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Sosyobilimsel argümantasyona yönelik pedagojik alan bilgisi (PAB) bileşenlerinin etkileşimindeki değişimin incelenmesi: Deneyimlerin etkisi

Examination of changes in interaction of pedagogical content knowledge (PCK) components for socioscientific argumen-tation: The effect of experiences

Ali Yiğit Kutluca, https://orcid.org/0000-0002-1341-3432
İstanbul Aydın Üniversitesi, Eğitim Fakültesi, alikutluca@aydin.edu.tr

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ÖZ

Bu araştırmanın amacı, sınıf öğretmenlerinin öğrenme ve öğretme deneyimlerinin ve kıdemlerinin sosyobilimsel argümantasyona yönelik pedagojik alan bilgisi (PAB) bileşenleri arasındaki etkileşimi nasıl değiş-tirdiğini incelemektir. Bu amaçlara ulaşmak için resimsel bir metodolojik yaklaşım olan PAB Haritalama kullanılmıştır. Bu araştırma beş sınıf öğretmeninin katılımıyla gerçekleştirilmiştir. Toplam 10 hafta süren bu çoklu durum çalışmasında tüm öğretmenler sosyobilimsel argümantasyon ve PAB ile ilgili öğrenme ve öğretme sürecine dâhil edilmişlerdir. Sürecin başında ve sonunda katılımcılara Ders Yapılandırma Görevi (DYG) ve yarı yapılandırılmış görüşme soruları uygulanmıştır. Bu uygulamalardan gelen veriler uygun bir şekilde bütünleştirilerek PAB bileşenlerine göre alt kategorilere ayrılmıştır. Bu veriler, doğrudan derinlemesine PAB analizi, tümevarım yöntemi, numaralandırma yaklaşımı, PAB haritalama ve sürekli karşılaştır-ma yöntemi aracılığıyla analiz edilmiştir. Sonuçlar, deneyimlerin sosyobilimsel argümantasyona yönelik PAB bileşenleri arasındaki etkileşimlere farklı şekillerde katkıda bulunduğunu ortaya çıkarmıştır. Öğrenme ve öğretme deneyimleri, öğrenci anlayışları bilgisi bileşeninin önemini arttırmıştır. Ayrıca bu sürecin mesleki deneyimi az olan sınıf öğretmenlerini daha az etkilediği, mesleki deneyimi daha fazla olan sınıf öğretmenlerini ise daha fazla etkilediği tespit edilmiştir. Sosyobilimsel argümantasyon süreçleri göz önüne alındığında, kendine özgü bir yapıya sahip olan PAB bileşenleri arasındaki etkileşimlerin değişmesinde kıdem eşiğinden söz edilebilir. Mevcut literatür ışığında tartışılan bu sonuçların eğitsel çıkarımlarına da değinilmiştir.

Anahtar Sözcükler: sosyobilimsel argümantasyon, SBK, pedagojik alan bilgisi, PAB

ABSTRACT

The purpose of this research is to examine how elementary teachers' learning and teaching experiences and seniority change pedagogical content knowledge (PCK) integrations for socioscientific argumentation. PCK Mapping, which is a pictorial methodology approach, was used to achieve these aims. This research is a multiple case study, which is one of the qualitative research patterns. In this study, which lasted for a total of 10 weeks, five elementary teachers were included in the learning and teaching process related to socioscientific argumentation and PCK. The data were collected from all participants through the lesson plan and PCK interview protocol at the beginning and end of the course. Data from these applications have been appropriately integrated and subcategorized according to PCK components. These data were analysed through in-depth analysis of explicit PCK, inductive method, enumerative approach, PCK mapping and the constant comparative method. The results revealed that experiences contributed in different ways to the integration of PCK for socioscientific argumentation. Experiences increased the importance of the knowledge of students' understanding. Furthermore, it was determined that while this course less affected the elementary teachers with little professional experience, it more affected the elementary teachers with more professional experience. In view of socioscientific argumentation processes, seniority threshold can be mentioned in the change of the integration of PCK which has an idiosyncratic nature. The educational implications of these results, which have been discussed in the light of the existing literature, have been also mentioned..

Keywords: socioscientific argumentation, SSI, pedagogical content knowledge, PCK

INTRODUCTION

Scientific literacy has been a long-standing goal for a qualified science education (Roberts & Bybee, 2014). It is of critical importance to include students in scientific and socioscientific discussions to achieve this goal (Sampson & Clark, 2009; Sadler, 2006). SSI and argumentation practices should start early, as learning in the elementary classrooms creates critical foundations for more complex understandings and competences (Duschl et al. 2007; Evagorou, 2011). Therefore, many countries have included socioscientific issues (SSI) and argumentation practices in their science curricula (National Research Council [NRC], 2013; Ministry of National Education [MoNE], 2018). In many studies, it was reported that the inclusion of students in socioscientific argumentation processes was useful for them to create active scientific discourse, to have multiple perspectives and to develop their subject matter knowledge, understanding of the nature of science, and reasoning skills (e.g., Zeidler & Nichols, 2009; McNeill & Knight, 2013). The role of the teacher here is to develop a classroom culture that successfully supports discussion by moving away from authority by means of an epistemological orientation which is compatible with constructivism (McNeill, 2009). However, especially elementary teachers' experience in teaching socioscientific issues is quite limited. Teaching socioscientific issues makes a request from elementary teachers to bring together knowledge about science, technology, and society and present it to students (Evagorou & Mauriz, 2017). For new elementary teachers and those who have not tried to integrate socioscientific issues into their teaching, SSI-based teaching may seem like an overwhelming hurdle. As a result, they are not familiar with how these topics support student learning (Zangori et al. 2018). So, they will need PCK, which has been conceptualized as a special form of teacher knowledge (Kind & Chan, 2019). Accordingly, PCK, which is recommended as an important knowledge base for constructivist approach and inquiry-based teaching, is a special type of knowledge that enables teachers to have knowledge and skills that can transform their subject matter knowledge into a form that students can understand (Shulman, 2015). Two basic conceptualizations can be mentioned for PCK, which is a subject-specific and individual professional type of knowledge (Neumann, Kind, & Harms, 2019). The first one is experimental knowledge and skills acquired through PCK teaching experience (Hashweh, 2005). The second one is an integrated structure of knowledge, concepts, beliefs and values developed by teachers within the context of teaching status (Loughran, Mulhall, & Berry, 2004).

PCK can be discussed in two ways: espoused and enacted. Espoused PCK represents content knowledge and pedagogical strategies required for teachers to be able to plan teaching effectively (Gess-Newsome, 2015). On the other hand, enacted PCK represents the PCK of the teacher observed while teaching in the classroom (Park & Suh, 2019). For the last 20 years, the most commonly used PCK model in science education has been the model proposed by Magnusson, Krajcik and Borko (1999) and this model revised by other researchers (Park & Oliver, 2008a, 2008b). According to this, it has been presented a five-component PCK structure to characterize effective science teaching. This PCK components include orientations to teaching science (OTS), knowledge about students' understanding (KSU), Knowledge about science curriculum (KSC), Knowledge about instructional strategies (KISR) and Knowledge about assessment of science learning (KAs). On the other hand, the PCK model conceptualized by Park and Chen (2012) is a pentagon model emphasizing the interrelatedness and interactions among these components. Furthermore, the pentagon model of PCK is associated with an analytic approach, PCK mapping (Park & Suh, 2019), capable of providing both quantitative and qualitative analyses of teachers' PCK. The analysis of PCK in this respect may provide more perceptible and traceable knowledge about the processes of developing teachers' subject-specific PCK and realizing this knowledge.

In recent years, most of the discussions about the quality of teaching have been related to teachers' professional knowledge and experience. To train teachers who have a strong knowledge base (PCK) and make reliable decisions about teaching using this base has an increasingly greater meaning in modern societies (Nilsson & Loughran, 2012). Therefore, teachers should improve their professional knowledge by focusing on specific science content and students' learning styles (Gess-Newsome, 2015). Furthermore, teachers need to develop qualified pedagogical strategies for SSI and argumentation that support the development of science literacy (Carson & Dawson, 2016; Tidemand & Nielsen, 2017). However, it is a complex and difficult process to reconstruct or improve teachers' knowledge and beliefs (Neumann, Kind, & Harms, 2019).

In many studies in the literature, it has been argued that teachers should undergo learning and teaching experiences to overcome this difficulty (Chan & Yung, 2018; Hanuscin, de Araujo, Cisterna, Lipsitz, & van Garderen, 2020; Minken, Macalalag, Clarke, Marco-Bujosa, & Rulli, 2021). However, there has not been any research on how learning and teaching experiences have changed the integration among PCK components for socioscientific argumentation. In brief, this situation has revealed the necessity of determining PCK interaction regarding the argumentation process within the context of any socioscientific subject in the based on experiences.

Rationale of the Study

Many studies in the SSI literature have emphasized that elementary students' participation in socioscientific argumentation processes is effective in terms of improving their science perceptions and being qualified decision makers (e.g., Dolan et al. 2009; Yacoubian & Khishfe, 2018; Zeidler, Herman, & Sadler, 2019). But it is a difficult and ongoing process to develop expertise in guiding students' science education. Teachers should first have a student-centered epistemological orientation and also appropriate pedagogical strategies for science practices such as SSI and argumentation (Baytelman, Iordanou, & Constantinou, 2020). Furthermore, teachers should develop pedagogical knowledge and practices such as PCK to help their students to integrate science concepts with SSI, to think based on evidences and to do reasoning (Han-Tosunoğlu & Lederman, 2021). Therefore, PCK was proposed as an important knowledge base for the implementation of discussion-based inquiry (Sengul, Enderle, & Schwartz, 2020). Thus, it is considered that teachers with strong PCK for SSI teaching and argumentation are more likely to include these approaches in their classrooms (Bayram-Jacobs et al. 2019; McNeill, González-Howard, Katsh-Singer, & Loper, 2017).

Expanding PCK research have claimed that PCK and its development was affected by the nature of the subject, the context in which the subject was taught, and the reflection of teachers on teaching (Hanuscin et al. 2020; Neumann et al. 2019). Nevertheless, it is indicated that each component of PCK has different qualities specific to each different subject in science education (Kind & Chan, 2019). Therefore, teachers have specific knowledge differentiated by subject for each individual component (Gess-Newsome et al. 2019). The studies aimed at determining the PCK and the structure and nature relationship between the components that constitute PCK have revealed that these components interact with each other in very complicated ways (Suh & Park, 2017; Park & Suh, 2019) and that a consistent integration between them is of critical importance for PCK development and the changes in practice, which reveals that PCK is more than the sum of its components (Reynolds & Park, 2021). Teachers should have all PCK components and integrate them while planning and implementing teaching (Abell, 2008). The consistent relationships between them are important for the development of the PCK, and these relationships are quite complicated by their nature (Park, 2019). According to the common consensus, experiences are the complementary and perhaps the most important predictor of PCK development (e.g., Carlson et al., 2019; Kind, 2019). Accordingly, PCK of experienced teachers has a more integrated structure compared to the PCK of pre-service teachers or less experienced teachers (Akın & Uzuntiryaki-Kondakçı, 2018; Aydin et al. 2015). Accordingly, the interactions between synergistic and synthetic knowledge before and after teaching determine the structure of PCK. Knowledge-in-action refers to the acquired knowledge structure that the teacher has during planning and plans to use and uses in the classroom. On the other hand, knowledge-on-action refers to detailed and activated knowledge after teaching (Alonzo, Berry, &

Nilsson, 2019). In summary, the teacher has a certain theoretical understanding and knowledge about PCK and its components before teaching. Teachers put these insights into action when planning instruction. On the other hand, after teaching, most of the understandings about PCK and its components, which are constructed on a theory-based basis, undergo some changes. The reason for this is the interactions between teachers and students during teaching (Furtak, Bakeman, & Buell, 2018).

To sum up, studies revealing a more holistic picture of PCK by examining many components may provide a deeper insight into PCK, which may also provide enriched knowledge to what the PCK really is and how teacher's PCK changes. In the literature, there are many studies that focus on which individual component contributes to the quality of teaching and in which the five-component PCK structure is considered (e.g., Aydin et al. 2015; Kutluca, 2021; Suh & Park, 2017). However, little is known about PCK components and their interactions, especially during SSI and argumentation teaching (Bayram-Jacobs et al. 2019). Therefore, it is important to investigate how PCK components develop after teachers learn and teach socioscientific argumentation. Based on all these reasons, the aim of this study is to examine how elementary teachers' learning and teaching experiences and seniority change PCK integrations for socioscientific argumentation. For this purpose, answers to the following sub-problems were sought.

1. How do learning and teaching experiences change the interaction among PCK components for socioscientific argumentation?
2. How do professional experiences change the interaction among PCK components for socioscientific argumentation?

METHODOLOGY

Research Design

This research is a multiple case study, which is one of the qualitative research patterns. Multiple case study allows to describe more than one situation and phenomenon by comparing them with each other (Stake, 2013). The main case addressed in this study is the possible impact of learning and teaching experiences related to PCK, SSI and Argumentation on the interactions between PCK and its components. In order to describe this situation, the PCK Maps of five elementary teachers before and after experiences were compared. It is thought that learning and teaching experiences will affect each elementary teacher's PCK conceptualizations in different ways. Therefore, each teacher represents a different situation (Aydeniz & Kırbulut, 2014; Kind, 2009). More than one data source (interviews, lesson plans) was used in order to describe the main situation discussed in the light of more rational grounds and to make healthy comparisons (Denzin, 2015). In this way, data triangulation has been provided. In addition, based on the subject and teacher-specific nature of PCK, the study was carried out within the context of global warming (Park & Suh, 2015; Smith & Banilower, 2015).

Participants

Five teachers selected from among 12 elementary teachers participated in this study. These participants were determined based on criterion sampling, which is one of the purposeful sampling methods (Patton, 2002). Three criteria were considered in the selection of participants.

Firstly, teachers should have at least one year of teaching experience. Secondly, their duration of professional experience should be different from each other. Thirdly, they should not have any instructional experience on socioscientific issues and argumentation. The participants were aged between 23 and 32 years and consisted of three male *(Ali, Erhan, Okay)* and two female *(Mine, Fatma)* individuals (see Table 1).

Table 1
Participants' Features

Teacher*	Type of School	Age	Professional Experience
Ali	Private school (urban)	23	1 year
Erhan	Private school (suburban)	25	3 years
Mine	Private school (urban)	26	4 years
Okay	Public school (suburban)	29	7 years
Fatma	Public school (suburban)	32	9 years

**Pseudonym.*

Data Collection

This study was carried out in the 2018-2019 fall semester within the scope of the graduate course named "Human, Environment and Science Education". The evaluation of PCK, which represents teachers' pedagogical structures related to any context of the subject and their knowledge about how to adapt them to the teaching process, is a complex task that requires the combined use of different approaches (Baxter & Lederman, 1999). Therefore, multiple data sources were used to answer the sub-problems in this study. The main data source was semi-structured interview questions asked to participating teachers. The secondary data source was Lesson Construction Task (LCT) created by elementary teachers through Content Representation (CoRe). These two data sources are enriched with observations and the researcher's field notes. Semi-structured interviews and LCTs were conducted with all participants at the beginning and end of the course. The steps for data collection process are presented in Figure 1.

Figure 1
Steps for Data Collection

The questions in the LCT and interview protocol were created based on research in the literature (e.g., Nilsson & Loughran, 2012; Suh & Park, 2017). Then, expert opinions were taken to ensure the internal validity and external control (Onwuegbuzie & Leech, 2007). Finally, a pilot application was conducted with a teacher other than the sample.

Semi-structured interview questions

An interview protocol consisting of 22 questions, including five main questions and 17 probe questions, was used to determine elementary teachers' PCKs for socioscientific argumentation in the context of global warming (see Appendix 1). The questions were developed based on the five-component PAB structure proposed by Magnusson et al. (1999). Therefore, each question represent a PCK component (For example, the first question is related to OTS). While creating this questions, similar studies in the literature were also used (örn. Bayram-Jacobs et al. 2019; Kutluca, 2021). In addition, expert opinions of two academicians who are experts in elementary teacher education and science education were consulted. Based on the feedback from the expert opinions, the questions were revised in terms of language and content, and a pilot application was conducted with an elementary teacher who was excluded from the sample. All interviews using a voice recorder lasted between 50-60 minutes on average.

Lesson construction task (LCT)

The CoRe methodology was used for teachers' LCTs for socioscientific argumentation within the context of global warming (Loughran et al., 2004). CoRes attempt to describe the holistic views of teachers' PCK on teaching a certain subject based on big ideas to make the implicit nature of PCK open to others. Therefore, a CoRe was designed to reveal participating teachers' knowledge of teaching a particular science concept/subject. The CoRe instrument in this study was designed to reveal participating teachers' knowledge of teaching the issue of global warming by contextualizing with socioscientific argumentation.

Table 2
Learning Outcomes for LCTs

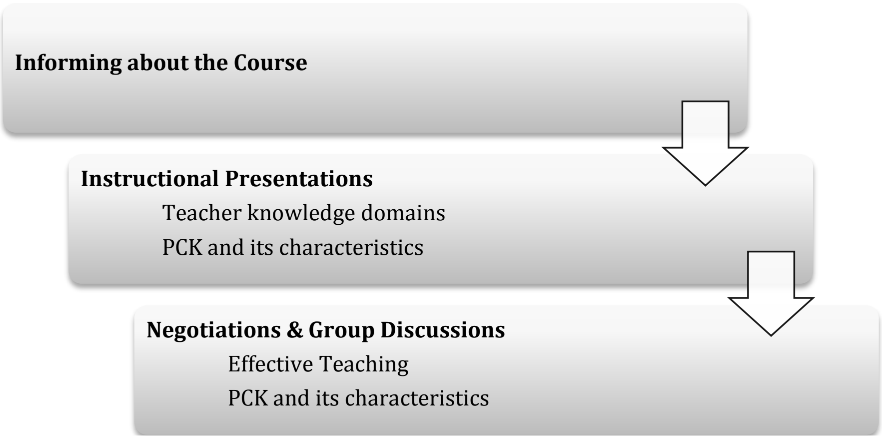
Teacher	Learning outcomes	
	LCT-pre	**LCT-post**
Ali	He/she realize the importance of resources and recycling necessary for life.	He/she realize the importance of the natural environment for living things.
Erhan	He/she explain the events that occurred as a result of world movements.	He/she express the importance of interaction between human and environment.
Mine	He/she propose solutions by doing research to protect the natural environment.	He/she become aware of the importance of the natural environment for living things.
Okay	He/she become aware of the importance of the natural environment for living things.	He/she discusses the cases of benefit and harm in human-environment interaction.
Fatma	He/she explain that there is an air layer that surrounds the world.	He/she make inferences about future environmental problems as a result of human activities.

The questions in the form proposed by Loughran et al. (2004) were rearranged taking into account Magnusson et al.'s (1999) five-component PCK model and the nature of socioscientific argumentation. Care was taken to ensure that the questions were integrated with the interview protocol questions. The application was carried out with a written and voice recorder together. Learning outcomes that teachers determined based on MoNE (2018) science education curriculum while preparing LCT are presented in Table 2. It took approximately 20-30 minutes for each teacher to respond to the LCT.

Presentations and discussions

This step lasted for four weeks (see Figure 2). Participating teachers were provided to teach in their own classrooms at the beginning and end of the course to gain teaching experience. Firstly, at the beginning of the course, all participants were informed about the aims of the course.

Figure 2
Course Details



Then, instructional presentations (Teacher knowledge domains, PCK and its characteristics, SSI, Global Warming, Argumentation) were conducted. Lastly, Negotiation processes were also carried out during the instructional presentations

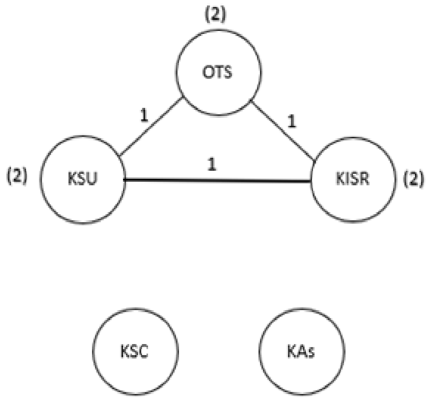
Data Analysis

The sub-problems in this study were answered through PCK Mapping. In order to identify interactions between PCK components for socioscientific argumentation, data were analyzed through in-depth analysis of explicit PCK, inductive method, enumerative approach, PCK Mapping, and constant comparative method. Firstly, participants' transcribed responses were subcategorized according to PCK components. Then, teaching episodes were determined for each PCK component. Here, each episode represents a unit of analysis (Fraenkel, Wallen, & Hyun, 2012). To reveal a teacher's PCK interaction within a particular teaching episode, it was conducted in-depth analysis of explicit PCK (Park & Oliver, 2008a). In addition, the inductive approach was also used in this process (Patton, 2002). In this way, it has been labeled which PCK components elementary teachers refer to when extending any PCK component through their pedagogical explanations. For example, teachers' use of student challenges and understandings to address the OTS component indicates an interaction between the OTS and KSU components (see Table 3 for an example). After PCK analysis which was conducted in-depth and inductively, the enumerative approach was focused on to quantitatively describe the interactions among the PCK components that the teachers put forward (Park & Chen, 2012). In this context, each dyad interaction of PCK components in any teaching episode was counted as "1" to indicate its strength. Thus, a unit system was created to measure teachers' pre- and post-PCK interconnections. After the enumeration process was completed, the PAB Mapping stage was started. Here, Park and Chen's (2012) pentagon model was used as analytical device. Dyads from the enumeration process are engraved in this device. As a result, interactions identified in the pentagon model were visualized through PCK Mapping.

According to Table 3, it is seen that Erhan referred to KISR during his statements about pre-OTS in Episode #1. He also elaborated the pre-KSU conceptualizations in Episode #2 by using KISR and OTS. Each interaction seen here was assigned as a connection to PCK Map. The numbers between components represent how many times identified connections between PCK components were. Accordingly, the greater the amount of dyad connections between a teacher's PCK components, the stronger the PCK interaction.

One participant's (Ali) responses were analyzed together with an independent expert researcher working in the PCK, SSI, and Argumentation contexts. As a result of this analysis, the inter-coder reliability percentage was calculated. Here, the agreed-upon number of units of analysis was divided by all units of analysis and converted to a percentage value. After this process, the value of 93% was reached (Kurasaki, 2000). Finally, the constant comparison method was used to compare elementary teachers' PCK interactions for socioscientific argumentation according to their seniority and learning and teaching experience. In this way, the existing patterns were tried to be discovered by distinguishing the conceptual similarities underlying the PCK Maps of the participants (Tesch, 1990). This process also allowed for methodological triangulation.

Table 3
Example Episodes for Interactions among PCK Components

	Erhan's PCK Episodes	Connections
Episode #1	*(pre-OTS)* I think that the more information we provide, the more benefits we will provide. In this way, how important global warming is, and how much information in front of them, more information, million information, is always more useful. In the simplest term, I mean, for instance, I can ensure that they obtain information by performing a steam experiment.	OTS-KISR
Episode #2	*(pre-KSU)* Previously, they taught us about ozone layer depletion, always indicating that harmful gases, harmful gases released from factories harmful things like deodorants caused damages. We always heard them, but they made no impression. For this purpose, for instance, if more experiential studies are carried out, and if children can see, there would be greater impressions. In this way, their awareness increases even more.	KSU-KISR KSU-OTS
PCK map for example episodes		

Research Ethics

All the rules stated in the "Higher Education Institutions Scientific Research and Publication Ethics Directive" were followed in the entire process from the planning, implementation, data collection to the analysis of the data. None of the actions specified under the second section of the Directive, "Scientific Research and Publication Ethics Actions" have been carried out.

During the writing process of this study, scientific, ethical and citation rules were followed; no falsification was made on the collected data and this study was not sent to any other academic media for evaluation.

Research ethics committee approval information

Name of the committee that made the ethical evaluation: İstanbul Aydin University Social and Human Sciences Ethics Committee

Date of ethical review decision: 13 July 2021

Ethics assessment document issue number: E-45379966-050.06.04-17510

FINDINGS

In this section, first of all, the amount of teaching episodes and the amount of dyad connections between PCK components in these episodes were determined. The findings have been presented in Table 4. Then, the findings related to the sub-problems were interpreted.

Table 4
Teaching Episodes and Connections

	Pre		Post	
	Episodes	Dyad connections among components	Episodes	Dyad connections among components
Ali	20	61	25	66
Erhan	12	34	29	69
Mine	9	18	28	66
Okay	21	58	32	68
Fatma	19	46	28	65
Total	81	217	142	334

The results presented in Table 4 showed that elementary teachers' teaching episodes for socioscientific argumentation after experiences were more than the previous ones. Furthermore, it was also revealed that the dyad connections among PCK components increased after the course.

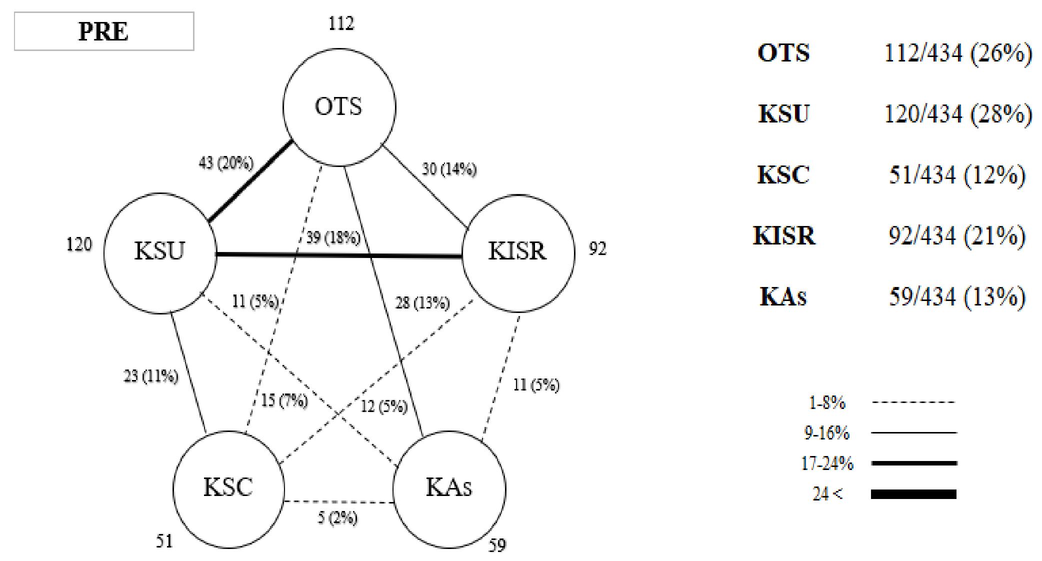
> **Mine (pre-KSU):** ... May be. I do not know. We have never had such a discussion environment with them, we have not done such a study in schools, so I don't know at all. (pre-KSC): I don't know it. In other words, as I said, such a thing was included in the social studies course, I saw in the course book, but in the last part, how much time was allocated, I saw while I was looking at the book, how much time was allocated in the curriculum, what the subjects are, what the subtitles are...I am inadequate because I do not know them.
>
> **Okay (pre-KAS):** I don't know about this subject, namely. I do not know what to say. The time will tell it. Let me put it this way, with respect to the process, something may happen based on the knowledge and experiences that the process gives us.
>
> As it can be seen in the examples from teaching episodes given for different PCK components, teachers expressed their inadequacy related to global warming or socioscientific argumentation before the course. They indicated experiences as the source of these inadequacies.
>
> **Mine (post-KAS):** For instance, I began to feel more comfortable while applying it. More beautiful examples also appeared. Nice feedback was provided from the students. I felt that they learned.
>
> **Okay (post-OTS):** I think such things can be done by making you cover the argumentation subjects in your lesson and based on our own examples we presented in the classroom.

Otherwise, I had no prior knowledge related to them, I mean. The examples from post-PCK statements given above confirmed the idea that learning and teaching experiences extended teachers' conceptualizations for PCK components with the help of teacher efficacy (Park & Oliver, 2008a).

Common Nature of the Interaction among PCK Components for Socioscientific Argumentation

Elementary teachers' teaching episodes were combined to determine how learning and teaching experiences changed the interaction among PCK components for socioscientific argumentation. Pre- and post-PCK Maps created in this way are presented in Figure 3.

Figure 3
The Effect of Learning and Teaching Experience



Accordingly, it is observed that the strongest interaction before learning and teaching experiences was between OTS-KSU (20%) and KSU-KISR (18%) components. Furthermore, OTS (26%) and KSU (18%) stood out as the components that mostly interacted with other components in the pre-course teaching episodes. On the other hand, it was revealed that the weakest interaction among the components was present between the KSC-KAs (1%). Furthermore, KSC (12%) and KAs (13%) were the components that least interacted with other components.

> **Erhan (pre-OTS):** I think it would be useful to include students in terms of awareness as follows. Yes, because the earlier they learn, the better they will be in the future. (**pre-KSU**) In science, for instance, even though living creatures are included in the concept of nature, I mean, they have the ability to empathize, and in this way, we can improve them as individuals with higher awareness.

> **Okay (pre-OTS):** Our level is mainly perceptible, term lessons, and a level at which children can comprehend something with more concrete examples. Therefore, these can only be discussed at a simple level. (**pre-KSU**) Both in the concept and in the subject, children say very irrelevant things about the subject. In general, they are unaware of why they discuss.

As it is seen in sample quotations, it was revealed that elementary teachers conceptualized the OTS and KSU in an embedded form, however, they referred to argumentation processes, that have a strategy feature, in a limited way. This situation became better after learning and teaching experiences. In particular, the fact that a stronger interaction was observed between KSU-KISR (22%) confirmed it. Furthermore, the development of KSU (33%), that interacted strongly with KISR, stood out as the most important component.

> **Fatma (post-OTS):** I also provided an atmosphere of discussion at a simple level in my classroom, but it was shaped according to the knowledge of the students. In other words, when the child expresses his/her own opinions on such issues loudly, he/she never forgets. (**post-KSU**) In this process, I think that children should be informed and should have argumentation skills. As I said, it would not enough to directly give the subject about global warming.

> **Mine (post-OTS):** The difference from other methods is, for instance, that it is a process in which they are personally present in the environment, they express their opinions, they defend them with reasons and develop opposing views. They add something from

> themselves and display their own cognition. (**post-KSU**) They should know the argument structures about global warming. They should be able to defend themselves and should be conscious. Just having knowledge is not enough.

The sample statements of Fatma and Mine showed that argumentation processes were more contextual and embedded among other components, which was also reflected in teachers' teaching in their own classrooms. While teachers mainly included question-answer interactions (teacher-student) in their first teaching experiences about socio-scientific argumentation practices on global warming in their classrooms, they mainly included small group discussions and negotiation interactions (student-student) in their teaching after the learning and teaching process (Field Notes & Observations).

Change of the Interaction among PCK Components for Socioscientific Argumentation

To reveal how the seniority of participating teachers changed their pre- and post-PCK integrations for socioscientific argumentation, their PCK maps were evaluated individually. The idiosyncratic nature of PCK was considered during interpretations (Kind, 2009). Firstly, the rates of interaction of teachers' PCK components before and after learning and teaching experiences with other components were presented (Table 5). Then, the nature and changes of interactions among PCK components were evaluated with the help of pre and post PCK maps of teachers.

Table 5
Interaction Percentages among PCK Components

		OTS	KSU	KSC	KISR	KAs
Ali	*Pre*	29/122 (24%)	36/122 (29%)	12/122 (10%)	28/122 (23%)	17/122 (14%)
	Post	32/132 (24%)	44/132 (33%)	11/132 (8%)	26/132 (20%)	19/132 (15%)
Erhan	*Pre*	21/68 (31%)	21/68 (31%)	6/68 (9%)	9/68 (13%)	11/68 (16%)
	Post	34/138 (25%)	44/138 (32%)	12/138 (9%)	25/138 (18%)	23/138 (17%)
Mine	*Pre*	9/36 (25%)	10/36 (28%)	7/36 (19%)	6/36 (17%)	4/36 (11%)
	Post	34/132 (26%)	38/132 (29%)	16/132 (12%)	32/132 (24%)	12/132 (9%)
Okay	*Pre*	31/116 (27%)	33/116 (28%)	14/116 (12%)	24/116 (21%)	14/116 (12%)
	Post	36/136 (27%)	44/136 (32%)	14/136 (10%)	27/136 (20%)	15/136 (11%)
Fatma	*Pre*	22/92 (24%)	20/92 (22%)	12/92 (13%)	25/92 (27%)	13/92 (14%)
	Post	26/130 (20%)	47/130 (36%)	6/130 (5%)	29/130 (22%)	22/130 (17%)

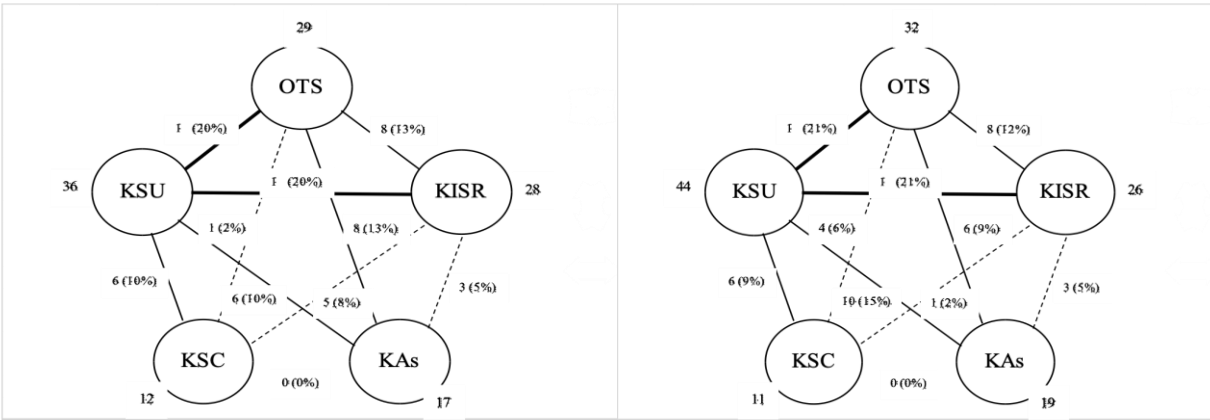
According to the results presented in Table 5, it was observed that OTS and KSU were the most significant components and KSC and KAs were the most insignificant components. When the effects of learning and teaching experiences on components were evaluated, it was revealed that Erhan and Mine's KISR, Ali, Erhan and Fatma's KAs and all elementary teachers' KSU interaction percentages were increased. Furthermore, it was determined that Erhan and Fatma's OTS interaction percentages and KSC interaction percentages of all elementary teachers except Erhan were decreased. The results stated here were interpreted separately according to the PCK maps of the elementary teachers.

Ali

The pre and post PCK map created based on the teaching episodes Ali, who was teaching in a private school and had one year of experience, is presented in Figure 4. Ali was more participatory and more open to innovation compared to other teachers with the motivation of being a new graduate from teacher education especially before the learning and teaching experiences and during the course.

Figure 4
Ali's PCK Maps

PRE **POST**



As it is seen in Figure 4, the most interacting components in Ali's pre and post teaching episodes were OTS-KSU and KSU-KISR components. The weakest connection was between KSC and KAs. Furthermore, OTS, KSU and KISR components interacted with all other components, though slightly. However, it is difficult to say that learning and teaching experiences led to a noticeable change in Ali's PCK map. The only change was that the connection between OTS-KSU and KSU-KISR components was strengthened some more.

> **Ali (pre-KSU):** The level of keeping knowledge in mind is important, I mean, the student can keep the knowledge he/she has learned in his/her mind and associate it with daily life. I mean, the child just don't memorize. They should learn by discussing. (**pre-KISR**) So, how many groups of children will perform socio-scientific argumentation? How will they do it? We need to provide them…

> **Ali (post-KSU):** Since global warming is mostly about daily life and when we include students in argumentation, it becomes easier for them to learn. (**post-KISR**) They did not have much information before. Then, one of my students watched a news indicating that chocolate production was decreasing due to global warming. Based on it, I made students perform argumentation.

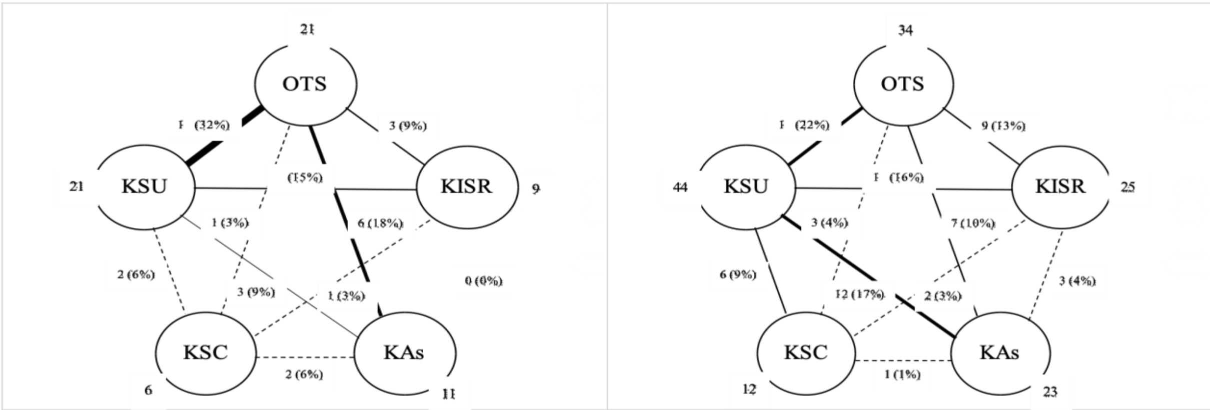
Ali's pre-course conceptualizations on the importance of socio-scientific argumentation process contextualized with the issue of global warming indicated that he was in a dilemma with regard to performing argumentation practices. The structure of his conceptualizations did not also change after the learning and teaching experiences. However, the quality of teaching that Ali performed in his classroom before and after the course gave a clue that there was a slight difference. Accordingly, during pre-teaching, Ali included his students in structured practices (formal) accompanied by all classroom activities and mainly performed lecturing and question-answer interactions. After the course, Ali added small group discussions and few negotiation interactions to teaching (Field Notes & Observations).

Erhan

It was observed that Erhan, who had three years of teaching experience, had difficulty in responding to the questions asked to him before the course. It was remarkable that he made conceptualizations more comfortably in the practices performed after the course, which was con-firmed by the number of participants' teaching episodes and dyad connections.

Figure 5
Erhan's PCK Maps

PRE **POST**



Erhan's pre and post PCK maps presented in Figure 5 showed that learning and teaching experiences helped strengthening the connection among components. Accordingly, while there was a strong interaction between Erhan's pre-OTS-KSU and OTS-KAS components, there was no inter-action between KISR-KAS components. It was observed that the pentagon model was completed after the learning and teaching experiences. In particular, it was determined that the interactions between OTS-KISR, KSU-KSC, KSU-KAS and KISR-KAS components were improved.

> **Erhan (pre-KSU):** Previously, they taught us that harmful gases and deodorants from the factories lead to the depletion of ozone layer, but it always remained in theory. It had no effect on us. More practical lessons, such as discussion are needed for it. (**pre-KISR**) I mean, if there is an opportunity, I will do an experiment. If they do not have knowledge, I will use the materials we prepare and I will make a presentation.
>
> **Erhan (post-KSU):** Since our main point is to reach accurate knowledge, the child can discuss and make conscious decisions when he/she encounters this issue. Of course, if they have lack of knowledge, we observe it anyway while discussing. (**post-KISR**) As I said, tasks are given in the practice part and they are observed while discussing. Both the child is included in the subject and the observation of changes leaves a permanent trace. Ultimately, it becomes easier for them to learn since they use more than one sense.

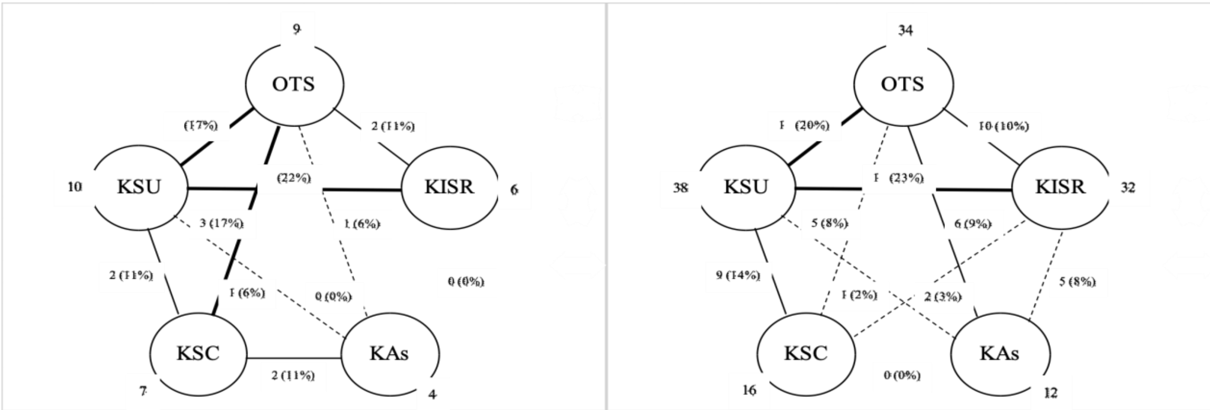
When sample teaching episodes given for pre-KSU and pre-KISR components were examined, it was revealed that Erhan had misconception about the global warming issue and mentioned socioscientific argumentation only embedded in KSU. Furthermore, he conceptualized a hands-on activity like an experiment with a teacher-centered orientation. On the other hand, he referred to the KAs component with a student-centered orientation while explaining the KSU and KISR components after learning and teaching experiences. As he mentioned before, Erhan made his students to perform group works in small groups during his pre-course teaching. He also included question-answer interactions in these group works (Field Notes & Observations). However, he performed a formal teaching with very intense directives. After the course, it was observed that he focused on negotiation interactions by including his students in small and large group discussions depending on the nature of socio-scientific argumentation within the context of global warming (Field Notes & Observations). Furthermore, he gave voice to one student from each group and allowed him/her to speak especially while managing small group discussions and he took observation notes, which provides practical evidence for the formation of connection especially between KISR-KAs.

Mine

Mine was the teacher who had the greatest difficulty during learning and teaching experiences. In particular, the pre-PCK conceptualizations of Mine, who had been working in a private institution for four years after graduation, were quite limited and she was constantly questioning her professional competence. However, although the number of teaching episodes and dyad connections of Mine was limited compared to other teachers before her learning and teaching experiences, her OTS-KSU, OTS-KSC and KSU-KISR interactions were strong (Figure 6). Furthermore, there was no KISR-KAs and KISR-KSC interaction.

Figure 6
Mine's PCK Maps

PRE **POST**



After the learning and teaching experiences, it was observed that Mine's number of teaching episodes and dyad connections and also the interactions between OTS-KSU, KSU-KSC, KISR-KAs and KISR-KSC were noticeably increased. On the other hand, it was revealed that the interactions between OTS-KSC, OTS-KAs and KSC-KAs were decreased. However, the connections in the post-PCK map were more balanced.

> **Mine (pre-KISR):** I need to know the method exactly. I do not know it exactly. Groups can be created. I mean, two groups can be created and the duties are distributed between the groups. (**pre-KAs**) In other words, it can be determined by exam. A test can be performed according to the achievements. The concepts can be given in certain frameworks, they may be asked what they think and be asked to convey what they know.

> **Mine (post-KISR):** It will already create prior knowledge by researching. Their knowledge can be supported through sample videos and then scenario can be given. Of course, before I can remind the argumentation and socio-scientific issues in advance as we performed with you in the lesson. Then, I leave it to them completely and observe them. (**post-KAs**) Scores can be made according to certain criteria through a rubric. I look at the number of reasons and refutations for the quality of argumentation. We can use concept maps for their conceptual understanding. At the end of the process, the more relationships are, the more they have gained.

The sample conceptualizations showing the quality of the interaction between KISR-KAs indicated that Mine actually had a teacher-centered orientation before the course and could not con-textualize the global warming and socio-scientific argumentation process. After the course, she made conceptualizations which were more appropriate to the nature of socio-scientific argumentation. However, she did not include any explanation related to the curriculum while directly referring to the socio-scientific argumentation process. Mine's change within the context of PCK conceptualizations was also reflected in her teachings she performed in her own classroom before and after the course. Like other teachers, Mine also started to include her students in small and large group discussions and negotiation interactions after the learning and teaching experiences (Field Notes & Observations).

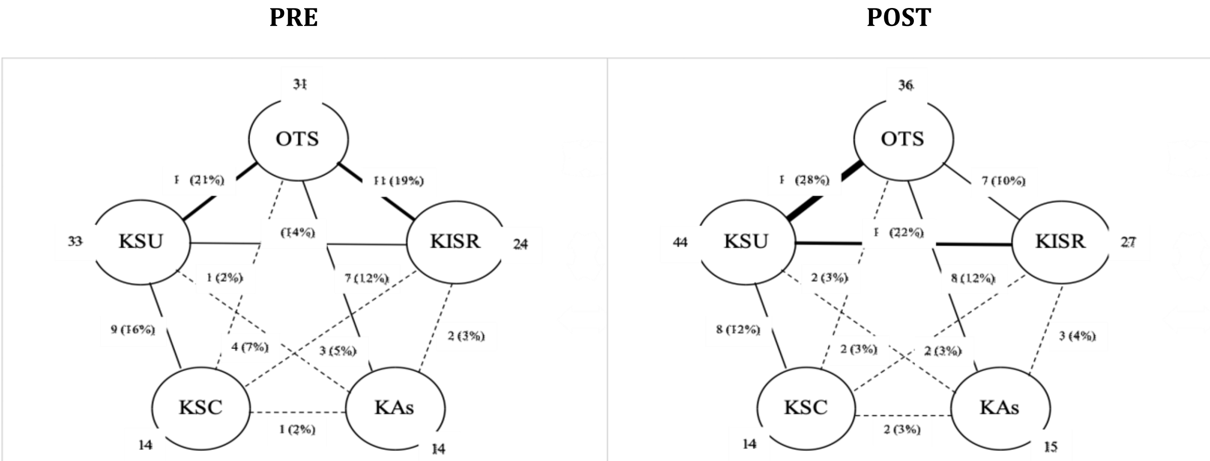
Okay

Okay was a teacher with seven years of experience and was working in a public school. His self-confidence and detailedness during PCK conceptualizations and classroom teaching were remarkable. At the beginning of the course, even though he had no experience on socio-scientific argumentation, he did qualified reasoning with the comfort of his professional experience. Therefore, all components in the pre-PCK map interacted with each other (Figure 7). Furthermore, the strong interactions between OTS-KSU and OTS-KISR were also remarkable. Learning and teaching experiences affected the interactions in the PCK map of Okay, as was the case with the three teachers mentioned earlier. Furthermore, this effect indicated a more visible change compared to other teachers. Accordingly, there was a stronger connection between OTS-KSU and KSU-KISR. It was revealed that the connection between OTS-KISR was weakened.

> **Okay (pre-OTS):** If perceptible knowledge is given to children, for instance, perfume is said to thin the ozone layer. For instance, we can make children do experiments in groups in the classroom and ensure that they obtain knowledge that they will not forget for life. However, it is necessary to do them under the guidance of the teacher. I mean, it is a little difficult for children to think about it and come to the conclusion. (**pre-KISR**) I do not interfere in terms of knowledge, the only thing I can do is to guide the child in different ways. For instance, like collaborative teaching. Of course, I will make some explanations so that they will create the rest, will study and have their own ideas on what is right and what is wrong.

> **Okay (post-OTS):** When I evaluated the curriculum from this perspective, I thought that the issue of global warming was suitable for socio-scientific argumentation. I think that children internalize it when they express themselves seriously. The children are already ready for it and their motivation is increasing. When the child does it with argumentation, awareness and consciousness occur, which creates a lasting effect. (**post-KISR**) First of all, all students should know the concepts related to global warming. Samples from daily life are also needed. Thus, I think that the argumentation process will be implemented more properly when they learn them properly and come to the classroom environment. I also attempted to apply it in my classroom and I saw that it was really useful.

Figure 7
Okay's PCK Maps



Okay did not directly refer to the socio-scientific argumentation process in his conceptualizations related to OTS and KISR before learning and teaching experiences. However, he talked about student-centered pedagogical strategies on global warming. After the course, he contextualized the issue of global warming with the socio-scientific argumentation process. Furthermore, it was observed that he did more qualified reasoning for students' understanding. The situation in the classroom teaching of Okay, who had 37 students in his classroom, was slightly different from his theoretical conceptualizations. Before the course, he tended to use teacher-centered strategies due to the large number of students. After the teaching and learning experiences, he included his students in small groups and then in large group discussions. However, he had great difficulty in performing negotiation interactions (Field Notes & Observations).

Fatma

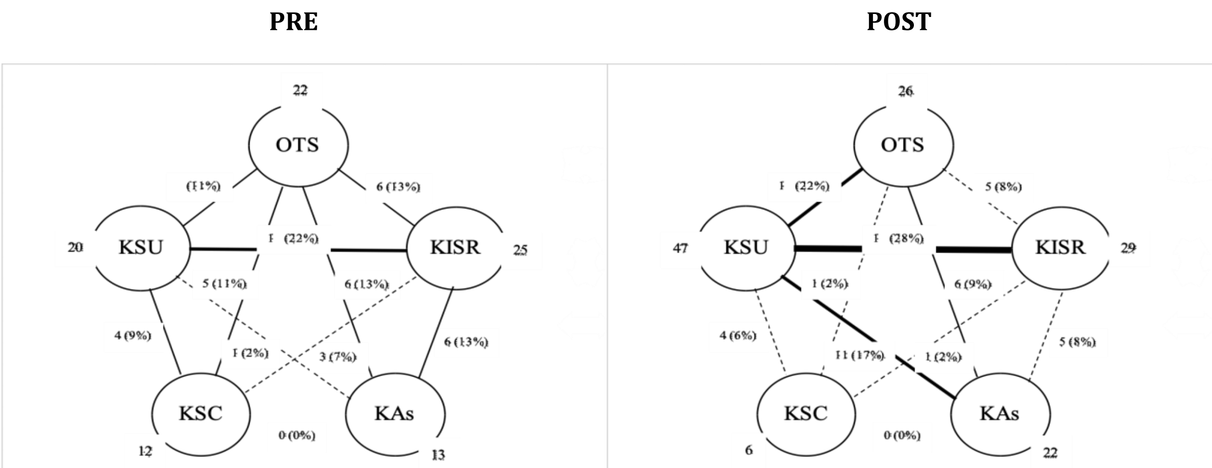
Fatma, who was the most experienced elementary teacher in the group, was the teacher who showed the most remarkable development in terms of the interactions among PCK components. Accordingly, it was observed that only KSU-KISR interaction was strong before the learning and teaching experiences. There was no connection between KSC-KAs. There were normal or weak interactions among other components (Figure 8).

It was revealed that learning and teaching experiences strengthened Fatma's OTS-KSU, KSU-KISR and KSU-KAs interactions. However, after the course, it was observed that the connection between some components were weakened. The most notable weaknesses were between OTS-KISR, KSU-KSC and KISR-KAs. Accordingly, Fatma tended to ignore other components by focusing more on one component while explaining any component.

> **Fatma (pre-OTS):** In other words, when students are involved in the socio-scientific argumentation process on global warming, they will become individuals with higher awareness. We can make children perform more flexible and different activities, not depending on the book. (**post-OTS**) For instance, we went over carbon dioxide gas. While carbon dioxide gas is always known as such a harmful bad gas, you know, but now the presence of gas has also gained importance for them, well, they learn to be able to look at it from a different perspective, and in the same way, natural awareness has also given them additional knowledge.

> **Fatma (pre-KSU):** I think they don't have misconceptions when they come to course. Because we do not make introduction to these subjects in the curriculum. I should look at the curriculum for a more detailed explanation. (**post-KSU**) In general, children of certain character be-came more dominant. They had difficulty when they looked at the knowledge and did not think about it, well, when they were stuck to it, they remained attached to the knowledge provided, and then they could not produce different ideas. Actually, I implemented argumentation well. However, they could not do reasoning using different knowledge. I saw them when I observed them.

Figure 8
Fatma's PCK Maps



According to the sample teaching episodes above, while Fatma tended to elaborate her statements on OTS before the course with the KISR component, she tended to elaborate them with the KSU component after the course. On the other hand, she used the KSC component before the course and the KISR and KAs components after the course to elaborate her statements on KSU.

This situation regarding the interaction among PCK components of Fatma was different from other teachers. Because Fatma did not depend only on the experiences she had in this study while making conceptualizations. Instead, she made her statements mainly around the OTS and KSU components, using her nine-year professional experiences in a public school, which was also proven by her teaching she performed in her classroom. For instance, Fatma, who taught the lesson specifically within the context of the achievement 'He/she explain that there is an air layer that surrounds the world.' before the course, gave lectures about atmosphere in the first minutes of the course and explained the concepts such as ozone layer and gases in it. Furthermore, she performed question-answer interactions only in a limited part of the course (Field Notes & Observations). After the course, she became the teacher who most intensely performed small group discussions and negotiation interactions. In addition, she used videos, news clippings, pictures and different technological tools as an auxiliary resource during the course (Field Notes & Observations).

DISCUSSION and CONCLUSION

In this study, it was investigated how experiences affect elementary teachers' PCK integrations for socioscientific argumentation. For this, two different perspectives were focused through PCK maps. First of all, the teaching episodes obtained through LCT and interviews were combined and integrated PCK Maps were created as pre-process/post-process. In this way, the overall impact of elementary teachers' learning and teaching experiences on PCK integration was interpreted. Afterwards, pre- and post-PCK maps of elementary teachers who had different seniority were evaluated individually. In this way, the possible effect of seniority on PCK integration for socioscientific argumentation was described. The results obtained in this context are discussed in depth based on the existing literature.

The Effect of Learning and Teaching Experiences

The first remarkable result in this study was that teacher efficacy, which is a new affective element of PCK, affected PCK conceptualizations (Park & Oliver, 2008a). PCK is considered as a dynamic form of knowledge which constantly expands through elementary teachers' learning and teaching experiences and is converted from other forms of teacher knowledge (Nilsson, 2008). In parallel with this claim, teachers who participated in this study without any teaching experience related to socioscientific argumentation mentioned their inadequacies by referring to their experiences. In addition, some other studies also support this result (Özden, 2015; Zangori et al. 2018). Accordingly, the fact that elementary teachers or candidates have not encountered socioscientific issues before may have caused them to feel inadequate in terms of pedagogy (Kinskey & Zeidler, 2021). They expanded their PCK conceptualizations through teacher efficacy after SSI, argumentation and PCK based learning and teaching experiences.

The idea that PCK is more than the sum of its components is dominant in the literature (e.g., Abell, 2008; Park & Chen, 2012). However, consistent relationships between components are important for the development of PCK. At this point, many studies reported that learning and teaching experiences, which are considered as the primary source of PCK development, contributed to the interaction among the components (e.g., Friedrichsen et al. 2009; Nilsson & Loughran, 2012). When it is considered from the common nature of the interaction among PCK components for socioscientific argumentation, the strongest interactions were between OTS-KSU and KSU-KISR components in this study. Furthermore, OTS and KSU components were at the center. This result confirms the results of similar studies on the nature of the interaction among PCK components (Park & Chen, 2012; Reynolds & Park, 2021; Suh & Park, 2017). Although learning and teaching experiences did not lead to an explicit change in terms of PCK interaction, it was revealed that the connection between OTS-KSU, KSU-KISR and KSU-KAS was strengthened at the end of the course. This result supports the findings obtained in many studies (e.g., Bravo & Cofré, 2016; Bayram-Jacobs et al. 2019). Furthermore, it was observed that learning and teaching experiences increased the importance of the KSU component in particular

(Park & Oliver. 2008b; Reynolds & Park, 2021). This development may contribute to teachers in terms of understanding student potential, responding to different ideas and considering personal perspectives (Sadler, 2006; McNeill & Pimentel, 2010). For example according to Zangori et al. (2018), student potential will be better perceived when teaching experiences are combined with seniority and personal passions. The field notes and observations support this claim practically.

The Effect of Professional Experience

PCK is a quality that is developed by teachers and specific to teachers (Shulman, 2015). Furthermore, one of the most important predictors of PCK development is professional experience (Loughran et al., 2004). Therefore, what kinds of contributions elementary teachers' professional experiences made to the interaction among PCK components for socioscientific argumentation was examined in this study. The results indicated that the interaction among PCK components and the development of this interaction differed from teacher to teacher (Sickel & Friedrichsen, 2018). At the beginning of the course, the OTS-KSU interaction of all elementary teachers except Fatma was strong, however, they did not have a common ground in terms of other dyad connections. For instance, Mine had no KISR-KAS and KISR-KSC interaction. In other words, Mine never interacted her knowledge of strategy with her knowledge of curriculum and assessment. Erhan was also unable to establish the KISR-KAS connection in the same way, which revealed the idea that professional experience contributed to elementary teachers' PCK integration in different ways. Loughran et al. (2004) argued that experienced teachers did not often talk about PCK while discussing their teachings, and instead, they focused more on teaching procedures, activities and strategies. Therefore, PCK is not a part of their professional language or a structure to which they are absolutely familiar. Such a situation was really encountered specifically to Fatma. The strongest interaction of Fatma was between KSU-KISR, and she performed a better teaching compared to other elementary teachers.

It would not be wrong to expect an experienced teacher to emphasize KSU more often compared to less experienced teachers (Cochran, DeRuiter, & King, 1993). As it is known, the most experienced teacher in the group was Fatma. However, it was remarkable that KSU was the most important component in the PCK conceptualizations of teachers other than Fatma. Furthermore, it was claimed in some studies that KSU facilitated the PCK development (e.g., Clermont, Krajcik, & Borko, 1993; Van Driel, Verloop, & De Vos, 1998). In this study, the results on the change of PCK interaction and the effect of professional experience on it showed the exact opposite. In other words, the most remarkable change occurred in the PCK integration of Fatma.

The learning and teaching experiences within the scope of this study served each teacher's PCK interaction in different ways. Aydin et al. (2015) argued that the development of integrations among PCK components was unique and that this integration evolved from fragmented to more integrated and consistent structure after experiences. This evolution was valid only for Fatma and maybe a little bit for Erhan and Mine. However, Fatma reflected this evolution in classroom practices more. Ali, who did not make any visible progress in terms of PCK interaction, made a standard way for himself. Although his PCK integration was initially integrated like Fatma's PCK integration, it also remained the same at the end. This remarkable result revealed the claim that learning and teaching experiences less affected the elementary teachers with little professional experience and more affected the elementary teachers with more professional experience. The common idea that PCK maps of inexperienced teachers have fragmented structure and PCK maps of experienced teachers have and integrated structure is dominant in the literature (Friedrichsen et al., 2009). However, when PCK, which has an idiosyncratic nature, is evaluated in terms of socioscientific argumentation processes, a professional experience threshold can be mentioned.

Implications

In this study, it was revealed that experiences contributed to PCK integration for socioscientific argumentation in different ways. It is difficult and also important to keep theories and practices for SSI and argumentation pedagogies together (Simonneaux, 2014). The main expectation in this study was that experiences would increase the interactions among PCK components for socioscientific argumentation. However, when PCK (Shulman, 1987), which is a special amalgam of content and pedagogy, was combined with SSI and argumentation processes, it also took on a unique nature, which revealed the idea of seniority threshold, which may be considered to be assertive. Therefore, there is a need for more extensive research on elementary school teachers' PCKs for socioscientific argumentation. In addition, it can be examined how the PCK for socioscientific argumentation changes according to the context of the subject.

Limitations of the Study

Unlike other studies, in this study, PCK Maps for socioscientific argumentation of five elementary teachers with different professional experiences were compared. Therefore, this study is considered to provide a different perspective to science education literature by its results. In addition, the results obtained are limited to global warming context. Accordingly, depicting other SSI contexts through PCK maps will contribute to the existing literature.

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As the author, I do not have any support or acknowledgment for the process of conducting the research.

Statement of Contribution Rate

All processes in the study were carried out by the only declared author of the manuscript.

Declaration of Conflict of Interest

As the authors of the study, we declare that we do not have any declaration of interest/conflict.

Statement of Publication Ethics

All the rules stated in the "Higher Education Institutions Scientific Research and Publication Ethics Directive" were complied with in all the processes from the planning of this research to the analysis of the data. On the other hand, none of the actions specified under the title of "Actions Contrary to Scientific Research and Publication Ethics", which is the second part of the directive, were not carried out. Scientific, ethical and citation rules were followed during the writing process of this study. In addition, no falsification was made on the collected data and this study was not sent to any other academic publication medium for evaluation.

Research ethics committee approval information

Name of the committee that made the ethical evaluation: Istanbul Aydin University Social and Human Sciences Ethics Committee

Date of ethical review decision: 13 July 2021

Ethics assessment document issue number: E-45379966-050.06.04-17510

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GENİŞLETİLMİŞ ÖZET

Giriş

Bilimsel okuryazarlık, nitelikli bir fen eğitimi için uzun süredir devam eden bir hedef olmuştur (Roberts & Bybee, 2014). Bu amaca ulaşmak için öğrencileri bilimsel ve sosyobilimsel tartışmalara dâhil etmek kritik öneme sahiptir (Sampson & Clark, 2009; Sadler, 2006). İlköğretim sınıflarında öğrenme, daha karmaşık anlayışlar ve yeterlilikler için kritik temeller oluşturduğundan, Sosyobilimsel konular ve argümantasyon uygulamaları erken başlamalıdır (Duschl et al. 2007; Evagorou, 2011). Bu nedenle birçok ülke fen müfredatlarında sosyobilimsel konulara (SBK) ve argümantasyon uygulamalarına yer vermiştir (NRC, 2013; MEB, 2018). Birçok çalışmada öğrencilerin sosyobilimsel argümantasyon süreçlerine dâhil edilmesinin onların aktif bilimsel söylem oluşturmalarında, çoklu bakış açılarına sahip olmalarında ve konu bilgilerini, bilimin doğasını anlamaları ve muhakeme becerilerini geliştirmelerinde faydalı olduğu bildirilmiştir (örn. Zeidler & Nichols, 2009; McNeill & Knight, 2013). Burada öğretmenin rolü, yapılandırmacılıkla uyumlu epistemolojik bir yönelimle otoriteden uzaklaşarak tartışmayı başarıyla destekleyen bir sınıf kültürü geliştirmektir (McNeill, 2009). Bu nedenle öğretmenlerin, öğretmen bilgisinin özel bir biçimi olarak kavramsallaştırılan PAB'a ihtiyaçları olacaktır (Kind & Chan, 2019). Son 20 yıldır fen eğitiminde en yaygın kullanılan PAB modeli Magnusson et al. (1999) tarafından önerilen ve diğer araştırmacılar tarafından revize edilen model olmuştur (Park & Oliver, 2008a, 2008b). Buna göre etkili fen öğretimini karakterize etmek için beş bileşenli bir PAB yapısı sunulmuştur. Park & Chen (2012) tarafından kavramsallaştırılan PAB modeli ise bu bileşenler arasındaki karşılıklı ilişkiyi ve etkileşimleri vurgulayan beşgen bir modeldir. Ayrıca, PAB beşgen modeli, öğretmenlerin PAB'larının hem nicel hem de nitel analizlerini sağlayabilen bir analitik yaklaşım olan PAB haritalama (Park & Suh, 2019) ile ilişkilidir. PAB'ın bu açıdan analizi, öğretmenlerin konuya özel PAB geliştirme ve bu bilgiyi gerçekleştirme süreçleri hakkında daha algılanabilir ve izlenebilir bilgiler sağlayabilir. PAB'ı ve onu oluşturan bileşenler arasındaki yapı ve doğa ilişkisini belirlemeye yönelik çalışmalar, bu bileşenlerin birbirleriyle çok karmaşık şekillerde etkileşime girdiğini (Suh & Park, 2017; Park & Suh, 2019) ve tutarlı bir etkileşimin öğretimin niteliği için önemli olduğunu ortaya koymuştur. Özetlemek gerekirse, birçok bileşeni inceleyerek PAB'ın daha bütünsel bir resmini ortaya koyan çalışmalar PAB hakkında daha derin bir kavrayış sağlayabilir, bu da PAB'ın gerçekte ne olduğu ve öğretmenin PAB'sinin nasıl değiştiği konusunda zenginleştirilmiş bilgi sağlayabilir. Literatürde hangi tekil bileşenin öğretimin kalitesine ne kadar katkı sağladığına odaklanan ve beş bileşenli PAB yapısını ele alan birçok çalışma bulunmaktadır (örn. Kutluca, 2021; Suh & Park, 2017). Ancak, özellikle SBK ve argümantasyon öğretimi sırasın-da PAB bileşenleri ve etkileşimleri hakkında çok az şey bilinmektedir. Bu nedenle, öğretmenlerin sosyobilimsel argümantasyonu öğrendikten ve öğrettikten sonra PAB bileşenlerinin nasıl geliş-tiğini araştırmak önemlidir. Tüm bu gerekçelerden hareketle bu çalışmada, sosyobilimsel argümantasyon için PAB bileşenleri arasındaki etkileşimin mesleki ve öğrenme ve öğretme deneyimlerine göre nasıl değiştiğini göstermek için resimsel bir metodolojik yaklaşım olan PAB Harita-lama kullanılmıştır.

Yöntem

Bu araştırma çoklu durum çalışması aracılığıyla gerçekleştirilmiştir. Bu araştırmada temel anlamda, öğrenme ve öğretme deneyimlerinin birbirinden farklı meslekî kıdemdeki öğretmenlerin sosyobilimsel argümantasyona yönelik PAB'ları üzerindeki etkilerine odaklanılmıştır. Bundan dolayı, birden fazla durumu ortak bir biçimde temsil eden PAB gelişimi olgusu sosyobilimsel argümantasyon bağlamına özel olarak, PAB bileşenlerinin etkileşimlerinin resimsel bir temsili olan PAB Haritası kullanılarak betimlenmiştir. Bu çalışma beş sınıf öğretmeninin katılımıyla gerçekleştirilmiştir. Katılımcılar, Türkiye'deki bir vakıf üniversitesinin sınıf öğretmenliği yüksek lisans programında öğrenim gören 12 sınıf öğretmeni arasından seçilmiştir.

Bu araştırmadaki alt problemleri yanıtlamak için çoklu veri kaynaklarından yararlanılmıştır. Temel veri kaynağı katılımcı öğretmenlere yöneltilen yarı yapılandırılmış görüşme sorularıdır. Görüşme protokolü, Magnusson et al. (1999) tarafından önerilen beş bileşenli PAB yapısını temsil eden sorulardan oluşmuştur. Beş PAB bileşenini temsil edecek şekilde düzenlenen bu protokolde beş ana soru ve 17 sondaj sorusu olmak üzere toplam 22 soru yer almıştır. İkincil veri kaynağı öğretmenlerin İçerik Temsili (CoRe) metodolojisine dayanarak oluşturdukları ders planlarıdır (Loughran et al. 2004). Bu iki veri kaynağı gözlem ve araştırmacının alan notları ile zenginleştirilmiştir. Veriler, tüm katılımcılardan sürecin başında ve sonunda ders planı ve PAB görüşme protokolü aracılığıyla toplanmıştır. Katılımcıların görüşme ve ders planı yanıtları birleştirilmiş, bütünleştirilmiş ve PAB bileşenlerine göre alt kategorilere ayrılmıştır. Bu veriler, doğrudan derinlemesine PAB analizi, tümevarım yöntemi, numaralandırma yaklaşımı, PAB haritalaması ve sürekli karşılaştırma yöntemi aracılığıyla analiz edilmiştir.

Bulgular

Bu çalışmada, sınıf öğretmenlerinin sosyobilimsel argümantasyona yönelik PAB bileşenleri arasındaki etkileşimlerin değişimi incelenmiştir. Resimsel bir metodoloji yaklaşımı olan PAB Harita-lama ile gösterilen değişiklikler için iki farklı bakış açısı benimsenmiştir. İlk olarak sınıf öğretmenlerinin öğretim bölümleri birleştirilerek ön ve son şeklinde bütünleşik PAB Haritaları oluşturulmuştur. Bu şekilde, öğrenme ve öğretme deneyimlerinin PAB bileşenlerinin etkileşimi üzerindeki genel etkisi değerlendirilmiştir. İkinci olarak, her öğretmenin ön ve son PAB haritaları ayrı ayrı değerlendirilmiştir. Bu şekilde mesleki deneyimin PAB bileşenlerinin etkileşimini nasıl etkilediği ortaya konmuştur. Ulaşılan sonuçlar ilgili literatüre dayalı olarak ayrıntılı olarak tartışılmıştır. Araştırmanın bulguları, öğretmenlerin öğrenme ve öğretme deneyimleri sonrasındaki sosyobilimsel argümantasyona yönelik öğretim bölümlerinin öncesine göre daha fazla olduğunu göstermiştir. Ayrıca PAB bileşenleri arasındaki ikili bağlantıların süreç sonrasında artış gösterdiği ortaya çıkmıştır.

Tartışma ve Sonuç

Bu çalışmada dikkat çeken ilk sonuç, PAB'ın yeni bir duyuşsal öğesi olan öğretmen yetkinliğinin PAB kavramsallaştırmalarını etkilediğidir (Park ve Oliver, 2008a). PAB, sınıf öğretmenlerinin öğrenme ve öğretme deneyimleri yoluyla sürekli genişleyen ve diğer öğretmen bilgi biçimlerinden dönüştürülen dinamik bir bilgi biçimi olarak kabul edilir (Nilsson, 2008). Bu iddia doğrultusunda sosyobilimsel argümantasyon ile ilgili herhangi bir öğretim deneyimi olmadan bu araştırmaya katılan öğretmenler deneyimlerine atıfta bulunarak yetersizliklerini dile getirmişlerdir. SBK, argümantasyon ve PAB temelli öğrenme ve öğretme deneyimlerinden sonra öğretmen ye-terliği yoluyla PAB kavramsallaştırmalarını genişletmişlerdir.

Sosyobilimsel argümantasyon için PAB bileşenleri arasındaki etkileşimin ortak doğasından bakıldığında, bu çalışmada en güçlü etkileşimler OTS-KSU (amaç ve hedef bilgisi-öğrenci anlayışları bilgisi) ve KSU-KISR (öğrenci anlayışları bilgisi-öğretim stratejileri bilgisi) bileşenleri arasında olmuştur. Ayrıca OTS ve KSU bileşenleri merkezdedir. Bu sonuç, PAB bileşenleri arasındaki etkileşimin doğası üzerine benzer çalışmaların sonuçlarını doğrulamaktadır (Reynolds & Park, 2021; Suh & Park, 2017). Ayrıca öğrenme ve öğretme deneyimlerinin özellikle KSU bileşeninin önemini arttırdığı görülmüştür (Park & Oliver. 2008b; Reynolds & Park, 2021). Bu gelişme, öğrencilerin potansiyelini anlama, farklı fikirlere yanıt verme ve kişisel bakış açılarını dikkate alma açısından öğretmenlere katkı sağlayabilir (Sadler, 2006; McNeill & Pimentel, 2010). Alan notları ve gözlemler bu iddiayı pratik olarak da desteklemektedir.

Sonuçlar, PAB bileşenleri arasındaki etkileşimin ve bu etkileşimin gelişiminin öğretmenden öğretmene farklılık gösterdiğini göstermiştir (Sickel & Friedrichsen, 2018). Bu çalışmadaki temel beklenti, deneyimlerin sosyobilimsel argümantasyona yönelik PAB bileşenleri arasındaki etkileşimleri artıracağıydı. Ancak içerik ve pedagojinin özel bir karışımı olan PAB (Shulman, 1987), SBK ve argümantasyon süreçleri ile birleştirildiğinde, aynı zamanda özgün bir nitelik kazanmış ve kıdem eşiği fikrini ortaya çıkarmıştır.

Appendix-1. Interview Protocol

Question Set		Data Source
1	Why do you think we should involve students in a socioscientific argumentation process in the context of global warming? Could you explain your answers? • *How did you set these goals?* • *How and where do you expect students to use what they have learned at the end of this process?* • *Do you think that at the end of this process, what students learn will be useful for their daily lives?*	Orientations to teaching science (OTS)
2	What do you think the students might need to have a good discussion on global warming (qualified reasoning)? Could you explain your answers? (*Prior knowledge, skills*) • *What kind of difficulties do you think students may experience in this process? Why?* • *Do you think the students need a preparation before the socioscientific argumentation process? If so, can you elaborate?*	Knowledge about students' understanding in science (KSU)
3	Do you think global warming has been adequately included in the curriculum in a way that is suitable for socioscientific argumentation? Could you explain your answers? • *If yes, do you know where these topics are located and at what grade levels?* • *If your answer is no, at what grade level should gains be included?* • *Are there guidelines in the curriculum on how to incorporate global warming into the socioscientific argumentation process?*	Knowledge of science curriculum (KSC)
4	What preparations do you make before you involve students in the socioscientific argumentation process on global warming? Could you explain your answers? • *How do you direct student discussions in the process of socioscientific argumentation?* • *What kind of activities do you support the socioscientific argumentation process?* • *Do you need additional resources to encourage participation in the socioscientific argumentation process?*	Knowledge of instructional strategies for teaching science (KISR)
5	What exactly do you aim to measure about students' participation in the socioscientific argumentation process on global warming? Could you explain your answers? • *How do you determine if students make good reasoning in the socioscientific argumentation process?* • *What measurement-assessment techniques do you use to measure your students' conceptual understanding of global warming?* • *How do you measure students' socioscientific argumentation skills, qualities or qualifications?*	Knowledge of assessment of science learning (KAS)