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USING REAL ENGAGEMENT IN THE ACTIVE PROBLEM-SOLVING MODEL IN TEACHING SCIENCE: AN INTERPRETIVE PEDAGOGICAL CONTENT KNOWLEDGE STUDY OF AN EXPERIENCED SCIENCE TEACHER

Research Article

Ümit Duruk
Adıyaman University
uduruk86@gmail.com

Abuzer Akgun
Adıyaman University
aakgun@adiyaman.edu.tr

Umit Duruk has a PhD Degree in Science Education and works as a research assistant in the College of Education at Adıyaman University. He is interested in metacognition, reflective practice and pedagogical content knowledge for nature of science.

Abuzer Akgun works as a professor in the College of Education at Adiyaman University. He has a PhD Degree in Chemistry Education. His research area includes conceptual change and pedagogical content knowledge.

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Ümit Duruk

uduruk86@gmail.com

Abuzer Akgun

aakgun@adiyaman.edu.tr

Abstract

The study aimed to examine and interpret the experiences of an experienced science teacher in Real Engagement in Active Problem Solving Model (REAPS) implementation conducted within the Electricity Unit through a validated pedagogical content knowledge (PCK) framework. To this end, the study examined the efforts of an experienced middle school science teacher, in helping her seventh graders in a rural public school improve conceptual understandings of electricity. She was an information-rich teacher and agreed voluntarily participation in the study. The study was based on a basic qualitative study design. REAPS interview questions and guiding interview questions with prompts were employed as the data collection tools. The data were analysed via in-depth analysis of explicit PCK, enumerative approach, and constant comparisons. The results revealed various characteristics of the usage of REAPS Model, the interactions between the PCK components, and emerged critical incidents in teaching practice. Regarding the usage of REAPS Model, the science teaching experience of the paticipant teacher was expanded with the themes of engagement, real-life experiences, socialization in diverse cultural contexts, teaching in varied physical conditions through argumentation and retention. As an experienced teacher, the interactions between knowledge of learners and knowledge of instructional strategies were central in the teaching performance of the participant reacher. Self-efficacy was specifically found conducive for triggering these interactions together with knowledge of curriculum. However, her science teaching orientation impeded the interactions between most of the PCK components. Finally, critical incidents were found beneficial to the investigations looking for the interactions between three or more PCK components, in particular.

Keywords: Science education, REAPS model, PCK Map, critical incidents, experienced science teachers

1. Introduction

Today, it is known that teachers need more than just having subject matter knowledge (SMK) in understanding, planning, and enacting stages of teaching (Abell, 2008; Alonzo & Kim, 2016). One of the most important factors affecting student learning is the level of the teacher and his/her pedagogical content knowledge (PCK) (Coe, Aloisi, Higgins & Major, 2014; Hill, Rowan & Ball, 2005). Teachers might grasp their students' cognitive and affective capabilities in a particular topic when they use their pedagogical content knowledge base that facilitates student learning (Park & Oliver, 2008b). PCK is a predictive teacher knowledge base that guides teachers' classroom practices (Abell, 2007; Van Driel, Verloop & de Vos, 1998). With this feature, PCK distinguishes teachers from SMK specialists (Shulman, 1986). In addition, it has the characteristics of an amalgam that serves as a bridge between SMK that provides learning content to the student and pedagogical knowledge (PK) (Berry, Depaepe & Van Driel, 2016). Adequate SMK is a pre-requisite that has a major impact on PCK development (Abell, 2007; Rollnick, 2017). In this context, PCK provides the teachers with a pedagogical scaffold to ensure them making abstract and difficult SMK be accessible for student understanding (Mavhunga, 2019). Therefore, the teacher with a robust PCK is more successful in using the specific terminology of the science course and in relating concepts to real-life and other topics (Ingber, 2009). However, to focus only on SMK development in order to understand PCK is not a realistic approach for teacher knowledge base inquiry (Rollnick, Bennett, Rhemtula, Dharsey & Ndlovu, 2008). The context in which the teaching takes place (Grossman, 1990) is also important at this point. Because PCK is discipline-specific, topic-specific, person-specific and context-specific at the same time (Kind, 2009).

Effective teachers should have robust PCK by developing all PCK components (Magnusson, Krajcik & Borko, 1999). However, robust PCK does not guarantee effective teaching in all situations. Because, the effectiveness of teaching is closely related to the interactions of the PCK components of this amalgam to what extent (Abell, 2008; Shulman, 1987). In other words, a teacher's PCK level depends on the interaction among the components and the consistency of these interactions as well as being robust on the basis of each component (Friedrichsen et al. 2009). It was observed that empirical studies related to this were recent and few (Akin & Uzuntiryaki-Kondakci, 2018; Aydin & Boz, 2013; Aydin, Demirdogen, Akin, Uzuntiryaki-Kondakci & Tarkin, 2015; Demirdogen, Hanuscin, Uzuntiryaki-Kondakci & Koseoglu, 2016; Friedrichsen, Driel & Abell, 2011; Park & Chen, 2012). In addition, studies have shown that although the PCK is topic-specific (Abell, 2008; Loughran, Mulhall & Berry, 2004), it is also discipline-specific (Davis & Krajcik, 2005). Teachers' knowledge about discipline-specific strategies (learning cycle) and strategies for specific science topics (images and analogies) (Akin & Uzuntiryaki-Kondakci, 2018). However, self-efficacy of prospective teachers was found to be low in terms of using discipline-specific strategies (e.g. learning cycle) (Uzuntiryaki-Kondakci, Demirdogen, Akin, Tarkin & Aydin-Gunbatar, 2017). Moreover, to the best of our knowledge, studies examining the interactions among PCK components of science teachers using discipline-specific strategies are limited.

As mentioned above, in order to determine the cognitive and affective states of the students effectively with pedagogical maneuvers and to organize teaching accordingly, teachers should create learning environments where students can take their own learning responsibilities and find the opportunity to build knowledge through inquiry. Because students experience their best learning experiences when they actively participate in learning activities (Wu, Paese & Maker, 2015). It is known that students' academic success and conceptual understanding can be improved through active learning (Lumpkin, Achen & Dodd, 2015). In addition to models, which can trigger active learning, and models such as the 5E learning cycle as a discipline-specific strategy that teachers are familiar with from the science teacher education program, relatively new models such as REAPS can also be used. The REAPS Model was developed in 2004 by Maker et al. to develop creative problem-solving skills of gifted students regarding real-life problems (Alhusaini, 2016). Shaping teaching with model is useful in checking the consistency of goals, and innovative pedagogical models serve meaningful and permanent science learning (Gomez-Arizaga, Bahar, Maker, Zimmerman & Paese, 2016). The general impression obtained from the studies is that the model exhibits a discipline-specific strategy feature in a structure suitable for all science subject content (Gomez-Arizaga et al. 2016; Zimmerman, Maker, Gomez-Arizaga & Paese, 2011). Moreover, it was observed that the REAPS Model can be adapted to the teaching programs of middle school students (Reinoso, 2011).

2. Theoretical Background

The present study was guided by two main frameworks: Hexagonal Model of PCK, and REAPS Model. In this section, these theoretical frameworks were explained to some extent and then related results in the literature were given. Finally, the grounds, purpose, and research questions of this study were included.

The study was both theoretically and analytically grounded in the Hexagonal Model, which identifies PCK as an integration of the six PCK components. The Hexagonal Model is the added heuristic version of the self-efficacy component of the Pentagon Model, which was proposed by Park & Oliver (2008b). The basic assumption the model embraced is that PCK includes reported and enacted stages regarding student learning. Teacher self-efficacy is a mediator factor and serves as a conduit to bring together the stages of PCK in practice. The more teachers report high self-efficacy before teaching, the more they enact effectively their teaching plans. This cycle becomes more strengthened and cohent in turn following successful teaching performances. All the components in the model are in ongoing interactions within a given context (e.g. electricity). These integrations rely heavily on the reflections including reflection-on-action and reflection-in-action. It means that as a teacher develops PCK through reflection, the interactions between and consistency among the PCK components may improve. However, improvement within a single component is not necessarily guarantee high level reported and enacted interactions among the components in practice.

Unlike the Pentagon Model, in the Hexagonal Model, the knowledge of learners (KoL) component is positioned as a relative starting point. It can be said that understanding and implementation of the reflective process is directed towards the KoL-originated sub-components (e.g. needs, interest/motivation, and learning difficulties). In this case, it can be said that the learning outcomes of the REAPS teaching model discussed in this section are similar to the Hexagonal Model. Problem-based learning is based on experience-based learning related to solving and investigating complex and real-life problems (Torp & Sage, 2002). The purpose of the REAPS model, which is based on problem-based learning, is to complete the traditional science teaching program for ensuring meaningful learning and permanent learning, with the participation of different problem-solving strategies (Gomez-Arizaga et al. 2016). As well as being a model that aims to improve students' creative problem-solving skills, REAPS Model is also an integrated model, which is based on the concept of engagement and offers a three-component structure on the basis of student interests, needs, and learning difficulties (Maker & Zimmerman, 2008). In other words, the REAPS Model is an inclusive teaching model supported by DISCOVER (Discovering Intellectual Strengths and Capabilities while Observing Varied Ethnic Responses) and TASC (Thinking Actively in a Social Context) components (Maker, Zimmerman, Alhusaini & Paese, 2015). During the use of closed-ended and open-ended problem scenarios, the DISCOVER component acts as an agent and allows it to be adjusted according to the place of scientific inquiry in the learning process. The development of multiple skills is key for this component (Webber, Riley, Sylva & Scobie-Jennings, 2018). Therefore, teachers who will teach with DISCOVER were given a guideline in this multi-skill development process. In this directive, teachers are expected a) to provide their students with the opportunity to solve different types of open-ended problems during their teaching, b) to actively use hands-on activities for each skill development, and c) to reflect the elements based on the student's own cultural background and the sensitivities of the civil society that shaped it on the curriculum in practice (Maker & Zimmerman, 2008). In making open-ended problem scenarios functional, the TASC component performs duty rather. The TASC component is based on the use of thinking skills and thus ensuring that students find answers to their own questions (Ball & Henderson, 2008). Like the Hexagonal Model, the REAPS Model refers to students' learning through reflections. These similarities encouraged us to combine these models in a teaching context using REAPS Model as a discipline-specific strategy in the theoretical framework of Hexagon PCK Model.

Since PCK has a tacit structure, it can be said that setting out operational definitions of its components will serve to make the comments made on the assumptions of the two models more valid (Henze & Van Driel, 2015). The six components included in the Hexagon PCK Model were covered under the following definitions:

- STO typically refers to teacher’s knowledge and beliefs about the goals and purposes of science teaching at a specific grade level.
- KoC contains knowledge about compulsory goals and objectives mandated by national science teaching programs, as well as the characteristics of vertical and horizontal curriculum.
- KoL consists of knowledge about the learners’ prior knowledge and learning difficulties they often encounter during science learning.
- KoA includes two distinct but interacted sub-dimensions that define teacher knowledge about what to assess (e.g. science process skills) and how to assess (through portfolios or written tests).
- KoIS comprises of two sub-dimensions: knowledge of discipline-specific strategies (e.g. learning cycle) and knowledge of topic-specific strategies (representations and analogies). Knowledge of topic-specific strategies consists of teachers’ knowledge about useful strategies for teaching particular topics in science teaching program, with topic-specific representations and activities. The activities including demonstrations, experiments or simulations serve as facilitators to provide students the chance to construct the knowledge in the learning environments (Akin & Uzuntiryaki-Kondakci, 2018; Magnusson et al. 1999).
- Teacher self-efficacy is a wide-ranging belief that has its origins in socio-cognitive theory and is closely related to positive teaching actions and qualified student learning. When teachers believe that their capacity is sufficient to successfully execute the PCK, they tend to pursue teaching practices in that direction. Moreover, self-efficacy was found to be linked with the integration among PCK components (Henson, 2001; Pajares, 1992; Park & Oliver, 2008b).

Based on the Hexagon PCK model, reflection is an agent that triggers interaction among components (see, Park & Oliver, 2008b). Therefore, reflection has a highly invaluable role in professional development (Schön, 1987). Reflective practice is linked with the use of critical incidents (Tripp, 2011). Because critical incidents are reflective thinking tools (Bruster & Peterson, 2013). Critical incident refers to turning points or changes of perception of success (Thuynsma, 2001). Thanks to critical incidents, teachers might question their practice more deeply and get new insights into the challenging nature of teaching (Nilsson & Loughran, 2012). Examination of critical incidents that teachers give meaning in their teaching processes and that have positive or negative pedagogical traces can give access to more in-depth information about the reflection-laden theoretical structure of the Hexagon model. Departing from this assumption, it was thought that it would be beneficial to make interpretations in the name of understanding and enactment of PCK, which strengthens the interaction among PCK components through reflections carried out on critical incidents that have recently been used frequently in the educational field. Critical incidents, which provide information about the real experiences of the participants, to which they attach importance, can be revealed through personal narrative vignettes (Angelides, 2001; Howitt & Venville, 2008). The reflective process in the hexagon model was triggered by uncovering and discussing the critical incidents during the interviews.

To date, it was observed that there are few empirical studies examining the interaction among PCK components explicitly and that the general trend in studying these interactions is the use of PCK Maps (e.g. Akin & Uzuntiryaki-Kondakci, 2018; Aydin & Boz, 2013; Aydin et al. 2015; Demirdogen et al. 2016; Park & Chen, 2012). For example, in their study investigating the teaching practices of biology teachers, Park & Chen (2012) examined the interaction among five PCK components. Due to the topic-specific structure of the PCK, its implementations were discussed under photosynthesis and heredity topics. In-depth analysis of explicit PCK, various results were reached through the enumerative approach and constant comparisons. Accordingly, it was found that the KoL-KoIS interaction was at the center of the interaction among all components, that the KoC and KoA components were the components that interact the least with the other components, and that the KoA component interacts more frequently with KoL and KoIS components. Findings regarding the KoL-KoIS interaction were also found in the more recent study of the first author (Suh & Park, 2017). It was also concluded that the didactics orientation makes the interaction of the KoIS component with other components impede. In a similar vein, Aydin & Boz (2013) discussed the interaction among PCK components of two experienced chemistry teachers under the electrochemical cells and redox reactions topics. The methodological process was conducted in accordance with the previous study. Similarly, as a result of this study, it was observed that the KoL-KoIS interaction was at the center of the interaction among all components and the KoC and KoA components were the components that interact the least with other components. In another study, Aydin et al (2015) examined prospective teachers' PCK development through the core-based mentoring practicum course, again on the basis of interactions among components. As a result of the study, it was seen that the most development was in the interactions among KoC and other components and no interaction of KoA with KoIS was found. The fact that the KoA level of experienced chemistry teachers is at the level of pedagogical knowledge may explain this situation (Aydin et al. 2014). In the conclusion, the practicum course was found to be effective, because, it was determined that the prospective chemistry teachers' PCK Maps, which were fragmented before the course, became integrated after the course. Through pedagogical instruction framed by PCK for NOS, Demirdogen et al. (2016) reached various results in the name of PCK for NOS through in-depth analysis of explicit PCK and constant comparisons. Unlike previous studies, PCK Maps of prospective chemistry teachers were drawn according to interactions obtained through lesson plans and reflection paper rather than observing teaching performance. The researchers created a coding scheme that examines whether these interactions show consistency or connection. As a result of the study, it was understood that the pedagogical instruction framed by PCK for NOS was effective on the interaction among components. Besides, it was concluded that pre-requisite knowledge is required for effective NOS teaching, that PCK for NOS level improved from knowledge level to application level, and that highly-level interactions among PCK components lead to effective NOS teaching. Finally, Akin & Uzuntiryaki-Kondakci (2018) examined the interaction among PCK components by comparing the teaching performance of novice and experienced chemistry teachers. In the methodological sense, the same three approaches gave direction to this study. Eight general patterns were reached after constant comparisons. Accordingly, novice teachers' broad and non-specific science teaching orientation impedes the topic-specific interaction among PCK components. Experienced teachers were able to interact more than two PCK components in most cases and therefore, their PCK Maps were more integrated. As in previous studies, the KoL-KoIS interaction was central, finally, teacher self-efficacy was effective in increasing or decreasing interactions among PCK components.

The model of Magnusson et al. (1999) continues to be the first PCK framework in the context of science education. However, its explanatory power on how to ensure the interaction among PCK components is limited. Therefore, in this study, the Hexagon PCK Model, which deals with the interaction among PCK components as a sixth component, together with teacher self-efficacy, and evaluates this interaction process in the context of activating reflective thinking, was adopted as the theoretical framework (Park & Oliver, 2008b). To the best of our knowledge, this study is the first study based on this model in questioning the experiences regarding PCK enactment. In a recent study, Hanuscin, Cisterna & Lipsitz (2018) found that teachers with more teaching experience in a class developed better PCK than teachers with more experience. The science teacher, who is the participant of this study and is a REAPS practitioner, has more than three years of science teaching experience with her students in her classroom. Therefore, it has information-rich feature in this and many similar aspects. Reviewing the relevant literature, it was seen that the studies on the REAPS Model, one of the relatively new discipline-specific teaching strategies generally focused on determining the views on the implementation of the model (Gomez-Arizaga et al. 2015; Wu et al. 2015), determining the effect on creative problem solving skills (Reinoso, 2011), its effect on class participation and academic success (Riley et al. 2017; Webber et al. 2018). Therefore, in terms of the original and possible results in regard of examining the teaching experiences of a science teacher implementing the REAPS model under the framework of PCK, it can be said that this study is a research report that can potentially guide future studies. To address above gaps in the literature, the purpose of the study was to examine and interpret the experiences of an experienced science teacher in REAPS Model teaching practice conducted within the Electricity Unit. The following tree research questions guided the investigation:

1. What are the perceptions of the participant about her own REAPS implementation?
2. What is the participant's perception of the interaction among her REAPS implementation and the PCK components that arise meanwhile?
3. What do critical incidents indicate about the interaction between the various components of PCK?

3. Method

The present investigation was interpretive and emergent in nature (Bogdan & Biklen, 2003; Tobin, 2000). In particular, the investigation focused on the meanings that an experienced science teacher ascribed to her REAPS implementation carried out in a rural middle school with seventh grade students.

3.1. Research Design

Basic qualitative research design was used in the study (Merriam, 2002, 2009). The fundamental assumption that qualitative research is based on is that reality is formed by the interaction of individuals with the social environment they live in (Merriam, 1998, 2015). As a matter of purposive sampling, this study was carried out with a single participant who was thought to be information-rich. For confidentiality, she was given pseudonym as “Beyza”. When Beyza started practicing, she has 3-year experience of science education. In order to better demonstrate the tacit interactions among PCK components, she has performed the REAPS Model, which she uses as a discipline-specific instructional strategy, by using the electricity unit in a topic-specific direction.

3.2. Data Collection

In this study, data were collected using a semi-structured interview form. The interviews were conducted in two sessions under the supervision of the first researcher. The first session mainly consisted of questions involving the implementation of the REAPS Model, while the second session was carried out through questions aimed at revealing the interactions among PCK components.

3.3. Data Analysis

The data obtained from the interviews were analyzed through four different methodological analyzes and thus, triangulation was performed. At this point, the purpose is to examine Beyza’s perceptions about the implementation realized through the REAPS Model using different methodological analyzes and thus, to minimize the validity problems that may arise from using a single data collection tool.

Semi-structured interviews were analyzed separately. In the first interview covering the questions about the implementation of REAPS, in order to determine the participant's teaching experiences, the interview questions prepared by Wu et al. (2015) were used as a guideline. The content analysis method was used to identify the concepts and relationships that explain the data obtained. In content analysis, similar data are brought together and interpreted within the framework of certain concepts and themes (Yıldırım & Simsek, 2013). In the second interview, PCK interview questions were used which mainly covered the questions to identify the PCK components that were prepared by Carpendale (2018) and the interactions among PCK components. The data obtained as a result of these interviews were interpreted in line with the Hexagonal Model of PCK introduced by Park & Oliver (2008b).

The data obtained by performing an in-depth analysis of explicit PCK over the data obtained from both interviews were used for drawing the PCK Maps of Beyza. The PCK mapping method is a useful tool in making the tacit PCK explicit (Park & Chen, 2012). Since it was aimed to determine Beyza’s general perception of teaching instead of monitoring the teaching performance itself; rather than teaching in one course, the entire REAPS implementation was accepted as a single session. This analysis was used to determine the interactions among PCK components that emerge in a particular teaching segment in a particular session. The mutual interaction among the two components has formed the operational definition of the segment. Rather than interactions among each segment, the entire implementation process is covered under a single PCK Episode consisting of possible segments.

The data obtained after the in-depth analysis of explicit PCK were visualized as a PCK Map using the enumerative approach. Numerative approach is an approach in which the mutual interactions among PCK components are considered equal in strength (LeCompte & Preissle, 1993). It is assumed that the more numbers indicated on the arrows, the more interacting the components are. Excessive strong interactions among components indicate robust PCK. Since the conceptual framework of the analysis used to find answers to the second and third research questions of the PCK Map is a Hexagonal Model of PCK, it consists of arrows showing the five components and the possible relationships among these components, except for self-efficacy. In the interest of providing analytical convenience, it is assumed that all of these arrows have the same strength (Park & Chen, 2012). In categorizing these interaction numbers, the framework suggested by Aydin et al (2015) was used. Accordingly, the bold lines among components point to the upper level, solid lines medium level, and dashed lines lower level PCK interaction categories.

Since the PCK Map that was created to show the interaction among the REAPS model and PCK focuses on binary interactions among components, the coding scheme developed by Demirdogen et al. (2016) was used as it has a similar analysis logic (see Table 1). In accordance with this coding scheme, in the present study, the analysis was made according to whether binary interactions show consistency or connection. Since STO influenced other components, attention was paid to the presence of consistency in STO interactions and the presence of connection in other components as they inform each other.

Table 1. *Coding scheme for the interactions among PCK components*

PCK Components	Explanation	Consistency/ Connection	Direction
STO-KoC	Considering a particular curriculum emphasis in class (i.e., nature of science objectives) because of his/her goals and purposes for science teaching	Consistent	STO influenced KoC
STO-KoL	Considering students' difficulties, misconceptions or pre-requisite knowledge based on the teacher's goals and purposes for science teaching	Consistent	STO influenced KoL
STO-KoIS	Using a particular instructional strategy to reach goals and purposes for science teaching	Consistent	STO influenced KoIS
STO-KoA	Assessing a particular knowledge or skill for determining whether students reached his/her goals and purposes for science teaching	Consistent	STO influenced KoA
KoC-KoL	Considering a difficulty, misconception, or pre-requisite knowledge by reviewing the curriculum in terms of what students should have learned and will learn about those topics	Connection	KoC informed KoL
KoC-KoIS	Using a particular instructional strategy to address a particular curriculum objective	Connection	KoC informed KoIS
KoC-KoA	Using various assessment strategies to identify students' achievement in the curriculum objectives related to the topic, or to reveal what students know about the topic from the same and different grades	Connection	KoC informed KoA
KoL-KoIS	Using a particular instructional strategy to remedy a difficulty, misconception, pre-requisite or knowledge	Connection	KoL informed KoIS
KoL-KoA	Using various assessment strategies to identify students' difficulties, misconceptions or pre-requisite knowledge	Connection	KoL informed KoA

KoIS-KoA	Revising the instruction based on the feedback taken from assessments	Connection	KoIS informed KoA

Finally, the incident form suggested by Nilsson & Karlsson (2019) was used in the examination of critical incident in the center of REAPS model and PCK interaction. In this form, titles of incident where she thinks she succeeded/failed, why she thinks she succeeded/failed and consequences for further teaching and their corresponding PCK components take place. While searching for critical incidents within the scope of all interview data, the researchers based the criteria of the participant's self-expression of the success or failure situation and the presence of evidence on the fact that at least three PCK components affect each other positively or negatively in the mentioned cases (Kilgour, Northcote & Herman, 2015). By this process, a list of potential critical incidents was identified. Finally, six incidents were then discussed during semi-structured interviews in detail using probe questions to bring out the meaning of these incidents to Beyza, and to determine their significance from her perspective (Hanuscin, 2013).

3.4. Credibility Issues of the Study

The present study included only semi-structured interview data. To increase and ensure credibility issues of the study, we triangulated the study theoretically. Theory triangulation uses different theories or theoretical frameworks (REAPS Model, Hegzagon PCK Model, PCK Components Coding Scheme) to analyze and interpret data. With this type of triangulation, various theories or hypotheses in contact can make the researcher available for providing supporting or refuting findings (Patton, 1999).

A three-step coding procedure was employed. The first and second steps were about the analysis of the data collected through open-ended questions and related semi-structured interviews. The remainder was about the emerging patterns brought about through comparing and contrasting the data including REAPS implementation, interactions between PCK components and critical incidents. To begin, the first researcher having studies on REAPS implementation and an expert on PCK analyzed the entire data set independently, but all the steps were proceeded in turn. Discrepancies between coders were resolved through weekly negotiations. Interrater reliability on the course of deductive coding ranged from 78 to 86 % (Miles & Huberman, 1994).

3.5. Ethical Considerations

In Turkey, a permission for conducting research studies is required and given by Institutional Review Board. We obtained this permission from Adiyaman University Institutional Review Board. In addition, Beyza voluntarily participated in the study after being informed that she is among the first REAPS implementers in Turkey. She flushed with pleasure to participate in the interviews to share her specific teaching experiences regarding the implementation and receive constructive feedbacks with her science teaching in the near future. She consented to make the findings available for researchers to validate (Creswell & Miller, 2000).

4. Results

4.1. Results Related to the Participant's REAPS Implementation Experiences

In the content analysis made through data obtained from semi-structured interviews, various themes have been reached under the category of Beyza's (the participant) REAPS implementation. It was seen that these themes consisted of retention, engagement, physical conditions, real-life experiences and socialization, cultural context, emotions, intrapersonal skills, collaboration, and argumentation. Table 2 shows the excerpts of participant's responses.

Table 2. *Emerging themes regarding the participant teacher's REAPS implementation*

Category	Themes	Related excerpts
Beyza's REAPS implementation	Retention	As it includes skills such as generating ideas and making decisions by students, TASC remembered easily. The fact that students develop their ideas gradually throughout the TASC component deepens their conceptual understanding and makes these ideas more retained.
	Engagement	Prior to implementation, I had thought cognitive engagement was sufficient. As time progressed, I realized that this model requires affective and behavioral engagement and I observed that. I saw that even students who remained passive in the classroom took action and participated more actively in some thinking skills, especially in group discussions and discussion activities. The TASC component is the vital component because in this component the student becomes more active.
	Physical conditions	I tried to bring everything to the classroom in the whole process. However, I think that lack of physical conditions negatively affects the learning process. Because there is no laboratory since it is a village school.
	Real-life experiences and socialization	My initial perception against REAPS began to develop over time with the idea that it improved life skills and enabled them to socialize. I noticed that the model improved life skills over time.
	Cultural context	Particularly the DISCOVER component of REAPS enables students to face the problems they encounter in their own sociocultural environment. This situation contributed to the acceleration of the development of life skills of students.
	Emotions	The experiments attracted a lot of attention. I observed that the female students remained a little more passive during the experiments. This may be due to the fact that the topic of the lesson was electricity. Working in touch and being able to comment on their own were making the students happy. This situation was appealing to me, too. Before the implementation, I performed semi-structured interviews with the students in order to get suggestions for the course. I noticed that the students were always actively depicting me during the interviews. This was a disappointing moment for me because I supposed that I stayed away from traditional approaches throughout my teaching life. It was not in my plans to develop students' argumentation skills. However, seeing my students improve these skills over time made me very happy.
	Intrapersonal skills	When my students study in groups in constant touch, all of them were satisfied as one of them assists and supports her friend in the moments she falls behind.
	Collaboration	In order for my other student to assist the lack of his/her friend, I tried to create heterogeneous groups before the application steps. The students wrote something and delivered it in writing. However, to understand whether they were studying collaboratively, I reviewed the concept maps they generated.
	Argumentation	Unlike the traditional approach, my students have begun to justify their claims and to present counter-claims, especially in the last few weeks, while using the REAPS Model. The whole class was very enthusiastic and motivated about this. While defending their claims in the discussion activity, they did not defend them in a hardheaded manner. They based their claims on certain bases. By listening to the other's opinions, they were asserting arguments in a way to refute the justifications of them. The development of skills that I had not planned at first and that emerged throughout the process made me happy.

When asked about her first impression of REAPS, it was seen that Beyza (the participant teacher) classified the model with active learning models. Defining active learning potentially as "*the type of learning in which the teacher is a guide who designs or uses activities that will enable students to be more active, and the students are participants who build knowledge in this process*", Beyza placed the concept of "engagement" at the center of this type of learning. Emphasizing the importance of cognitive, affective and behavioral engagement, Beyza stated that towards the last weeks of her practice, students systematized affective and behavioral participation as well as cognitive participation. Beyza expressed her opinion that what distinguishes the model from other models is that it has sub-components. She stated that the active learning models which she used previously led the students to participate more cognitively and she thought she fell behind due to being inexperienced in conducting model-based lessons. As the interview progressed, Beyza stated that her perception of the model was not limited to active learning and that she gradually saw that this model was more effective for students to gain real-life experiences, to socialize and to communicate with each other in this way. Beyza touched on this subject as follows:

"*As the weeks progressed, I realized that the model was trying to teach life skills. Because these life skills are also included in the skills section of the science teaching program. We have to upskill students with these skills. I have seen that the purpose of the model is also compatible with the aims of the program.*"

In addition to the perception that the model is compatible with the program, Beyza emphasized the importance of problem scenarios in gaining life skills as follows:

"*Since the issues I am linking with are life itself, I thought that I should prepare particularly the problem scenarios in line with the program's learning outcomes. Furthermore, because the scenarios are inherent in REAPS, I can say that I did not find it difficult to associate the problem scenarios with daily life.*"

Beyza stated that when creating problem scenarios, she particularly touched on the items related to the students' own culture because she believes that teaching the DISCOVER component of REAPS should be associated with the cultural and social environment of the students. Beyza especially emphasized the fact that she understood that the model aims to provide life skills thanks to this component of the model. She pointed out that through discussions and debates in accord with REAPS, even the students who remain passive and do not show any attendance to the lesson became more active.

Beyza stated that REAPS is related to decision-making skills, one of the life skills in the curriculum, as follows:

"*I saw that, in the TASC component, it was focused on students' skills such as generating an idea, implementation, and decision making. The science teaching program also includes the goal of developing this skill.*"

Stating that TASC is the propellent component of the model, Beyza mentioned that this component is the one that activates the other two components. Because, according to her, students were most active during the activities related to this component in the classroom.

Regarding content teaching, Beyza thinks that she used alternative teaching approaches compared to the past during the implementation of this model. She stated that she felt more comfortable in the DISCOVER and PBL components in terms of teaching the content within the electricity unit and she understood that it is more appropriate to transfer the content with these two components. Beyza has expanded her experience with content teaching as follows:

"*Compared to my previous lessons, which I supposed that I have my students make active-learning, I think the model has a serious contribution to me in content teaching. I noticed this very clearly in the classroom.*"

In general, Beyza stated that the physical conditions of the school and the classroom limit the implementation of REAPS. According to her, the absence of a lab prevented some experiments from being performed. Beyza expressed that instead of these experiments structured on the TASC component, she continued the lesson with discussion-based group work, and that she had to perform demonstration experiments using simple materials.

Beyza mentioned that most of the experiments she had done with simple materials aimed at the development of multiple skills in the DISCOVER component of the REAPS model. Moreover, she stated that she included these multiple skills in problem scenarios as a precaution due to the lack of materials.

Beyza pointed out that student interest emerged mostly during the experiments, but that the female students remained passive during the experiments compared to the male students. Stating that being in contact motivates the students, Beyza added the following views:

"*Some of my students contributed a lot, some did not. This may be due to the fact that the topic of the lesson was electricity. Because the female students were very active in group discussions while remaining passive in experiments. However, I think this is mainly due to the fact that I did not give them enough opportunity to reflect within the group. Because, in some cases when they work as a group, I noticed that they shared things that each other did not know, as they shared their ideas.*"

"*Things written about problem scenarios during group activities were often similar. Answers were often given under the supervision of the dominant student within the group. I did not like this situation. I decided to have a concept map drawn in order to reach the answers of all students. To reach the answers of all students, I decided to ask my students to draw concept maps. Thus, I have seen better the difference and variation between the answers.*"

Finally, Beyza explained how the model affected scientific discourse in the classroom as follows:

"*Especially in the last two weeks of the five-week implementation process, I saw that female students are now starting to defend their claims not only in journals but also during discussions. Meanwhile, I asked them to carefully listen to their peers' opinions and I insistently stated that they could also change their own claims according to these views. I saw that they stopped being hardheaded at their discussion activities. The justification of the allegations had become a habit. Some students were quite good at producing opposite and confuting arguments.*

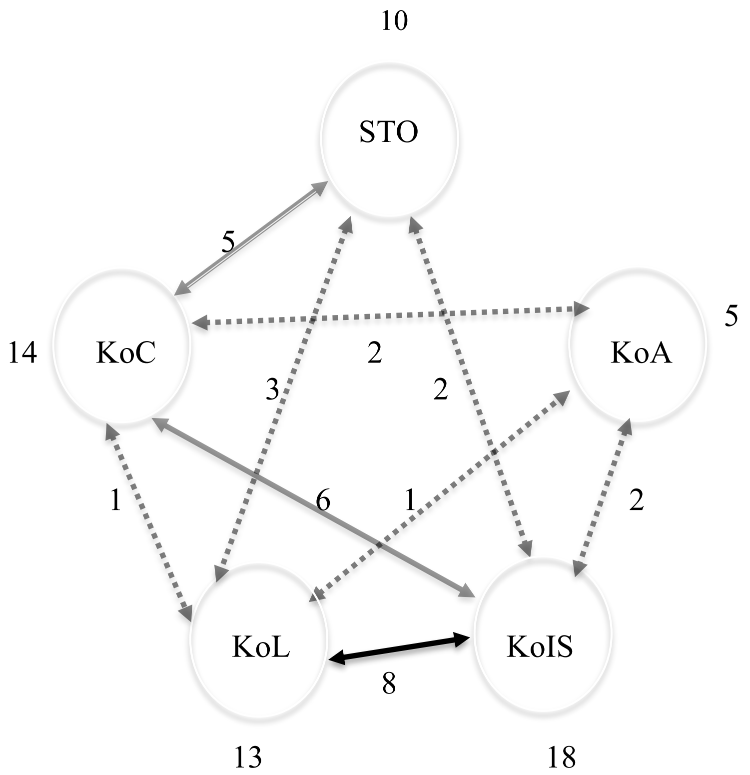
4.2. Results Regarding the Perception of Interaction Among the Participant's Own REAPS Implementation and the PCK Components that Emerged

This study, in order to reveal the interactions among PCK components more clearly, first revealed Beyza's science teaching profile, and then interactions were visualized through PCK Maps. The strength of each interaction in the map was assumed to be the same. Hence, increasing the number of interactions among binary components indicates that the interaction is strong to that extent (Park & Chen, 2012). Table 3 shows the profile information of Beyza.

When Table 3 is examined, it is seen that the central orientation of Beyza, who teaches in the context of the electricity unit, was everyday coping, while her peripheral orientation, on the other hand, was didactics (Friedrichsen & Dana, 2005). It was observed that Beyza, who uses the REAPS Model as a discipline-specific instructional strategy during her teaching, has peripheral learning outcomes including multiple skills, social and communication, and critical thinking skills, as well as SMK learning outcomes.

Table 3. *Beyza's PCK profile*

Subject Matter:	Electricity
Science teaching orientations:	Central: Everyday coping; Peripheral: Didactics
Discipline-specific instructional strategy:	REAPS Model
Peripheral learning outcomes:	Multiple skills, social and communication skills, critical thinking skills



1-3: dashed lines
4-7: solid lines
8+: bold lines
(Aydin et al. 2015).

As shown in Table 3, Beyza integrated the components of KoIS, KoC, KoL, and KoA 18, 14, 13, and 5 times, respectively. Examining the PCK Map of Beyza, it was seen that the number of interactions between components was predominantly in the category of low-level interactions (1-3 interval). It was observed that the interactions in this category were minimum between the components of KoL with KoC and KoA. It was remarkable that particularly the interactions among KoA and other components accumulated in this category. It was seen that the interaction of KoC with STO and KoIS was central in the upper category. It was determined that only KoL and KoIS interactions took place in the upper category (8+). Unlike the many interactions particularly in the medium and upper level categories, it was found that there was no interaction among STO and KoA components. KoC allows to reveal the difference in importance between key concepts and peripheral concepts. KoC-KoIS interaction of Beyza emerged in the lower category. However, it was remarkable that, during the interviews, Beyza stated that she thought that her KoC was weak since she could not fully teach the learning outcomes in the program. Table 4 shows the coding scheme analysis of the data obtained from the first interview.

Table 4. *Results* obtained *from the interview through REAPS questions*

PCK Components	Explanation	Consistency/ Connection	Direction
STO-KoC	STO: Everyday coping; KoC: Life skills	Consistent	STO influenced KoC
STO-KoIS	STO: Everyday coping; KoIS: REAPS model	Consistent	STO influenced KoIS
KoC-KoIS	KoC: Learning outcomes in electricity unit; KoIS: Experiments and problem scenarios	Disconnection	KoC informed KoIS
KoC-KoIS	KoC: Life skills; KoIS: Problem scenarios	Connection	KoC informed KoIS
KoC-KoIS	KoC: Learning outcomes in electricity unit; KoIS: Activities, REAPS Model	Connection	KoC informed KoIS
KoL-KoIS	KoL: Pre-requisite knowledge, learning speed; KoIS: Question-answer	Disconnection	KoL informed KoIS
KoL-KoIS	KoL: Pre-requisite knowledge ; KoIS: Concept maps	Connection	KoL informed KoIS
KoL-KoIS	KoL: Lack of interest in electricity; KoIS: Out-of-school trip	Connection	KoL informed KoIS
KoL-KoIS	KoL: Needs; KoIS: Reflective journals	Connection	KoL informed KoIS
KoL-KoA	KoL: Pre-requisite knowledge, conceptual understandings; KoA: Working papers, POE strategy, concept map, reflective journals	Connection	KoL informed KoA

Various inferences have been reached through the interactions specified in Table 4:

- KoC-KoIS interaction that takes place in the medium category on the PCK Map provides REAPS-specific activities for learning outcomes in electricity unit, while it provides connection with each other when using problem scenarios. However, disconnection occurs between components when using experiments.
- Everyday coping orientation consistently influenced the teaching life skills included in the program and using of REAPS Model as a discipline-specific instructional strategy.
- Concept maps, reflective journals, and out-of-school trips show a connection in revealing the pre-requisite knowledge, needs, and interest on the topic, respectively. It was seen that, on the other hand, the question-answer strategy shows disconnection in revealing the pre-requisite knowledge.

- Two contradictions draw the attention in this analysis. It was seen that STO-KoIS interaction that showed only two interactions in the PCK Map was consistent, contrary to expectations, while KoL-KoIS interaction that showed eight interactions showed disconnection. According to Beyza's perception, the reasons that created this situation were the fact that Beyza thought she could not use the experiments effectively and the fact that she had to use the question-answer method too much, respectively. Another contradictory example was the fact that there was consistency between KoL and KoA, showing only one interaction. These contradictory examples provide evidence that the strong relationships identified in the PCK Map do not always guarantee consistent relationships.

Table 5 shows the coding scheme analysis of data obtained from second interview. Various inferences have been reached through the interactions specified in Table 5:

- It was seen that STO-KoL interaction that presents interaction at a low level in the PCK Map showed consistency by determining the pre-requisite knowledge and needs of the everyday coping orientation in learning outcomes in electricity unit, however, it showed the same consistent effect in determining students' interests and motivations of didactics orientation. Due to the fact that it took place at a low level in the PCK Map, the first two findings can be regarded as unexpected situations and the last finding as an expected situation.
- In STO-KoC interaction that shows medium interaction in the PCK Map, the everyday coping orientation has consistently influenced the teaching of key concepts and the learning outcomes in electricity unit, while didactics orientation inconsistently influenced KoC.
- KoC-KoIS interaction that shows medium interaction in PCK Map was provided through activities based on the learning outcomes in electricity unit, while through experiments on electrical circuit elements in introducing the materials recommended in the curriculum, and through connections between experiments for multiple skills under the DISCOVER component of the REAPS Model.
- KoL-KoIS interaction that shows upper interaction in the PCK Map leads to the use of REAPS activities thanks to the availability of classroom size, besides, the use of the question-answer strategy reveals pre-requisite knowledge. POE activity provides connections to overcome misconceptions; concept maps and reflective journals to overcome learning difficulties.
- In this analysis, seven contradictions draw attention.

Table 5. *Results obtained from the interview through PCK questions*

PCK Components	Explanation	Consistency/ Connection	Direction
STO-KoL	STO: Didactics; KoL: Interest, motivation	Consistent	STO influenced KoL
STO-KoL	STO: Everyday coping; KoL: Needs	Consistent	STO influenced KoL
STO-KoL	STO: Everyday coping; KoL: Pre-requisite knowledge	Consistent	STO influenced KoL
STO-KoC	STO: Didactics; KoC: Learning outcomes	Inconsistent	STO influenced KoC
STO-KoC	STO: Everyday coping; KoC: Learning outcomes	Consistent	STO influenced KoC
STO-KoC	STO: Didactics; KoC: Handling the learning outcomes under inquiry	Inconsistent	STO influenced KoC
STO-KoC	STO: Everyday coping; KoC: Core concepts in science teaching program	Consistent	STO influenced KoC
STO-KoIS	STO: Everyday coping; KoIS: Activities, teaching techniques	Consistent	STO influenced KoIS
KoC-KoIS	KoC: Multiple skills under the DISCOVER component; KoIS: Experiments	Connection	KoC informed KoIS
KoC-KoIS	KoC: Materials suggested in the program; KoIS: Experiments related with circuit elements	Connection	KoC informed KoIS
KoC-KoIS	KoC: Learning outcomes; KoIS: Activities	Connection	KoC informed KoIS
KoL-KoIS	KoL: Classroom size; KoIS: REAPS usage	Connection	KoL informed KoIS
KoL-KoIS	KoL: Pre-requisite knowledge; KoIS: Question-answer	Connection	KoL informed KoIS
KoL-KoIS	KoL: Misconceptions; KoIS: POE activity	Connection	KoL informed KoIS
KoL-KoIS	KoL: Learning difficulties; KoIS: Concept map, reflective journals	Connection	KoL informed KoIS
KoL-KoC	KoL: Readiness; KoC: Curricular saliency	Connection	KoL informed KoC
KoC-KoA	KoC: Learning outcomes; KoA: Concept map, reflective journals	Connection	KoC informed KoA
KoIS-KoA	KoIS: Problem scenarios; KoA: Evaluation form	Connection	KoIS informed KoA
KoIS-KoA	KoIS: Problem scenarios; KoA: Rubric	Connection	KoIS informed KoA

4.3. Results Regarding Critical Incidents Emergent During REAPS Implementation

It was observed that experienced teachers were able to interact more than two components (Akin & Uzuntiryaki-Kondakci, 2018). In this study, the critical incident operational definition was structured through this information. Departing from this point, in order for a situation to be a critical incident, it was sought that it occurred in the interaction of at least three PCK components. In this part, six critical incidents determined based on Beyza's experience in REAPS implementation were exemplified in detail with tables and extended excerpts (EE) accompanying each table. Three of these critical incidents were successful incidents (S1, S2, S3), while the other three were failed (F1, F2, F3) incidents.

4.3.1. Successful critical incidents

Course of events (S1)	**Interacted PCK components**
Incident where she thinks she succeed Designing a classroom environment suitable for group discussions	KoC: Communatication skills KoL: Student interest KoIS: REAPS activities
Why she thinks she succeed She says that the activities she developed according to the REAPS Model increased intra-group interaction, the engagement level of female students, and the frequency of communication with other students.	
Consequences for further teaching She says she will try to increase students' oral communication in her next lectures.	

EE-S1: Students' interest was generally at high levels during the experiments. However, female students' interest was significantly lower than male students and during the experiments, the female students took supporting roles more. During the group discussions, on the other hand, the female students were more eager and active. My incapability to create a learning environment that would provide them with equal opportunity to communicate may have been effective in this case. As the implementation continued, their communication increased thanks to the group work and they began to recover each other's shortages. After I began to revise the group studies formed during the experiments by following the steps in the TASC component of REAPS, I noticed that a more balanced communication process started to work. Thus, group discussions began to be organized around a scientific discourse in which scientific claims were justified and appropriate refutation elements provided.

Course of events (S2)	**Interacted PCK components**
Incident where she thinks she succeed Revealing the interests and needs of female students	KoL: Student interest/needs KoA: Concept maps, reflective journals KoIS: Concept maps, reflective journals
Why she thinks she succeed She shows the reason for using concept maps both as a teaching strategy and as an evaluation tool.	
Consequences for further teaching She says she plans to create a more effective individual learning monitoring system using portfolios in her next lessons.	

EE-S2: I only had two female students. I observed that they did not provide enough engagement during implementation. I noticed that they formed strong relationships with the core concepts in their concept maps although they did not ensure participation. When I read their reflective journals, I saw that they frequently talk about their learning difficulties and that they have started to learn better thanks to the journal. After this stage, I began reading the reflective journals after each lesson and taking notes. Thanks to those notes, I was able to estimate where they might have difficulties while drawing a concept map.

Course of events (S3)	**Interacted PCK components**
Incident where she thinks she succeed She believes that thanks to REAPS activities, she was able to provide knowledge building about the key concepts involved in each learning outcome.	STO: Conceptual change KoL: Misconceptions KoIS: TASC activities within the REAPS Model
Why she thinks she succeed She says that REAPS activities are a model that takes students' learning needs and interests into consideration.	
Consequences for further teaching She says she plans to use metacognitive strategies in her later lessons for her students to enable more meaningful conceptual learning.	

EE-S3: One of the situations that I did not expect to occur before the implementation but I witnessed as the implementation progressed was the fact that students generated ideas by constructing knowledge. I think the TASC component has a great effect on this surprise. I think, the fact that it is a model appealing to everyone increases the interaction and communication within the group. In this way, students may have had more opportunities to build knowledge. To see that they use the knowledge they construct to understand the events in their daily lives makes me happy.

4.3.1. Failed critical incidents

Course of events (F1)	**Interacted PCK components**
Incident where she thinks she failed She confessed that in the first weeks of the REAPS implementation she was not able to ensure that male and female students show a balanced engagement.	KoL: Student engagement KoC: Learning outcomes in electricity unit KoIS: Experiments
Why she thinks she failed She says that her aim is to uncover the pre-requisite knowledge of the students, but because of having poor knowledge of KoC, she made the wrong choices in choosing instructional strategies.	
Consequences for further teaching She says she will design an inquiry-based instruction to enable students to explore the learning outcomes in her next lessons.	

EE-F1: I was distributing problem scenarios during group activities or experiments and I asked them to solve problems together. I wanted them to study first individually and then as a group. Some students contributed a lot while others did not. Actually, while starting teaching, I thought they would all contribute. But I was not able to quite prevent this. I prepared the activities by correlating the learning outcomes in the program with the REAPS components. For students to acquire these outcomes, I expected them to discover the outcomes and key concepts during teaching. Maybe it was my fault.

Course of events (F2)	**Interacted PCK components**
Incident where she thinks she failed She thinks that she was not able to improve students' self-efficacy levels towards learning the science course.	STO: Beliefs regarding science learning and teaching KoL: Misconceptions KoIS: Experiments
Why she thinks she failed She states that students' positivist beliefs about learning science prevent them from understanding their misconceptions and that the experiments used could not change this situation.	
Consequences for further teaching In order to make experiments more effective, I will ask the school management to provide funding support to strengthen the physical conditions of the school and the laboratory.	

EE-F2: I don't think my students will be able to say “now we can easily learn science course” although the implementation was completed. Because even though I've performed so many activities, I noticed that students had constant confirmatory tendencies during experiments, in particular. I realized that, during open-ended inquiries, on the other hand, I had to make more effort to motivate the students. Misconceptions occur more in abstract concepts such as electricity, compared to other concepts. Therefore, I can say that the experiments I used during the practices I conducted around everyday coping were ineffective in revealing and eliminating misconceptions.

Course of events (F3)	**Interacted PCK components**
Incident where she thinks she failed She thinks that she cannot adequately provide active learning, which is one of the requirements of the constructivist teaching approach.	STO: Didactics KoL: Misconceptions, engagement KoIS: REAPS activities
Why she thinks she failed She thinks she failed due to her not getting enough practicum in line with her teacher education program and that the few observations she made are mostly related to the lessons conducted with the traditional approach.	
Consequences for further teaching She states that she plans to apply student voice and authentic learning principles in order to create a classroom environment based on active learning.	

EE-F3: Before the implementation, I prepared activities for each component of REAPS. During these activities, I was heavily influenced by didactics, especially in some cases where there was a lot of SMK. I think this situation decreases the active engagement capacity of activities. Because I started to observe that the activities of the students for the group decreased and some students started to carry out the activities alone. Actually, I think this may be due to the fact that, before the implementation, I didn't know exactly what active participation is and what its principles are. During the internship, most of the teachers in the lessons we make observations were making traditional science teaching. Therefore, I was not able to develop my knowledge of active learning also at that time.

5. Discussion

The main purpose of this study is to examine thoroughly Beyza's, an experienced science teacher, teaching practice that she performs using the REAPS Model. In this context, various findings were reached as a result of the analysis and these findings were discussed separately by making use of the findings of the studies available in the relevant literature.

5.1. Discussion on the First Research Question

Findings regarding the question of "What were the participants' perceptions of her own REAPS implementation?" were discussed under this title. As a result of the content analysis, it was found that Beyza's perceptions about REAPS implementation were gathered under 9 themes. Various inferences can be made from the functional definitions of these themes (see Table 2).

Creating a student-centered learning environment is a pre-requisite for active learning (Pedersen & Liu, 2003). In these environments, students' learning experiences are designed and students are given the opportunity to construct knowledge (Wu et al. 2015). The first of the criteria that can be used in the control of meaningful learning opportunities offered by student-centered learning environments is engagement (Buncick, Betts & Horgan, 2001).

Similarly, it has drawn attention that Beyza primarily emphasizes engagement among these categories. This may be related to the fact that Beyza perceived the model as one of the active learning models. She stated that she believes that this model is beneficial in terms of affective and behavioral engagement as well as cognitive engagement. This statement is one of the situations mentioned in the related literature. As a matter of fact, active learning is a wide-ranging approach to learning that includes not only cognitive involvement of students, but also affective and behavioral engagement (Frederiks, Blumend & Paris, 2004). On the other hand, it was observed that Beyza stated that the active learning process accelerated especially with the effect of the TASC component. This finding is compatible with the theoretical background in the literature. TASC component is important in terms of being the propellent component of the REAPS Model (Ball & Henderson, 2008).

For students to solve problems related to their real-life situations, creative problem solving skills must be developed (Dondlinger & McLeod, 2015). It can be said that students who find solutions to their problems with their own thinking styles have more meaningful learning experiences. Similarly, real-life experiences and socialization were among the concepts that Beyza brought forward. During the interviews, she stated that she noticed that the REAPS implementation, which is also organized for the acquisition of life skills included in the program, has improved students' life skills. This is not surprising because the REAPS Model is an invaluable teaching model with any curriculum framework (Maker et al. 2015). This experience of Beyza is in harmony with the relevant literature. Because, the students, who structure knowledge through real-life experiences and solve related problems using their own creative problem-solving skills, are likely to develop life skills such as decision-making, analytical thinking, creative thinking, entrepreneurship, establishing communication, and teamwork, which are included in the science program in practice in Turkey. At this point, Beyza underlined that she especially associates the subjects from life with the lesson and includes them in problem scenarios. The fact that Beyza has the perception that the purpose of the model in terms of life skills is compatible with the aim of the program is important for the consistency of the implementation.

Beyza stated that while preparing the problem scenarios by being influenced by the DISCOVER component, students also pay attention to the characteristics of their own culture. Because, according to her, problem scenarios prepared in accordance with the DISCOVER component enabled students to face the problems in their own lives. This is important in order to provide the social context of teaching through multiple skills and Beyza aimed to teach multiple skills in accordance with DISCOVER (Maker & Schiever, 2010). It was remarkable that Beyza expressed the perceptions gathered under themes such as collaboration, intrapersonal skills and emotions, which emerged as a result of group work during the implementation of many other activities, by generally relating them to each other. She tried to establish heterogeneous groups for collaborative learning, gave importance to the continuity of communication within the group and mentioned that she observed the emotions and made new moves accordingly. In short, Beyza has a strong perception that learning experiences accompanied by positive emotions are provided in a collaborative teaching environment where the groups she formed develop intrapersonal skills. One of the themes that emerged in this process was argumentation. The fact that she frequently gets her students to perform debates and asks them to justify their claims was an important indicator in terms of ensuring the construction of knowledge through evidence-based inquiry and participation of even the most passive students in the argument formation process. It is likely that the argumentation course conducted by the first researcher of this study during Beyza's teaching program in previous years and the argumentation forms that Beyza prepared in that lesson had an effect on the occurrence of this situation. It can be said that this inference will be effective in increasing the belief that REAPS model applications, which offer a discipline-specific teaching strategy, can be developed especially through teacher education programs.

To the best of our knowledge, there is no study on the REAPS implementation experiences of teachers other than one study examining student perceptions about REAPS implementation (Wu et al. 2015). It was observed that some of the themes obtained from this study were similar to the mentioned study (collaboration, intrapersonal skills, emotions), while some of them differs (engagement, real-life experiences and socialization, cultural context, physical conditions, argumentation and retention). It is thought that along with existing themes, emerged themes will provide new perspectives, especially in teacher education studies. Finally, it can be thought that the fact that Beyza has consistently implemented almost all of the theoretical background information regarding the REAPS implementation indicates that the fidelity of implementation is high (Alfaiz, 2019). Therefore, the realization of implementations in which new themes are addressed in studies based on the REAPS implementation and attention to their implementation reliability may increase the validity of the results obtained.

5.2. Discussion on the Second Research Question

The discussion on the question of “What is the participant's perception of the interaction among her own REAPS implementation and the PCK components that arise meanwhile?” was included under this title.

It would be useful to remember Beyza’s general teacher profile before the discussion. Beyza’s perceptions of her teaching were discussed in the context of the electricity unit. During the analysis, it was understood that Beyza’s central orientation was everyday coping and that her students' priority was to associate the concepts on this topic with their daily lives. Besides, her peripheral orientation was didactics. Beyza used the REAPS implementation as a discipline-specific strategy. Developing multiple skills, social and communication skills, and finally, critical thinking skills within the scope of the DISCOVER component, as well as the learning outcomes in the program are among the teaching purposes, on the other hand. In summary, Beyza is an experienced science teacher who frequently uses the everyday coping orientation and occasionally uses traditional science teaching approaches.

Teachers should have firm understanding of all PCK components (Aydin et al. 2015). Examining the PCK Map of Beyza, it was seen that the most interacting PCK components with the others were KoIS (18), KoC (14), KoL (13), STO (10), and KoA (5), respectively. However, it may not be enough to comment on the number of interactions for each component alone. Instead, one should look at the interaction among components and their consistency (Loughran, Berry, Mulhall & Woolnough, 2006; Park & Chen, 2012). The most interaction in Beyza’s Map was determined among KoL and KoIS components. This finding is similar to the findings in the literature (Akin & Uzuntiryaki-Kondakci, 2018; Park & Chen, 2012). The fact that interactions were particularly among KoL-KoIS components can be attributed to Beyza’s being an experienced teacher. Because, the findings about PCK implementations of experienced teachers indicate that this interaction is much stronger than prospective teachers. From another angle, this situation can be evaluated in terms of ensuring PCK development by finding the opportunity of continuous teaching by teachers and enabling students to access KoL more easily. Researchers often mention that the interactions among these two components are particularly central to the interactions of experienced teachers (Aydin & Uzuntiryaki-Kondakci, 2018). It was found that the KoL and KoIS interactions showed the highest interaction among experienced teachers, regardless of the topic (Aydin & Boz, 2013). Similarly, Aydin et al. (2014) determined that KoC, KoL and KoIS components are topic-specific, while the KoA and STO components are not topic-specific. The STO component did not change from topic to topic, because the STO was discipline-specific (Friedrichsen et al. 2009). Hence, Beyza, who carries out the discipline-specific REAPS implementation, may have relied on everyday coping throughout her teaching, as the model is directly related to the acquisition of life skills. The ideal orientation of Beyza was everyday coping, but she stated that didactics outweighed in the process. This is similar to the findings of Aydin et al (2014). Disconnection may occur between STO and KoIS because this is related to context and restrictions rather than just consistency in orientation. Teachers state that they want inquiry, but they attribute the reason for not having it to the education system (Aydin et al. 2014).

On the other hand, there are findings indicating that PCK Maps of experienced teachers are more integrated compared to prospective teachers. Unlike the findings of Akin & Uzuntiryaki-Kondakci (2018), Beyza's STO was broad and non-specific. This, as a matter of course, impacted the interactions among components, particularly among KoA and KoIS (Aydin & Boz, 2013; Park & Chen, 2012). Again, unlike the same study, the map of the experienced Beyza was fragmented. Similarly, teacher self-efficacy facilitates the interaction among components. Besides, at the center of the interaction, the triple interaction among KoC, KoL and KoIS was found (Park & Chen, 2012). This finding is consistent with the finding obtained from the study. Contrary to the findings of Park & Chen (2012), no interaction was seen among the KoA and STO components. Akin & Uzuntiryaki-Kondakci (2018) found that STO, KoL and KoIS interactions were more frequent and KoC and KoA interactions were less in the first maps of prospective teachers. It was observed that the least interaction in the other studies was among KoC and other components (Aydin & Boz, 2013; Park & Chen, 2012). Surprisingly, although the interaction among KoA and KoIS was undeveloped despite taking practicum, the most improvement was seen among KoC and other components. The findings that indicate the less interaction between KoC and KoA are consistent with the current study (Aydin & Boz, 2013). It was even found that KoA does not have a significant relationship with all components (Kaya, 2009). Beyza stated that she used the evaluation criteria based on general observations instead of validated evaluation criteria. When asked about the measurement rule, it seems that she confuses it with the learning outcomes. In conclusion, although she says she knows what she measures, it can be said that Beyza's evaluation knowledge is insufficient due to her failure to apply the measurement rule. On the other hand, the KoL knowledge significantly affects the components of KoA and KoIS (Park & Oliver, 2008b). Even if they sometimes detect their misconceptions, teachers do not tailor their teaching strategies (Park & Chen, 2012). Beyza confesses a similar situation, too. Therefore, weakness in the KoL component may have affected the KoA component.

Going a step further in mapping the interaction among PCK components and evaluating the general patterns obtained after constant comparisons, it was examined through the coding scheme developed by Demirdogen et al. (2016) whether binary interactions show consistency. This examination, made separately for the first and second interviews, was carried out under the hypothesis that low-level interacting components show disconnection and high-level interacting components show a connection in the PCK Map and that the STO component consistently influences the others. The examples nonconforming to this hypothesis were called contradictory examples.

As a result of the analysis of the first interview, it was found that the everyday coping central orientation consistently influenced the teaching of life skills take part in the program and the implementation of the REAPS Model, which is a discipline-specific instructional strategy. This finding is consistent with the findings in the literature indicating that the STO component has the ability to direct and influence other components. However, the KoC-KoIS interaction showing medium interaction in the PCK Map was found to show disconnection in terms of the use of experiments. The following words of Beyza confirm this disconnection:

"*While developing activities for the REAPS Model, I made use of problem scenarios, concept maps and experiments. But, as they do not adequately activate inquiry skills, I think that experiments were not as effective as I would like.*"

Another disconnection between KoL-KoIS was found in the use of a question-answer strategy to activate pre-requisite knowledge. It was seen that during the interviews, Beyza frequently used a question-answer strategy after the introduction of the lesson was completed and she stated that she felt discomfort with this situation. In the rest of the interview, Beyza confessed that she was worried that too much question-answer interaction before the activities would damage the inquiry-based structure of the course. She stated that she was also worried that the lesson would be perceived as relatively teacher-centered because she often asked the questions herself. This is surprising because the Beyza's orientation is neither central nor peripheral. There are similar cases in the literature (Aydin et al. 2014). The evidence related to this point out that the orientation which teachers intend to use when planning the lesson and the orientations in practice may not be the same.

In conclusion, there were two contradictions during the first interview. While the STO-KoIS interaction, which only interacts twice in the PCK Map, is consistent contrary to expectations, the KoL-KoIS interaction presenting eight interactions showed disconnection. In light of these findings, it was concluded that taking place in the upper category with high-level interactions in the PCK Map does not guarantee to be consistent in another analysis framework. It can be said that one of the main factors that cause this result is that the interactions are considered the same in terms of strength in the PCK mapping process.

As a result of the analysis of the second interview, it was observed that similar to the findings in the first interview, the everyday coping central orientation has consistently influenced the identification of students' learning needs and revealing their pre-requisite knowledge. However, didactics orientation was found to show an inconsistent influence in terms of the teaching outcomes and handling outcomes in an inquiry-based manner. In contrast, everyday coping orientation has consistently influenced the teaching of the core concepts and the learning outcomes in the program. Another interaction was between the KoC-KoIS components. It was found that there were consistent relationships that multiple skills are taught through experiments, the materials proposed in the program are taught with circuit elements used in the classroom, and the learning outcomes are taught through activities. These consistent relationships continued their existence also in terms of KoL-KoIS and KoIS-KoA interactions.

More contradictions were encountered during the second interview. All of these contradictory consequences arose during interactions in the lower interaction category. Again, it was remarkable that almost all of these contradictions occurred between STO and KoA components and others. Considering that the components that show disconnection during binary interactions are generally STO components and while the few interacting components are KoA components, it can be interpreted that there is a link between these two consequences.

5.3. Discussion on the Third Research Question

Under this title, findings related to the question of "What do critical incidents indicate about the interplay between the various components of PCK?" were discussed in line with the relevant literature.

The fact that the two components interacted too much in the PCK Map do not guarantee that these components point to effective teaching (For example, KoC-KoIS 6 interactions). Binary relations under PCK Maps should be interpreted at the intersection of three or more components under critical incidents (Nilsson & Karlsson, 2019; Park & Chen, 2012). It was remarkable that KoL and KoIS components were included in all of the triple interactions that constituted the six identified critical incidents. It was an expected result to see KoL-KoIS interaction intensively in an experienced teacher like Beyza (Akin & Uzuntiryaki-Kondakci, 2018; Park & Chen, 2012). However, it is important that this situation has arisen regardless of the successful or failed critical incidents. Because it can be thought that using the perceptions of Beyza's performance as data, rather than observing her performance, ambiguated the transition between successful and failed critical incidents not significant in terms of increasing the possibility of confirmation bias.

Beyza stated that in successful critical incidents, she created a classroom environment suitable for group discussions, revealed the interest and learning needs of female students, and enabled the construction of knowledge around key concepts, respectively. In failed critical incidents, on the other hand, she stated that she was not able to provide a balanced engagement within the classroom, that she could not develop students' self-efficacy about science learning, and that she could not trigger active learning sufficiently. Departing from this point, it can be said that Beyza has the perception that she provided a classroom environment suitable for group discussions but could not create a balanced engagement in the classroom since she was not able to trigger active learning sufficiently. Surprisingly, it was observed that Beyza stated that she provided knowledge construction although she confesses that she was not able to adequately provide active learning. This situation indicates that there is a difference between PCK and enacted PCK, which is turned into performance especially in the planning phase.

It was seen that successful critical incidents were shaped around the STO that drive the KoL and KoIS components, and the KoC and KoA components that interact with them, while failed critical incidents were shaped around the STO, which drives the KoL and KoIS components, and the KoC component that interacts with them. It can be said that the fact that STO took place in both consequences indicates that it has both positive and negative effects on the critical incidents of Beyza's teaching. Contrary to the findings in the literature (Akin & Uzuntiryaki-Kondakci, 2018), this may provide evidence that her STO may begin to exhibit broad and non-specific characteristics during critical incidents that show at least triple interactions rather than binary interactions. For example, when asked about the most important characteristic of a teacher, Beyza said that it is to have a high level of SMK. Beyza stated that there was an inquiry among the objectives of the program during teaching and mentioned that this is the most important feature of science teaching. However, it was seen that in practice, Beyza did not design inquiry-based teaching and could not make an inquiry-based operational definition. However, it was observed that when asked about specific situations regarding electricity related to REAPS implementation, Beyza tended to give answers only based on the learning outcomes. This continued in the later parts of the interview and Beyza continued to state that her aim was to make her students gain inquiry skills. It can be said that this situation provides a clear example that pPCK does not guarantee ePCK. One of the underlying reasons may be that Beyza's STO is dominantly everyday coping rather than inquiry, and secondarily didactics. Beyza's discipline-specific strategy knowledge base can be interpreted as insufficient, as she considers the 5E model as teacher-centered. However, Beyza stated during the interviews that she was aware of using the REAPS model as a discipline-specific strategy in this practice. Lack of discipline-specific strategy knowledge may have negatively affected Beyza's teaching practice. Not having inquiry orientation in terms of orientation and failure to make an operational definition of inquiry orientation can be considered as evidence for these inferences.

It was seen that two of these factors included student interests and needs, and one included revealing misconceptions. It was observed that engagement and misconceptions were central in the failed critical incidents. This situation may provide evidence that Beyza perceives her teaching as more effective in revealing interests and needs, and as less effective in providing engagement and revealing misconceptions. Beyza stated that to assume during the interview that participating students' pre-requisite knowledge was the same prevented her and pointed to the weakness of KoL. It was seen that the fact that the reflective process remained weak due to indirect teaching negatively affected science teaching based on students' prior knowledge. Thus, in the event of considering the KoL component as the starting point, the reflective cycle was seen to have a very important place in topic-specific science teaching.

When it is examined specific to the KoIS component, it was observed that the REAPS Model-originated activities were predominant in successful critical incidents, while experiments were predominant in the failed critical incidents. This consequence may suggest that Beyza associates the outputs arising from the practice with the REAPS Model, which is one of the contemporary teaching approaches according to her, while she associates other negative outcomes with experiments that are frequently used in traditional science education approaches and often conducted with positivist concerns. The fact that she stated during interviews that the experiments were not as effective as she wanted due to various impossibilities and that REAPS was insufficient to meet her goal of life skills development confirms this consequence.

6. Conclusion, Limitations and Recommendations

In accordance with the relevant research problems, the following general results were obtained in the study:

- It was concluded that Beyza's perception of the REAPS Model regarding student learning contribution was generally positive, that the implementation of the model had higher self-efficacy in the following weeks, and in addition to the findings from the previous study (Wu et al. 2015), that the practical experiences were expanded with the themes of engagement, real-life experiences and socialization, cultural context, physical conditions, argumentation and retention.
- In terms of the compatibility of REAPS Model implementation with the program, it was concluded that Beyza established KoC-originated analogies and she may also increase the KoL-KoIS interaction seen predominantly during implementations of possible individual development in this component.
- Because of the relatively high number of KoL interactions and consistent relationships seen in interactions involving KoL, it was concluded that Beyza's experience with REAPS implementation under the discipline-specific strategy was sufficient.
- In terms of determining that the most interaction was found in the interaction among KoL-KoIS components, it was concluded that Beyza made the implementation as a relatively experienced teacher in the name of general science teaching.
- It might be concluded that the fact that the purpose of the REAPS Model is to bring creative solutions to real-life problems pushed Beyza to choose everyday coping instead of inquiry.

- It was concluded that the self-efficacy level of Beyza has an effect on increasing the interaction among KoC, KoL and KoIS components.
- Similar to previous studies, it was concluded that the interaction of the KoA component with other components was weak.
- It was concluded that in most of the present binary interactions, STO consistently informed other components, and likewise, that most of the other binary interactions were consistent.
- It was concluded that critical incidents were effective in revealing the complex relationships between PCK components.
- It was concluded that Beyza's KoL-KoIS interaction, which was central to the PCK Map, continued to maintain this feature during critical incidents.
- It was concluded that contradictions can also be seen in KoL-KoIS interactions, which are frequently interacted in the PCK Map, and therefore, it would be more correct to interpret the contradictory consequences within the scope of critical incidents.
- It was concluded that patterns that are similar to the PCK Map patterns obtained from previous studies can also occur in-depth during semi-structured interviews where only perceptions about teaching performance are tried to be determined.

The results achieved are valid under various limits. In this study, interactions among binary components in the second research question and triple components in the third research question were taken into account. In further studies, these interactions may be mapped under multiple relationships. The obtained PCK Map is limited to the topic-specific PCK for the electricity unit of Beyza. The interaction numbers on the maps were determined in accordance with the self-report in which the semi-structured interviews were written on paper. This gives clearer information about the reported PCK, which is elicited through Beyza's perceptions of teaching performance, instead of the enacted PCK regarding performance. However, the interpretation of this experience goes beyond information obtained from reported PCK. Departing from this point, it can be said that deepening the perception of performance regarding teaching by observing the teaching performance or by video recording can give more accurate results. As a result of the positive perception of the REAPS Model, it can be suggested that the model should be used in the teaching of topics other than electricity in science courses at middle school level. In order to provide the PCK competence required by this teaching, it might be helpful to organize short and intensive programs where teachers can improve interactions among PCK components. Since the REAP Model has a limited implementation area in Turkey, just like the implementation of learning cycle teaching strategies, it can be ensured that academic community with REAPS teaching experience create REAPS implementation guidelines.

7. Conflict of Interest

The authors declare that there is no conflict of interest.

8. Ethics Committee Approval

The authors confirm that the present study needs ethics committee approval according to the research integrity rules in Turkey. Therefore, the authors obtained ethics committee permission form numbered 17/07/2020-6 for the study from Adiyaman University Human Research Ethics Committee.

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