

Review of Researches on Pedagogical Content Knowledge Published in ESERA (2009-2019) Conference Books

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Abstract

This study aims to examine the papers prepared on pedagogical content knowledge published in European Science Education Research Association (2009-2019) conference books from a thematic and methodological point of view. For this purpose, 65 papers were examined. Data were collected through document analysis within the framework of the qualitative research approach. Descriptive analysis was used in the analysis of the data. NVivo 12 program was used to present the research data. Researchers mainly conducted studies on the development/detection of PCK. It has been determined that student knowledge and teaching methods knowledge, which are the components of pedagogical content knowledge, are investigated more. As a sample, it mostly worked with secondary school teachers. The qualitative research method was mainly preferred in the research. It has been determined that tests, interviews, and questionnaires are used primarily as data collection tools. In the data analysis, it was seen that the focus was more on content analysis.

Keywords: Pedagogical Content Knowledge, Conference Proceedings ESERA, Science Education

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INTRODUCTION

Rapid developments in science and technology increase the importance of science education, which is also reflected in studies on science education. Sharing these studies in the field with other researchers will ensure that scientific knowledge is accessible and developed by everyone. Current trends, attitudes, and subjects that reached saturation in science education can be followed via review studies, graduate theses, handbooks, and international congresses like European Science Education Research Association (ESERA) and National Association for Research in Science Teaching (NARST).

International congresses are a significant part of research and research dissemination. ESERA and NARST are international meetings having great importance in science education. Firstly, papers from NARST and ESERA conferences had been chosen for this study. But most studies handled at the NARST conference were published as summaries and didn't provide extensive knowledge; only papers from the ESERA conference were covered. ESERA conference handles subjects carrying great importance for researchers of science education as one of the leading conferences of the world (Sormunen et al., 2017). This conference has been held regularly since 1995 bi-annually and gives direction to research towards science education. A lot of researchers in the content of science education from developed and developing countries show participation in this conference and share their experiences with each other, and they make contributions to the content of science education with their thoughts and abilities (Alshamrani & Aldahmash, 2020). The selection of papers presented at the ESERA conference is subject to strict arrangements, and complete text or wider summaries are published.

Science and science education are generally discussed with the following sub-dimensions in ESERA declarations:

1. Learning Science: Conceptual Understanding
2. Learning Science: Cognitive, Affective, and Social Aspects
3. Science Teaching Processes
4. Digital Resources for Science Teaching and Learning
5. Teaching-Learning Sequences as Innovations for Science Teaching and Learning
6. Nature of Science: History, Philosophy and Sociology of Science
7. Discourse and Argumentation in Science Education
8. Scientific Literacy and Socio-scientific Issues
9. Environmental, Health, and Outdoor Science Education
10. Science Curriculum and Educational Policy
11. Evaluation and Assessment of Student Learning and Development
12. Cultural, Social and Gender Issues in Science and Technology Education
13. Pre-service Science Teacher Education
14. In-service Science Teacher Education, Continued Professional Development
15. Early Years Science Education

16. Science in the Primary School

17. Science Teaching at the University Level

18. Methodological Issues in Science Education Research (<https://www.esera.org/publications/esera-conference-proceedings>; Retrived March 22, 2021).

This article analyzes the studies on pre-service science teacher education and, inservice science teacher education, continued professional development. In these studies, the professional knowledge of teachers was mainly discussed. Indeed, in recent years, research on teacher competence has focused chiefly on teachers' professional knowledge (Meschede et al., 2017).

An essential aspect of the professional competence of teachers is professional knowledge. Shulman (1986) has indicated that teachers' professional knowledge consisted of different categories. Shulman (1987) has expressed professional knowledge of teachers in a classification of seven types; content knowledge, curricular knowledge, general pedagogical knowledge, knowledge of learners and their characteristics, knowledge of education contexts, pedagogical content knowledge (PCK) and aims, values related to education and their philosophical and historical knowledge. Among these categories, PCK has raised a particular interest because it represents a unique area of expertise that discriminates teachers from content experts (Chan & Hume, 2019).

Shulman (1987) defined PCK as “the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners and presented for instruction” (p.8). Following Shulman’s (1986) context of pedagogical content knowledge, many researchers in education content have recommended many PCK models (Gess-Newsome, 1999, 2015; Grossman, 1990; Hume et al., 2019; Magnusson et al., 1999; Park & Oliver, 2008). Among these emerging PCK models, Magnusson, Krajcik, and Borko's (1999) PCK model is widely used, especially in the science education community. (Abell, 2008; Kind, 2009). Magnusson et al. (1999) put forward their own model of teacher knowledge by utilizing the teacher knowledge model of Shulman (1987) and Grossman (1990). According to the model, PCK consists of five components. These components are orientations to science teaching, knowledge and beliefs about science curriculum, knowledge and beliefs about students’ understanding of specific science topics, knowledge and beliefs about assessment in science, and knowledge and beliefs about instructional strategies for teaching science.

Abell (2008) has expressed that studies related to PCK would keep its popularity as long as teachers and education exist, and science teachers would continue to conduct research towards PCK even 20 years later because PCK makes teaching possible as a profession and legitimizes it (Melo et al., 2017). PCK is accepted as an important element of successful teaching (Park et al., 2011). PCK enlightens researchers and educators of teachers about which forms a good education of science and how science teachers should be (Abell, 2008; Kind, 2009).

The interest of researchers in the subject of PCK continues to increase every day, both in our country and the world, and many theses, articles, and papers are published on this subject. Within this context, a need appears to examine studies conducted in the area of PCK and to evaluate findings. Many studies have been performed targeting to review PCK studies in the area of science towards this need (Abell, 2007; Aydın & Boz, 2012; Belge-Can, 2019; Chan & Hume, 2019; Kind, 2009).

Many researchers have focused on research tendency studies in these papers to determine tendencies of studies in science content through ESERA conference papers in the literature and put forward these studies as a whole. For instance, Alshamrani and Aldahmash (2020) analyzed ESERA papers published between 2011 and 2017 according to their titles, approaches, purposes, data types, and samples. According to the findings, pre-service education of science teachers, in-service education of science teachers, continued professional development, environmental, health, and informal-outdoor science education have been the research subjects that have been most focused on.

Related to research approaches, they have determined that quantitative and mixed methods have been used more in papers. Özcan and Kaptan (2020) have examined papers having socio-scientific content published in the 2016 National Congress of Science and Mathematics Education, and 2017 ESERA conference by descriptive analysis and have reached the finding that the subject of the environment has been the one most examined in 2017 ESERA papers for the aspect of the subject theme. Ecevit et al. (2017) analyzed ESERA papers during the period between 2009 and 2013 according to subject distribution, the number of researchers, and the participation status of countries in conferences. As a finding of the study, they determined that subjects of science education and teaching have been researched subjects taking the most attention in 2009-2011 and in-service education of science teachers in 2013 ESERA conference. Öztürk and Kaptan (2014) have taken 2009 ESERA papers under focus for the aspect of the nature of scientific content, history of science, its sociology, philosophy, and argumentation. As a finding of the study, they have determined that subjects of argumentation hadn't been given any place in our country.

However, any study in which researches about PCK presented on the content of science education has been examined hasn't been found. For this aspect, it is thought that this study will provide a contribution to the literature to demonstrate the general status of research containing the subject of PCK in ESERA conference books and to show their deficient points, prevent their repeat, and provide insight for new studies. When it is thought that PCK is a subject studied for approximately the last thirty-five years, it is expected that this study would act as a source for future studies and show the road to researchers. Starting from this point, it has been aimed in this study that papers prepared about PCK would be examined for thematic and methodological aspects.

1. What are the general thematic characteristics of papers prepared on PCK?

Of papers prepared on PCK;

- i) how is the distribution of themes?
- ii) how is the distribution of PCK component/components?
- iii) were PCK components taken as a whole or a separate component?
- iv) what are subject contents and subjects of science?

2. What are general methodological characteristics of papers prepared on PCK?

Of papers prepared on PCK;

- i) how is distribution according to years?
- ii) what is profile and number of participants?
- iii) how is research method?
- iv) how is distribution according to data collection tools?
- v) what are data analysis methods?

METHOD

A qualitative research approach was adopted in this study in which the papers prepared on PCK were examined. Qualitative research provides the presentation of research results by reading the collected documents in detail (Merriam, 2009).

Data Collection and Inclusion Criteria

Data have been collected by document examination technique within the qualitative research approach in the study, and they have been tried to be described. Document examination can be defined as obtaining, reviewing, questioning, and analyzing various documents qualified as primary or secondary sources forming the data set of the research (Özkan, 2019 p.63).

ESERA conference paper books (2009 ESERA conference five books, 14 books in 2011, 16 books in 2013, 19 books in 2015, 18 books for each in 2017 and 2019) were found between 2009-2019 from the research data. Books have been downloaded from <https://www.esera.org/publications/esera-conference-proceedings>, and 1724 papers have been accessed. Browsing has been made using the keyword “pedagogical content knowledge” in conference paper books from 2009-2019. Firstly titles, keywords, and abstracts of research were examined while performing browsing. After the summaries of all documents were scanned, technological pedagogical content knowledge studies were not taken into account. Then, obtained studies were re-examined towards the purpose of the study, and 65 studies were obtained as a finding of required investigations. A matrix has been prepared at the stage of data collection. Educational research made on the content has been utilized while forming the matrix (Çalık & Sözbilir, 2014; Saraç, 2017; Yücel-toy, 2015; Ormancı et al., 2015). The title of papers, author, year, subject studied, research method, profile and a number of participants, data collection tool, and data analysis have been included in this matrix. The process applied in this study is shown in Figure 1.

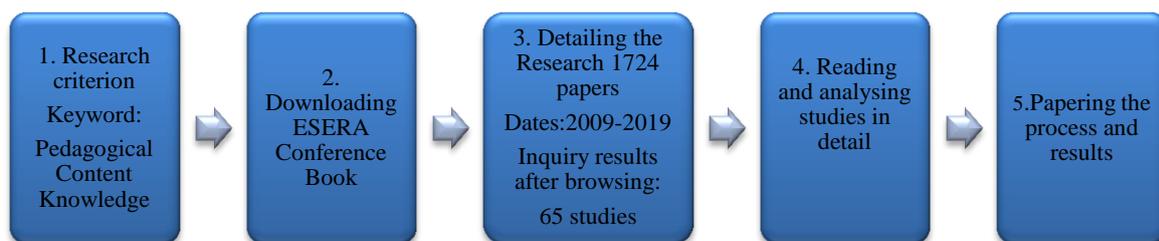


Figure 1 Research process

Data Analysis

Descriptive analysis was used in this study, in which the papers on PCK in the field of science education published in ESERA conference books were examined. In the study, descriptive analysis was deemed appropriate since it included a detailed examination of the studies on pedagogical content knowledge in the field of science education, grouping and interpreting the data according to predetermined themes.

Firstly papers have been numbered from 1 to 65 in data analysis. These numbers have been used for providing ease for a researcher. Each study has been read in detail towards the purpose and data obtained from each study according to research problems have been transferred to NVivo 12 program. Data have been coded into the program through the matrix. An example of the matrix is shown in figure 2.

Author, year of the study	Aims	PCK components in the studies	Science subjects of the PCK studies	Samples of the studies	Number of participants	Research methods	Data collection	Data analyses
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Figure 2 Example of matrix used in data collection in the research

Research questions and themes were created by examining the literature studies carried out in the field of PCK (Aydın & Boz, 2012; Belge-Can, 2019; Depaepe et al., 2013; Şimşek & Boz, 2016), and as a result of the examinations, themes, and codes were expanded when necessary. The results of the analyzed studies are presented by examining them in terms of themes. Frequency values were used in the analysis of the data. Data; is presented in figures and graphs.

Studies have been read and analyzed complying with research problems in order to prevent any fault during the coding process. The coding process lasted approximately eight weeks. In order to provide reliability and validity of coding, analyses have been performed again four weeks later. Personal biases sourced from long-term interaction with data sources have been tried to be prevented by careful analyses (Şimşek & Boz, 2016). Similarities and differences between analyses performed with four weeks intervals have been determined and an increase in reliability has been obtained. When discordance occurred between analyses, a common an opinion has been reached by obtaining opinion from an expert academician on content education.

FINDINGS

The findings of the studies examined within the scope of the research are presented in two parts. The first chapter is presented under three headings as themes, PCK components, science fields, and subjects, which are examined in PCK research. In the second part, general methodological features of PCK studies in science education are presented in five parts year, research method, participant profile and number, data collection tool, and data analysis.

Findings related to general thematic characteristics of papers prepared on PCK

When the purposes and research questions of papers prepared on PCK were examined, it has been determined that the research have been arranged around nine subjects. Data related to general thematic characteristics of papers prepared on PCK are presented in Table 1.

Table 1 Themes examined in analyzed papers

Theme	f
Determining PCK competences/status/levels	18
Examination of PCK development	25
Developmental studies of Scale/Test etc. related to PCK	18
PCK relation with different variables	8
PCK comparison	5
Relation/association between PCK components	2
Relation between PCK and student learning outputs	4
PCK review studies	3
Theoretical structure/frame of PCK	2

When Table 1 is examined, the majority of studies aim to address the examination of PCK development and the status of teachers and teacher candidates. There are 25 studies examining PCK development. Some the studies for developing and evaluating educational programs associated with science content have aimed to examine PCK development of teachers or teacher candidates in line with intervention studies such as the use of CoRe (content representation) and professional development. Some of these studies have focused on the development of PCK of teacher candidates during the education of teachers. 18 studies have been conducted for developing scales/tests etc. related to PCK. They are tools, of which validity and reliability have been obtained for measuring the PCK of teacher candidates and teachers. There are 8 studies examining the relation of PCK with different variables. The association of PCK with variables such as subject content knowledge, pedagogical knowledge, personal characteristics, conceptual knowledge, professional experience, cognitive and psychological aspects, etc. has been investigated. There are 5 studies performing PCK comparison. These studies aim to make comparisons of PCKs of teachers having different professional experiences, PCKs of teachers or teacher candidates with different gender and academic success status, PCK status of teachers or teacher candidates on different subjects, PCK status of teachers and

teacher candidates in different countries and PCK status of teachers and teacher candidates from different educational systems. There are 4 studies examining association between PCK and student-learning outputs. These studies have examined reflections of PCK status of teachers having different teaching experiences on their subject onto academic success and motivations of students. There are 2 studies handling association/interaction between PCK components that participants have. While 3 of the studies are in the form of review, 2 describe the theoretical structure or frame of PCK.

Findings related to PCK component/components in examined papers prepared on PCK

Five components of PCK have been revealed by examining papers prepared on PCK. Data related to PCK components are presented in Table 2.

Table 2 PCK component examined in papers analyzed

PCK Component	f
Knowledge of instructional strategies (KIS)	36
Knowledge of students (KS)	40
Knowledge of curriculum (KC)	27
Knowledge of measurement and evaluation (KME)	20
Orientation to teaching science (orientation)(O)	23
Ones not indicated	17

When Table 2 is examined, it is seen that researchers mostly focus on student knowledge and teaching methods knowledge. It can be said that student knowledge is the PCK component that is researched more by science education researchers in ESERA papers, and measurement and evaluation knowledge is less researched. There are also studies in which any component of PCK is not expressed, but the main subject of the study is PCK. More than one PCK component has been studied in the papers on PCK.

Table 3 Status of being together of PCK components in papers analyzed

Type	Total (f)	PCK Component	f
Ones studying single PCK component	12	(KIS), (KS), (KC), (O)	12
Ones studying two PCK components	10	(KS)+(KIS)	7
		(KC)+(KS)	2
		(O)+(KS)	1
Ones studying three PCK components	9	(KIS)+(O)+(KS)	2
		(KIS)+(KME)+(KC)	2
		(KIS)+(KC)+(KS)	4
		(KS)+(KME)+(KIS)	1
Ones studying four PCK components	-	-	-
Ones studying five PCK components	17	(KIS)+(KS)+(KC)+(KME)+(O)	17

When Table 3 is examined, Magnusson et al. (1999)'s proposed model of PCK studies examining all PCK components are intense. It is possible to say that a significant part of the researchers focuses on examining more than one PCK component. In addition, it is seen that the majority of PCK researchers deal with the teaching methods component in their studies.

Findings related to science areas examined in PCK studies

Science contents in papers prepared on PCK have been examined in the categories of physics, chemistry, biology, and astronomy.

Table 4 Areas of science handled in subject-specific PCK studies

Field	Total (f)
Physics	22
Chemistry	28
Biology	14
Astronomy	1
Ones not indicated	16

According to Table 4, it is seen that the majority of papers prepared on PCK have been conducted on the subject contents of chemistry followed by the subject content of physics. Only one study has been done on astronomy. The content of science has been clearly indicated in 16 types of research. Detailed information associated with subjects of chemistry, physics and biology in papers related to PCK are presented in Table 5, 6 and 7.

Table 5 Chosen chemistry subjects in papers examined

Field	Total (f)	Subject	f
Chemistry	28	Chemical Balance	4
		Electrochemistry	3
		States of Matter	3
		Redox Reaction	2
		Particulate Structure of Matter	2
		Chemical Reactions	2
		Acids and Bases	2
		Gases	1
		Solutions	1
		Atom Models	1
		Melting	1
		Thermochemistry	1
		Reaction Rate	1
		States of Matter	1
		Organic Chemistry	1
		Environmental Chemistry	1
Periodic Table	1		

When Table 5 is examined, chemical equilibrium, states of matter and electrochemistry are most chosen subjects in the content of chemistry. Other chemistry topics studied are Redox Reactions, Particulate Structure of Matter, and Chemical reactions. Subjects included in the subject content of physics are presented in Table 6.

Table 6 Chosen physics subjects in papers examined

Field	Total (f)	Subject	f
Physics	22	Mechanics	6
		Optic	5
		Electricity	3
		Electric Field	1
		Heat	1
		Particle Theory	1
		Conservation of Energy	1
		Thermodynamics	1
		Energy	1
		Quantum Physics	1
		Newton Laws	1

As can be seen in Table 6, the most frequently handled subjects of physics are mechanics, optics, and electricity.

Table 7 Chosen biology subjects in papers examined

Field	Total (f)	Subject	f
Biology	14	Respiratory System	3
		Genetics	3
		Photosynthesis	1
		Central Nervous System	1
		Ecology	1
		Meiotic Division	1
		Mitotic Division	1
		Water cycle	1
		Clotting	1
		Circulatory System	1

When Table 7 is examined, it is seen that most chosen subjects of biology are respiratory systems and genetics in PCK papers.

Findings associated with general methodological characteristics of papers prepared on PCK

In this section of the research, findings related to the year, the content of the discipline, research method, type and size of sample, data collection tool, and data analysis of papers prepared on PCK have been presented in the form of tables or figures.

Distribution of papers on PCK according to years

Distribution of papers prepared on PCK according to years is presented in Figure 3.

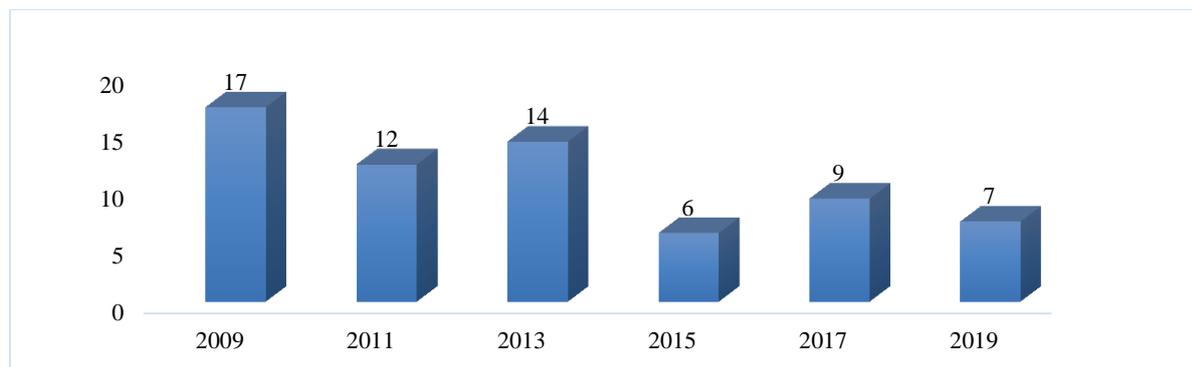


Figure 3 Distribution of papers prepared on the subject of PCK according to years

When Figure 3 is examined, it is seen that papers on PCK have been made most in 2009 and least in 2015. However, it can be told that PCK studies have been included each year when the ESERA conference was arranged.

Findings related to profile and number of participants of papers prepared on PCK

The Participant profile of papers prepared on PCK is presented in Table 8 and data related to the number of participants are presented in Figure 4.

Table 8 Participant profile of papers prepared on the subject of PCK

Participant Profile	Total (f)	Branches	f
Teacher	39	Biology Teacher	8
		Science Teacher	8
		Physics Teacher	9
		Chemistry Teacher	11
		Class Teacher	1
		Pre-school Teacher	2
		Teacher Candidate	26
Science Teacher Candidate	5		
Physics Teacher Candidate	9		
Chemistry Teacher Candidate	10		
Mathematics Teacher Candidate	1		
Academician	5	Professor	2
		Lecturer	2
		One for whom any title wasn't indicated	1
Student	6	High School Student	3
		Middle School Student	1
		Elementary School Student	1
		Student of Psychology Department	1
Other	3	Biologist	1
		Chemist	1
		Physicist	1

When Table 8 is examined, it is seen that PCK studies were conducted mostly with teachers. Studies with teacher candidates and academicians follow it. Physics and chemistry teachers have been studied most among teachers. Most of the data on teacher candidates have been collected from teacher candidates in chemistry and physics. Figure 4 gives data related to the number of participants.

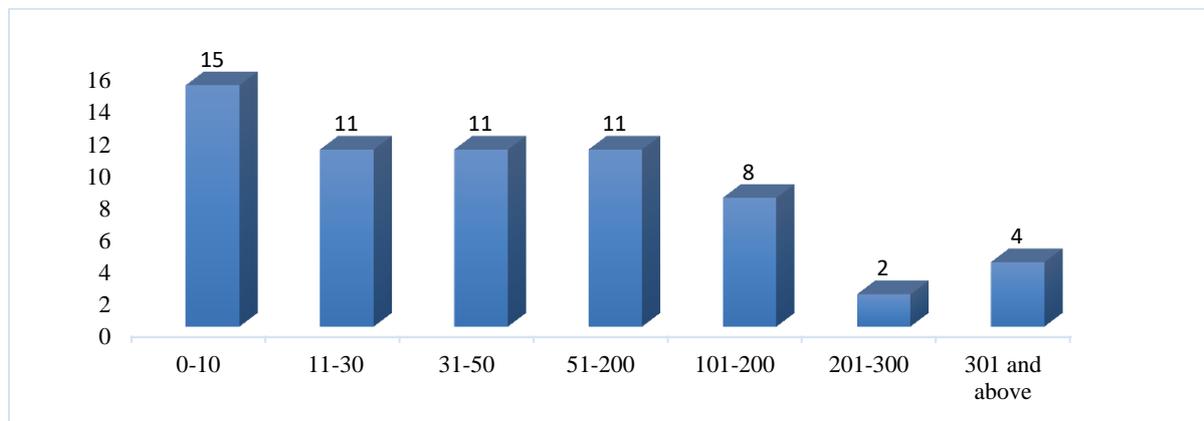


Figure 4 Distribution of papers prepared on the subject of PCK related to number of participants

When Figure 4 is examined, the most chosen number of participants ranges between 0-10 in papers made on PCK. Ranges of participant numbers 11-30, 31-50, and 51-100 follow it. On the other hand, studies with a large number of participants were also preferred in the papers.

Findings related to method/types of research used in papers prepared on PCK

When Figure 4 is examined, the most chosen number of participants ranges between 0-10 in papers made on PCK. Ranges of participant numbers 11-30, 31-50, and 51-100 follow it. On the other hand, studies with a large number of participants were also preferred in the papers.

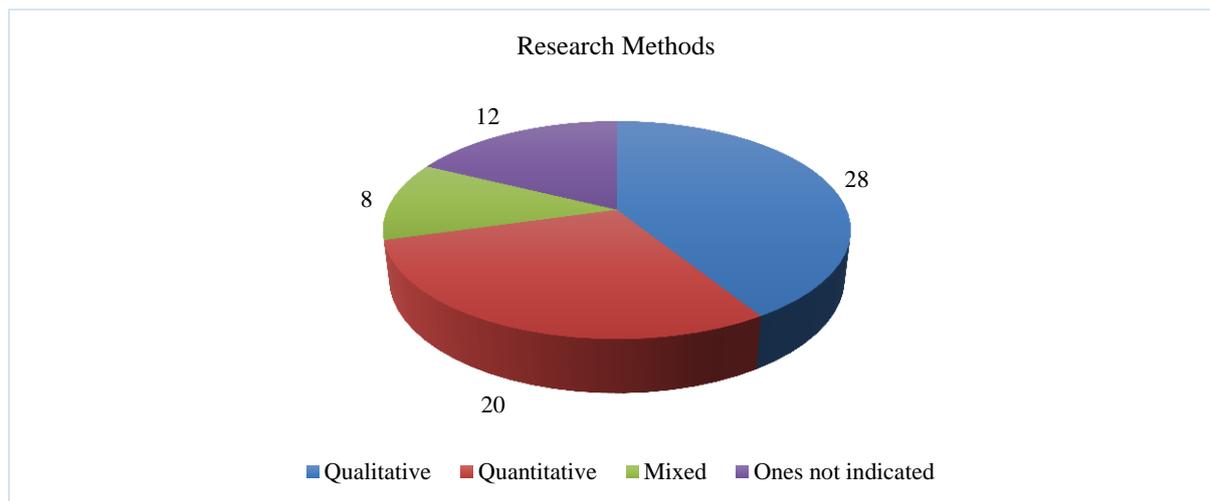


Figure 5 Research methods used in papers prepared on the subject of PCK

As is seen in Figure 5, researchers tend to use qualitative research methods more in studies made. The second most chosen research method is quantitative research methods. The least chosen research method is the mixed research method. In addition, any research method hasn't been indicated in the twelve studies.

Findings related to data collection tools used in papers on PCK

Distributions according to data collection tools used in papers prepared on PCK are shown in Table 9.

Table 9 Data collection tools used in papers prepared on the subject of PCK

Data collection tools	f
Test	22
Interview	18
Questionnaire	11
Observation/ Video records	11
Content Representation (CoRe)	8
Scales	6
Lecture plan	5
Vignette	4
Inventory	3
Pedagogical and Professional Experience Repertoire (<i>PaP-eRs</i>)	2
Concept map	2
Field notes	2
Diaries	1
Reports	1
Rubrics	1

When Table 9 is examined, it is seen that the most chosen data collection tool is the test. Another data collection tool frequently preferred by researchers is interviewing. Questionnaire, observation/video records and content representation follows it, respectively. The least chosen data collection tools are diaries, papers, and rubrics.

Findings related to data analysis method used in papers prepared on PCK

Findings related to data analysis methods used in papers prepared on PCK are presented in Table 10.

Table 10 Distribution related to data analysis method of papers

Theme	Code	f
Data analysis	Frequency/percent	4
	Mean/Standard deviation	3
	Correlation Analysis	8
	Rasch Analysis	7
	t test	7
	ANOVA	5
	Regression Analysis	3
	MANOVA	2
	Mann-Whitney-U test	2
	Kruskal-Wallis test	1
	Chi-Square Test	1
	Structural Equity Model	1
	Wilcoxon T-test	1
	Content Analysis	22

When Table 10 is examined, it is seen that the quantitative data analysis method is used most as a data analysis method. Correlation analysis, rasch analysis and t test have been used most in researches where quantitative data analysis had been chosen. It has been determined that content analysis method is used in qualitative data analysis.

CONCLUSION, DISCUSSION AND RECOMMENDATIONS

This study aimed to examine the papers prepared on PCK for thematic and methodological aspects published in ESERA (2009-2019) conference books to put forward the general tendencies and to provide guidance for future studies. In line with this purpose, 65 papers have been examined, and reached findings have been included below.

PCK studies conducted in science education have been executed towards determining PCK competencies, examination of PCK development, PCK relation with different variables, scale/test, etc. development studies related to PCK, the relation between PCK and student learning outputs, PCK comparison, relation/interaction between PCK components, review studies and theoretical structure/frame of PCK.

Most studies have been performed by researchers on PCK development, scale/ test, etc. development related to PCK and determining PCK status. These types of studies are essential because they will reveal detailed results about what should be done to develop the PCK of teachers and teacher candidates, which methods should be preferred, and how the lessons should be designed. Studies about the theoretical structure of PCK and about the relation/interaction between PCK components are limited. When these findings are compared with the results obtained from international PCK literature, it can be expressed that similarities and differences are present. When PCK literature research is examined, it is seen that there is a tendency to investigate the nature of PCK towards determining PCK development and developing measuring-evaluation tools (Belge-Can, 2019). This is due to the need to provide stronger empirical evidence and develop a tool that is easy to apply to many participants. Belge-Can's (2019) review pointed out that build-up is excessive in studies towards the development/determination of PCK in research related to PCK in Turkey and that scale development studies rarely differ from international literature. Though it is seen that there are an excessive the number of research about PCK development, valid measuring tools that permit larger scale research with more comprehensive participants for a longer duration are still lacking related to PCK development (Chan & Hume, 2019). However, more research is needed on the influence of contextual knowledge, cognitive and sensual factors on PCK and the relationship between PCK and student-learning outputs.

It has been determined that student knowledge and knowledge of teaching strategy have been studied most in research among PCK components. This is due to the fact that researchers do not base their study on a particular model of PCK. This situation shows parallelism with the findings obtained

from national and international literature. Belge-Can (2019) has indicated that knowledge of teaching strategy and student knowledge have been the PCK components that have been examined most by science researchers in Turkey. Sayın et al. (2021) have pointed out that most knowledge of teaching strategy and student knowledge have similarly been included in studies. One of the striking findings in this study is that the great majority of researchers have included an orientation component in their studies. Abell (2007) and Belge Can (2019) have indicated that the least handled PCK component has been orientation. It is also recognized that there aren't enough studies related to measuring and evaluation in ESERA papers. Avargil et al. (2012) have indicated that the knowledge of measuring and evaluation has been the hardest task faced, which is an advanced professional development stage for teachers. Unfortunately, the component of knowledge of measuring and evaluation, which is extremely important for the learning and teaching process, hasn't been an open target of research. In 17 studies, researchers did not explicitly state any component of PCK, but PCK was the main subject of the study.

When the PCK components examined in the studies were examined, it was seen that the researchers worked with more than one PCK component. However, some studies deal with all components of PCK together. More research can be given to the researchers questioning the relationship/interaction between PCK components.

When papers prepared on PCK are examined according to their subjects, it has been seen that mainly chemistry and physics subjects have been studied. Only a limited number of studies have focused on the subjects of astronomy. Although Aydın and Boz (2012) have indicated that any PCK study couldn't be accessed in the context of physics, there are PCK studies on every continent and various subjects such as astronomy, physics, chemistry, biology as well as national (Belge-Can, 2019) and international literature (Abell, 2007) in subsequent years. Popular subjects in PCK research are chemical equilibrium, states of matter, and electrochemistry in the context of chemistry, while they are mechanics, electricity, and optics in physics. While they are the respiratory system and genetics in the context of biology, they are the solar system and universe in astronomy. Therefore, giving importance to astronomy and biology subjects may contribute to subject content because PCK should be studied subject-based due to its subject-specific nature (Abell, 2008).

It was concluded that the highest number of papers on PCK was made in 2009, followed by 2013, and the least published year was 2015. Schneider and Plazman (2011) have pointed out that PCK is a popular but still developing structure.

The participant profile of PCK studies consists mainly of teachers and teacher candidates. This situation also parallels the literature (Abell, 2007; Belge-Can, 2019; Loughran et al., 2004; Sayın et al., 2021). Most studies have been performed with teacher candidates and chemistry and physics teachers.

When the research on science education related to PCK is considered, it is seen that they have been performed primarily with middle school science teachers as participants (Chan & Hume, 2019). In PCK studies in which teacher candidates participated, teacher candidates of biology were less included. There are few studies in which academicians were included in the sample profile of PCK studies. As Sayın et al. (2021) indicated, reasons that researchers and academicians who will perform analysis are busy that quantitative long-term data collection from academicians might be complex and personal causes may be shown as a cause for this situation. Studies conducted with biology teacher candidates, academicians, and lecturers would contribute to future research.

When the sample sizes of the papers included in the research were examined, it was seen that the groups of 0-10 people were studied at most. One of the remarkable results of the analysis is that some studies collect data from a wide range of participants. PAB-related scale/test etc. To carry out development studies, the targeted sample size should be large. More large-scale studies on PCK are needed. It can be stated that the research method preferred in the study affects the number of participants.

It has been determined that most studies are qualitative research, and therefore qualitative data collection tools and qualitative data analysis methods have been used excessively. Mainly the use of qualitative methods in studies may find from the thought that it would be more suitable due to PCK having a complex structure and providing more in-depth and detailed information. Several studies using qualitative and quantitative research methods are numerically superior to studies by the mixed method. Findings obtained in PCK studies comply with findings obtained in PCK literature (Chan & Hume, 2019). Sayın et al. (2021) and Belge-Can (2019) have pointed out that the great majority of studies have been performed by using qualitative research methods. Abell (2008) has criticized giving priority to qualitative status studies in the international areas and has recommended that quantitative and mixed design researches on PCK content need to be given place. It can be said that studies adopting quantitative and mixed research methods with long-term and larger groups of participants are needed for future research. Although research methods are an essential part of studies, any suitable research method hasn't been indicated in 12 studies. This finding may be explained by not being careful while writing a scientific letter about research methods.

It has been determined that tests are mainly used as a data collection tool in the studies. Easy evaluation of PCK, especially in large samples, ease of data collection, accessing more data in a shorter time, and ability to analyze data quickly can be shown as a reason for choosing those tests. There is a need for valid and reliable measuring tools for the future to provide more powerful empirical evidence. However, interviews, observations, and questionnaires have been prominent data collection tools in studies. This shows similarity with findings obtained from literature screening related to PCK on the content of science education (Aydın & Boz, 2012; Belge-Can, 2019; Chan & Hume, 2019; Sayın et al., 2021). Mostly different data collection tools have been used together in studies. Due to the complex nature of PCK, using multiple methods presents a clearer picture of PCK (Baxter & Lederman, 1999; Park & Suh, 2015).

Mainly quantitative data analyses have been used in examined studies. Among these methods, analyses such as correlation analysis, Rasch analysis, and t-tests have been made frequently. It has been determined that the content analysis method has been used in qualitative data analysis. Although qualitative research methods have been used more in studies performed, an excess number of quantitative data analyses may demonstrate the use of more than one analysis in quantitative data analysis. Consequently, PCK starting from its appearance, occurs as a powerful focus where the professional knowledge of teachers can be examined by using different participants, contexts, data, methods, and analyses.

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