Macrothink Institute™

Journal of Educational Issues
ISSN 2377-2263
2019, Vol. 5, No. 2

Learning Science Teaching by Taking Advantages of Lesson Study: An Effective Form of Professional Development

Hatice Belge Can (Corresponding author)

Department of Elementary Science Education

Burdur Mehmet Akif Ersoy University, Burdur, Turkey

E-mail: hbelgecan@mehmetakif.edu.tr

Received: September 20, 2019 Accepted: October 25, 2019
Published: November 3, 2019

doi:10.5296/jei.v5i2.15497 URL: https://doi.org/10.5296/jei.v5i2.15497

Abstract

It is important to enhance pre-service science teachers' pedagogical content knowledge (PCK) during teacher education programs. As an alternative, this research aims to investigate whether participating in a lesson study enriched with content representation contributes to pre-service science teachers' PCK improvement in the heat and temperature topic. Three pre-service science teachers participated in the study. The study can be localized under the instrumental case study approach. Semi-structured interviews, content representations, observations, and field notes were used as sources of data collection. Results assert that participants' science teaching orientations did not change a lot, participants improved in terms of knowledge of curriculum and knowledge of learner components of PCK, and participants improved in terms of knowledge of instructional strategies and knowledge of assessment components of PCK excluding subject-specific strategies dimension of the former, and what and why to assess dimensions of the latter. This study has several implications for teacher educators and science education research.

Keywords: Pedagogical content knowledge, Lesson study, Content representation, Science teaching

1. Introduction

Teacher education programs should support pre-service science teachers' professional development by making them involved in effective contexts for science teaching. Had graduated from those programs, science teachers ought to be able to synchronize content and pedagogical knowledge bases. Pedagogical content knowledge (PCK) is the result of this amalgamation which differentiates a science teacher from a subject matter specialist (Shulman, 1987). Being one of the purposeful instructional methods (Juhler, 2016), lesson study (LS) provides a fruitful context for developing pre-service science teachers' PCK (Marble, 2007; Darling-Hammond, 1999; Lewis, 2002; Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003). Collaboration among teachers throughout the whole pedagogical cycle is one of the aspects of LS that help teacher candidates learning science teaching effectively. In other words, teacher candidates develop their professionality by being involved in joint planning of, teaching of, and reflecting on an enacted lesson. Reflection stage of LS is carried out after the teaching stage is completed that can truly be defined as reflection-on-action (Schon, 1987). In this way, participants of LS have a chance to modify or extend their planning and teaching practice, and hence their substantial PCK.

As all other professional development methods, LS does not contribute to participants' PCK unless the practice is supported by beneficial tools. Hart, Alston and Murata (2011), for instance, asserted that the reason why some practices of LS do not result in improved PCK is related to participants' need for scaffolding. Content representation (CoRe) has widespread usage as a pedagogical tool in the field of science PCK for attaining many purposes, such as to elicit and/or enhance pre-service science teachers' PCK, to make planning stage of a lesson more detailed and systematic, and to foster reflections (Loughran, Mulhall, & Berry, 2004; Rollnick, Bennett, Rhemtula, Dharsey, & Ndlovu, 2008; Hume, 2010; Hume & Berry, 2011; Nilsson & Loughran, 2012; Williams, Eames, Hume, & Lockley, 2012). Despite LS and CoRe are proved to be effective means individually to improve pre-service teachers' PCK, few researches have been conducted in the science education literature about the combination of them. Correspondingly, this study investigates the influence of LS enriched with CoRe on pre-service science teachers' PCK regarding heat and temperature concepts.

2. Theoretical Framework

2.1 Pedagogical Content Knowledge

Shulman (1987) conceptualized PCK as "the special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding" (p. 8). After then, numerous scholars have asserted PCK models within the context of science education (*e.g.*, Grossman, 1990; Magnusson, Krajcik, & Borko, 1999; Park & Oliver, 2008; Gess-Newsome, 2015; Carlson & Daehler, 2019). This research uses the modified version of Magnusson's et al. (1999) model as the theoretical framework. The model views PCK as the transformation of content knowledge, pedagogical knowledge, and contextual knowledge. This is a five-component model that involves:

1) "orientations toward science teaching and learning" refers to "the purposes and goals for teaching science at a particular grade level" (p. 97);

2) knowledge on "science curriculum" is made up of "mandated goals and objectives, and specific curricular programs and materials" categories (p. 103);

3) knowledge on "students' understanding of specific science topics" relates to "the

knowledge teachers must have about students in order to help them develop specific scientific knowledge" and is comprised of "requirements for learning specific science concepts, and areas of science that students find difficult" categories (p. 104);

4) knowledge on "instructional strategies for teaching science" includes knowledge of "subject- and topic-specific strategies" (p. 109). While the former involves general approaches to science teaching (*e.g.*, learning cycle, conceptual change strategies), the latter includes topic-specific representations (*e.g.*, examples, analogies, illustrations), and topic-specific activities (*e.g.*, demonstrations, simulations, experiments);

5) knowledge on "assessment in science" involves knowledge of "the dimensions of science learning to assess, and the methods of assessment" categories (p. 108). "What to assess" (*e.g.*, conceptual understanding, science process skills), and "how to assess" (*e.g.*, quiz, observation, questions) are the categories located under this last knowledge base.

The original model was modified by adding two categories to knowledge of curriculum (Grossman, 1990; Park & Oliver, 2008), and one to knowledge of assessment (Friedrichsen et al., 2007) (Table 2).

2.2 Lesson Study Enriched with Content Representation

Literature regards collaboration among teachers as one of the predominant features of effective teacher development (Garet et al., 2001; Guskey, 2003). By structuring context for cooperation, LS enables teachers to improve their PCK (Marble, 2007; Darling-Hammond, 1999; Lewis, 2002; Loucks-Horsley et al., 2003). A typical lesson study group is made up of four to six participants (Bridges, 2015). However the size of sample may change in distinct LS practices. In the study of Juhler (2016), for example, three to four pre-service teachers worked in a LS group. Based on social constructivist underpinnings (Bridges, 2015), LS presents opportunities for joint planning, joint teaching/observing and joint reflecting phases of a lesson-so called "research lesson" (Lewis, 2002). Although the number of cycles and the steps may change in practice (Lewis, Perry, & Hurd, 2009), a typical lesson study group; 1) meets to determine goal(s) of the lesson, 2) collectively plans the lesson according to the predetermined goals and possible challenges students face with, 3) teaches the planned lesson by selecting one of the teachers among the group as a teacher and others as observers of student learning and teacher knowledge, and 4) jointly reflects on the performed research lesson in terms of its strengths and weaknesses to revise the plan for the second cycle of LS process. Collectively planned second, and generally third research lesson, then, is taught by another selected teacher of the lesson study group to another classroom of students with the same steps (Lewis, 2002; Fernandez & Yoshida, 2004; Lewis, Perry, & Murata, 2006).

LS literature suggests widespread applications of this strategy for developing pre-service science teachers' PCK (Loucks-Horsley et al., 2003; Marble, 2007; Lewis et al., 2009; Dudley, 2013; Lucenario, Yangco, Punzalan, & Espinosa, 2016). Apart from that line of research, scholars frequently prefer examining the effect of solely one of the stages of LS on teachers' PCK development instead of taking LS as a strategy that is composed of three main stages (*i.e.*, planning, teaching/observing, and reflecting). On the contrary to Hart et al.

(2011), who viewed the planning as the most challenging stage of LS, Akerson, Pongsanon, Rogers, Carter, and Galindo (2017) stated it is the reflection stage of LS that is responsible for enhancing pre-service teachers' PCK. Actual classroom teaching, furthermore, has already been introduced as the fundamental source for developing pre-service teachers' PCK (Nilsson, 2008; Van Driel, De Jong, & Verloop, 2002).

Rather than focusing on which of the stages of LS is responsible for professional development of teachers, all of its three main stages are included within the scope of this research. That is to say, the researcher collected data on planning, teaching/observing, and reflecting stages of this promising strategy before concluding on PCK development of pre-service science teachers (see Method). Since participants of this study have not been engaged in LS before, the context was supported by CoRe. It requires practitioners to think about the content of a specific science topic (*i.e.*, big ideas) according to pedagogical prompts (Loughran et al., 2004), such as, what concepts/big ideas do you intend students to learn?, why is it important for students to learn this concept?, as a teacher, what should you know about this topic?, etc. Collectively, LS was enriched with CoRe to investigate pre-service science teachers' PCK while teaching heat and temperature topic. Following research question guides this research:

- ✓ Which PCK components (science teaching orientations, knowledge of curriculum, knowledge of students, knowledge of instructional strategies, and knowledge of assessment) of pre-service science teachers improved while teaching heat and temperature topic within the context of LS enriched with CoRe?

3. Significance of the Study

Literature points out the importance of research that examines development of pre- and in-service science teachers' PCK as a whole (Magnusson et al., 1999) without ignoring the overarching role of orientations (Friedrichsen, Van Driel, & Abell, 2011). In that sense, this research hopes to contribute to research need through exploring development of pre-service science teachers' PCK by framing Magnusson et al.'s (1999) model with its five components.

Researchers in science education have documented topic-specific nature of PCK (Abell, 2007; Kind, 2009; Mavhunga & Rollnick, 2013; Gess-Newsome, 2015). Accordingly, PCK development in heat and temperature topic was determined as the research context. LS literature suggests that it is important to select difficult topics to be learned by students or to be taught by teachers (Lewis, 2002). Heat and temperature topic was chosen for the present study because it is one of the basic science topics and it is a difficult topic for students to learn (Duit & Kesidou, 1988; Linn & Songer, 1991).

The present study is hoped to contribute to the related literature since few researchers investigated development of pre-service science teachers' PCK within the context of LS (Dudley, 2013; Juhler, 2016; Lucenario et al., 2016), even more scarcely in a context of LS enriched with CoRe. An example of such a research was conducted by Juhler (2016), who enriched LS with CoRe to develop participants' PCK. In that study, the researcher excluded the "orientations" component and collected data only in the planning stage of LS in physics lessons. This research, on the other hand, enriches LS with CoRe to explore pre-service science teachers' PCK development with all of the components of Magnusson et al. (1999) model through collecting data on each of the stages of LS.

4. Method

4.1 Research Design

The present study has a qualitative research methodology (Merriam, 1998). It can further be localized under the instrumental case study approach (Stake, 1995) since the aim is to document experiences of pre-service science teachers within the context of LS enriched with CoRe in terms of their PCK improvement.

4.2 Participants

Three pre-service science teachers participated in the study, voluntarily. Two of the teacher candidates were male (Ali and Burak), and one of them was female (Ceren). Pseudonyms were used instead of participants' actual names for saving confidentiality. All of the participants were 23 years old. Participants were attending their last semester in a science teacher education program which gives them the opportunity for science teaching at grades five to eight. Pre-service science teachers must achieve science courses (*e.g.*, general chemistry), pedagogical courses (*e.g.*, guidance), and subject-specific pedagogical courses (*e.g.*, special issues in chemistry) to graduate from the program. Participants have known one another for almost four years which helped this triad work smoothly, but they were nevertheless being trained in terms of effective communication in group works in the first meeting (see section 4.4). The mentoring teacher was teaching science in a public middle school (*i.e.*, grades 5-8). Both the teacher and the author observed participants while they were teaching of and reflecting on the research lessons.

4.3 Data Collection

CoRe, observations, field notes, and semi-structured interviews were used to collect data. The reason why multiple data sources were included within the scope of the current study is threefold: first is to enrich LS with CoRe to enable pre-service science teachers to transmit advantages of this collaborative approach effectively to their individual professional development, second is to collect not only group but also personal data, and third is to provide trustworthiness of the research by triangulating those sources of data. The workflow for data collection is depicted in Figure 1.

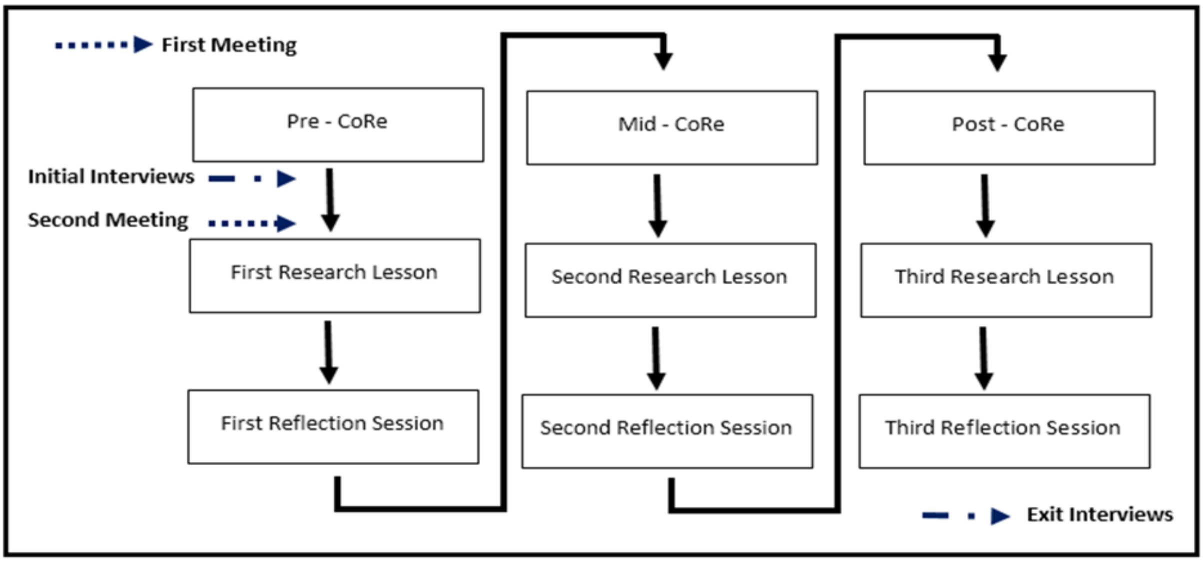

Figure 1. The workflow for data collection

4.3.1 CoRe

CoRes were constructed collaboratively by pre-service teachers three times. Specifically, pre-CoRe is the first group task to be prepared before the first research lesson, mid-CoRe is the second one to be prepared before the second research lesson, and post-CoRe is the last one to be prepared before the third research lesson (Figure 1). The revised version of Core (Aydın et al., 2013) was slightly modified by excluding the last prompt (*i.e.*, what materials/equipment are needed to teach the lesson?) and by including "prerequisite knowledge" in the fourth prompt to make an adjustment to the framed model of PCK (Table 1). CoRe was used as a lesson-planning format to enrich planning stages and as an interview format to enrich reflecting stages of LS. One more purpose of using CoRe was to manage a platform for individual interviews since interviews were constructed primarily on PCK components and what CoRes involve.

Table 1. Prompts of CoRe within the scope of this study

1. What concepts/big ideas do you intend students to learn?
2. Why is it important for students to learn this concept?
3. As a teacher, what should you know about this topic?
4. What prerequisite knowledge, difficulties and misconceptions do students typically have about each concept?
5. Which teaching strategy and what specific activities might be useful for helping students develop an understanding of the concept?
6. In what ways would you assess students' understanding or confusion about this concept?

4.3.2 Observations and Field Notes

Research lessons were observed by non-teaching group members, the mentoring science teacher, and the researcher-so called "research team". While one of the participants was teaching on heat and temperature topic, observers took field notes to inform reflection sessions, each of which were held right after the corresponding research lesson (Figure 1). Although lessons could not be videotaped because of administrative issues, investigator triangulation (Patton, 2002) was provided hence all three research lessons were observed by the research team.

4.3.3 Semi-structured Interviews

Initial and exit semi-structured interviews were the main sources of data. Pre-service science teachers were interviewed individually. Though the initial interview was conducted after construction of pre-CoRe, the exit interview was conducted right after participation of third reflection session as a group (Figure 1). Interview questions were prepared with regard to the five knowledge bases of the modified version of Magnusson et al.'s model of PCK (1999). Each of the interviews proceeded about 60 minutes, which were transcribed verbatim.

4.4 Research Context

This research took place in the course of teaching practice. Though five pre-service science teachers were attending the course, three of them were volunteered to participate in the study.

Researcher, initially, met with those three participants in the college of education to train them in terms of social skills needed to work in a group (*e.g.*, conflict management, democratic decision making, listening to and respecting each other, giving and receiving help). Then, the purpose of the research was introduced. Researcher helped participants become familiar with LS through explaining historical background of it, the position of it in teachers' professional development in Japan (as LS is a Japanese instructional method), similarities and differences of enacted research lessons in Japan and in Turkey, and implementation of LS in this context. What CoRe is and how it relates to design of this research were also within the scope of the first meeting (Figure 1). CoRe was presented to participants by translating a well-prepared CoRe sample to Turkish, which was shared by Aydın et al. (2013) on rate of reaction topic. Moreover, PCK and Magnusson et al. (1999) model was introduced to the pre-service science teachers. The last issue that was handled in the first meeting was the introduction of the selected science topic that was heat and temperature. Reasons of why heat and temperature had been chosen as the research topic were mentioned in previous parts. Here, how this topic fits in the program for grade 8 students will be presented. Instead of "heat transfer and temperature change", which is written in the program (MONE, 2013) as it is, "heat and temperature" was used throughout this research for simplicity. This topic is one of the topics of the "states of matter and heat" unit. Relationships between heat-mass, temperature-mass and heat-specific heat are the concepts that are suggested to be taught under this topic.

After these preliminary preparations, LS was started to be enacted through following the forthcoming stages: 1) planning the first research lesson (RL), 2) teaching the first RL, 3) reflecting on the first RL, 4) planning the second RL, 5) teaching the second RL, 6) reflecting on the second RL, 7) planning the third RL, 8) teaching the third RL, and 9) reflecting on the third RL (Figure 1). In planning stages (*i.e.*, 1, 4, and 7), pre-CoRe, mid-CoRe, and post-CoRe were prepared by participants as a group in a lesson-planning format. Hence planning stage is assumed to be the heart of LS, writing CoRes in a manner that include as much detail as possible about the corresponding RL was a significant issue. Therefore, the group was expected to examine educational resources regarding heat and temperature, profoundly.

RLs were enacted by Burak, Ceren, and Ali within three different classes of 8th grades, respectively (*i.e.*, stages 2, 5, and 8). That is to say, Burak taught a lesson which focused on heat and temperature topic to one of the classes of 8th grade, and so on. Although RLs had been planned as a group, participants taught lessons individually without intervening each other's enactments. The aforementioned research team observed RLs and took field notes to be shared in reflection sessions that were conducted right after each RL.

During reflection sessions (*i.e.*, stages 3, 6, and 9), the corresponding CoRe, which had been prepared before the RL was enacted, was used as an interview format. Specifically, the research team discussed on RLs regarding to what extent the RL was successful with respect to prompts of the CoRe. As an example, in the first reflection session, the research team discussed on the lesson that was taught by Burak in terms of the degree to which the enacted lesson had reflected pre-CoRe. The research team members followed a protocol while reflecting on RLs in which the teacher who had taught the lesson shared his/her experiences, other two participants, the mentoring science teacher, and lastly, the researcher introduced their notes, respectively. Soon after the team had reflected on the third RL, exit interviews were conducted by participants, individually (Figure 1).

4.5 Data Analysis

Semi-structured interviews and CoRes were analyzed deductively on the basis of a coding framework that was the modified version of Magnusson et al.'s model of PCK (1999) (Table 2). Data drawn from observations and field notes were used as sources that support those data. Interviews supplied data on whether individual participants' PCK developed while CoRes revealed that if participants, as a group, benefitted from LS enriched with CoRe when teaching heat and temperature topic.

Table 2. The modified version of Magnusson et al. model of PCK (1999)

PCK component	Sub-component(s)
STOs	Beliefs about purposes of science teaching
KoC	Goals and objectives Vertical link* Horizontal link* Link with other disciplines*
KoL	Prerequisite knowledge Misconceptions* Learning difficulties
KoIS	Topic-specific strategies Topic-specific representations Topic-specific activities Subject-specific strategies
KoA	What to assess Why to assess** How to assess

Note. *STOs*: science teaching orientations; *KoC*: knowledge of curriculum; *KoL*: knowledge of learner; *KoIS*: knowledge of instructional strategies; *KoA*: knowledge of assessment.

* Grossman (1990) and Park & Oliver (2008); ** Friedrichsen et al. (2007).

The researcher and one of the colleagues, who studies PCK for a long time, have coded data. After coding data independently, researchers compared and contrasted those to provide interrater reliability. It ranged from 90% to 98% for each PCK component. In case of conflicts between codes, researchers discussed them and finally reached a consensus. Apart from interrater reliability, prolonged engagement, persistent observation, data and analyst triangulation were conducted to verify trustworthiness of the research.

5. Results

5.1 Orientations toward Science Teaching and Learning

This component is mostly known as "Science Teaching Orientations (STOs)" which refers to beliefs about purposes of science teaching with regard to the framed model of PCK (Table 2).

Participants' STOs did not undergo a radical change from initial to exit interviews. Specifically, Ali's purpose of science teaching remained the same, which was to help students be prepared to national examinations which are carried after completing 8^{th} grade to be enrolled in a high school in the Turkish context (*i.e.*, 9^{th} to 12^{th} grades). Ceren continued to believe in educating scientifically literate citizens should be the purpose of science teaching.

In contrast to these two participants, who did not show any change from initial interviews to exit ones, Burak slightly changed his STOs by adding one more purpose of science teaching in the exit interview. While he specified that science teaching is a way of making students to understand daily events in the initial interview, Burak started to believe in the importance of educating scientifically literate students, as well, in the exit interview.

When lessons of participants were observed, Ceren and Burak tried to establish scientifically correct knowledge through confronting students with their alternative explanations while Ali transmitted scientifically correct knowledge to students without taking their prior knowledge into account. Therefore, according to Magnusson et al.'s model of PCK (1999), science teaching orientation for two participants (Ceren and Burak) can be categorized under "conceptual change" orientation and the other participant (Ali) under "didactic" orientation with regard to their purpose of science teaching and characteristics of their instruction (p. 100, 101).

5.2 Knowledge of Science Curriculum (KoC)

Knowledge of goals and objectives of science curriculum, vertical and horizontal relations of heat and temperature topic to other chemistry topics, and relations of heat and temperature topic to other disciplines of science are the dimensions of this component with regard to the framed model of PCK (Table 2). Data regarding KoC were collected through interviews, observations during teaching, the first and second prompts of CoRes, and observations during reflecting on the corresponding RL.

As depicted in Figure 1, participants have already prepared pre-CoRe before they were interviewed for the first time. Since they have decided content of the first RL with regard to the national curriculum, participants recalled goals and objectives of heat and temperature topic in the course of initial interviews. Specifically, when participants were asked "what concepts/big ideas do you expect students to learn" they listed nationally stated concepts of heat and temperature topic (*e.g.* heat, temperature, mass, etc.) as big ideas to be learned. On the other hand, participants did not emphasize on their expectations of student learning at the beginning of the study. As pre-service teachers gain experience through filling CoRes out, enacting lessons, and reflecting on RLs, they started to learn how to adapt curriculum goals and objectives to lessons. Ali's and Ceren's following transcripts reveal their gradual development on adaptation of goals and objectives to student understanding:

> *At the beginning, I thought that a teacher must teach all the objectives as stated in the curriculum ... very difficult to complete actually ... As we filled CoRes out however we realized that it is not the case ... that is, a teacher should select key conceptions from it [curriculum] in an order and in a way to fit well with their [students] capacity to help students learn scientific knowledge ... That's why we focused solely on relationships between mass-heat and mass-temperature in the last research lesson excluding other related factors with heat and temperature, like specific heat ...* (Ali, Exit Interview)

> *Now, I want to laugh when I remember our first research lesson… describing only definitions and units of heat and temperature and making them [students] to write all of*

> *them. The second one was rather well but the third research lesson was the best.....instead of low level knowledge acquisition we tried to help students learn the difference between heat and temperature through supplying some chemicals and expecting them to design an experiment.* (Ceren, Exit Interview)

Furthermore, pre-service teachers started to be more successful in reflecting their expectations to lessons and CoRes. Burak's following case and post-CoRe document give an apparent hint to this result;

> *I think students learn what heat or temperature means as they are written in their textbooks ... I mean, rote learning happened which disturbed me as we want them to learn meaningfully ...* (Burak, First Reflection Session)

Mentoring science teacher and the researcher asked what to do to change this annoying situation to participants and they started to think on their expectations while preparing mid- and post-CoRes.

> *Big ideas of the lesson are mass-heat and mass-temperature relationships. We expect students to set up two experiments by selecting relevant materials on the table, one of them for the former and the second experiment for the latter concept. As heat and temperature terms were used interchangeably most of the time in our daily lives, we introduced numerous examples from daily life, e.g., think that a child's body heat is 38, should we give syrup to the child to decrease him fever? (an example involving a common misconception)* (As a group, Post-Core)

Data regarding relations of heat and temperature topic to other topics vertically, *i.e.*, relations to the previous and next grades (*e.g.*, heat and temperature topic in the 5th grade, heat change in exothermic and endothermic reactions in the 11th grade), and horizontally, *i.e.*, relations to the same grade chemistry topics (*e.g.*, chemical reactions topic in the 8th grade), and to other subsets of science were collected primarily through "Why is it important for students to learn this topic?" prompt of CoRe. It was found that participants were unaware of the rationale of learning this topic at the beginning of the study whereas they showed a gradual improvement. Although participants' ideas were limited regarding prior units in the initial interview, they started to refer to the 5th grade content in the exit interview. For instance,

> *They [Students] are expected to learn basic differences between heat and temperature and the fact that heat transfers when two liquids with different temperatures are mixed, in the 5th grade.* (Ali, Exit Interview)

> *Though the heat related topic ... that is, heat conductors and nonconductors ... is presented in the 6th grade, the main base for this [heat and temperature topic which is localized under the 8th grade program] is established in the 5th grade.* (Burak, Exit Interview)

Similarly, participants became aware of the importance of heat and temperature topic for students' following chemistry and physics courses, both of which include heat and temperature concepts in the high school curriculum, and for transferring that knowledge to daily life, which were omitted in initial interviews. For example,

> *Heat and temperature are frequently used terms in our daily lives ... then, comprehending this topic will enable us to comment on the reasons we encountered in daily life events ... e.g., why streets paved with asphalt are deformed as seasons change?* (Ceren, Exit Interview)

To sum up, participants became aware of the significance of adapting curriculum goals and objectives to student learning, and of relating heat and temperature concepts to prior and following topics of chemistry and to relevant contexts.

5.3 Knowledge of Students' Understanding of Specific Science Topics (KoL)

Prerequisite knowledge, misconceptions, and learning difficulties are dimensions of KoL with regard to the framed model of PCK (Table 2). Interviews, the third and fourth prompts of CoRes, and observations during teaching and reflection sessions were used to collect data on this component of PCK.

When participants had been asked "what should a teacher know about heat and temperature topic", they referred not only to KoL but also to KoC, KoIS, and KoA while filling the third prompt of post-CoRe out. On the contrary to pre-CoRe, in which only superficial statements of knowledge a teacher should have had been listed (*e.g.*, teachers should know objectives of the curriculum, concepts regarding heat and temperature, etc.), participants started to use more PCK-related language as the study progresses. In the post-CoRe, for example, participants shared the following thoughts,

> *Besides to know heat and temperature concepts, a teacher should know how to interpret national objectives while planning lessons in terms of their coherence to students' prior knowledge, how to help students transfer it [heat and temperature related knowledge] to their [students] daily lives, how to teach heat and temperature concepts, how to anticipate and address difficulties and misconceptions students have about it [heat and temperature topic], and how and when to assess students.* (As a group, Post-Core)

Pre-service teachers' thoughts about prerequisite knowledge, difficulties, and misconceptions students have about heat and temperature topic showed a gradual improvement from the beginning to the end of the study. In other words, participants started to view science learning more complicated The following excerpt indicates participants' views about importance of taking necessary skills for learning science and individual differences into account,

> *I realized in the second RL that some students' motivation was razed to the ground when Ceren put various laboratory equipment on one of the visible desk ... though they [students whose motivation decreased] were successful at that time. After the lesson we debriefed on this issue and decided to alter something not to lose those who may learn with different ways ...* (Ali, Exit Interview)

Although participants shared the reason why students experience difficulties while learning heat and temperature concepts as the abstract nature of the topic in the pre-CoRe, they began to think that misconceptions and deficient knowledge and skills students have, were responsible for those troubles in the post-CoRe. For instance,

> *As nearly all chemistry topics, heat and temperature concepts will be viewed as abstract by students ... they will find the topic difficult for this [viewing heat and temperature concepts as abstract].* (Ceren, Initial Interview)

> *I thought they [heat and temperature concepts] were abstract in the beginning ... but ... actually, teachers can find ways to make those [heat and temperature concepts] more concrete by referring to daily life. Instead of it [abstract nature of the topic], the main reason why students find these [heat and temperature concepts] difficult is their lack of relevant prior knowledge, like the particulate nature of matter. If students would understand that [the particulate nature of matter], they can understand basic differences between heat and temperature, as well.* (Burak, Exit Interview)

> *I believe that students lack laboratory skills that is hall-mark of science learning indeed ... and lack hypothetical thinking skills ... and they [students] have misconceptions, e.g., when same amount of heat was given to the same two matter with different masses, the matter with lower mass will have lower temperature ... we should address these [aforementioned aspects of difficulties] for the following RL.* (Ali, Second Reflection Session)

Participants are assumed to improve most in terms of their knowledge of misconceptions about heat and temperature. While they had not specified any misconception in the pre-CoRe, they started both to specify and to address those conceptions in the post-CoRe.

5.4 Knowledge of Instructional Strategies for Teaching Science (KoIS)

KoIS is made up of knowledge of topic-specific strategies, topic-specific representations, topic-specific activities, and subject-specific strategies with regard to the framed model of PCK (Table 2). Interviews, the fifth prompt of CoRes, and observations during teaching and reflection sessions were used to collect data on this component of PCK.

As a general result, pre-service teachers persist on using the same topic-specific strategies from the beginning to the end of the study instead of enriching their knowledge of various sorts of strategies. However, participants' way of using those strategies moved from superficial to effective. Daily life examples of heat and temperature, for example, was one of the topic-specific representation participants used during the second and third RLs. In the last RL, however, the representation was used more effectively in terms of its content and timing. Instead of listing them at the beginning of the lesson, examples were handled as teaching materials to be used throughout the lesson. Moreover, though participants continued to use experiments as topic-specific activities from the beginning to the end of the study, they changed the way to conduct those experiments on the basis of misconceptions students hold and learning styles students adopt. For instance,

> *I shared my observations with the group after the second research lesson ... which were, some students were de-moralized when the teacher set up the experiment ... the experiment conducted was not successful to address the anticipated misconception [as*

> *mass of a substance increase, temperature of that substance also increases like it gains more heat]. Then, we thought that we should incorporate students into the by requiring students design an experiment and set it up. I believe in how prospering an instructional strategy depends on to what extent it corresponds to students' needs.* (Ali, Exit Interview)

Although the pre-service teachers demonstrated the experiment in the first lesson, in the third lesson, the pre-service teachers made students actively involved in the design of the experiment. In a way, they used the experiment in a student-centered way.

Another result regarding KoIS is related overall to science teaching; that is, subject-specific strategies. This dimension caused intensive discussions among pre-service teachers while they were constructing CoRes and reflecting on RLs because their science teaching views contradicted. Specifically, although two participants (Burak and Ceren) declared that students learn scientific concepts meaningfully and be scientifically literate when they are faced with opposing situations (*i.e.*, conceptual change strategies), the other participant (Ali) stated that students acquire scientific knowledge better when teachers introduce concepts in a well-organized manner and ask critical questions (*i.e.*, lecturing). It was apparent in this study that participants select subject-specific strategies according to STOs they possess.

5.5 Knowledge of Assessment in Science (KoA)

KoA involves knowledge of what to assess, why to assess, and how to assess dimensions with regard to the framed model of PCK (Table 2). Interviews, the last prompt of CoRes, and observations during teaching and reflection sessions were used to collect data on this component of PCK.

Intensive discussions on which subject-specific strategies to select continued while pre-service teachers were deciding on what to assess and on why to assess. Since participants' science teaching views contradicted, it is not surprising actually to observe such a situation. Following examples make it evident that pre-service teachers' instructional decisions (*i.e.*, how to teach, what to assess, why to assess) are shaped mainly by their STOs,

> *People who prepare questions for national examinations are fond of heat and temperature concepts ... so, students have to learn these [heat and temperature concepts] very well ... so, we [participants] have to teach these [heat and temperature concepts] very well ... like a chain ... assessing their [students'] understanding can be done by testing them right before the first RL ends ... while they [students] were in classroom.* (Ali, Second Reflection Session)

> *As we [university students] learned, the main idea behind assessment is to evaluate whether rote learning occurred or conceptual understanding of scientific concepts achieved ... our [university students'] main goal of assessment is the latter as our [university students'] principle purpose of science teaching is to educate scientifically literate students ... but I am not sure about which assessment methods are more convenient exactly for this [educate scientifically literate students].* (Ceren, Initial Interview)

Ceren's above excerpt indicates the influence of STOs on participants' knowledge of why to assess, as well. More specifically, participants' decisions on what and why to assess are manifestations of their STOs.

Both Ceren's above excerpt and reflection session observations reveal that participants were not aware of how to assess conceptual understanding at the beginning of the study. Although the content of this dimension of KoA covers the knowledge of specific assessment methods in science, and their strengths and weaknesses (Magnusson et al., 1999), the present study marks one more aspect to be introduced under this dimension, which is *when to assess*. In other words, pre-service teachers are assumed to improve both on how to assess students' conceptual understanding and on when to employ those assessment methods. For instance, a diagnostic tree sheet had been prepared by participants in the mid-CoRe to be assigned as homework. After renewing the sheet in terms of its content, it was distributed to students in the third RL to evaluate individual students' understanding instead of the class as a whole. As an another instance, while participants had been included brainstorming at the beginning of the first RL only as an instructional strategy to motivate students to the lesson, they used brainstorming at the beginning of the class as an instructional strategy as well as assessment tool after LS. The discussions about what brainstorming is during the reflection sessions helped them learn about the brainstorming more. Implementing brainstorming both for instruction and for assessment purposes is assumed to increase power of the strategy because students had an opportunity to assess what they had stated at the beginning of the lesson. Being involved in the process of their own assessment was highly motivating for students.

6. Conclusion and Discussion

This research investigated how pre-service science teachers' participation in LS enriched with CoRe application influenced the development of their knowledge bases of PCK for teaching heat and temperature topic. Results of the current study were introduced on the basis of each component and dimensions of those components as put forth by the framed model of PCK (Table 2). Results can be categorized under three assertions namely; 1) STOs held by participants did not change a lot, 2) participants improved in terms of KoC and KoL components of PCK, and 3) participants improved in terms of KoIS and KoA components of PCK excluding subject-specific strategies dimension of the former, and what and why to assess dimensions of the latter.

One of the findings of this study was pre-service science teachers' orientations with respect to the purposes of science teaching did not undergo a radical change from the beginning to the end of the LS. It is not surprising that pre-service teachers' orientations did not change drastically because teachers' science teaching orientations are reported as resistant to change in the related literature (Brown, Friedrichsen, & Abell, 2013; Friedrichsen, 2015). Another finding of the present study was that pre-service teachers' science teaching orientations shaped up their knowledge of instructional strategy and assessment. This is an evidence that science teaching orientations influence other knowledge components of PCK, which is also supported by research studies (Park & Oliver, 2008; Aydın et al, 2013; Magnusson et al, 1999).

Another finding of the present study was that though participants improved in terms of all dimensions of KoC and KoL, they improved in terms of KoIS and KoA components of PCK excluding subject-specific strategies dimension of KOIS, and what and why to assess dimensions of KoA. This result is supported by other researchers who had reported uneven improvement among PCK components (Magnusson et al, 1999). In contrast to previous research having found KoC not to develop or to develop slightly (Park & Oliver, 2008; Henze, Van Driel, & Verloop, 2008), results of this study revealed considerable improvement of KoC with its all framed dimensions. Furthermore, while KoIS is reported repeatedly as one of the most developed component of PCK (Park & Oliver, 2008), this study traces improvement in terms of topic-specific strategies dimension of KoIS alone. Moreover, results regarding pre-service science teachers' KoA revealed other aspects to what to assess and how to assess (Magnusson et al., 1999), which were why to assess and when to assess that is in the same line with the research of Aydın et al. (2013). To sum up, LS enriched with CoRe can be suggested as an effective form of professional development for pre-service science teachers.

7. Implications

This study has several implications for teacher educators and science education research. First of all, since science teaching orientations of pre-service science teachers are found to influence their knowledge of instructional strategy and assessment, it is crucial to make pre-service teachers' beliefs explicit in teacher education programs. Another finding of this study is that students' knowledge of instructional strategy influenced their knowledge of assessment. Therefore, as an implication, both theoretical information about different instructional strategies and how to implement them should be discussed in teacher education programs. Another important finding of the present study was that LS enriched with CoRe application showed considerable improvement in pre-service teachers' PCK. Therefore, we would recommend the use of LS with CoRe in teacher education programs. Despite a growth in knowledge of instructional strategy and assessment, their development was a bit less compared to the other components. This might be due to pre-service teachers' lack of knowledge in instructional strategies and assessment methods. Another factor may be that pre-service science teachers were reluctant to implement different instructional strategies and assessment techniques due to their lack of experience in implementing those in class. Therefore, we would recommend that different instructional strategies and assessment techniques as well as the implementation of those should be discussed in teacher education programs. Researchers can be suggested to report their findings on the basis of dimensions of the framed PCK model instead of components of PCK so that results can be compared and contrasted more accurately. Future researchers may focus on the nature of discourses while pre-service science teachers work within LS context or on interplays among PCK components and dimensions. Exploration of the influence of microteaching LS on pre-service/in-service science teachers' PCK development may also be a research theme for following research.

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