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ORIGINAL ARTICLE

Do Pre-service Chemistry Teachers' Collective Pedagogical Content Knowledge Regarding Solubility Concepts Enhance after Participating in a Microteaching Lesson Study?

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ABSTRACT

The purpose of this study was to investigate the influence of a microteaching lesson study on pre-service chemistry teachers' collective pedagogical content knowledge (PCK) regarding solubility concepts. Three pre-service chemistry teachers participated in this study. Data were collected by means of lesson plans, semi-structured interviews, observations, and field notes. Results indicated that participants' PCK shows uneven development in terms of its components. Specifically, pre-service chemistry teachers' collective PCK was developed in all subcomponents with respect to the knowledge of instructional strategies component whereas only in some of the subcomponents with respect to the knowledge of curriculum, learner, and assessment. Time of assessment, knowledge of students' alternative conceptions, and knowledge of the goals and objectives of the curriculum were the subcomponents changed in terms of knowledge of assessment, knowledge of learner, and knowledge of curriculum, respectively. Reflection on action, content knowledge, pedagogical knowledge, and previous experiences of participants were determined as factors influencing their collective PCK development. The present study has several implications for teacher educators.

KEY WORDS: collective pedagogical content knowledge; microteaching lesson study; pre-service chemistry teachers

INTRODUCTION

It is important to support pre-service teachers' professional development in teacher education programs since well-educated pre-service teachers will apply effective teaching in their future classes and this will positively influence the education of their future students. Pedagogical content knowledge (PCK), one of the important constructs in teacher education, has been linked to effective science teaching (Magnusson et al., 1999). Therefore, teacher education programs should promote pre-service teachers' PCK. PCK was described by Shulman (1987) 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). PCK is the type of knowledge that distinguishes a science teacher from a subject matter specialist (Magnusson et al., 1999). One of the strategies used to enhance pre-service teachers' PCK is microteaching (Kartal et al., 2017). In this research, the microteaching strategy was unified with an instructional method, i.e., lesson study. Within the microteaching lesson study (MTLS) context, pre-service chemistry teachers jointly plan a lesson, taught the planned lesson in front of their classmates from their College of Education, reflected on the taught lesson, and revised it (Fernandez, 2005). In other words, participants took advantage of both microteaching and lesson study through being involved in a collective work in real classroom context. Few research studies have been conducted in the science education literature to explore the impact of MTLS on the development of pre-service teachers' PCK (e.g., Bahçıvan, 2017). Correspondingly, this study focused on the influence of MTLS on pre-service chemistry teachers' collective PCK regarding solubility concepts.

Theoretical Framework

PCK

Shulman (1986) stated three types of content knowledge, which were subject matter content knowledge, PCK, and curricular knowledge. PCK included two features which were the knowledge of instructional strategies and the knowledge of students. While the former category of knowledge involves "… the ways of representing and formulating the subject that make it comprehensible to others," the latter involved "an understanding of what makes the learning of specific concepts easy or difficult: The conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning" (Shulman, 1986. p. 9).

In his second paper about PCK, Shulman (1987) suggested it as one of the categories of teacher's knowledge base and defined it as "represents 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

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abilities of learners, and presented for instruction" (Shulman, 1987. p. 8). Shulman took a transformative view of PCK, that is, he considered PCK as separate knowledge and viewed it as knowledge that is formed through the transformation of content knowledge, pedagogical knowledge, and contextual knowledge.

Based on Shulman's suggestions, other researchers proposed various PCK models (e.g., Tamir, 1988; Grossman, 1990; Marks, 1990; Cochran et al., 1993; Fernández-Balboa and Stiehl, 1995; Magnusson et al., 1999; Park and Oliver, 2008; Gess-Newsome, 2015; Carlson and Daehler, 2019). The PCK model, offered as a result of the 2012 PCK summit, reflects various international researchers' consensual views on PCK in the field of science education. According to this model (Figure 1), the model of teacher professional knowledge and skill (TPK&S), there are teacher professional knowledge bases, involves assessment knowledge, pedagogical knowledge, content knowledge, knowledge of students, and curricular knowledge (Gess-Newsome, 2015). These knowledge bases are general, not specific to a topic and they influence and are influenced by TSPK. TSPK, as its name implies, is topic-specific and it involves understanding of students' misconceptions, difficulties with respect to that specific topic, selection of suitable instructional strategies to teach that particular topic, and awareness of how to link the topic with other disciplines and other concepts. As Gess-Newsome (2015) noted, we could find the appearance of TSPK in the content representations (CoRes) developed by Loughran et al. (2004). TSPK is canonical; however, PCK is related to classroom practice and it is private, personal, and held by an individual. Personal PCK and PCK and skill (PCK&S) were explained in terms of reflection in action and reflection on action (Schön, 1987). The former refers to reflection on action. We could explore teachers' personal PCK by understanding their reasoning of their instructional decisions. The latter, on the other hand, refers to reflection in action and involves reflecting during teaching. It is dynamic and teachers need to make some decisions about their instruction during the act of teaching after reflecting in action.

The most recent model in the context of science education is the refined consensus model (RCM) which is a result of the 2nd PCK summit in 2016 in Leiden, the Netherlands (Carlson and Daehler, 2019). According to the RCM (Figure 2), there are three types of PCK; collective PCK (cPCK), personal PCK (pPCK), and enacted PCK (ePCK). The outer layer consists of professional knowledge bases, i.e., content knowledge, pedagogical knowledge, knowledge of students, curricular knowledge, and assessment knowledge. These knowledge bases are general and transformed into distinct realms of PCK. In that sense, it can be readily acknowledged that the RCM of PCK takes the transformative views of PCK (Tepner and Sumfleth, 2019). The first layer coming inside professional knowledge bases is the cPCK. cPCK is not private knowledge. It is the knowledge held collectively by a group of teachers to teach a particular concept to particular students. To illustrate, cPCK can be found in a CoRe prepared by a group of teachers. There is also the knowledge exchanged between professional knowledge bases and cPCK. Another type of PCK, pPCK involves "a teacher's personal knowledge and unique expertise about teaching a given subject area, resulting

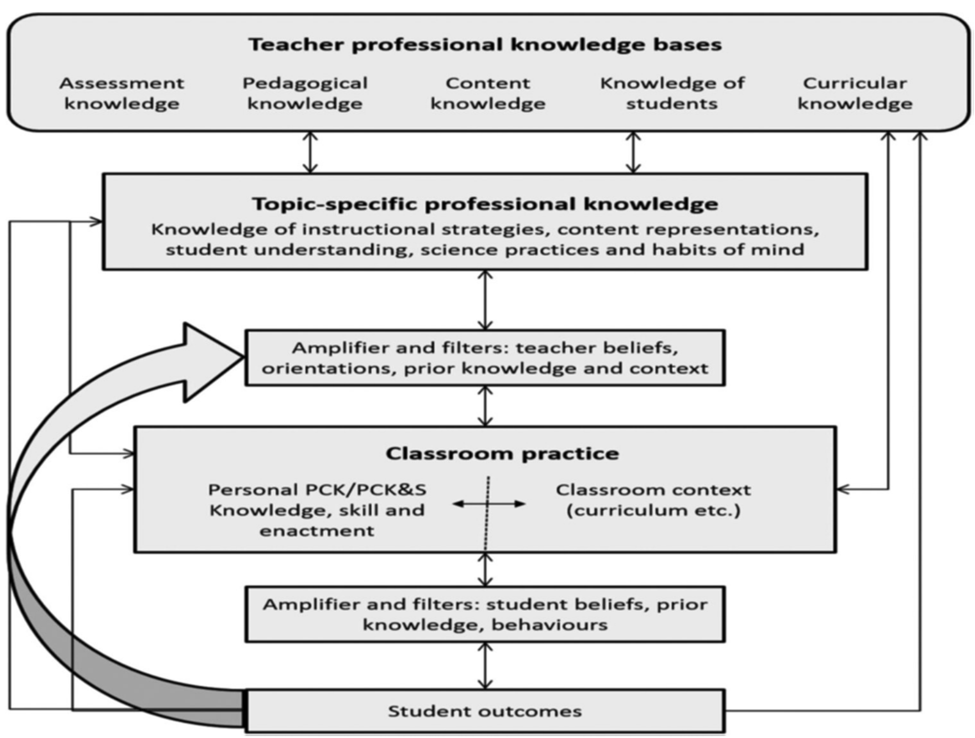

Figure 1: Teacher professional knowledge and skill model (Taken from Gess-Newsome, 2015. p. 31)

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from the cumulative experiences with and contributions from students, peers, and others" (Carlsen and Daehler, 2019, p. 86). When a teacher uses some of the knowledge and skills from his/her pPCK, ePCK, a subset of pPCK comes into action. In the RCM, there is knowledge exchange among each PCK type. Through certain features (e.g., the dynamic nature and uniqueness), ePCK has potential to explain other attributes of the RCM of PCK that is the learning context (LC) and pedagogical reasoning (PR), both of which function as a filter or amplifier between distinct realms.

How Microteaching Lesson Study Can Help to Enhance Pre-service Teachers' PCK?

Lesson study is an approach originally used by Japanese teachers as a professional development tool to enhance the effectiveness of their instruction (Fernandez and Yoshida, 2004). In the lesson study, (1) a group of teachers meet together to determine the goal of the lesson and make a lesson plan with respect to these goals; (2) one of the teachers in the group teaches the lesson and the other teachers in the group observe the taught lesson; (3) the group comes together and they collaboratively reflect on the taught lesson. The lesson study may end at this point. However, another cycle may begin by (4) revising the taught lesson and planning the second research lesson (this step is optional); (5) teaching the second research lesson and observation of this lesson by other teachers (this step is optional); and (6) reflecting on the second research lesson. Similarly, teachers may collectively plan the third research lesson and conduct the lesson by following the same steps (Fernandez and Yoshida, 2004; Lewis et al., 2006).

Lesson study has been reported to enhance teachers' PCK (Lucenario et al., 2016; Dudley, 2013; Juhler, 2016). MTLS involves characteristics of microteaching and lesson study. MTLS differs from microteaching study in that it promotes group work and gives the opportunity for pre-service teachers to engage in a cooperative learning environment where pre-service teachers mutually plan the lesson, conduct the lesson, reflect on the taught lesson, and revise it (Fernandez, 2005). Few research studies have been conducted about the influence of MTLS on pre-service teachers' PCK in the context of mathematics (Fernandez, 2005; 2010) and science (Bahçıvan, 2017). The present study would contribute to the related literature since it would evaluate the impact of MTLS on pre-service chemistry teachers' development of cPCK with respect to the solubility concepts, thereby give suggestions about the use of MTLS in teacher education programs (Figure 3).

Solubility Concepts

Mixtures, a chemistry topic that covers solubility concepts, are taught in both the elementary and secondary school curriculum. The content of mixtures involves nature of mixtures, dissolution process, types of solutions (saturated, unsaturated, supersaturated, diluted, and concentrated solutions), factors affecting solubility (temperature, pressure, surface area of solute, stirring, and amount of solute), colligative properties of solutions (boiling point, freezing point, mass, and density),

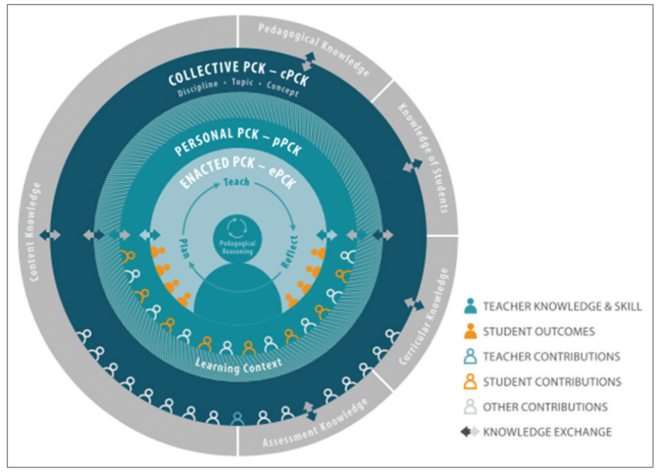

Figure 2: Refined consensus model (Taken from Carlson and Daehler, 2019, p. 83)

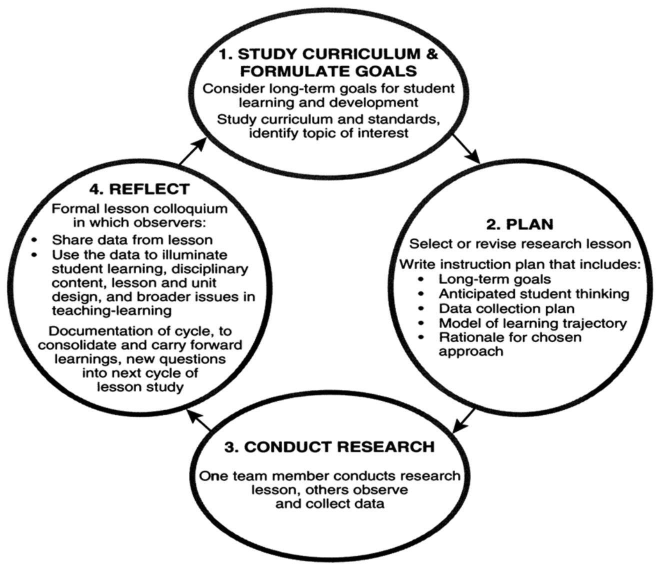

Figure 3: Lesson study cycle (Taken from Lewis et al., 2006, p. 4)

and separation of mixtures. For the current study, we explored pre-service chemistry teachers' development of cPCK with respect to the types of solutions (saturated, unsaturated, supersaturated, diluted, and concentrated solutions).

Solubility concepts are often one of the chemistry concepts that students at all levels find difficult to understand. To illustrate, regarding types of solutions (unsaturated, saturated, supersaturated, diluted, and concentrated), Pınarbaşı and Canpolat (2003) examined undergraduate students' ideas about the microscopic representation of unsaturated, saturated, and supersaturated solutions. They concluded that undergraduate students believed that undissolved solute is a component of solution and supersaturated solutions contain undissolved solute at the bottom of the beaker. Similarly, Pınarbaşı et al. (2006) confirmed these alternative conceptions held by undergraduate students. Özden (2009) stated that pre-service science teachers thought saturated solutions as always being concentrated and unsaturated solutions as always being diluted.

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Similar to the above studies, undergraduate students were selected as participants of this research while investigating the impact of MTLS on the development of cPCK.

Research questions of the present study are as follows:

- What is the impact of MTLS on pre-service chemistry teachers' development of cPCK regarding solubility concepts?
- Which factors influence the development of pre-service chemistry teachers' cPCK regarding solubility concepts?

METHODOLOGY

Sample

Before conducting the study, we obtained permission from the ethics committee of the first author's university. Although there were 13 pre-service teachers enrolled to the "School Experience in Science Education" course, three pre-service chemistry teachers (Deniz, Derya, and Beril) participated in this study voluntarily. They were all 21 years old. Each of them had signed consent form to be a participant of this research. To protect confidentiality, pseudonyms were used. All of them were female. Deniz cumulative grade point average (CGPA) was 3.03 (out of 4.00) while CGPAs of Derya and Beril were 2.54 and 2.48, respectively. All of them were interested in classes and they were eager to learn and participate in class discussions. They were studying in their 4th year of their 5-year chemistry teacher education program. They completed most of the subject matter courses (i.e., General Chemistry I and II, Analytical Chemistry) and took some of the educational courses (i.e., Introduction to Education, Educational Psychology, Curriculum Development in Science Education, and Methods of Science Teaching I). At the time of the study, they were taking Methods of Science Teaching II, Assessment and Evaluation in Science Education, Instructional Technology and Material Development courses, and School Experience in Science Education courses. The present study was conducted in the School Experience course.

Context of the Study: School Experience Course

The aim of this course was to help students better understand the teaching profession, class, and school environment. For this course, pre-service chemistry teachers were placed at high schools for 4 h a week for 10 weeks in a semester. They had five activities to complete. The first three activities were mainly about reporting their observations of chemistry teachers' instruction at high schools in terms of classroom management, teaching methods, questioning, and explanations. To complete these observations, they had checklists to complete. In the fourth activity, pre-service chemistry teachers evaluated their mentors' PCK for an hour of class instruction. In the last activity, they carried out group work with students at high schools and reflected on the group work.

As well as placements in high schools, pre-service teachers attend one class hour at the university for 14 weeks. In this session, pre-service chemistry teachers performed microteaching about chemistry topics. Lesson study was employed during the performance of microteaching. To do this, we formed groups, each group involved two or three pre-service chemistry teachers, and each group had one chemistry topic to teach. They decided on their own topics. They conducted a lesson lasting approximately 30 min. While pre-service teachers taught the topic, their peers in class acted as high school students. To clarify, they asked and answered the questions by thinking how high school students would ask and answer. After the instruction, their classmates and the instructor evaluated the effectiveness of the instruction. As this was an MTLS, the three participating pre-service chemistry teachers prepared a lesson plan as a group and then one of them taught the topic. After reflection on the first instruction, they modified the lesson plan and a second pre-service teacher taught the same topic. After the evaluation of the effectiveness of the second instruction, they prepared a third variation of the lesson plan and the last person in the group taught the topic. As a result, they prepared three lesson plans and conducted three instructions for the same topic.

Instruments

Data were collected by means of lesson plans, semi-structured interviews, observations, and field notes.

Lesson Plans

Pre-service chemistry teachers prepared lesson plans before instruction. In the lesson plan, we used some of the prompts (e.g., "What prerequisite knowledge, difficulties, and misconceptions do students typically have about each concept?," "Which teaching strategy and what specific activities might be useful for helping students develop an understanding of the concept?," and "In what ways would you assess students' understanding or confusion about this concept?") from the content representation (CoRe) developed by Loughran et al. (2004). In the lesson plan, pre-service teachers wrote general and specific objectives, pre-requisite knowledge required to understand the types of solutions (unsaturated, saturated, supersaturated, diluted, and concentrated solutions), students' difficulties, misconceptions, their teaching strategy and teaching activities, presentation of the topic integrated with objectives, teaching aids and teaching strategies and their assessment and evaluation techniques. The participating pre-service teachers collaboratively prepared the three lesson plans before each instruction.

Semi-structured Interviews

The first author of the study conducted the interviews with the participating group of pre-service chemistry teachers. As Patton (2002) states, there is an interaction among participants in a group interview because participants in a group listen to each other's answers and in some cases, they may not agree with them and they may comment on each other responses. Since pre-service teachers prepared lesson plans as a group and we wanted to obtain the group's opinions, we decided to conduct group interviews.

After the pre-service chemistry teachers prepared the 1st lesson plan, but before the 1st instruction, we conducted a

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group interview with them to understand their thoughts and reasoning in details about what was written in their lesson plan. We asked several in-depth questions to elicit their PCK. For example, they wrote in their lesson plan that they would have students play a game. In the interviews, we asked why did you choose that game? Can you describe the game in details? Other interview question examples were “Why did you choose conceptual change as a strategy?” and “What were the students’ difficulties and misconceptions regarding the types of solutions?” They taught the topic 3 times. After they prepared their last (third) lesson plan and completed their last (third) lesson, we conducted another group interview with them to understand their PCK and the change in their PCK. Similar questions like the ones in the first interview were asked. Some of the question examples “why did you choose 5E as a strategy?,” “What made you change your mind?,” “Why did you use that simulation,” etc.

Observation and Field Notes

Each pre-service chemistry teacher in the group taught the solubility concepts to their peers. Their instruction was videotaped and observed by the first author of the study. Some field notes were taken during the observation. After observation, the participating pre-service chemistry teachers’ reflections on their instruction were obtained in a group interview format. Before the reflections, participants watched the videotaped instruction and after watching the video, these pre-service chemistry teachers came together to reflect on the instruction. During the interview, the researcher asked several questions to facilitate the pre-service teachers’ reflection on their instruction. For example, what went well during your instruction, what are the things you need to change for the next instruction, why did you make that explanation, etc. There were three reflections made on the instruction.

Data Analysis

Pre-service chemistry teachers’ collective PCK was assessed by the lesson plans they made. Responses given to the lesson plan were analyzed deductively. To clarify, they were categorized under four categories, which were knowledge of learner, knowledge of curriculum, knowledge of assessment, and knowledge of instructional strategies. These were the components based on the Magnusson et al.’s (1999) PCK model. Some codes considering Magnusson et al.’s (1999) model were determined under each category. For example, pre-requisite knowledge, learner’s difficulties, and misconceptions were the codes used to categorize pre-service teachers’ responses under knowledge of learner category. Under the knowledge of curriculum category, knowledge of the goals and objectives of the curriculum and link the topic with other disciplines were the codes that were used to analyze the data. Subject-specific and topic-specific strategies were the codes of knowledge of instructional strategies category. Finally, what to assess and how to assess were the codes of knowledge of assessment category used to analyze the data. For the reliability, according to these codes, the first author of the study analyzed the data. Next, the codes were given to the second author and she formed categories by considering these codes. Afterward, these two categories were compared and there was a complete match between the categories.

RESULTS

Knowledge of Learner

With respect to the students’ difficulties of understanding the unsaturated, saturated, supersaturated solutions, diluted, and concentrated solutions, these pre-service chemistry teachers’ collective PCK did not change. In the first, second, and third lesson plans, the pre-service chemistry teachers mentioned that both lack of students’ pre-requisite knowledge (particulate and void structure of matter, intermolecular forces, concept of solubility, and dissolution concepts) and misconceptions about these pre-requisite concepts may cause students to have difficulty in understanding the unsaturated, saturated, and supersaturated solutions.

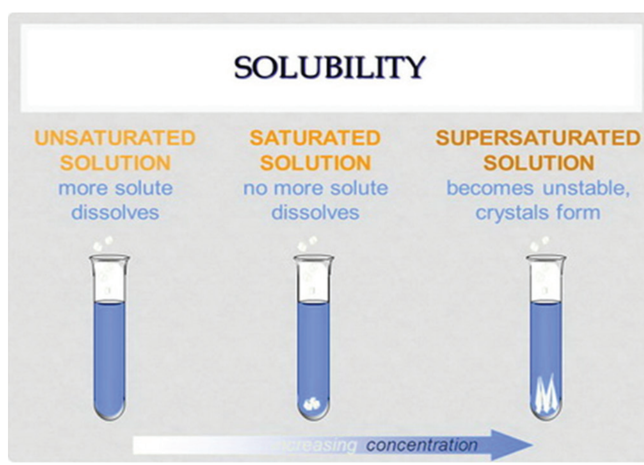
In terms of students’ alternative conceptions, their collective PCK enhanced. In their first lesson plan, they mentioned many alternative conceptions; students may have about unsaturated, saturated, supersaturated solutions, diluted, and concentrated solutions. In the first interview, they stated that they found these alternative conceptions by searching the related literature. Some of these alternative conceptions are as follows:

- If there is solid at the bottom of the beaker, students always think that it is supersaturated solution
- The dissolution is a chemical change
- Solid disappears/melts/evaporates during dissolution

In their last lesson plan, they added another alternative conception which is “unsaturated solutions are diluted while supersaturated solutions are concentrated.” For the reflection on Deniz instruction, the researchers wanted these pre-service teachers to evaluate the illustrations used in class critically:

Researcher: How were the illustrations (figures, tables)? Do you think that they may have caused any alternative conception?

Deniz: I just used a figure (taken from https://www.quora.com/What-are-the-different-types-of-solubility) in the summary of the class.



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I tried to summarize the unsaturated, saturated, and supersaturated solutions by linking the amount of the solutes in a solution. The concentration increases as the solution becomes supersaturated. I just realized that now. This figure may cause misconception. Although the figure is not incorrect, students may generalize and think that all supersaturated solutions are concentrated while all unsaturated solutions are diluted (reflection session 1).

Derya: Students may think that all supersaturated solutions are concentrated while all unsaturated solutions are diluted. We should also emphasize this alternative conception in our next class (reflection session 1)

Giving pre-service teachers, the opportunity to evaluate the illustrations used in the first class in terms of the alternative conception may have helped these pre-service teachers identify new alternative conception students may have regarding solubility concepts. We could infer that reflecting on the class, which is one of the phases of MTLS, caused the extension of collective PCK.

After reflecting on their second lesson, they decided to make the topic more relevant to students' daily life:

> I think that explanation of making jam may be a good example to link saturated, unsaturated, and supersaturated solutions with daily life. We should make students compare what would happen when we put the jam in the fridge to allow it cool slowly and what would happen when we put it in the deep freezer to make it cool rapidly (reflection session 2).

After these evaluations, in the class, Derya showed the picture of the crystallized jam to the students and asked how crystallized jam occurs and what type of solution it is. After the lesson, when asked the reason of using the jam as an example:

> We stated that when the crystalline form of the jam occurs, it means that the solution is saturated. We did not emphasize that in the first and second lessons. Most students may think that when crystalline formed, the solution was supersaturated solution. Therefore, in our last lesson, we tried to emphasize that when the crystalline form of the jam occurs, the solution was saturated not supersaturated not to cause that alternative conception.

Derya strategy to address the alternative conceptions was just to tell the students the scientifically accepted conception. However, this is a very simplistic approach to avoid students' alternative conceptions.

Knowledge of Curriculum

These pre-service chemistry teachers' collective PCK regarding curriculum enhanced by the end of the MTLS. In the first lesson plan, these pre-service teachers stated five general objectives and eight specific objectives. In the first interview, we asked how they came up with these objectives, Deniz stated that they felt the need to write objectives themselves because there was only one objective related to the topic in the curriculum "In the curriculum, there was only one objective that was, students know supersaturated, unsaturated, saturated, diluted, and concentrated solutions. We found it too general and inadequate; therefore, we elaborated on that objective." While writing the objectives for the first class, they paid attention to include objectives at different cognitive levels:

> We tried to include objectives with different cognitive levels. For example, the specific objectives were at the knowledge, comprehension, analysis, and synthesis levels. We asked students to set up an experiment about the diluted and concentrated solutions. Moreover, we wanted students to be able to identify the types of solutions given the particular representation of them.

Although they continued with the same objectives for the second lesson, for the last lesson, they added two more objectives to the already written objectives from the first lesson. One of them was that students will explain the simulation about the solubility. In the interview, when asked the reason of using that simulation (https://phet.colorado.edu/en/simulation/legacy/soluble-salts), Derya stated that simulation was useful for explaining dynamic equilibrium "It is important to visualize the event in the microlevel. We see the macrolevel we know the jam from daily life but we cannot visualize what happens inside it. The aim of the simulation was two-fold; to show the dynamic equilibrium and to show that there is not any chemical reaction going on."

When we asked whether it is necessary to involve the dynamic equilibrium concept in the dissolution process, Derya stated that dynamic equilibrium was an important concept that needed to be mentioned at the dissolution process:

> There is equilibrium at the saturated solutions and this equilibrium is dynamic. Equilibrium is thought as static. Think about the seesaw. When it is at the equilibrium, it is constant and it stops. However, in chemistry, the reaction does not stop at equilibrium. It is dynamic. It is important to mention this dynamic equilibrium at the saturated solutions. The dissolution process does not stop.

From the above statements, we could infer that these pre-service teachers' content knowledge had an influence in shaping their collective PCK regarding knowledge of the curriculum.

Another objective that they decided to include in the third lesson was that students would be able to discuss saturated, unsaturated, and supersaturated solution (Figure 4).

By referring the above graph, Derya asked students in the class whether the graph was correct or not. We asked them why they included this objective in their lesson, they stated that it was important to interpret the graph and understand the types of solutions on the graph. They also stated that instructors used the same graph in the "Laboratory Experiments in Science Education" course. Their previous experiences in their own teacher education program had influenced choosing this objective, their collective PCK:

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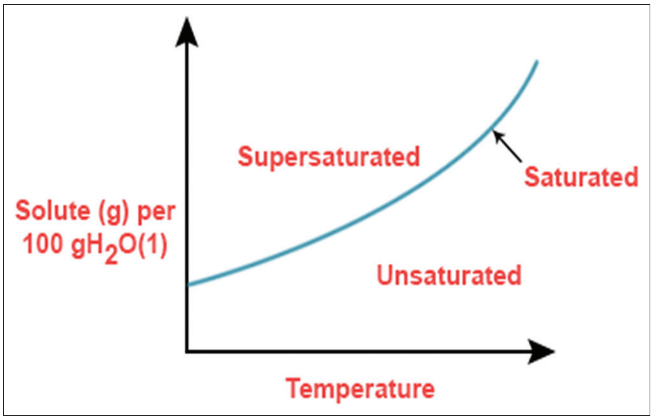

Figure 4: Solubility curve

> This graph was used in our course. We discussed it in that course whether it is wrong or not. It should be interpreted correctly. I think it is a good graph to explain the supersaturated solutions.

During the class, students discussed whether the graph was correct or not. Derya gave students a hint by wanting them to take a constant temperature and then increase the mass of solute.

> Derya: What happens when you increase the mass of solute, say at temperature 20°C. First, take 15 g solute at 20°C. Let's look at the graph. It is unsaturated solution according to the graph. Again at the same temperature take 25 g solute. Let's look at the graph. Now, it is a saturated solution. What happens when I increase the mass of solute to 40 g solute at 20°C. According to the graph, it becomes supersaturated solution. Is it true?

Some students reported that the solution was now supersaturated since it involved more solute than it can dissolve. However, some students claimed that it was not correct. They stated that the solution was still a saturated solution with 40 g solute at 20°C and it had undissolved solute. Derya emphasized that, for a supersaturated solution, the temperature needs to be increased so that it will be able to dissolve more solute and then temperature should be decreased. At a point, the solution is supersaturated which is unstable.

When asked whether they linked the topic with other disciplines such as biology and physics, they stated that they did not link the topic with other disciplines in the second and third lesson. However, Deniz stated that the solubility of sugar increased with increase in temperature and she linked this with physics in the first lesson when a student in class asked a question:

> S: Does solubility increase whether dissolution is exothermic or endothermic?

> D: Yes, it does not matter whether the dissolution is exothermic and endothermic. Solubility always increases with temperature because kinetic energy of particles increases with temperature increase and number of collisions increases.

Deniz lack of content knowledge caused her to give a wrong explanation to the question one of the students in class asked.

Knowledge of Instructional Strategies

With respect to the instructional strategy and activities, in their lesson plan for the first lesson, they mentioned that they would use conceptual change strategy. When we asked the reason for using conceptual change strategy, they replied that they decided the strategy by considering the nature of the topic:

> Students have lots of alternative conceptions about this topic. Even we as university students had misconceptions regarding this topic. We realized those in the "Laboratory Experiments in Science Education" course. Therefore, we thought that those misconceptions should be eliminated. Therefore, we tried to remedy students' misconceptions step by step by the conceptual change strategy.

In the second lesson, Beril complained that she found it very hard to put what she would teach in order "While planning the instruction, the organization of the lesson was very hard for me. I could not decide the order of my instruction easily."

In their lesson plan for the last lesson, they mentioned that they would use 5E (Trowbridge et al., 2000) as an instructional strategy. They stated three reasons for choosing 5E in their last lesson. First, they mentioned that their lack of knowledge of 5E learning cycle as an instructional strategy at the beginning prevented them to use it in their first lesson "At first, we did not know 5E well but now we know how to implement it. It is a good strategy to eliminate students' misconceptions. We can also use 5E in order to remedy misconceptions." Second, the reason for why they choose 5E was that it provided a pathway for instruction. "We found it very hard to put the instruction in order in the planning stage. However, 5E has some steps and these steps provide a route for instruction and make us order what we will teach easier." Finally, they believed that it enhanced students' motivation and curiosity "It is a good way to enhance students' motivation. I believe students learn better because it increases curiosity at the beginning. After a while, we returned to the questions we asked at the beginning. Therefore, learning process was complete."

The above statements show that as these pre-service teachers become more knowledgeable about instructional strategies and characteristics, their preferences to choose the strategies to teach a chemistry topic may change. Growth in their pedagogical knowledge, which is one of the teacher professional knowledge bases, influenced their choice of the instructional strategy to teach a specific chemistry topic, their collective PCK.

Pre-service chemistry teachers' collective PCK regarding the instructional strategies enhanced at the end of the MTLS because they enriched their topic-specific strategies to teach the topic. As topic-specific strategies, at the first lesson, they stated that they would use a simulation about the concentrated and diluted solutions (https://phet.colorado.edu/en/simulation/concentration), an experiment related to unsaturated, saturated, and supersaturated solutions and a game about microlevel representation of the particles of unsaturated, saturated, and supersaturated solutions.

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At the beginning of the first lesson, Deniz explained the differences between dilute and concentrated solutions using sour cherry juice. She prepared three sour cherry juice solutions before coming to class. During the class, she showed a solution of sour cherry juice and wanted the other pre-service teachers to estimate whether it was diluted or concentrated. The pre-service teachers told her that it was impossible to determine without any reference. Then, she showed two solutions and wanted to decide whether it was diluted or concentrated. Afterward, she solved the problem using the formula, $M_1*V_1 = M_2*V_2$. She also explained how to make a solution more concentrated or more diluted using the simulation above. Afterward, she asked the definition of solubility after taking opinions of students, she explained the solubility. Then, students formed groups to play the game using the cartoons related to sodium chloride ions and water molecules. Next, she returned to the simulation (https://phet.colorado.edu/en/simulation/concentration) and explained that the solution comes to saturation after a certain amount of solute has been added.

Afterward, she wanted students to conduct an experiment in groups. The experiment was about the preparation of unsaturated, saturated, and supersaturated solutions of the sodium thiosulfate. First, they prepared an unsaturated solution. To do this, they put a few crystals of sodium thiosulfate in a test tube filled with 2 ml of water, stirred it, and saw that all the crystals were dissolved. Then, they put more sodium thiosulfate into the test tube, stirred it until no more sodium thiosulfate could be dissolved. At that time, the solution became saturated. To prepare a supersaturated solution, the solution was heated until a total of 15 g of sodium thiosulfate had been dissolved and after that, the solution was allowed to cool by putting it in a beaker of cold water. At this point, the solution was supersaturated. Then, dropping a few crystals of sodium thiosulfate into the test tube results in crystallization occurring.

Deniz taught the concepts of saturated, unsaturated, and supersaturated concepts by means of this experiment. Students worked in groups to conduct the experiment. Deniz continuously asked questions to the students about the types of solutions. Although, after the experiment, they planned a game about the microlevel representation of particles about the unsaturated, saturated, and supersaturated solutions before class, Deniz did not include that game in her instruction. Therefore, in the second lesson, they decided to use the experiment as a demonstration "I think the experiment caused distraction in class. It caused a lot of classroom management problems. We think that in order to cause less distraction, we should include the experiment as demonstration in the second class (reflection session 1)." After this reflection, they included the experiment as a demonstration in their lesson plan for the second class. This is an evidence for the influence of reflection on class on the development of collective PCK.

For the third lesson, they used 5E learning cycle model and differently from the first lesson, they gave importance to link the topic with daily life, microlevel representation of particles of unsaturated, saturated, and supersaturated solutions, graph interpretation, and dynamic equilibrium at saturated solutions.

At the beginning of the class, Derya stated today's topic and then she showed a picture of strawberry jam asking a question about how to make a strawberry jam, the ingredients of the jam. After getting the students' responses, she asked several questions with respect to the four conditions of jam making. The first condition was about the mixture containing undissolved sugar in it before heating the jam. The second condition was related to the homogenous mixture containing all the dissolved sugar before heating the jam. The third condition was about after keeping the heated jam wait at room temperature. The fourth condition was related to the after keeping the heated jam wait in the fridge. With respect to these four conditions, Derya asked students whether or not the solution was saturated, unsaturated, and supersaturated and wanted students to explain their reasons. They gave different responses and reasons for these conditions. Derya told students to keep their responses in their mind and stated that they will return back to these later in class. This was the engagement stage of 5E. Afterward, she asked students what diluted and concentrated solutions meant and how they decided whether a solution was concentrated or diluted. She showed three pictures of ink solutions with differing concentration and asked which one(s) was diluted or concentrated.

At the explore phase, Derya gave students three problems and wanted them to discuss it with their friends and explain their reasoning. The first problem was about the microlevel representation of particles of unsaturated, saturated, and supersaturated solutions and given below (Figure 5), students were to label the solutions as saturated, unsaturated, and supersaturated solutions.

The second problem was about the graph interpretation (Figure 4), given the unsaturated, saturated, and supersaturated solutions in the graph, students were asked to interpret whether the graph was correct or not. The third problem was about finding out whether the solution was concentrated or diluted when three sugar solutions with differing concentration in 100 ml of water were given.

At the explain phase, Derya explained the definition of solubility, unsaturated, saturated, supersaturated, concentrated,

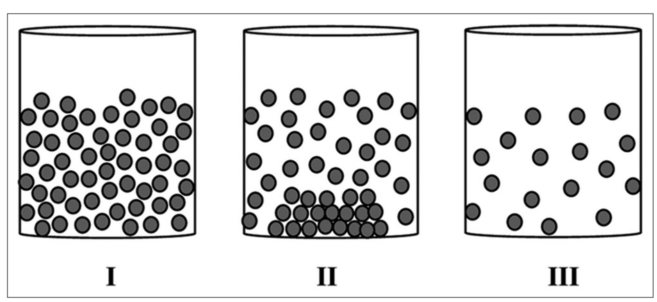

Figure 5: Microlevel representations of particles in unsaturated, saturated, and supersaturated solutions

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and diluted solutions. Afterward, she showed a simulation (https://phet.colorado.edu/en/simulation/concentration) regarding diluted and concentrated solutions. Using this simulation, she explained how to make a solution more diluted or more concentrated. Moreover, after a certain amount of solute has been added to the solution and when it cannot dissolve any more solute, the solution becomes saturated. She emphasized that even they continue to add more solute, the solution is still saturated. Afterward, she showed another simulation (https://phet.colorado.edu/en/simulation/soluble-salts) to explain unsaturated and saturated solutions and dynamic equilibrium at the saturated solutions.

At the elaborate phase, she returned to the four conditions of jam making and crystallized sugar and asked students questions, all the class discussed whether the solution is unsaturated, supersaturated, and saturated. Then, she gave an analogy. There is a bus that holds 25 people maximum. First, 20 people got on the bus and now the solution is unsaturated at this time. After a while, five more people get on the bus and now the bus holds 25 people. At that point, it is saturated. I stated that at the time of 25 people on the bus, five people will try to get on the bus when the driver opens the door and five people will get on the bus forcibly but after getting on, they will get off immediately. The time there are 30 people on the bus, it is supersaturated. However, this situation is temporary, it is unstable because these five people will get off the bus. One of the students asked: But, we said that to be a supersaturated solution, we need to increase temperature. Then, Derya explained "You are right. We should assume that when five more people got on the bus, the temperature has increased and more collisions occur."

For the evaluation phase, she gave a quiz to the students and she explained the homework to the students.

Knowledge of Assessment

Regarding pre-service chemistry teachers' collective PCK about assessment, after participation in the MTLS, only the time of assessment changed while methods used to assess students' understanding did not show any changes. In their first lesson plan, they stated that they would use formative assessment throughout the instruction to assess whether students understood what is taught during the class and they have misconceptions or not. They stated that feedback taken from the formative assessment could be a clue about their instruction in class. In case of necessity, they could revise their instruction. At the end of the class, they would give two homework tasks. One of them would involve different types of questions such as multiple choice, true/false, and open ended about the topic taught. The other was about setting up concentrated and diluted solutions using a material that could be found at home. Students would finish these assignments at home.

After participation in MTLS, only the time of assessment changed. Similar to the first and second lesson, though they used formative assessment throughout the instruction, and in the third lesson, they used one of the assignments, as a quiz during the class time rather than out of class time after finishing the topic. Hence, they used both formative and summative assessment in the last lesson. Similar to the first and second lesson, they used formative assessment to check students' understanding and their misconceptions. They explained the benefit of summative assessment:

> When you ask questions to the class, you can only check the understanding of the student who responds. However, there are also some silent students in class that do not participate in class. We cannot know the reason. Maybe the question is too easy for them or they do not understand at all. When you do a quiz, you can evaluate all students' responses. Another benefit of conducting the quiz in class rather than giving an assignment that needs to be made out of class time is that feedback can be given simultaneously after conducting the quiz in class. When you make a quiz in the class, you can distribute the quiz to each student and the quizzes can be read all together. And you can give feedback immediately. If you give it as homework, you give feedback 2 days later, then this affects students' learning and their motivation decreases.

In the last lesson, they also gave homework about setting up concentrated and diluted solutions using materials that could be found at home. We could state that MTLS did not enhance much regarding the development of pre-service chemistry teachers' knowledge of assessment.

DISCUSSION AND CONCLUSION

The present study aimed to investigate the impact of MTLS on the development of pre-service chemistry teachers' cPCK in the context of solubility concepts. Participants' cPCK was coded considering the four components of the Magnusson et al.'s (1999) PCK model for science teaching (i.e., knowledge of curriculum, knowledge of learner, knowledge of instructional strategies, and knowledge of assessment) and subcomponents of those. Many studies in science PCK do not involve "science teaching orientations (STOs)" component though they refer to Magnusson et al.'s (1999) model (Friedrichsen et al., 2010). For instance, Juhler (2016) examined pre-service physics teachers' PCK development using lesson study combined with CoRe by referring to Magnusson et al. (1999) model's four components. Similarly, Aydın et al. (2013) explored the effect of a practicum on pre-service chemistry teachers' PCK development by taking the four components of Magnusson et al.'s PCK model. When they have suggested STOs as a component of PCK, Magnusson et al. (1999) conceptualized it as an overarching component both influences and are influenced by other four components of PCK. In the TPK&S (Gess-Newsome, 2015) and RCM of PCK (Carlson and Daehler, 2019), on the other hand, orientations were regarded as a filter or an amplifier instead of a component of PCK. Since this research investigates cPCK, one of the recently suggested realms of PCK by the RCM of PCK, orientations were out of the scope.

In this section, results were discussed under the two research questions of the study. The impact of MTLS on

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participants' cPCK development and the factors influencing this development in the solubility concepts were discussed below, respectively.

The Influence of MTLS on Pre-service Teachers' cPCK

Regarding the impact of MTLS on pre-service chemistry teachers' cPCK, it was found that the intervention has not influenced all PCK components and subcomponents in the same manner. While some components of pre-service teachers' cPCK enhanced after participated in MTLS, some components did not show any improvement. In other words, growth in one component of PCK does not provide the development of other components in the same degree. Some PCK researchers have found uneven PCK development in terms of its components, as well (Henze et al., 2008; Magnusson et al., 1999). While, others asserted that their implication contributed to the development of all components of PCK (e.g. Aydın et al., 2013).

To conclude, it can be stated that pre-service chemistry teachers' cPCK was developed in its all subcomponents with respect to the knowledge of instructional strategies component whereas in their some subcomponents with respect to the knowledge of curriculum, learner, and assessment. Specifically, while methods used to assess students' understanding of solubility concepts did not show any changes, the time of assessment changed in terms of knowledge of assessment. Moreover, though pre-service teachers' knowledge of students' difficulties did not change, knowledge of students' alternative conceptions enhanced by the end of MTLS in terms of knowledge of learner. Furthermore, while participants' knowledge of the link with other disciplines did not show any improvements, their knowledge of the goals and objectives enhanced after the MTLS in terms of knowledge of curriculum. Science PCK literature support certain parts of the above conclusions. For instance, knowledge of instructional strategies and knowledge of learner have been reported as the most easily developed components (Henze et al., 2008; Park and Oliver, 2008). In this research, only knowledge of instructional strategies can be reported as the most developed component. Regarding other PCK components, related literature revealed that knowledge of curriculum and knowledge of assessment are the least or slightly developed components (Henze et al., 2008).

Factors Influencing Pre-service Chemistry Teachers' cPCK

The present study revealed several factors that impact pre-service chemistry teachers' cPCK. One of those factors was reflection on the instruction that seems to have an influence on the enhancement of pre-service chemistry teachers' knowledge of instructional strategy and knowledge of learner. For example, pre-service chemistry teachers decided to include more daily life examples and exclude the experiment since it caused many classroom management problems. Moreover, while discussing and reflecting on Deniz instruction, these pre-service teachers realized that the figure she used in class may be the source of a misconception. Since reflection on the instruction is one of the characteristics of the lesson study, we could state that MTLS helps to promote pre-service teachers' collective PCK. Moreover, since they planned the class and reflected on the instruction cooperatively, the discussion environment may cause the exchange of different ideas and they became aware of these alternative ideas and this discussion environment, which is another characteristic of the lesson study, may cause to enhance the professional growth of pre-service teachers. Research studies also revealed that reflection was found to be an effective way of enhancing pre-service teachers' PCK (De Jong et al., 2005; Nilsson, 2008; Park and Oliver, 2008). Schön (1987) stated PCK as a kind of knowledge developed by means of both reflection in action and reflection on action. In the present study, pre-service chemistry teachers' instruction was videotaped and after watching their videos, they could find the chance to evaluate their instruction critically. Moreover, they could reflect on their instruction more easily. We could recommend the use of videos in teacher education programs.

Another factor that influenced pre-service teachers' cPCK development was the content knowledge. MTLS enhanced pre-service chemistry teachers' content knowledge. As they taught and reflected on their instruction critically, their content knowledge increased and this influenced their knowledge of curriculum and knowledge of instructional strategy. They included an objective related to the dynamic equilibrium. Moreover, they gave importance to the dynamic equilibrium in the explanation of solubility concepts by means of a simulation and they included explanations regarding dynamic equilibrium in their third instruction. The positive influence of MTLS on pre-service teachers' content knowledge has also been confirmed by research studies (Bahçıvan, 2017). Moreover, enhancement of the content knowledge, one of the teacher professional knowledge bases, had an impact on the development of pre-service teachers' collective PCK. For example, they included a simulation regarding dynamic equilibrium in the third lesson. As they understood the link between dynamic equilibrium and solubility, their collective PCK developed. The strong relationship between pre-service teachers' content knowledge and their PCK was also reported by the study of Großschedl et al. (2015). Aydın et al. (2010) revealed the influence of pre-service teachers' content knowledge of their choice of instructional methods. Similarly, the interaction between content knowledge and the collective PCK has also been supported by the revised consensus model (Carlsen and Daehler, 2019).

Another factor influencing pre-service chemistry teachers' cPCK was pedagogical knowledge, which is one of the teacher professional knowledge bases. In the present study, when pre-service chemistry teachers' knowledge of teaching methods enhanced, they decided to change the instructional strategy to teach the saturated, unsaturated, and supersaturated solutions. They decided to use 5E learning cycle. Therefore, enhancement of pre-service teachers' pedagogical knowledge has caused the development of their knowledge of instructional strategy. Grossman (1990) and Magnusson et al. (1999) revealed the impact of teachers' pedagogical knowledge of their PCK. Großschedl et al. (2015) reported a moderate correlation between pre-service teachers' pedagogical knowledge and

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their PCK. Similarly, the interaction between pedagogical knowledge, which is one of the teacher professional knowledge bases, and the cPCK has also been put forward by the revised consensus model (Carlsen and Daehler, 2019).

As another factor, the previous experiences of pre-service chemistry teachers in teacher education program had an influence on their cPCK. To clarify, they used the same graph that was used in one of the courses in teacher education program. They discussed the graph in that course. They thought that they would also include this graph in their instruction. They decided to include an objective considering the interpretation of graph. Moreover, they involved the graph in their instruction. Pre-service chemistry teachers' previous experiences in a course had an impact both on their knowledge of curriculum and instructional strategies. Grossman (1990) stated that teachers' previous experiences as students during their schooling years, for example, university, influenced their PCK development. Similarly, Aydın et al. (2010) mentioned that both pre-service teachers' experiences as students and courses taken in teacher education programs had an impact on pre-service teachers' instructional decisions and their choice of instructional strategies.

We adopted transformative PCK for this study. In the present study, transformative nature of PCK seemed to explain pre-service chemistry teachers' cPCK development. The present study showed that both pedagogical knowledge and content knowledge influenced pre-service teachers' development of cPCK. Pre-service teachers transformed their content and pedagogical knowledge into PCK. They transformed both their content and pedagogical knowledge in the selection of instructional strategies, which is another knowledge, PCK.

IMPLICATIONS

The present study has several implications for teacher educators. Since MTLS enhanced pre-service teachers' collective PCK, we suggest the use of MTLS as a fruitful way of enhancing the pre-service teachers' professional growth in teacher education programs. Another implication is that both theoretical knowledge regarding different instructional methods and strategies and the chance to apply them in the classroom should be provided to the pre-service teachers in teacher education programs because the present study revealed pre-service teachers' growth in pedagogical knowledge influenced their collective PCK. It is important for pre-service teachers to have sound content knowledge since pre-service teachers' content knowledge was found to have an impact on their collective PCK and explanations during class. Therefore, it is important to enhance pre-service teachers' content knowledge through discussing students' alternative conceptions about chemistry topics as well as giving pre-service teachers the opportunity to teach different chemistry topics both in the university and high schools.

Therefore, pre-service teachers should be given the opportunity to apply their collective PCK in different class contexts such as high school classes. However, like other research studies do have, the present study has some limitations. First of all, pre-service chemistry teachers taught chemistry to their peers, who acted as high school students, in the university sessions. This situation may not reflect the real classroom environment of high schools. For future study, we would recommend the impact of lesson study on pre-service teachers' collective PCK. Second, this study was limited to the topic of solutions. This study should be replicated for other chemistry topics.

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