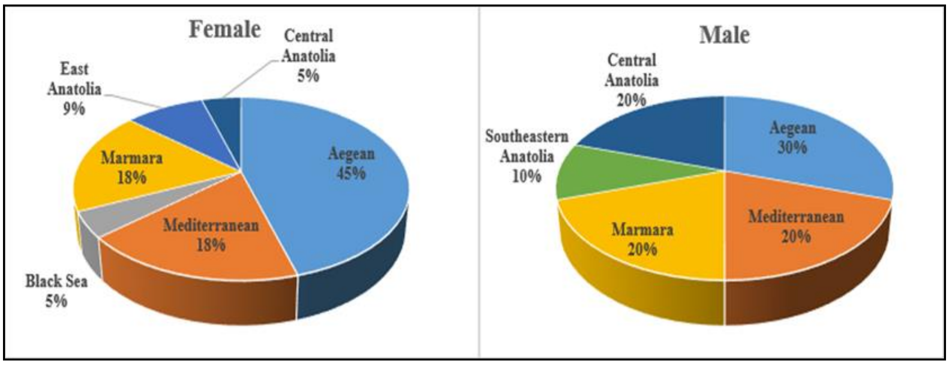
This study was on a holistic single-case study approach to reveal the extent of participant teachers' performances in designing TPACK-bAP lesson plans. In this approach, the single case, which can be critical, extreme/unique, revelatory, or longitudinal case representative, is described in detail from various perspectives (Yin, 2002). The single case in this study was science teachers who participated in TPACK-bAP professional development program.

Participants

The participants were thirty-two science teachers who were selected based on purposive sampling. This sampling technique was preferred to create a heterogeneous group. According to this, teachers having different years of professional experience and working in different regions of the country were selected. Further, it was also considered to have nearly equal distribution in terms of their gender. Information about participants is presented in Figure 3.

Figure 3

Teachers' Demographic Information based on Gender and Region



22 female (68.75%) and ten male (31.25%) teachers participated in this study. There were thirteen teachers from Aegean, six from both Mediterranean and Marmara, one from both the Black Sea and Southeastern Anatolia, two from East Anatolia, and three from Central Anatolia regions. Figure 3 shows the distribution of teachers according to their gender and regions in which they work.

Data Collection Tools

Lesson Plans

After completing the TPACK-bAP professional development program, teachers designed lesson plans based on their learning. All materials such as PowerPoint presentations, videos, and handouts that they used when preparing lesson plans generated the source of data.

Pedagogical Reasoning Assessment Form

Pedagogical reasoning can be defined as the decision-making process for teachers about which practices they do, how, and why. To determine teachers' pedagogical reasoning about TPACK-bAP to explain the tendencies in their lesson plan, Pedagogical Reasoning Assessment Form (PRAF) was developed by the researchers based on Shulman's (1987) six stages model (*comprehension of subject knowledge, transformation of subject knowledge into teachable representations, instruction, evaluation of students' learning and teacher performance, reflection, and new comprehensions*) and implemented to science teachers after the professional development program. The validity of the form was provided by expert views and revised accordingly. In the final form, there were six questions, each corresponding to Shulman's six stages model.

Application Process

To make sense of the application process, Table 1 was created.

Table 1

Summary of the Process

Criteria considered for the development of the application	According to Essam (2021), two main criteria should be considered when designing a PDP for technology integration. The first is that PDP should include activities in which appropriate technology and pedagogy are used for content. The second one is pedagogical use of technology should be based on teachers' needs. Supporting this, Irmak (2018) stated that for effective technology integration, how the technology and pedagogy integrate into each other should be explained explicitly. Based on these views, we designed TPACK-bAP professional development program by considering the integrative view of TPACK.
Purpose of the application	The purpose of the application process was to promote the development of teachers' TPACK knowledge; in this way, we aimed to encourage them to design a TPACK-based argumentation lesson plan without guidance.
Implementation process	We firstly ensured teachers develop their PK regarding argumentation. They learned what argumentation and its

	components were and how it was constructed and used as a teaching-learning tool or assessment tool. Secondly, teachers experienced technology activities for their TK development. They learned the effective use of word-processing programs, smart boards, and social media platforms for educational aims, creating videos, web 2.0 applications, creating virtual classes, and preparing animations and simulations. Thirdly, teachers experienced TPK, PCK, and TCK activities. For example, science teachers used digital measurement tools such as digital pH-meter, digital ampere meter, digital voltmeter, TDS-meter, lux-meter, etc. to answer scientific problems such as “determining the difference between seawater from salt water” or “creating the luminance map of the class” etc. in the context of TCK activity. Fourthly, teachers engaged in activities to develop their CK regarding geology. The geological activities aimed to enhance teachers’ preparedness for the geological field trip. In the context of CK activities, firstly the lecturer presented the principles of geology (uniformitarianism, original horizontality, superposition, cross-cutting relationships, relative age, and stratigraphy), and then teachers modeled these principles with the help of play-doughs. After that, teachers engaged in a thematic game for learning the geologic time scale. The next day, teachers participated in a geological field trip. They were asked to take photos, videos, notes, etc., on the field trip. They observed the original horizontality and superposition principles in the curved argillaceous limestone layers and discussed why the layers curved and how the relative age could be determined in the curved layers in the first observation point. They observed the point of contact exposure between the curved argillaceous limestone layers and igneous rocks and discussed the relative ages of these rocks in the context of the superposition principle in the second observation point. In the third observation point, teachers observed limestone layers with large and little deformations and alluvium in the streambed at that time and discussed their relative ages based on the principles of geology. In the fourth observation point, teachers examined the laminated limestone and made inferences about the formation and relative age based on microfossils inside it. Then, they observed the point of contact exposure between laminated limestone and limestone with rudist fossils and they compared the relative ages of these two rocks in the context of the principle of inclusion. At the end of the field trip, teachers were asked to draw a stratigraphic column. On the last day of PDP, teachers designed TPACK-bAP in the context of geology based on the field trip’s data (notes, photos, videos, etc.). For this, worksheets (Figure 4) which included learning scenarios that were following the learning in the field trip, were distributed to teachers, and they used their pedagogical, technological, and content knowledge to design this lesson plan.
Anticipated time	The program covered a week; each day, the studies lasted from 9^{00} am to 17^{00} pm. The activities took from 30 to 90 minutes or more. At the end of two or more activities, there was a coffee break or lunch.

Figure 4

Sections from the Sample Worksheets

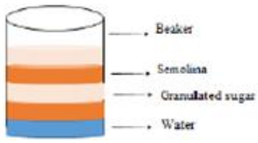
Activity Name: Designing TPACK-based argumentation lesson plan

Scenario: Zeynep went to school-trip one day and the appearance (in the picture) took Zeynep's attraction. Zeynep wondered about how it was formed and started to investigate it.

Can you help Zeynep to answer the research question?

Group Work

Materials Needed: Beaker (500 ml), Granulated sugar, Semolina and a pencil.



Procedure: Pour some water at the bottom of the beaker. Then, add semolina nearly in 5 mm thickness. After that, add granulated sugar in nearly same thickness to the semolina layer. Repeat this procedure until you have two layers semolina and two layers granulated sugar.

Which principles of geology do you see in your model?

____

____

____

Activity Name: Designing TPACK-based argumentation lesson plan

Scenario: Think that you are a geologist and you met a unit as shown in Figure 1 below in the field trip. Your mission is to find the chronological order of the event E. How do you know the order of event E?

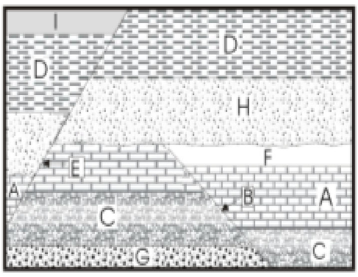


Figure 1. Appearance of the unit

What do you think about the relative age of the event E?

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____

____

Which evidences do you present for your answer?

____

____

____

Present some daily life examples or theoretical knowledge in order to support the evidences you presented

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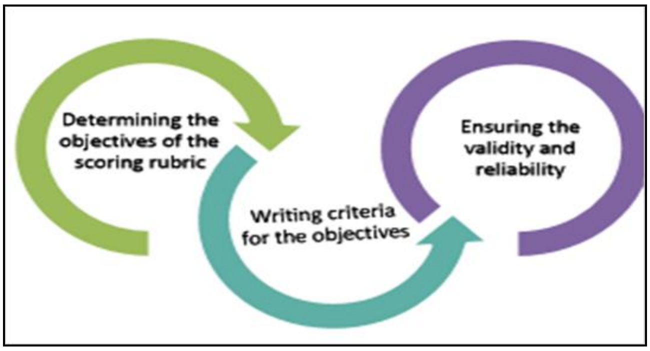
Data Analysis

Content analysis was used for the analysis of PRAF. Two researchers coded and categorized the obtained data. Agreement on the categorization process was found as .93, which was accepted as reliable. Descriptive analysis was used for the analysis of lesson plans. For this reason, researchers developed *The Scoring Rubric for TPACK-bAP Lesson Plans (RuTbA-LP)*. The development process of the scoring rubric was conducted based on the steps proposed by Moskal and Leydens (2000).

Figure 5

Steps for Developing a Scoring Rubric



Note. (Created based on Moskal & Leydens, 2000)

The scoring rubric aimed to evaluate science teachers' lesson plans for TPACK-bAP. For this, existing scoring rubrics were examined first in stage Step 1. Literature review pointed out that knowledge and efficacy towards TPACK were the mostly measured factors through Likert-type scales (Akman & Guven, 2015; Sahin, 2011; Schmid et al., 2020) and other alternative data collection tools for examining TPACK in the classes were rare (Akyuz, 2018; Kirikcilar & Yildiz, 2019) and not suitable for our purpose. The literature review also indicated that there were scoring rubrics for argumentation and they were mostly on the quality of arguments, epistemological levels of arguments, and the construct of arguments (Aslan, 2014; Erduran et al., 2004; Kelly & Takao, 2002; Lawson, 2003; Sandoval, 2003; Sandoval & Millwood, 2005; Wilson, 2014; Zohar & Nemet, 2002). Although scoring rubrics about argumentation shared common components to be evaluated, their criteria were not sufficiently suitable for our purpose. Therefore, in the stage of Step 2, criteria regarding the TPACK dimension of RuTbA-LP were created based on studies that reported the use of TPACK in the classes and indicators of TPACK-based lessons (Hidayat, 2019; Ocak & Baran, 2019; Yeh et al., 2013) and criteria regarding argumentation dimension were created based on the studies of Aldag (2006), Erduran et al. (2004) and Wilson (2014). Criteria in RuTbA-LP are presented in Table 2.

Table 2

The Scoring Rubric for Designing TPACK-bAP Lesson Plans

		3 point	2 point	1 point	0 point
The use of technological pedagogical content knowledge	Using appropriate technologies for content knowledge	The use of technology is appropriate	The use of technology is appropriate but can be improved	The use of technology is not appropriate	No technology is used for content knowledge
	Creating technology-supported learning materials	More than one material that is suitable for both content knowledge and students' needs has been created	Only one material that is suitable for both content knowledge and students' needs has been created	Material (s) which is not suitable for content knowledge or students' needs	Any technology-supported material has not been created.

	Using technology for presentation	An interesting and visually appropriate presentation has been prepared	The presentation has some deficiencies in terms of noticeability or visual appropriateness	The presentation is not interesting or visually appropriate	No technology has been used for the presentation
	Using technology for assessing the learning	A technology-supported assessment tool that is appropriate for both content and students' characteristics has been used	The technology-supported assessment tool is not fully appropriate for content or students' characteristics	An appropriate technology-supported assessment tool has not been used	No technology-supported assessment tool has been used
	5 point	4 point	3 point	2 point	1 point
Components of argument	Includes claim, data, warrant, backing, qualifier, and more than one rebuttal.	Includes claim, data, warrant, backing, qualifier, and only one rebuttal.	Includes claim, data, warrant, backing, qualifier, and no rebuttal.	Lacks at least one component such as claim, data, warrant, backing, or qualifier.	Includes only claim.
		3 point	2 point	1 point	0 point
The quality of the argument	Claim	More than one hypothesis has been proposed related to the problem and one of them has been stated clearly as the claim.	Only one hypothesis has been proposed related to the problem and has been stated clearly as the claim.	A claim related to the problem but not stated clearly has been proposed.	No claim or a claim not related to the problem has been proposed.
	Data	Enough and related data has been stated clearly to support the claim	Related, but not enough data has been stated to support the claim.	Related but weak data such as personal experiences/observations, prejudices, etc. have been stated.	No data that is not related to the claim has been stated.
	Warrant	Related directly to both the claim and data, and stated clearly how the data could explain the claim	Related directly to both the claim and data, but stated unclearly how the data could explain the claim	The data has some details but could not explain the claim	No warrant has been stated
	Backing	Complete and correct scientific principles that could support the warrant have been stated.	Scientific principles that could support the warrant but have uncertainties (need more tests) have been stated	Correct scientific principles that could not support the warrant or wrong scientific principles that could support the warrant have been stated	No warrant has been stated

Qualifier	The cases that the claim is valid have been identified in detail and are scientifically accurate	The cases that the claim is valid and has been identified as scientifically accurate but not in detail	The cases that the claim is valid and have been identified based on personal experiences and prejudices	No qualifier has been stated
Rebuttal	Related directly to the claim and the cases where the claim is invalid have been identified in detail	Related directly to the claim, but the cases that could not ensure sufficiently the invalidity of the claim have been stated	Not related to the claim and the cases that could not ensure the invalidity of the claim has been stated	No rebuttal has been stated

In the stage of ensuring the validity and reliability, one researcher studying only technology integration to learning environments, one studying only supporting argumentation in classes, and one studying both TPACK and argumentation examined the RuTbA-LP according to the questions in Table 3. They all gave the same answers, "Yes" or "No" to questions and agreed on the content and construct validity of the scoring rubric.

Table 3

Questions for Ensuring the Validity of the Scoring Rubric

Content Validity	*Are the components to be evaluated appropriately? *Is there any component that is not related to content? *Does the criteria meet all aspects of the component? *Is there any criteria that are not related to the component?
Construct Validity	*Do all criteria meet the objectives of the scoring rubric? *Is there any criteria that are not related to the objectives of the scoring?

Reliability studies were also conducted for the scoring rubric. Two groups of teachers designed TPACK-bAP lesson plans, and then three raters evaluated them using the scoring rubric. Percentage of agreement, Kendall's coefficient of concordance (also known as Kendall's W), and intraclass correlation coefficient (ICC) were calculated for reliability. The percentage of agreement value was 72.72% for three raters. Kendall-W, which is used for determining the degree of agreement on measurement values between more than two raters (Karagoz, 2017), also showed that there was an agreement between three raters (Kendall's W=.859, p=.000<.05). Besides, ICC was calculated based on two-way random effects model to generalize the reliability results and consistency agreement and mean of k-raters as assessment basis. It was found as .956. Although there is no standardized value for interpreting ICC, Portney and Watkins (2000) proposed that values greater than .90 are the indicator of excellent reliability. In sum, RuTbA-LP meets the requirements for validity and reliability.

Ethical Procedures

This study was carried out with the approval of the Dokuz Eylül University Institute of Educational Sciences Ethics Committee (30.12.2016/12). Before the implementation, all participants declared that they voluntarily participated in the study by completing the voluntary participant consent form.

Results

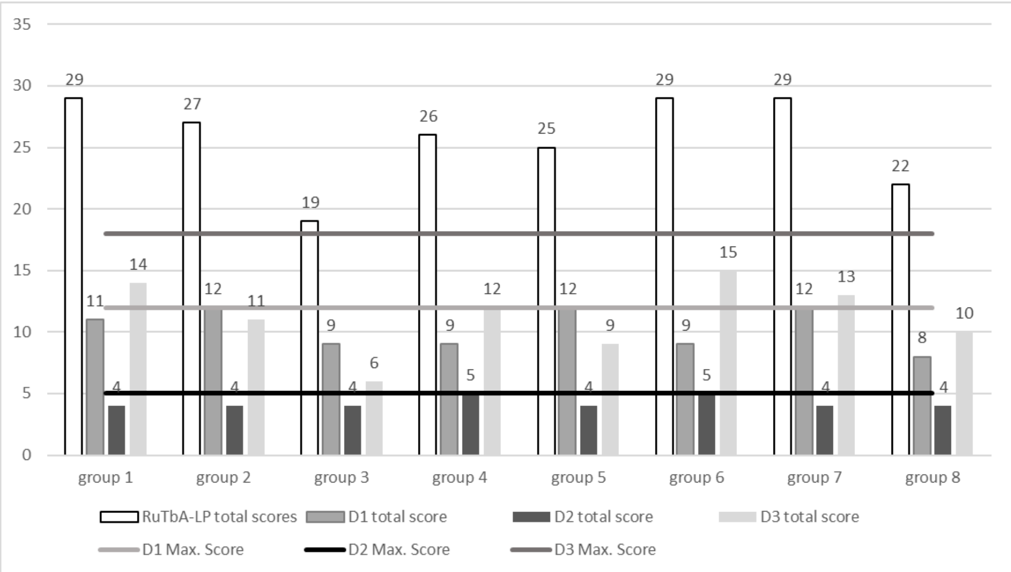
How Are the Status of Science Teachers in Designing TPACK-bAP Lesson Plans?

To answer the RQ1, the total scores and mean scores of each item in RuTbA-LP were calculated. Obtained results are presented in Figures 6 and 7, respectively.

Figure 6 indicated that groups' total scores of RuTbA-LP were generally high. They got an average of 25.75 points out of 35 and reached a success rate of 73.57% generally. According to dimensions, they got an average of 10.25 points out of 12 in the use of the TPACK dimension, 4.25 points out of 5 in components of argument dimension, and 11.25 points out of 18 in the quality of argument dimension. This showed that teachers had nearly the same success in both the use of TPACK 85.42%) and components of argument dimensions (85%) and relatively lower success in the quality of argument dimension (62.5%). Regarding the TPACK dimension, only three groups had the maximum score, which was 12. Related to the construction of the argument dimension, only two groups used more than one rebuttal in their arguments. None of the groups constructed a perfect quality argument related to the quality of the argument dimension.

Figure 6

Comparison of the Total Scores of RuTbA-LP

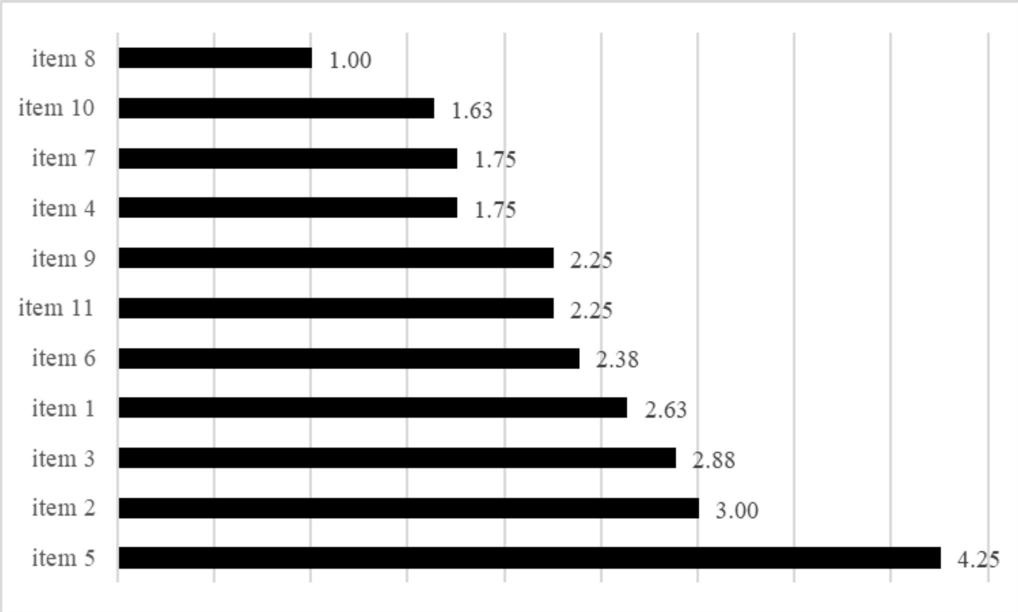


Note. D1: The use of TPACK; D2: Components of argument; D3: Quality of argument

In addition to total score analysis, mean scores for each item in RuTbA-LP were also analyzed.

Figure 7

Mean Scores for Each Item in RuTbA-LP



According to Figure 7, teachers got the highest score (*X*=4.25/5 points) in item 5, item 2 (*X*=3.00/3 points), and item 3 (*X*=2.88/3 points), respectively. Here, while item 5 was about components of argument, items 2 and 3 were related to the use of TPACK. However, they got the lowest score in item 8 (*X*=1.00/3points), item 10 (*X*=1.63/3 points), item 7 (1.75/3 points), which was about the quality of argument, and also item 4 (1.75/3 points) which was about the use of TPACK dimension. Apart from these, Table 4 was also created to examine teachers' scores on each item in detail.

Table 4

Teachers' Ability to Design TPACK-bAP Lesson Plan

		3 point		2 point		1point		0 point			
		f	%	f	%	f	%	f	%		
The use of TPACK	Item 1	5	62.5	3	37.5	-	-	-	-		
	Item 2	8	100	-	-	-	-	-	-		
	Item 3	7	87.5	1	12.5	-	-	-	-		
	Item 4	4	50	1	12.5	-	-	3	37.5		
		5 point		4 point		3 point		2 point		1 point	
		f	%	f	%	f	%	f	%	f	%
Components of argument	Item 5	2	25	6	75	-	-	-	-	-	-
		3 point		2 point		1point		0 point			
		f	%	f	%	f	%	f	%		
The quality of the argument	Item 6	5	62.5	2	25	-	-	1	12.5		
	Item7	1	12.5	4	50	3	37.5	-	-		
	Item 8	-	-	1	12.5	6	75	1	12.5		

Item 9	3	37.5	4	50	1	12.5	-	-
Item 10	2	25	3	37.5	1	12.5	2	25
Item 11	3	37.5	4	50	1	12.5	-	-

Table 4 showed that teachers were the most successful in creating technology-supported learning materials (such as videos, animations, etc.) (item 2) (100%), using technology for presentation (item 3) (87.5%), and using appropriate technologies for content knowledge (item 1) (62.5%) respectively. However, nearly half of them did not use technology for assessment (item 4). They showed a tendency to construct their argument with only one rebuttal (item 5). Furthermore, more than half of the teacher groups proposed alternative hypotheses for the research question and stated one of them as the claim (item 6). In their arguments, 37.5% of them used data from weak sources such as their observations, experiences, etc. (item 7). There was a similar situation for the warrant component. Most teachers used warrants that could not explain the claim (75%) (item 8). However, they were successful at proposing backings. They used correct but incomplete scientific principles to support the warrant (item 9). Besides, they were successful at proposing qualifiers and rebuttals. They proposed scientifically accurate qualifiers mostly but with a lack of detail for 37.5% of them (item 10). According to proposing rebuttal, most of them associated rebuttal with the claim, but 50% of them could not sufficiently ensure the claim's invalidity (item 11).

What Does Science Teachers' Pedagogical Reasoning Tell Us about TPACK-bAP?

In the first question, teachers were asked about how TPACK-bAP affected their educational aims, relationship with other courses, their contribution to students, and their content knowledge level regarding the learning gain they would teach. They stated that TPACK-bAP contributed to their planning skills, mostly regarding educational aims. They used expressions such as "*TPACK-bAP requires preliminary preparation so that my planning skills can enhance*," "*I was aware of planning technology for my lessons*," etc. On the other hand, they thought that TPACK-bAP has the potential to make students participate actively in a lesson regarding contribution to students. They said that "*TPACK-bAP allows students to practice*," "*I can engage students in inquiry process*", "*I can promote students' active participation with technology use*" and "*I can prevent students from remembering facts by engaging them in the argumentation process*". Corresponding with relating science with other courses, teachers expressed the effect of TPACK-bAP on their efficacy gain. For example, they said that "*I can relate science with other courses when constructing argument components*". Teachers evaluated the effect of TPACK-bAP on content knowledge levels in terms of both students' conceptual knowledge and theirs. They used expressions such that "*I can ensure students' meaningful learning through argumentation*" and "*Argumentation requires a solid content knowledge especially for constructing backing, qualifier, and rebuttal components. I can keep my content knowledge fresh and develop it through the use of argumentation*."

In the second question, teachers were asked about how and why TPACK-bAP contribute to their lesson plans. Teachers gave answers in terms of classroom learning, resource use, and evaluation process. Related to "classroom learning", teachers expressed that "*I can motivate students with different activities*," "*I can design activities for promoting argumentation*", "*I can plan the lesson effectively*", and "*I can promote the interactions in class*". Related to "resources use," teachers stated that they could use various resources effectively. Besides, they said that especially formative assessment could be improved with the learning from TPACK-bAP. For example, they used expressions such as "*I can use different assessment tools, this contributes to making more accurate formative assessments, and I will use my learning, especially in the evaluation process. I will use EDMODO*."

In the third question, teachers were asked how and why TPACK-bAP affects their teaching identity. They gave answers based on pedagogical interactions and content knowledge. For example, one teacher said, "My lessons were heavily teacher-centered but after I experienced the practices based on inquiry and technology, I will design my lessons *more student-centered*." Another teacher said, "*Although I have an understanding of student-centered learning, sometimes practicing this may be difficult. But I can teach effectively with the help of visual and digital resources*." As seen, teachers emphasized the active role of students in the learning process in the context of pedagogical interactions. Furthermore, teachers clarified that TPACK-bAP contributed to an increase in content knowledge and technology use for teaching content.

In the fourth question, teachers were asked whether TPACK-bAP would promote reviewing and re-examining their behaviors and instructional decisions when teaching. All teachers gave a "*Yes*" answer to this question and they explained that they asked questions to themselves regarding pedagogical and self-reflection questions. Related to pedagogical questions, teachers asked about how to evaluate students' arguments, how to find qualifiers and rebuttals to an argument, and how to enrich class activities. In the context of self-reflection questions, teachers mostly evaluated themselves among their colleagues.

In the fifth question, the potential effect of TPACK-bAP on gaining new knowledge and skills was questioned. All teachers clarified that they gained new knowledge and skills regarding pedagogy. For example, while one teacher said that "*I learned new method, argumentation and I would practice it in my class*," the other teachers explained "*I design my lessons emphasizing argument schema*", "*I have an opportunity about how to practice technology effectively*" and "*I had an awareness on the importance of using worksheets*".

In the last question, teachers' views about the practice and sustainability of TPACK-bAP were questioned. They expressed their views based on three categories: physical condition of class, using technology, and time. Related to the physical condition of the class, one teacher said, "*Although practicing TPACK-bAP is difficult in a crowded class, I will try it*." Related to using technology, it was stated "*Technology use is now a natural need, and it is required for adopting innovations*". Finally, related to time, teachers generally thought that using TPACK-bAP may be time-consuming in the beginning, but once students get used to it, it will be easier to practice.

Discussion and Conclusion

This study aimed to determine science teachers' performances in designing TPACK-bAP lesson plans for teaching principles of geology content. Two research questions were considered. One was about how science teachers' status was about designing TPACK-bAP lesson plans and the other was about their pedagogical reasoning about TPACK-bAP.

Data regarding the first research question were obtained through the lesson plans and analyzed through RuTbA-LP. Results indicated that teachers showed a success rate of 73.57% in designing TPACK-bAP lesson plans and especially in the use of TPACK indicators in their lessons. They got an average of 10.25 points out of 12 in the use of the TPACK indicators dimension. "*Creating technology-supported learning material*" was the item that teachers were the most successful in this dimension. This may stem from the TPACK-bAP PDP during which teachers experienced activities for their technological knowledge (TK) development. They learned to create animations and simulations and prepare and rearrange the videos. In other words, an increase in their TK ensured them to create effective TPACK-based lesson plans. This result supports the study by Long et al. (2020), in which they stated that each TPK, TK, and PK was a strong predictor of TPACK. Further, this result follows the studies by Trainin et al. (2018) in which they reported that technology knowledge predicted technology integration frequency, and by Lehtinen et al. (2016) which it was stated that technological knowledge was associated with the usefulness of simulation and the views for integrating them into teaching. Moreover, teachers had high mean scores in "*using technology for presentation*" and "*using appropriate technologies for content knowledge*" items. The TPACK's positive effects on both teaching (Akkoc et al., 2012) and the selection of appropriate educational activities based on technology (Aktas & Ozmen, 2020) may lead us to gather these results.

Another important finding pointed out that teachers succeed less in "*using technology for assessing the learning,*" although they declared in PRAF that formative assessment could be improved by learning from TPACK-bAP. Nearly half of them did not use technology for assessment in their lesson plans. The reason for this may stem from their lack of experience and efficacy in using technology for assessment in classes. Other studies reported that teachers needed to be confident in using technology in assessment (Jordan & Mitchell, 2009; Ridgway et al., 2004). Another reason for this finding may be teachers' beliefs about their students. They may think that the use of technology in assessment can be difficult with inexperienced students. This view is supported by Borko et al. (2000), declaring that teachers want to change their assessment practices to reflect those advocated by any reformist message so long as it reproduces features of teaching and learning mandated for their classrooms. Therefore, although technology is somewhat seen as a reform, it is not widely used as a general assessment media as the main way of educational evaluation is based on the paper-pencil test country-wide. So, science teachers who participated in our research are reluctant to disrupt their routine in their classrooms; as Lee and William (2005) emphasized, the practice of formative assessment demands reconstructing the teaching practices that they have worked so hard to build. They conducted a case study to describe the process of teacher change and the development of formative assessment practices and found six factors that could be attributed to the significant changes in teachers' practices, namely; credible evidence that motivated teachers to change their practices, having practical ideas to implement in the classrooms immediately, continuous support from the researchers and professional learning community, interventions to provide opportunities for reflection on immediate actions and further perspectives and insights, enough time to support teachers' slow pace of change, flexibility to use as many strategies presented to develop their formative assessment practice. As a result, teachers' motivation to change requires wider and systematical reform-like movements rather than a practice of a series of in-service training programs.

Another finding indicated that teachers had a success rate of 85% in the components of the argument dimension. This dimension was the second in RuTbA-LP that teachers had high scores. Findings related to this dimension pointed out that although some teachers used more than one rebuttal in their arguments, most of them tended to use only one rebuttal. This finding is consistent with the study by Zohar and Nemet (2002), even if the study groups are different. They found that students could propose rebuttals, but these rebuttals tended to be simple and included only one justification. According to Toulmin (1958), rebuttals serve as showing exceptional cases. Therefore, proposing a rebuttal requires solid content knowledge and evaluation of this. The reason for teachers' tendency to use only one rebuttal when constructing an argument may be related to the context. In our study, teachers studied principles of geology content. In geology, knowledge is generated based on inferences, as Ault (1998) said. Here, teachers devoted little time to gaining content knowledge about geology. They learned geology content intensely for about 1.5 days. Therefore, teachers' content knowledge may be insufficient for proposing more rebuttals. The other finding related to the quality of argument dimension supports this assumption. According to this, teachers could use correct but incomplete scientific principles to support the warrant. This finding also shows that teachers gained content knowledge with some deficiencies.

Findings about the quality of argument dimension in RuTbA-LP showed that teachers had relatively lower success. They got 11.25 points out of 18 and reached a success rate of 62.5%. Although teachers had high scores in the quality of claim, rebuttal, and backing respectively, they had some problems in presenting data and warrant for the claim. Most participants could not state enough data to support the claim or used weak data sources such as personal beliefs, prejudices, etc. This finding is consistent with other studies declaring that students could not use scientific evidence to support their claim and have enough understanding to explain how data is used as evidence (Sadler & Zeidler, 2004; Schimek, 2012) even if the study groups are different. The reason for this may be related to the content of the TPACK-bAP PDP. In training, teachers experienced the argumentation process as a teaching/learning and assessment tool, but they did not inform about what counts as data, evidence, or warrant, their similarities, and differences from each other. The lack of knowledge about the components of the argumentation process may cause this finding. Another reason may stem from the methodological problems of the Toulmin Argument Pattern (TAP), as Kelly and his colleagues (1998) said. TAP is useful for a solid understanding of the argumentation process; however, what counts as data, warrant, backing, etc., is not clear. This raises some difficulties, such as requiring a solid understanding of the language in the context of evaluating the argumentation process.

The findings about teachers' pedagogical reasoning indicated that all teachers agreed on the effect of TPACK-bAP on reviewing and re-examining the behaviors and instructional decisions. They stated that TPACK-bAP PDP enriched the lesson plans in terms of classroom learning especially related to pedagogical interactions, resources use, and technology use for content knowledge, determining educational aim, and gaining new knowledge and skills. According to Mailhos (1999), pedagogical reasoning requires the capacity to select adequate content knowledge, plan and implement the most proper learning situations, and reflect and make a decision in the teaching/learning process. Based on this definition, the finding shows the contribution of TPACK-bAP to their pedagogical reasoning and is consistent with Cunningham's study (2007). Both studies revealed that teachers considered three main factors: student-related, structural factors such as resources, and teacher-related factors when they reason pedagogically. They also showed a tendency to practice and sustain the learning from TPACK-bAP in their classes. This may be related to preparing learning environments after TPACK-bAP PDP. According to Loughran et al. (2016), the most effective way to develop pedagogical reasoning is through reflection. In supporting this, Dewey (1933) declared that reflection is important for shaping practical knowledge through experiential learning. Therefore, teachers may develop their pedagogical reasoning when they design lesson plans for implementing TPACK-bAP learning.

Similarly, Pella's (2015) study clarified that the practice-based learning model, which comprises teachers' active participation in professional development, facilitated the development of pedagogical reasoning. Another reason for this finding may stem from the content of TPACK-bAP PDP. In this study, teachers experienced the argumentation method and how it can be blended with technology in the context of geology. According to Northfield and Gunstone (1997), modeling and promoting instructional ways being advocated is an effective way of developing pedagogical reasoning. Based on this view, teachers may use argumentation and technology in their classes.

In conclusion, this study showed that the TPACK-based argumentation practices training contributed to their lesson plan designs and the findings of pedagogical reasoning confirmed this. Teachers could use technology to teach content knowledge and create instructional media; however, they did not prefer to use it for assessment. They also made quality claims, backings, and rebuttals, but they had some problems with data and warrant for their argument, and they tended to use only one rebuttal when constructing it. Although teachers had some deficiencies with technology use and argumentation process, TPACK-bAP PDP was able to affect their pedagogical reasoning. It could motivate them to practice and sustain the learning from the training in their classes.

Implications

This study provides evidence that TPACK-bAP professional development affected teachers' pedagogical reasoning, and they could reflect their decisions about TPACK-bAP in their lesson plans. Our study contributed to the effectiveness of the TPACK framework in geology education. It also showed the potential of the professional development program for effective geology education. For this, we suggest further training studies on geology education with different pedagogies, technologies, and frameworks. Our study revealed that teachers were more successful in using TPACK indicators than argumentation in their lessons and constructing arguments with components than constructing them with quality. We thought that the reason for teachers' problems with constructing quality arguments might stem from their epistemological views. Therefore, we suggest further training for the development of teachers' epistemological understanding. This study has also validated a scoring rubric for assessing the TPACK-based argumentation lesson plans. Other researchers can use this instrument to determine in-service or pre-service teachers' lesson designs based on TPACK-based argumentation.

Acknowledgments

We thank the Scientific and Technological Council of Turkey for supporting our study with project number 117B269. We also thank Prof. Dr. Bilal SARI for the geology field trip and the science teachers for participating in our project.

Statement of Responsibility

All authors have participated sufficiently in literature review, methodology, data analysis, data interpretation, writing and revisions of the manuscript.

Conflicts of Interest

We have no conflicts of interest to disclose.

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