

Seeking Traces of Filters and Amplifiers as Pre-service Teachers Perform their Pedagogical Content Knowledge

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ABSTRACT

This study examined how filters and amplifiers affect pre-service science teachers' pedagogical content knowledge (PCK) in a human and environment unit. The redefined consensus model for PCK and decision-making framework for identifying how personal and extra-personal factors act as filters and amplifiers were selected as theoretical frameworks. Two pre-service science teachers participated in the study. While pre-interviews were used to determine participants' PCK before teaching, observations and post-interviews were used to reveal participants' PCK after teaching, and how filters and amplifiers influenced PCK. Data were analyzed deductively to examine teachers' PCK including interactions among components and the way filters and amplifiers act on PCK. Constant comparison analysis revealed five general assertions of how filters and amplifiers shaped the decision-making process when these teachers enacted their PCK. First, the number of amplifiers and filters affecting knowledge of instructional strategies (KOIS) was the highest. Second, the number of amplifiers and filters affecting knowledge of curriculum in science was the lowest. Third, the effect of filters and amplifiers on PCK components was idiosyncratic. Fourth, the more (or the less) the map was integrated; the less (or the more) amplifier and filter influenced the PCK. Fifth, the number of personal factors affecting KOIS was highest. Implications are suggested considering the effects of filters and amplifiers on teachers' PCK.

KEY WORDS: Amplifiers; extra-personal factors; filters; pedagogical content knowledge; personal factors

INTRODUCTION

Science teachers are one of the most important decision-makers regarding teaching and learning in classrooms and their teaching practices are complex in nature, which is influenced by several factors (e.g., goals and purposes of science teaching) (Friedrichsen et al., 2011). More importantly, at least a decade is required for a science teacher to embrace robust beliefs about how good teaching occurs (Belo et al., 2014). Therefore, science teachers' beliefs should be considered first, if science teachers are expected to align their teaching practices with reform documents (Bryan and Abell, 1999).

Alignment of teachers' beliefs with their practice is not clear-cut. While some quantitative (e.g., Miranda and Damico, 2013) and qualitative (e.g., Demirdöğen and Uzuntiryaki-Kondağcı, 2016) studies indicated that teachers' beliefs influence their practice, other qualitative research studies reported the gap between what teachers believe and the way they teach (e.g., Hutner et al., 2021). Similar to inconsistent results about the translation of teachers' beliefs into their teaching, there has not been a clear definition of belief (Jones and Leagon, 2014). Teacher educators have used various terms to refer to teachers' beliefs such as conceptions of purposes for teaching subject matter (Grossman, 1990). Amplifiers and filters have been used in recent theoretical frameworks about teachers' professional knowledge base (i.e., pedagogical content knowledge [PCK],

Carlson and Daehler, 2019; Gess-Newsome, 2015) when describing how numerous factors (e.g., student attributes) including teacher beliefs (Luft and Roehrig, 2007) mediate teachers' professional knowledge bases during the act of teaching.

Given the novelty of amplifiers and filters in recent PCK models, there has been a scarcity of studies investigating how amplifiers and filters act during the enactment of teachers' PCK (e.g., Henze and Barendsen, 2019). Moreover, literature calls for research on not only which beliefs as amplifiers and filters are active during the decision-making processes of planning and teaching (Hutner and Markman, 2016), but also the role of personal and extra-personal factors when amplifying and filtering teachers' PCK (Henze and Barendsen, 2019). Therefore, the purpose of this study was to investigate how personal and extra-personal factors act as filters and amplifiers during pre-service science teachers' enactment of PCK in a human and environment unit.

THEORETICAL FRAMEWORK

The nature of this study required utilizing three different models to examine how filters and amplifiers affect PCK. Two models guided us in collecting, analyzing, and interpreting the data for PCK while one model was used for filters and amplifiers.

The refined consensus model (RCM) explained in Carlson and Daehler's (2019) study and Magnusson et al.'s (1999) model were used for investigating PCK in human environment unit. RCM is constructed on three different realms of PCK, which are enacted PCK (ePCK), personal PCK (pPCK), and collective PCK (cPCK). At the center of RCM, ePCK exists and teachers use this knowledge in planning, enactment, and reflection of teaching. By using ePCK during teaching, teachers perform their knowledge and use their reasoning when they interact with students (reflection in action). Similarly, teachers utilize their ePCK before (i.e., planning) and after teaching (i.e., reflection) while they report their lessons with their reasoning (reflection on action). ePCK is an active part of pPCK (Henze and Barendsen, 2019), the stored dynamic and accumulative knowledge of an individual teacher that reflects teaching and learning practices of that teacher. The third form of knowledge is cPCK produced and shared by different professionals. This study specifically focuses on teachers' ePCK in human and environment unit, and it is related with reflection on action rather than reflection in action. Therefore, this study deals with teachers' planning of teaching and reflections on their actions.

The second PCK model used in this study was Magnusson et al.'s (1999) model since RCM does not unpack the PCK components (Chan and Hume, 2019). This model includes five PCK components, which are orientations toward teaching science (STO), knowledge of science curriculum (KOC), knowledge of students' understanding in science (i.e., knowledge of learner) (KOL), knowledge of assessment in science (KOA), and knowledge of instructional strategies (KOIS) for teaching science. STO is related with teacher beliefs rather than knowledge (Henze and Barendsen, 2019); hence, we focused on the amplifying and filtering effect of this component and did not include it in this current study as a PCK component. Next, KOC includes teacher's knowledge about goals, objectives, and sources used in teaching science and KOL is about teachers' knowledge regarding students' pre-requisite knowledge and difficulties that students have. Similarly, KOA deals with what and how teachers assess particular science topics and lastly, KOIS includes subject-specific and topic-specific strategies (Magnusson et al., 1999). Interactions among PCK components are a sign of PCK quality (Park and Chen, 2012). Therefore, this study considered the interactions among PCK components.

We used decision making framework to investigate how filters and amplifiers affect teachers' PCK. According to Henze and Barendsen (2019), personal and extra-personal factors act as filters and amplifiers, and they affect teachers' decision-making processes and actions. They distinguished personal and extra-personal factors by advocating that the personal factors are related to teachers' identities whereas components of the teaching situations refer to extra-personal factors. Through the utilization of those personal and extra-personal factors, we investigated how those factors supported (i.e., act as amplifier) or limited (i.e., act as filter) pre-service teachers' ePCK.

LITERATURE REVIEW

How Do Amplifiers and Filters Affect PCK?

The answer for how personal and extra-personal factors mediate teachers' PCK is limited because of the scarcity of studies focusing on the way amplifiers and filters act during teaching. To the best of the authors' knowledge, Henze and Barendsen (2019) revealed how personal factors account for the differences between pre-service chemistry teachers' pPCK developmental steps. Efficacy, emotion, and micro-politics were found to be influential personal factors on pPCK in various frequencies and combinations. Also, positive factors (e.g., self-efficacy as an amplifier) predominated pre-service teachers' planning, enactment, and reflection steps of their pPCK development and were influential having a richer KOL and KOIS. However, when positive and negative (e.g., micro-politics as a filter) factors were concurrent, it led to inability to enact more and staying at planning step of pPCK development. Finally, the data indicated that if the personal factors were primarily negative this caused losing developmental steps mostly, lacking enactment, and undeveloped KOL and KOIS.

Even though literature on amplifiers and filters (Henze and Barendsen, 2019) is rare, there has been an attempt to determine the influence of contextual knowledge on PCK (Şen and Öztekin, 2019). It was revealed that teachers' experience and teachers' interest in topics, as personal factors were influential on teaching while students' readiness, students' interest, students' parents, curriculum load, and lack of materials were found to be extra-personal factors. In terms of how these factors mediated teachers' PCK, Şen and Öztekin (2019) proposed several assertions based on their data. First, teachers sometimes used their contextual knowledge to adjust their PCK. Lack of materials and students' readiness level led to a regulation of KOIS. Second, teachers' contextual knowledge sometimes supported their PCK. Teachers' interest in the topic facilitated enactment of their KOC whereas their past experiences as learners supported their KOL. Third, there were several instances where teachers were not able to eliminate negative effects of contextual factors on their PCK. Students' readiness level and intensity of curriculum had an unsupportive effect on KOIS. The curriculum load also was found to have a negative effect on KOC and KOIS. KOA is the only component on which teachers' interest in topic had an unsupportive effect. Fourth, textbooks, which were not considered as contextual factors by teachers, also had positive effects on KOC and KOIS, and negative effects on KOC.

To conclude, the previous studies do not directly provide clear and explicit evidence on how personal and extra-personal factors as amplifiers and filters mediate teachers' PCK including integration among components. More importantly, literature calls for research on personal and extra-personal factors amplifying and filtering teachers' PCK (Henze and Barendsen, 2019). This study may be one of the first attempts to fill the knowledge gap regarding how amplifiers and filters act on pre-service teachers' ePCK.

METHODOLOGY

Research Design

This research benefits from the strengths of qualitative methodology since it focuses on PCK, which is tacit in nature (Berry and Loughran, 2010), examines a little-known phenomenon that is the nature and role of filters and amplifiers during the enactment of PCK and delves into the complexities of how filters and amplifiers act on PCK (Marshall and Rossman, 2014). Among qualitative research designs, case study guided in designing the research and collecting and analyzing the data.

Participants

Two pre-service senior teachers enrolled in elementary science education department of a public university in Ankara (Turkey) voluntarily participated in the study. We informed pre-service teachers that they had the right to withdraw from the study. One of them was female (Cansu) and another was male (Mustafa). Both participants were 23 year olds and they did not participate in any professional development program to improve their PCK. After their graduation, these pre-service teachers were expected to qualify teaching science in middle school level. The pre-service teachers had no teaching experience in real science classes until this study. Current study was conducted in school experience course, practicum. Both participants were assigned to teach 5th grade level students. Pre-service teachers practiced their teaching in human and environment unit at this grade level.

Data Collection

Interviews and observations were the main data collection tools in this case study. As the study focused on how filters and amplifiers affect pre-service teachers' ePCK, we specifically prepared PCK pre-interviews and PCK post-interviews. While PCK pre-interviews informed us about teachers' planning of teaching, PCK post-interviews together with observations provided information about participants' reflection on teaching and filters and amplifiers affecting their teaching.

PCK pre-interview questions were prepared considering four PCK components of Magnusson et al.'s PCK model (1999). PCK pre-interviews were conducted before teaching and these interviews lasted one and half-hours for each teacher. Each interview was audio recorded and then transcribed by the authors.

After conducting PCK pre-interviews, we observed pre-service science teachers' teachings of the human and environment unit. The observations lasted 1 h for each participant. During observations, the role of researchers was non-participant observer taking field notes on teaching with a focus on PCK and amplifiers and filters. After class observations, PCK post-interviews were prepared. The content of the post-interview questions was similar to pre-interview questions and participants were asked to reflect on their teaching considering four components of the PCK model (Magnusson et al., 1999) and factors that amplify or filter their PCK enactment. PCK post-interviews lasted 1 h for each participant. Pre-service teachers' reflections on teaching during PCK post-interviews

helped us understand their ePCK and how personal and extra-personal factors act as filters and amplifiers on their ePCK.

Data Analysis

In this study, we aimed to understand pre-service teachers' PCK prior to teaching (pre-PCK), PCK they reflected after teaching (post-PCK, i.e., ePCK), and how filters and amplifiers mediated their teaching. We used PCK mapping approach (Park and Suh, 2019) to understand pre-PCK and post-PCK. While analyzing filters and amplifiers, we used decision making framework (Henze and Barendsen, 2019). Details of PCK mapping approach and analysis of filters and amplifiers are presented below:

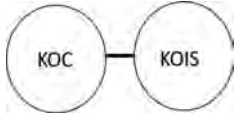
In the first step (in-depth analysis of explicit PCK), we identified teaching segments that pre-service science teachers talked about in pre-interviews (Park and Suh, 2019). Accordingly, both Mustafa and Cansu's PCK pre-interviews included 21 teaching segments in total. We named them according to their specific content such as 'examples of environmental problems.' Then, we looked for individual PCK components and their interactions in the teaching segments we identified before. After identification of PCK components and their interactions, we named the teaching segment as a PCK episode for teacher planning.

In the second step (enumerative approach), we visualized each PCK episode that is the product of in-depth analysis. In the visual representing an episode (i.e., PCK map), we indicated both PCK components and their interactions that are evident in the episode (Table 1). After creation of maps for each PCK episode, we summed up frequency of interactions between any two PCK components across all episodes (Park and Suh, 2019) and reached pre-PCK map, represented by tetragonal model (as we omitted orientation towards science from PCK) for each participant (findings section Figures 1 and 2).

We started analysis of PCK post-interview and observation data by utilizing the same PCK mapping approach that we had used for analyzing PCK pre-interview data. We detected 15 teaching segments for Mustafa and 13 teaching segments for Cansu during in-depth analysis of explicit PCK. Then, PCK episodes were formed by identification of PCK components and their interactions. Those episodes were visualized by creating PCK maps. Next, we summed up frequency of interactions between any two PCK components across all episodes and produced a post PCK map for each participant, Figures 1 and 2.

Third, we specifically focused on analysis of how filters and amplifiers affect PCK. In this analysis, we again utilized the data coming from observations and PCK-post interviews. During the analysis, we used decision making framework and coded factors as personal and extra-personal (Henze and Barendsen, 2019). Then, we looked for clues showing the effect of factor on PCK component. After identifying interaction between a factor and a PCK component, we examined whether the interaction supported participant to enact the interacted PCK component or limited the occurrence of interacted PCK component. If a factor facilitated the enactment of a PCK

Table 1: An example of visualization of PCK episode using PCK map

Participant	PCK episode	Pre-interview excerpt	PCK map of given episode
Mustafa	Teaching environmental problem examples	The curriculum does not provide so many examples about environmental problems (KOC). Therefore, I will not give detailed information about examples of environmental problems in my lesson (KOIS).	KOC informs KOIS 

PCK: Pedagogical content knowledge, KOC: Knowledge of curriculum, KOIS: Knowledge of instructional strategies

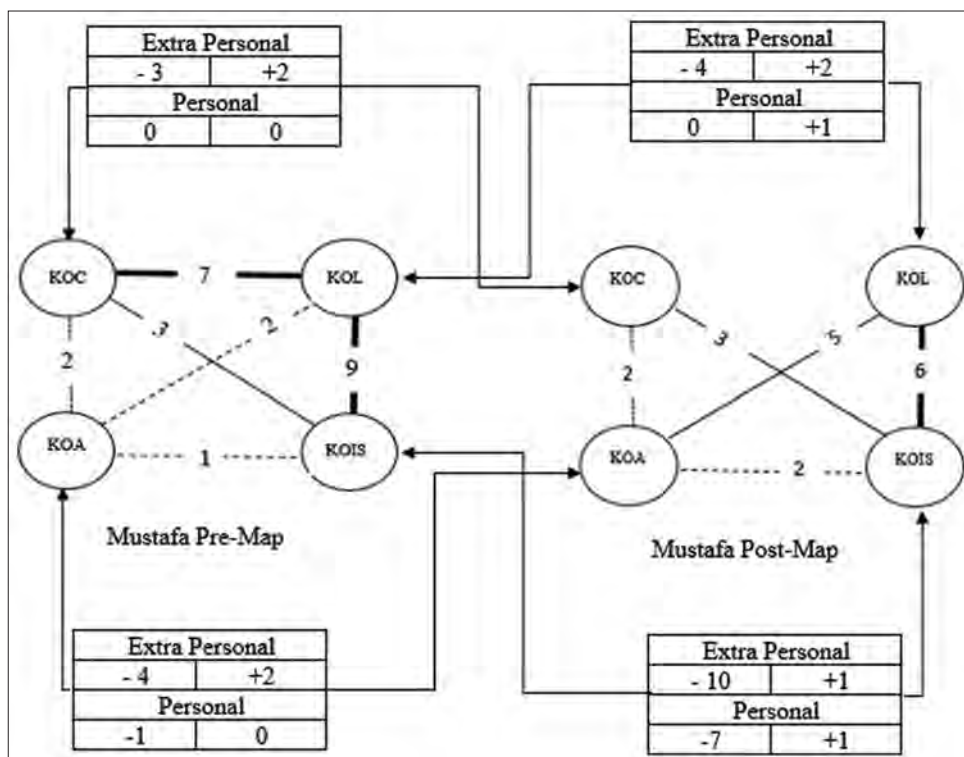


Figure 1: Mustafa's pedagogical content knowledge (PCK) profile indicating how factors mediated PCK components

affecting their PCK to reveal some patterns regarding how filters and amplifiers influenced PCK. These emerging themes formed our assertions we present in the findings section.

Trustworthiness

We compared PCK episodes, PCK maps, and interview results during analysis of both pre-interviews and post-interviews and this process contributed to methodological triangulation of the study (Park and Suh, 2019). In addition, researchers separately detected PCK codes and their interactions for each teaching segment. Then, researchers came together to discuss different points in their analysis. Inter-rater agreement was calculated as 85% for pre-interviews, 88% for observational data with post-interviews and 90% for interactions between filters, amplifiers, and PCK components. Those inter-rater agreements contributed to the peer review process of the study.

FINDINGS

We examined pre-service teachers' PCK in human and environment unit and how filters and amplifiers affect their

component, this factor was labeled as amplifier. A factor limiting enactment of a PCK component was labeled as filter. Then, these filters and amplifiers were classified as extra-personal filter, extra-personal amplifier, personal filter, and personal amplifier (Table 2).

Fourth, we summed up frequency of all interactions between each factor and each PCK component. For instance, Mustafa's PCK maps revealed 11 extra-personal factors influencing KOIS and 10 of them were filters while one is amplifier (Figure 1). Amplifiers were represented with "+" because of their supportive effect whereas filters were represented with "-" due to their inhibiting effect. Summing up procedure was applied for each factor including personal-filter, personal amplifier, extra-personal filter, and extra-personal amplifier. After quantifying interactions between each factor and each PCK component, we added these interactions and represented them on the PCK map of each participant (Figures 1 and 2).

Finally, we made constant comparative analysis by comparing participants' pre-PCK maps, post-PCK maps, and the factors

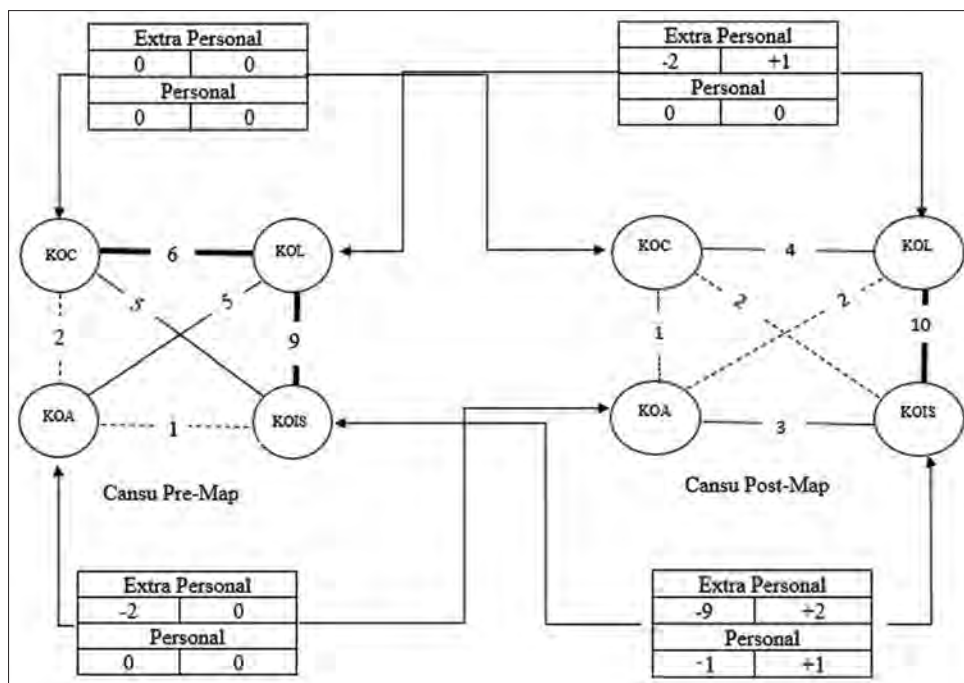


Figure 2: Cansu's pedagogical content knowledge (PCK) profile indicating how factors mediated PCK components

Table 2: Examples of factors and their interactions with PCK components

Excerpt	Factor code	PCK component code	Factor-PCK component interaction
I could not manage the classroom (Factor). I was concerned about my teaching when I had classroom management problems and I could not tell the examples I planned in teaching. (KOIS) Likewise, I could not make assessment (KOA)	Pedagogical professional weakness (Classroom management) Personal Filter	KOIS KOA	Personal filter-KOIS personal filter-KOA
I used photos from news for both students and myself (Factor). These photos got students' attention (KOL). After looking at photos, students read the news in detail. Therefore, use of photos facilitated students' participation in activity (KOIS)	Pedagogical professional strength (use of visuals) Personal Amplifier	KOL KOIS	Personal amplifier-KOL personal amplifier-KOIS
The education system ignores affective domain and just focuses on success (factor). Then, students do not develop their affective domain including respecting others. Therefore, when I ask students to engage in group work, they do not accurately perform in group work (KOIS) because students do not get respect from others	Broader educational climate (education system) extra-personal filter	KOIS	Extra-personal filter-KOIS
As students were familiar with direct instruction (Factor) the first few minutes of the lesson were good. They actively participated in the activities (KOIS)	Individual student attributes (familiarity with teaching method) extra-personal amplifier	KOIS	Extra-personal amplifier-KOIS

PCK: Pedagogical content knowledge, KOC: Knowledge of curriculum, KOIS: Knowledge of instructional strategies

PCK. Using PCK mapping approach, we produced two PCK maps (pre-PCK map and post-PCK map) including the factors (i.e., extra-personal factors, personal factors) for each participant (Figures 1 and 2). In these maps, circles represent the four PCK components (e.g., KOL), the lines between two PCK components show interaction among these components, the number on these lines points out frequency of interactions between two PCK components. When the number of interactions increases, dashed lines transform to bold lines. On the other hand, we added rectangular figures to PCK maps, and these rectangular figures represent extra-personal and

personal factors. The number of filters and amplifiers for each factor shows how many times a given factor (e.g., filter and amplifier) affects corresponding PCK components. The arrows on factor point which PCK component is affected by that factor.

Using the PCK profiles of each teacher, we reached five general assertions showing how filters and amplifiers affect pre-service teachers' decision-making process when they enacted their PCK: (1) The number of amplifiers and filters affecting KOIS is the highest, (2) the number of amplifiers and filters affecting KOC in science is the lowest, (3) the effect of filters and amplifiers on PCK components is idiosyncratic, (4) the

more (or the less) the map is integrated the less (or the more) amplifier and filter influence the PCK, and (5) the number of personal factors affecting KOIS is highest. These assertions are explained in the following part.

To gain more insight into personal and extra-personal factors, we also created Table 3 indicating the type of amplifiers and filters influencing each participant's PCK components.

Assertion 1: The Number of Amplifiers and Filters Affecting KOIS is the Highest

Examination of PCK maps for each participant showed that filters and amplifiers affected KOIS (i.e., KOIS) the most. Accordingly, 17 filters (10 extra-personal and seven personal) and two amplifiers (one extra-personal and one personal) affected Mustafa's KOIS. Likewise, 10 filters (nine extra-personal, one personal) and three amplifiers (two

extra-personal and one personal) mediated Cansu's KOIS. For example, individual student attributes including student characteristics limited Cansu's KOIS as in the following excerpt, which is an example for how extra-personal factors could act as filter for KOIS:

Students were not familiar with group working. They talked too much and this caused a noisy atmosphere in class, so my group working strategy did not work (Cansu, post-interview).

The effects of factors on other PCK components were not as high as factors influencing KOIS. While the number of total amplifiers and filters affecting Mustafa's KOC, KOL, and KOA were five, seven, and seven, respectively, the number of total amplifiers and filters affecting Cansu's KOC, KOL, and KOA were zero, three, and two, respectively.

Table 3: Amplifiers and filters as personal and extra-personal factors mediating participants' PCK components

PCK aspects and factors		Mustafa		Cansu	
PCK Aspect	Amplifier	Filter	Amplifier	Filter	Filter
KOA	<ul style="list-style-type: none"> Individual student attributes (attentive listener during teaching) (*f=2, extra personal) 	<ul style="list-style-type: none"> Pedagogical weaknesses (classroom management) (f=1, personal) Individual student attributes (inattentive listener) (f=3, extra personal) Broader educational climate (students learning with behaviorism) (f=1, extra personal) 			<ul style="list-style-type: none"> Individual student attributes (inattentive listener to peers, uninterested in the content) (f=2, extra personal)
KOL	<ul style="list-style-type: none"> Individual student attributes (attentive listener during teaching) (f=2, extra personal) Pedagogical strengths (use of visuals) (f=1, personal) 	<ul style="list-style-type: none"> Individual student attributes (inattentive listener, attentive listener) (f=3, extra personal) Specific learning environment (unfamiliar activity content) (f=1, extra personal) 	<ul style="list-style-type: none"> Individual student attributes (interested in the subject) (f=1, extra personal) 		<ul style="list-style-type: none"> Individual student attributes (noise) (f=1, extra personal) Specific learning environment (class size-overcrowded) (f=1, extra personal)
KOC	<ul style="list-style-type: none"> Individual student attributes (attentive listener during teaching) (f=2, extra personal) 	<ul style="list-style-type: none"> Individual student attributes (inattentive listener) (f=2, extra personal) Broader educational climate (time limitation) (f=1, extra personal) 			
KOIS	<ul style="list-style-type: none"> Individual student attributes (attentive listener during teaching) (f=1, extra personal) Pedagogical professional strengths (use of visuals) (f=1, personal) 	<ul style="list-style-type: none"> Pedagogical weaknesses (classroom management) (f=3, personal), (experience) (f=2, personal), (technological knowledge) (f=1, personal), (giving answers before planned time) (f=1, personal) Broader educational climate (lack of authority) (f=1, extra personal), (students' learning with behaviorism) (f=2, extra personal), (ignoring affective domain) (f=1, extra personal), (time limitation) (f=2, extra personal), Individual student attributes (inattentive listener, unfamiliar to group work, respect to others) (f=3, extra personal) Specific learning environment (overcrowded class) (f=1, extra personal) 	<ul style="list-style-type: none"> Individual student attributes (interest in the subject, familiarity with the instructional material) (f=2, extra personal) Pedagogical professional strengths (use of visuals) (f=1, personal) 		<ul style="list-style-type: none"> Individual student attributes (noise, unfamiliarity with group work, inattentive listeners to peers, uninterested in the content) (f=4, extra personal) Pedagogical professional weaknesses (classroom management) (f=1, personal) Broader educational climate (time limitation) (f=2, extra personal) Specific learning environment (class size -overcrowded) (f=2, extra personal) Specific learning environment (students' unfamiliarity to lab environment as a teaching context) (f=1, extra personal)

*f refers frequency of the observed factor

Assertion 2: The Number of Amplifiers and Filters Affecting KOC in Science is the Lowest

PCK maps of participants also showed that factors (filters and amplifiers) influencing KOC were less than the number of factors moderating other PCK components. For example, we did not observe any effect of personal factors on KOC for both participants. Furthermore, extra-personal factors did not have an impact on Cansu's KOC either (Figure 2). The effect of extra-personal factors on KOC was only observed in Mustafa's PCK map (Figure 1). Accordingly, extra-personal factors mediated his KOC 5 times, of which three of them were filters and two of them were amplifiers. The following is an example showing how individual student attributes (i.e., attentive listener to teacher and peers) as an extra-personal factor amplified the Mustafa to reach his curricular objectives:

There was a group of silent students listening to me. This group could understand my expectations. They analyzed the news I provided them. By using the information, this group could propose solutions for environmental problems. Therefore, I could reach my objectives at least for this group. (Mustafa, post-interview).

Meanwhile, time limitation, stemming from broader educational climate, as an extra-personal factor filtered Mustafa's KOC by restricting his teaching of curricular objectives. The following example shows how he had difficulty in teaching curricular objectives in an abbreviated time:

We expected students to propose solutions for environmental problems as a curricular objective, but students could not propose solutions in a delineated time. There were three more objectives I needed to teach, so I could not spend time teaching these objectives. (Mustafa, post-interview).

Assertion 3: The Effect of Filters and Amplifiers on PCK Components is Idiosyncratic

We have found that there were some differences in terms of both the kinds of factors (i.e., personal and extra-personal) influencing PCK components and how those factors influence the degree of integration among components. When personal and extra-personal factors were closely examined, it was revealed that both factors concurrently were influential on Mustafa's KOL, KOA, and KOIS whereas their impact existed only on Cansu's KOIS. The following is an example that pedagogical professional weakness as personal filter affecting Mustafa's KOA:

There was an objective stated as students predict what happens in future if environmental problems persist. To my questions for each news about environmental problem asking what expects us in 10 years if these (environmental problems) persist, they (students) gave simple answers. I would like to assess more than that. I could ask more questions. I should not ask open-ended questions as such might be. (Mustafa's post interviews).

In addition, Mustafa's KOC was filtered and amplified by extra-personal factors only while similar effect was observed for

Cansu's KOL. Moreover, there was no effect of personal and extra-personal factors on Cansu's KOC on contrary to Mustafa. Lastly, Cansu's KOA was filtered by extra-personal factors while both amplifiers and filters were observed as personal and extra-personal factors moderating Mustafa's KOA.

Furthermore, participants were different from each other in terms of the degree to which the integration among their PCK components (i.e., frequency of total interactions in a PCK map) was influenced by amplifiers and filters. As filters were observed more than amplifiers, we expected a decrease in terms of integration among PCK components from pre-maps to post-maps. There were decreases in the number of interactions between KOC-KOL (seven to zero) and KOL-KOIS (nine to six) in Mustafa's PCK whereas interactions between KOC-KOA (two to one), KOC-KOIS (five to two), and KOL-KOA (five to two) were decreased in Cansu's PCK as well. That is, the type of interactions that decreased differed in Mustafa and Cansu's PCK although filters had more moderating roles than amplifiers across all interactions. Overall, a noteworthy decline was not observed in interactions of KOIS with other PCK components, and such interactions were almost stable from pre-map to post map for Mustafa (from 12 to 11) and Cansu (from 15 to 15). However, KOC interactions sharply decreased from pre-map to post map for both participants (Figures 1 and 2). Interestingly, we observed increases in the number of interactions between some components of PCK. Interactions between KOA and KOIS increased from one to two in Mustafa's PCK and one to three in Cansu's PCK. Another increase in interactions occurred between KOL-KOA in Mustafa's PCK while it was observed between KOL-KOIS in Cansu's PCK. The type of interactions that increased from pre- to post-PCK was also different for participants as it was different for the decreases. Finally, there were no changes in the number of interactions between KOC-KOA and KOC-KOIS in Mustafa's PCK while this was not the case in Cansu's PCK.

Assertion 4: The more (or the less) the Map is Integrated; the less (or the more) Amplifier and Filter Influence the PCK

In this study, we observed a reverse relationship between integration of PCK map and frequency of factors affecting PCK components. Accordingly, Cansu's pre map was more integrated than Mustafa's pre map. While Cansu's pre map included 28 interactions among four PCK components, Mustafa's pre map included 24 interactions. Likewise, Cansu's post map consisted of 22 interactions and Mustafa's post map included 18 interactions. On the other hand, Cansu's PCK components were less affected by filters and amplifiers compared with Mustafa's PCK components. Findings showed that Cansu's PCK components were influenced by filters and amplifiers 18 times (14 filters, four amplifiers), but these factors affected Mustafa's PCK components 38 times (29 filters, nine amplifiers). Therefore, we can propose that pre-service teachers with more qualified PCK (i.e., teachers with more integrated PCK map) are resistant to learning context and better at implementing their plan to actual classroom teaching. On the

other hand, pre-service teachers with less qualified PCK (i.e., teachers with less integrated PCK map) are more susceptible to learning context and these teachers have potential risk of failure in actualization of their plan in teaching because of factors existed in learning context.

Assertion 5: The Number of Personal Factors Affecting KOIS is the Highest of all PCK Components

The last assertion is about classification of factors as personal and extra-personal. In this study, participants were mostly affected by extra-personal factors. Accordingly, 28 factors out of 38 were extra-personal for Mustafa and 16 factors out of 18 were extra-personal for Cansu. Extra-personal factors mediated all PCK components except Cansu's KOC. On the other hand, we did not observe the same situation for personal factors. Accordingly, personal factors only had an impact on KOIS for both participants. These factors did not affect the other three PCK components of Cansu and they influenced Mustafa's KOA and KOL only one time. Likewise, personal factors did not mediate Mustafa's KOC. The following are examples of personal factors that affect teachers' KOIS in this study:

Our topic was different ecosystems like desert, forest, and lake ecosystem. I thought that if I had asked them to draw these ecosystems that would have been more difficult for them because they might not know these ecosystems. Therefore, I used three different pictures showing examples of these ecosystems. Then, they understood my expectation. These pictures were examples for them, and they could draw their own ecosystems. (Cansu, post-interview-personal amplifier that is teacher's belief about students' familiarity to topic affects KOIS).

As I am not an experienced teacher, I could not think how many activity sheets are needed in class and I brought fewer activity sheets than total number of students. Then, some students could not get activity sheets, and some had to share their sheets with others. Some did not want to share, and some students could not benefit from the activity. (Mustafa, post-interview- personal filter that is lack of experience affects KOIS).

DISCUSSION

This study has been one of the first attempts conducted to gain an insight into how filters and amplifiers mediate pre-service science teachers' PCK. Five assertions reached through the analysis of qualitative data provided a deeper understanding about the role of amplifiers and filters on PCK. Since two assertions (one and five) are related, they will be discussed together as well as discussion of each assertion in the following parts.

First, KOIS was the PCK component affected by amplifiers and filters the most (assertion one). Therefore, this finding is consistent given the empirical evidence that KOIS is the most easily developed PCK component (Park and Oliver, 2008) and one of the key components of PCK (e.g., Park and Chen, 2012; Shulman, 1986, 1987) and hence susceptible of

any impact of personal and extra-personal factors indicated by relevant research (e.g., Boesdorfer and Lorschach, 2014; Demirdöğen, 2016; Park and Chen, 2012). Close examination of personal and extra-personal factors influencing participants PCK (Table 3) revealed a limited number of student attributes (i.e., attentive listener) and use of visuals amplified KOIS whereas numerous student attributes (e.g., making noise, unfamiliarity to group work, and uninterested in the content), ineffective classroom management, time limitation, lack of teaching experience, overcrowded class size, traditional teaching approaches dominated by behaviorist approaches and neglecting affective domain, lack of authority, and lack of technological knowledge filtered participants' enactment of instructional strategies. That is there were more filters than amplifiers, which is expected even in-service teachers were not always capable of compensating for the limitations of contextual factors on their PCK (Şen and Öztekin, 2019). Consistent with the high number of filters and nature of filters (i.e., personal factors), also the number of personal factors affecting KOIS is highest (assertion five) compared to other PCK components. Personal factors including ineffective classroom management, lack of authority stemming from being an intern, inadequate technological knowledge, and limited teaching experiences filtered participants' use of instructional strategies more than once. Those filtering factors might stem from pre-service teachers' lack of teaching experience that is one of the crucial factors supporting development of a robust PCK (Abell, 2007; Friedrichsen et al., 2009; Grossman, 1990).

Second, the number of amplifiers and filters affecting knowledge of curriculum in science is the lowest. This finding might be explained with the macro-policy of the country (Navy et al., 2018). Macro-policy refers to national curriculum standards for science teaching and national policies including qualification standards for beginning teachers. In terms of national curriculum standards, Turkey where the study was conducted has a national science curriculum with standardized objectives and time allocated for each objective adapted across all the schools. Regarding the national policies including qualification standards for beginning teachers, teacher education programs and national curriculum required pre-service teachers to be knowledgeable about the objectives and materials. Participating pre-service teachers have similar qualifications in their knowledge of curriculum since they completed the same courses (e.g., methods of science teaching, school experience, and practice teaching) during their undergraduate education and are expected to use the same science textbook provided by the National Ministry of Education across the country. Therefore, this might lead to pre-service teachers' knowledge of curriculum to be less susceptible to personal and extra-personal factors, which is compatible with the studies indicating that new teachers' instruction is often guided by curriculum in countries with standardized national curriculum (Luft et al., 2015; Navy et al., 2018).

Third, the effect of filters and amplifiers on PCK components is idiosyncratic. Differences evidenced in the data are the kinds of

factors influencing PCK components (e.g., personal and extra-personal factors concurrently were influential on Mustafa's KOL, KOA, and KOIS whereas their impact existed only on Cansu's KOIS) and the way personal and extra-personal factors affect the degree of integration among components (e.g., the type of interactions that decreased, increased, or stayed stable differed in participants' PCK). This finding is not only in line with the empirical evidence revealing idiosyncratic nature of teachers' PCK (Akın and Uzuntiryaki-Kondakçı, 2018; Aydın et al., 2015; Park and Chen, 2012) but also might be explained by the idiosyncratic nature. Although participants were similar in terms of their education, teaching experiences, and the classes they practiced teaching human and environment unit, person specific (van Driel and Berry, 2012), topic specific (Carlson and Daehler, 2019), and concept specific (Carlson and Daehler, 2019) nature of PCK might explain the differences in the way filters and amplifiers impacted PCK. Another reason regarding differences might be related to differences in participants' subject matter knowledge (Şen et al., 2018; Park and Oliver, 2008), which is a fundamental knowledge base forming PCK (Carlson and Daehler, 2019; Shulman, 1986).

Finally, the more (or the less) the map is integrated the less (or the more) amplifier and filter influence the PCK. Data revealed that Cansu's pre- and post-PCK maps were more integrated than Mustafa's whereas the lesser number of filters (14) and amplifiers (four) affected Cansu's PCK when compared filters (29) and amplifiers (nine) influencing Mustafa's PCK. This finding might be attributed to the fact that integration among PCK components leads to a robust PCK (Friedrichsen et al., 2009; Magnusson et al., 1999; Park and Chen, 2012). Although PCK has been inevitably influenced by numerous factors stemming from teachers (e.g., Akın and Uzuntiryaki-Kondakçı, 2018; Aydın and Boz, 2012; Bartos et al., 2014), students (e.g., Aydın et al., 2010), and context (e.g., Barnett and Hodson, 2001; Bartos et al., 2014), the finding of this study revealed that an integrated PCK is more robust to personal and extra personal factors.

CONCLUSIONS AND IMPLICATIONS

The study has valuable implications for science teacher educators. This study suggested that pre-service teachers' PCK are affected by extra-personal factors more than personal ones during their initial teaching. This effect is most evident on KOIS. This effect might be minimized through purposeful inclusion of personal and extra-personal factors in teacher education courses. Science teaching methods, school experience, and practicum courses could provide fruitful contexts for science teacher educators where they could both help pre-service teachers in increasing their KOIS and engage in reflective activities in adjusting their instructional strategies in the presence of personal and extra-personal factors in a way to support students' learning. For instance, science teacher educators could prepare scenarios for various types of filters that might mediate instructional strategies, ask pre-service science teachers how they act if they encounter these kinds

of scenarios, and lead the discussion on how to eliminate those filters during instruction in a way to support students' learning with the use of effective instructional strategies. The study also showed that pre-service teachers with richer PCK (i.e., more integrated PCK map) are less affected by factors. Therefore, science teacher educators should also stimulate the integration among PCK components in the courses such as science teaching methods and practicum by explicit and reflective inclusion of PCK framework through several ways (e.g., mentoring, topic-specific training, and reflection, see examples for Aydın et al., 2013 and Aydın-Günbatır and Akın, 2022). Pre-service teachers with more integrated PCK might be more successful in eliminating the filtering effect of personal and extra-personal factors and hence they develop more robust PCK, which supports students' understanding of science concepts.

Based on the available data and methodology used in this study, we could provide important suggestions for science education researchers. First, this study has been one of the first attempts revealing how personal and extra-personal factors amplify and filter PCK components. We utilized a revised PCK mapping approach by including how personal and extra-personal factors affect each PCK component, which compensates for the limitation PCK mapping approach (Park and Chen, 2012) ignoring contextual factors (Park and Suh, 2019).

Our study supported the applicability of this mapping approach. However, the approach needs further evidence for its fruitfulness and therefore, science teacher education researchers might utilize the factors-integrated PCK mapping approach to investigate how amplifiers and filters as personal and extra-personal impact pre- and in-service teachers' PCK for different science topics. Second, there were several instances where participants had difficulty in providing clear explanation of how a factor influenced a specific PCK component. Researchers investigating factors influencing PCK should provide more specific tools such as lesson evaluation and reflection forms (Henze and Barendsen, 2019) that include explicit questions directing toward the effect of a particular factor on both a single PCK component and interaction among PCK components.

Limitations

The study has two main limitations in terms of generalizability and data analysis. Firstly, our results regarding pre-service teachers' PCK and factors affecting PCK cannot be generalized to all pre-service teachers. However, we still believe that pre-service teachers working in similar context can benefit from the findings of this study. More importantly, the purpose of this case study was not to generalize results. Rather, this was one of the early attempts to expand the framework of decision-making (Henze and Barendsen, 2019) to understand how personal and extra-personal factors amplify or filter PCK components using RCM (Carlson and Daehler, 2019). The second limitation of the study is common with most PCK studies examining interactions among PCK components. In these studies, it

usually is assumed that interactions among PCK components have equal strength, but it is not (Park and Chen, 2012). This limitation is also true for our data analysis.

Ethical Statement

Before the study, ethical permissions were taken from the Ministry of National Education Ethics Committee. Then, we got permission from the school principals and class teacher to conduct this research. School principals allowed us to conduct this research, but they did not allow us to use video recordings. All rights of participating teacher were protected. Moreover, this study met the ethics/human subject requirements of university at the time the data were collected.

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